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Effect of *Acacia angustissima* leaf meal on performance, yield of carcass components and meat quality of broilers

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Abstract

The study determined the appropriate levels of including *Acacia angustissima* leaf meal in broiler diets for optimum performance, carcass part yield, and meat quality characteristics. One hundred and fifty broiler chicks were allocated to 0%, 5%, and 10% *A. angustissima* leaf meal-based diets in a completely randomized design, with five replicates per treatment. Weekly feed intake and live weights were measured. Weekly weight gains and feed conversion ratios were calculated. At six weeks, two birds per replicate were slaughtered and dressed. Carcass and portion yields were determined. Breast proximate components, CIELAB colour variations, cooking loss and shear force were estimated. Consumer preferences for colour, aroma, taste, flavour and tenderness were determined. Voluntary feed intake (VFI), weekly weight gain, weekly live weights and feed conversion ratios (FCR) were the same across treatments at two weeks. At weeks 4 and 6, the control and 5% groups outperformed the 10% group. Increasing dietary leaf meal had no effect on dressing out percentage, but decreased carcass weight from 1456 g to 1060 g, breast yield from 36.83% to 32.69%, breast meat to bone ratio from 4.77% to 2.94%, and proportion of drumstick skin from 11.57% to 7.92%. It also resulted in increased yield of thighs from 14.63% to 15.97%, proportion of thigh skin from 11.50% to 14.31% and breast skin proportion from 5.37% to 7.95%. The leaf meal had no effect on the proximate components of breast meat. The L* values decreased from 53.66 to 49.23; the b* values increased from 12.93 to 19.97; shear force increased from 14.14 N to 14.54 N; and cooking loss increased from 5.95% to 7.64% with increasing leaf meal levels. It was concluded that up to 5% *A. angustissima* leaf meal inclusion has no negative effect on performance, yield of carcass parts and meat quality characteristics of broilers.

Keywords: Breast, colour, cooking loss, shear force, taste
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Introduction

High feed costs (Bonsu *et al*., 2012) and competition for feed/food resources between human beings and poultry (Muktar *et al*., 2015) hinder the growth of the poultry industry in most developing countries, hence the need to explore the use of non-conventional feed resources, especially those that do not attract competition between humans and monogastric animals. Leaf meal from *Acacia angustissima* tree, a multi-purpose shrub legume, is one such resource. It is a thornless shrub legume tree of 2–7 m in height, with leaf capacity to produce leaf biomass of up to 12.4 t DM Ha^{-1} (Preece & Brook, 1999). It has shown superior fodder production characteristics (Dzowela *et al*., 1997; Hove *et al*., 1999; Reed *et al*., 2001) and ability to resist psyllid attack (Odenyo *et al*., 2003) compared with other shrubs under southern African conditions, making it a fodder tree of choice. Its potential to support broiler growth (Ncube *et al.,* 2012abc) and its effect on the physiological functions of broilers (Ncube *et al.,* 2017a, b) have been established. To date, optimum inclusion levels of the leaf meal in support of growth without negative effects on the digestive and metabolic processes have been established at 5% (Ncube *et al.,* 2017a, b). However, little is known about the effects of the same diets as used by Ncube *et al*. (2017a, b) on the yield of carcass parts and meat quality parameters. Thus, there is a need to determine levels at which the leaf meal would support acceptable yield of carcass parts, while simultaneously producing meat of acceptable chemical, physical, and organoleptic characteristics in broilers without compromising performance.

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Consideration of carcass part yield is important because marketing of broilers has shifted from whole chicken to portions (Rostagno *et al*., 2007). It is therefore important to give attention to the effect of the leaf meal on the yield of carcass parts. This is especially important for the breast, a portion of economic importance (Scheuermann *et al*., 2003; Petracci & Cavani, 2012; Shim *et al*., 2012). Since breast muscle provides the greatest portion of edible meat in broilers (Al-Owaimer *et al*., 2014), any new feeding intervention should consider the impact on breast yield and quality characteristics. Previous studies have focused on determining possible deleterious effects, and growth and fat reduction in broilers fed *A. angustissima* leaf meal-based diets. Consequently, 5% (Ncube *et al*., 2012a) and 10% (Ncube *et al*., 2012c) inclusion levels were recommended for optimum growth and reduction of fat, respectively, without affecting carcass weight. These past studies, as well as the most recent studies by Ncube *et al*. (2017ab), are silent on the possible effect of the leaf meal on yield of carcass parts. Information on portion yield could also help broiler producers decide on suitable markets (Faria *et al*., 2010) to optimize profits. While some markets may prefer portioned carcasses (Faria *et al*., 2010) others would rather have whole chicken carcasses (Karaoğlu *et al*., 2014).

Increased consumer awareness of meat quality is also a key driver in efforts to determine the effect of the leaf meal on meat quality characteristics. This would ensure satisfaction of consumer expectations (Grunert *et al*., 2004). Such expectations are addressed by the relationship between quality expectation and quality experience. The smaller the gap between expected and experienced quality, the higher the levels of satisfaction. Therefore, recommendations on the use of *A. angustissima* leaf meal in broiler diets should consider its effect on major meat quality parameters, such as the chemical composition, and physical and organoleptic attributes. This would help reduce the chances of product rejection in the market. Current recommendations on the use of the leaf meal in broiler diets are silent on its effect on meat quality parameters; hence, the need to determine the appropriate level of including in broiler diets for optimum growth and meat quality characteristics. The objective of this study was therefore to determine the appropriate levels of including *Acacia angustissima* leaf meal in broilers diets for optimum performance, carcass part yield and meat quality characteristics.

Materials and Methods

A. angustissima leaves were harvested at the mid maturity stage of growth and air dried in a well-ventilated room (Ncube *et al*., 2015). The dried samples were ground through a 1-mm sieve, sealed tightly in bags, and stored in a cool dry place for chemical analysis. Dry matter, crude protein, crude fibre, and ash contents were determined using AOAC (1990) methods. The content of condensed tannins was determined using the Butanol-HCL method (Porter *et al*., 1986). Soluble and insoluble fibres were determined through a procedure by Parsaie *et al*. (2006) (Table 1). Using the proximate composition of the leaf meal, three iso-nitrogenous and iso-energetic diets were formulated for a three-phase feeding programme at 0%, 5%, and 10% leaf meal inclusion (Table 2). One hundred and fifty day-old unsexed Cobb 500 broiler chicks were randomly allocated to 15 groups with 10 birds per group. The groups were randomly allocated to the three diets. The starter, grower, and finisher diets were fed from Week 1 to 2, Week 3 to 4, and Week 5 to 6, respectively. Environmental temperature was kept at 35 °C in the first week of life and gradually reduced to 22 °C by the fourth week. Feed and water were provided *ad libitum* throughout the trial. Broilers were kept under a 24-hour light schedule.

Table 1 Chemical composition of *Acacia angustissima* leaf meal

Chemical component	Percentage (%)
Dry matter	90.00
Ash	4.77
Crude protein	23.40
Crude fibre	13.00
Calcium	0.94
Phosphorus	0.17
Condensed tannins	1.06
Insoluble dietary fibre	9.24
Soluble dietary fibre	4.96

Table 2 Ingredient and chemical composition of starter, grower and finisher diets with increasing levels of *Acacia angustissima* leaf meal

Ingredient (kg)	Starter diets			Grower diets			Finisher diets		
	Control	Diet 1	Diet 2	Control	Diet 1	Diet 2	Control	Diet 1	Diet 2
Soya meal	30.00	25.00	20.00	18.7	13.70	8.70	18.60	13.60	8.60
Meat and bone meal	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00
Sorghum meal	10.00	0.00	10.00	0.00	9.90	10.00	0.00	0.00	0.00
Acacia leaf meal	0.00	5.00	10.00	0.00	5.00	10.00	0.00	5.00	10.00
Blood meal	0.00	0.00	0.00	0.00	2.00	3.00	1.20	1.80	3.00
Sunflower cake	2.50	1.30	0.00	1.70	1.50	2.1.0	0.00	0.00	0.00
L. Threonine	0.06	0.06	0.03	0.05	0.00	0.45	0.00	0.00	0.00
Soya oil	0.00	0.00	0.00	0.00	1.60	3.00	0.00	1.30	2.40
Wheat bran	0.00	0.00	2.10	0.00	0.00	0.00	0.00	0.00	0.00
Soya oil	0.00	0.00	1.50	0.00	0.00	0.00	0.00	0.00	0.00
Maize meal	48.60	56.90	44.00	68.1	55.00	51.40	73.00	70.40	67.50
Fish meal	1.20	4.90	5.00	4.6	4.60	5.00	0.10	1.00	2.00
DL Methionine	0.30	0.29	0.79	0.19	0.16	0.11	0.15	0.15	0.07
Lysine HCL	0.26	0.22	0.28	0.21	0.14	0.12	0.00	0.00	0.00
Monocalcium phosphate	0.50	0.30	0.30	0.2	0.30	0.30	0.16	0.15	0.07
Limestone	0.88	0.43	0.40	0.65	0.50	0.27	0.74	0.55	0.36
Salt	0.40	0.30	0.30	0.3	0.30	0.25	0.35	0.35	0.30
Broiler premix[123]	0.30	0.30	0.30	0.3	0.30	0.30	0.30	0.30	0.30
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Chemical composition									
Crude protein (g/kg)	226.00	226.13	225.28	199.90	199.74	200.12	175.00	174.94	174.93
ME (MJ/kg)	12.50	12.46	12.39	13.09	13.07	13.08	13.20	13.21	13.18
EE (g/kg)	36.80	39.04	51.94	41.64	55.17	67.71	39.19	51.27	61.45
CF (g/kg)	41.50	40.15	49.98	34.38	39.88	46.84	31.90	37.88	43.86
Ca (g/kg)	9.98	9.52	9.88	9.22	5.59	5.60	4.93	8.63	8.74
P (g/kg)	7.08	7.10	7.04	6.53	6.61	6.58	6.00	6.02	6.08
Condensed tannins (%)	0.004	0.059	0.076	0.0036	0.056	0.083	0.0043	0.055	0.077

[1]Composition: 9.9u.i vitamin A, 1.95u.i vitamin D_3, 30u.i vitamin E, 2.9g vitamin K3, 2g vitamin B1, 7.5g vitamin B2, 30g vitamin PP niacin, 12.1g vitamin B5, 3g vitamin B6, 1g vitamin b9 folic acid, 150mg vitamin B7/biotin, 20mg vitamin B12, 300g choline, 60g Iron, 10g copper, 100g manganese, 100g Zinc, 1g, iodine , 0.5g cobalt, 300mg selenium
[2]Composition: 8u.i vitamin A, 2u.i vitamin D, 25u.i vitamin E, 2g vitamin K3, 1.75g vitamin B1, 6g vitamin B2, 25g vitamin PP niacin, 10g vitamin B5, 2g vitamin B6, 1g vitamin B9 folic acid, 100mg vitamin B7/biotin, 15mg vitamin B12, 250g choline, 50g iron, 8g copper, 80g manganese, 80g zinc, 1g, iodine , 0.5g cobalt, 250mg selenium
[3]Composition: 6u.i vitamin A, 1.5u.i vitamin D_3, 20u.i vitamin E, 1.5g vitamin K3, 1.5g vitamin B1, 5g vitamin B2, 25g vitamin PP niacin, 8g vitamin B5, 1.5g vitamin B6, 0.6g vitamin B9 folic acid, 80mg vitamin B7/biotin, 15mg vitamin B12, 200g choline, 40g iron, 6g copper, 80g manganese, 60g zinc, 1g, Iodine , 0.25g cobalt, 200mg selenium
ME: Mechanical energy; CF: Crude fibre; EE: Ether extract

VFI and live weights of broilers were taken weekly. Weekly weight gain and FCR were calculated. At week 6, two broilers per replicate were randomly selected, weighed, slaughtered, and dressed. Cold dressed weight was measured and expressed as a percentage of live weight. Each carcass was cut into breasts, drumsticks, thighs, wings, back and chest. The yields of the various cuts were expressed as a proportion of cold dressed weight. The breast, thighs, and drumsticks were further separated into skin, flesh and bone.

Each of the components was weighed and expressed as a percentage of the portion weight. Meat to bone ratios for the drumstick, thigh, and breast were calculated (Marcu *et al*., 2013).

The colour values of the CIELAB colour system – L*(lightness), a* (redness), and b*(yellowness) – were determined. Pictures of the breast muscles were taken 15 hours after slaughter, before freezing, using a digital Canon Powershot SX400IS, with 16 megapixels, under daylight conditions without a camera flash. Adobe Photoshop Extended CS6 was used to determine the colour of the breast meat (Yam & Papadakis, 2004). The chemical composition of breast meat was determined using the AOAC (1990) procedure for dry matter, crude protein, crude fat and ash contents. Remaining breast samples were frozen for assessment of physical and organoleptic attributes. The frozen breast meat samples were thawed at 3 °C for 24 hours. A sample of 150 g were taken from each breast muscle, placed in a tight PVC bag, cooked in a water bath heated to 100 °C for 30 minutes, and cooled at room temperature. The water released after cooking and cooling was separated manually, and the weight of the cooked meat was taken to calculate the cooking loss using the following formula:

$$\text{Cooking loss} = \left[\frac{\text{weight of sample before cooking} - \text{weight of sample after cooking}}{\text{Weight of sample before cooking}}\right] \text{ x } 100\ \%$$

The cooked samples were used to determine shear force. Using a hand-held coring device, three cores of 1.2 cm in diameter were removed from each breast parallel to the longitudinal orientation of the muscle fibre so that the shearing action was perpendicular to the longitudinal orientation of the muscle fibres. Shearing of the cores was done by a Chatillan Warner-Bratzler shear machine of 50 LB capacity from G-R Manufacturing, Manhattan, Kansas, USA (serial number 13419), calibrated to a cutting speed of 2 mm per second. Core shearing was done at the centre, avoiding possible hardening at the end of the cores. For each breast, shear force was reported as the average of three replicates.

One hundred and thirty consumer panellists were randomly selected from the University of Zimbabwe community. Samples were thawed, washed individually in clean water, cut into cubes of 1 cm x 1 cm x 0.5 cm, and packed in transparent double-layer polythene bags per treatment and tagged for identification. The bagged meat was boiled in water for 30 minutes, wrapped in aluminium foil, labelled with three-digit random numbers and placed in warmed chafing dishes. The samples were presented randomly to panellists in different orders (AMSA, 2012). Each panellist ranked the samples on colour, aroma, flavour, juiciness, taste, tenderness and overall liking on a five-point hedonic scale, 1 referring to ‘extremely like’ and 5 to ‘extremely dislike’ For abnormal chicken flavour intensity, the scoring varied from extremely strong to extremely weak. The panellists were trained to infer and record the score for each variable. The waiting period between sample tastings was 10 minutes. Distilled water was served to panellists to rinse their mouths between sub-sample assessments (AMSA, 2012).

All data were analysed using Statistical Analysis System version 9.3 (SAS, 2010). The general linear model (GLM) procedure of SAS was used to determine the effect of diet on VFI, live weight, FCR, dressing percentage, chemical and physical characteristics of broiler meat. Organoleptic scores were ranked (PROC RANK) before analysis with the GLM procedure. Post hoc tests on the means or mean ranks were conducted with the Tukey-adjusted LSD method. Principal component analysis used PROC PRINCOMP to identify the organoleptic parameters that contributed to the highest variation in observed scores of each of the organoleptic parameters. Initial component patterns were obtained with PROC FACTOR and rotated with ROTATE = VARIMAX in SAS. Kaiser’s Eigenvalue-greater-than-one rule was used to select the most important principal components (Kaiser, 1960).

Results and Discussion

An interaction was noted between age of birds and treatment on VFI, live weight gain, live weight and FCR (P <0.0001) (Tables 3, 4, 5 and 6). VFI was the same across treatments (P >0.05) for the starter feeding period (Weeks 1 and 2) (Table 3). Significant variations with increasing levels of *A. angustissima* in VFI were noted during the growing phase (Weeks 3 and 4) and finishing phase (Week 5 and 6) of feeding. In the grower feeding phase, feed intake from birds on the control diet was higher than the birds fed 10% leaf meal (P <0.05), but the same as the birds fed 5% (P >0.05). During the finishing period, birds from the 5% diet consumed more than those on the control and 10% diets (P <0.05). VFI of birds on the control and 5% diets was superior to that of the birds on the 10% diet by the end of the finishing period (P <0.05). Weekly weight gains (Table 4), live weights (Table 5), and FCR (Table 6) were the same across treatments during the starter phase (P >0.05). For both the grower and finisher phases, birds on the control and 5% leaf meal diet gained more and were heavier, with better FCRs than those on the 10% diet (P <0.05).

Table 3 Voluntary feed intake (g) of broilers on increasing levels of *Acacia angustissima* leaf meal diets at different ages of growth

Week	Treatment			Standard Error
	Control	5% A. A	10% A. A	
1	112.40[a]	113.60[a]	116.60[a]	18.2
2	274.20[a]	281.60[a]	297.00[a]	18.2
3	492.44[a]	475.76[ab]	428.32[b]	18.2
4	648.00[a]	666.40[a]	625.00[a]	18.2
5	767.99[a]	841.29[b]	735.72[a]	18.2
6	773.88[a]	765.61[a]	718.17[b]	18.2

[ab]Within a row, means without a common superscript differ (*P* <0.05)
A. A: *Acacia angustissima*

Table 4 Average live weight gain (g) of broilers on increasing levels of *Acacia angustissima* leaf meal diets at different stages of growth

Week	Treatment			Standard Error
	Control	5% A. A	10% A. A	
1	95.74[a]	92.84[a]	87.22[a]	17.24
2	173.88[a]	191.36[a]	196.46[a]	17.24
3	338.50[a]	305.84[a]	170.46[b]	17.24
4	403.40[a]	430.00[a]	292.20[b]	17.24
5	362.40[a]	416.40[a]	320.00[a]	17.24
6	356.00[a]	354.00[a]	286.00[b]	17.24

[ab]Within a row, means without a common superscript differ (*P* <0.05)
A. A: *Acacia angustissima*

Table 5 Average live weights (g) of broilers on increasing levels of *Acacia angustissima* leaf meal diets at different stages of growth

Week	Treatment			Standard Error
	Control	5% A. A	10% A. A	
1	138.02[a]	112.82[a]	129.34[a]	34.36
2	311.90[a]	325.82[a]	326.80[a]	34.36
3	650.50[a]	631.70[a]	497.26[b]	34.36
4	1053.60[a]	1061.60[a]	789.20[b]	34.36
5	1416.00[a]	1418.00[a]	1109.20[b]	34.36
6	1771.60[a]	1772.80[a]	1401.60[b]	34.36

[ab]Within a row, means without a common superscript differ (*P* <0.05)
A. A: *Acacia angustissima*

Table 6 Feed conversion ratios of broilers on increasing levels of *Acacia angustissima* leaf meal diets at different stages of growth

Week	Treatment			Standard Error
	Control	5% leaf meal	10% leaf meal	
1	1.18[a]	1.22[a]	1.33[a]	0.102
2	1.73[a]	1.47[a]	1.51[a]	0.102
3	1.48[a]	1.56[a]	2.15[b]	0.102
4	1.61[a]	1.56[a]	2.51[b]	0.102
5	2.15[a]	2.09[a]	2.30[a]	0.102
6	2.18[a]	2.31[a]	2.52[b]	0.102

[ab]Within a row, means without a common superscript differ (*P* <0.05)

During the starter phase of growth, intake was not affected by treatment, implying the possibility of using *A. angustissima* leaf meal in broiler starter diets without negative effects on performance. While it is generally believed that broilers eat to satisfy energy requirements (Zijlstra *et al*., 1999; Leeson, 2002; Mbajiorgu *et al*., 2011), Taylor-Pickard & Spring (2008) indicated that broilers are able to do this only after two weeks old when the digestive systems have reached maturity. Mbarjiorgu *et al.* (2011) also reported that the effect of metabolizable energy (ME) on intake seem to have a greater effect during the growing and finishing phases of growth. Since maintenance requirements are a function of bodyweight and ME requirements for weight gain are a function of age of birds (Sakamura, 2004), it is also possible that the ME requirements and protein needs for weight gain were easily met at the given intake levels. As a result, weekly weights of the birds were the same across the three treatments by the end of the first two weeks, implying adequacy of nutrients across the three diets. Since VFI determines nutrient intake (Zijlstra *et al*., 1999; Mbarjiorgu *et al*., 2011), the results imply a possibility of using leaf meal in broiler starter diets without affecting nutrient intake and broiler growth performance.

Higher VFI during the growing and finisher phases of feeding also translated to superior live weight and weight gain for birds on the control and 5% leaf meal-based diets. According to Scott (2005), growth rate is influenced by feed intake. High positive correlations between VFI and growth rate were reported by Ferket & Gernat (2006). The higher weights during the growing and finishing phases for birds on the 5% and control diets could also be attributed to better FCRs associated with the two diets, compared with the 10% leaf meal-based diet, possibly because of its higher crude fibre content. It is also possible that during the growing and finishing phases of growth, inclusion of leaf meal had a nutrient diluting effect, given its fibrous nature. Since birds eat to satisfy their energy needs (Mbarjiorgu *et al*., 2011; Rosa *et al*., 2007), feed intake increased to cater for these needs. At 5% inclusion the dilution effect might not have been severe enough to cause insufficiency of nutrients compared with the 10% diet. Under such nutritional conditions, birds overeat in compensation (Richards & Proszkowiec-Weglarz, 2007; Uchegbu *et al*., 2009; McDonald *et al*., 2010; Sahraei, 2012). In addition, high levels of fibre might have increased the bulkiness at 10% inclusion, in which case gastrointestinal capacity becomes the limiting VFI factor. The increase in the concentration of condensed tannins may have contributed to the lowered intake at 10% inclusion. Tanniferous ingredients confer a bitter taste to the feed (Frutos *et al.,* 2004; Onyimonyi *et al*., 2009; Medugu *et al*., 2010; Onunkwo & George, 2015), but given the inability of broilers to detect taste, and the fibrous nature of the leaf meal, it is likely that feed intake was highly controlled by the gastrointestinal capacity of the broilers (McDonald *et al*., 2010).

Table 7 shows the carcass weight, dressing percentage and proportional yield of the various parts of broilers fed different levels of the leaf meal. Treatment had no effect on dressing percentage. However, 10% inclusion significantly reduced carcass weight (*P* <0.05). Inclusion of *A. angustissima* leaf meal had no influence (*P* >0.05) on the proportional yield of abdominal fat, wings, back, chest portions, entire drumstick and meat to bone ratio in thighs and drumsticks (*P* >0.05). Breast meat to bone ratio decreased with increasing levels of *A. angustissima* leaf meal. Birds on 10% diet had significantly lower breast flesh with higher proportional yield of breast bone and thigh bone than birds on the control and 5% diets. Broilers fed diets with leaf meal had higher thigh and breast skin yield and lower drumstick skin than the control (*P* <0.05).

The decrease in the weight of drumstick skin is a favourable response to reducing the economic losses associated with skin removal during processing and cooking. It also supports the expectations of today's health conscious society whereby skin from chicken meat is removed because of wax diesters and unusual triglycerides, which are bad for human health (Tinôco *et al*., 2003). Thus a decline in proportion of drumstick skin on addition of *A. angustissima* leaf meal increases the nutritional and economic value of the portion. The significant increase in the breast and thigh skin proportion could lead to a loss of economic value of those parts with increasing levels of leaf meal.

Table 7 Carcass yield of broilers fed increasing levels of *Acacia angustissima*

Variable (%)	**Control**	**5 % A. A**	**10% A. A**	**SE**	***P* Value**
Carcass weight	1476.45^{a}	1390.35^{a}	1060.10^{b}	47.659	<0.0001
Dressing %	70.00	68.00	65.00	1.700	0.1397
Abdominal fat	2.08	1.84	1.81	0.158	0.4480
Entire drumstick	12.99	13.21	13.93	0.301	0.0930
Drumstick skin	11.57^{a}	8.84^{b}	7.92^{b}	0.840	0.0110
Drumstick flesh	61.31	63.50	64.72	0.993	0.0650
Drumstick bones	26.50	26.70	26.98	0.691	0.8880
Drumstick meat : bone	2.35	2.38	2.41	0.084	0.8880
Entire Thigh	14.63^{a}	15.07^{ab}	15.97^{b}	0.262	0.0040
Thigh skin	11.50^{a}	14.31^{b}	13.71^{b}	0.633	0.0100
Thigh flesh	69.63	71.40	68.72	1.211	0.2930
Thigh bones	16.49^{a}	18.78^{a}	23.47^{b}	0.867	<0.0001
Thigh meat: bone	3.98	4.29	3.89	0.170	0.2320
Entire Breast	36.83^{a}	35.44^{a}	32.69^{b}	0.734	0.0020
Breast skin	5.37^{a}	7.03^{b}	7.95^{b}	0.345	<0.0001
Breast flesh	77.04^{a}	74.09^{a}	68.20^{b}	0.968	<0.0001
Breast bone	16.49^{a}	18.78^{a}	23.47^{b}	0.871	<0.0001
Breast meat : bone	4.77^{a}	4.11^{a}	2.94^{b}	0.254	<0.0001
Wings	11.75	11.20	11.68	0.243	0.2160
Back	11.64	11.60	12.19	0.491	0.6330
Chest	5.69	5.17	5.18	0.215	0.1710

^{abc} Within a row, means without a common superscript differ (P <0.05)
A. A: *Acacia angustissima*

The increase in the proportion of thighs with the addition of leaf meal could be related to the decrease in carcass weight with increasing levels of the leaf meal. According to Faria *et al*. (2010), for parts that are involved in locomotion, yield is increased as carcass weight is reduced, because the bones associated with movement develop early compared with other parts. The inclusion of leaf meal mostly affected the thigh and breast components, possibly due to higher nutritional requirements by the breast and thigh muscles.

At 5% inclusion, the leaf meal did not negatively affect breast muscle accretion. The significant decline in breast yield and meat to bone ratio at 10% inclusion indicates that the birds could not attain the desired breast muscle growth from the diet. This could be a result of nutritional inefficiencies associated with leaf meal presence at 10%. For instance, the diet may have failed to meet the high nutritional requirements required for maximal breast meat yield (Relandeau & Le Bellogo, 2004) owing to the effect of the fibrous nature of *A. angustissima* leaf meal on supply parameters such as VFI. Inclusion of the leaf meal may also have interfered with the availability and metabolism of lysine. Since the breast has specific lysine requirements for meat deposition (Labadan *et al*., 2001; Rostagno *et al*., 2007), any negative effect on its utilization would translate to inferior breast yield. It is also possible that at 10% inclusion, nutrients that would normally be designated to growth of late maturing tissues such as breast were used by supply organs such as the stomach and intestine for more important physiological supply functions (Ncube *et al*., 2017ab). The inclusion of the leaf meal may also have created a nutritional environment in which the breast tissue was catabolized (Noy & Sklan, 1998; Halevy *et al*., 2006) to supply nutrients required for maintenance of supply organs, resulting in inferior breast meat yield from the 10% group (Vieira & Angel, 2012).

There were no significant differences in the chemical composition of the breast meat (P >0.05) (Table 8). Physical analysis showed significantly lower lightness and higher shear force (P <0.05) of breast meat from broilers fed diets with 10% leaf meal. The cooking loss and yellowness were elevated in breasts from diets with leaf meal. The physical characteristics of the meat were maintained at 5% inclusion of the leaf meal. At 10% inclusion, the decline in meat lightness value, coupled with the increase in the yellowness, is indicative of a shift from the normal broiler meat colour. The lightness value from the broilers fed 10% was outside the expected range (Petracci *et al*., 2004). The meat colour shift on addition of the leaf meal could be explained by the presence of pigments. Legume leaf meals contain oxycarotenoids (D'Mello *et al*., 1987). Since colour is one of the most important parameters affecting initial purchase decisions (Resurreccion, 2003), inclusion of the leaf meal at 10% could have a negative effect on consumer buying decisions (Wilkins *et al*., 2000; Qiao *et al*., 2001; Perez-Alvarez & Fernandez-Lopez, 2012).

Table 8 Chemical and physical characteristics of breast meat of broilers fed graded levels of *A. angustissima* leaf meal

Variable	Control	5% A. A	10% A. A	*P* value
Chemical parameters				
Dry matter (%)	27.48 ± 0.91	27.79 ± 1.21	27.02 ± 1.59	0.2716
Crude protein (%)	25.71 ± 1.35	26.86 ± 1.47	25.66 ± 0.87	0.0699
Crude fat (%)	2.07 ± 1.30	1.12 ± 0.69	1.42 ± 0.60	0.0773
Ash (%)	1.13 ± 0.64	1.24 ± 0.54	1.26 ± 0.59	0.8824
Physical parameters				
Lightness (L*)	53.66 ± .062[a]	50.33 ± .062[a]	49.23 ± 1.062[b]	0.0172
Redness (a*)	10.53 ± 0.615	11.59 ± .615	10.15 ± 0.615	0.2467
Yellowness (b*)	12.93 ± .868[a]	18.25 ± .868[b]	19.97 ± 0.868[b]	<0.0001
Shear force (N)	14.14 ± .088[a]	14.19 ± .088[a]	14.54 ± 0.088[b]	0.0060
Cooking loss (%)	5.95 ± 0.411[a]	6.53 ± .411[ab]	7.64 ± 0.411[b]	0.0225

[abc] Within a row, means without a common superscript differ (P <0.05)
A. A = *Acacia angustissima*

Cooking loss refers to the water percentage that is lost in cooking (Al-Owaimer *et al*., 2014). Results from this study indicate that increasing levels of leaf meal made the broiler meat drier, and this is not a desirable effect. High cooking loss also implies the poor ability of the meat to hold water during processing and storage (Petracci & Cavani, 2012; Abu *et al*., 2015). High cooking loss from the birds fed 10% is also associated with high nutrient loss during cooking (Al-Owaimer *et al*., 2014). As a result, the breast meat of broilers fed 10% diets also became tougher.

Figure 1 and 2 show plots of the rotated loading matrix for the principal components, a visual relationship between attributes and treatment. As shown in Figures 1 and 2, taste varied, together with overall liking. In Figure 1, taste was the most important component across determining overall liking of meat in principal component 1, the horizontal axis. There was no established pattern for attributes along principal components 2 and 3, showing wide variations in scoring by the population of study. The correlations between taste and overall liking were 0.529, 0.606, and 0.607 for the control, 5%, and 10% diets, respectively. These results show that taste was strongly related to overall liking. This implies that taste was more important for the population of study than other attributes. As such, any treatment with negative effects on broiler meat taste is likely to affect repeat purchasing decisions by consumers in the current population. The positive correlation between taste and overall liking implies that an increase in meat taste led to increased overall preference of the meat. Concurring with the current results, Horsted *et al.* (2011) reported a significant correlation between overall liking and scores of taste in broiler meat.

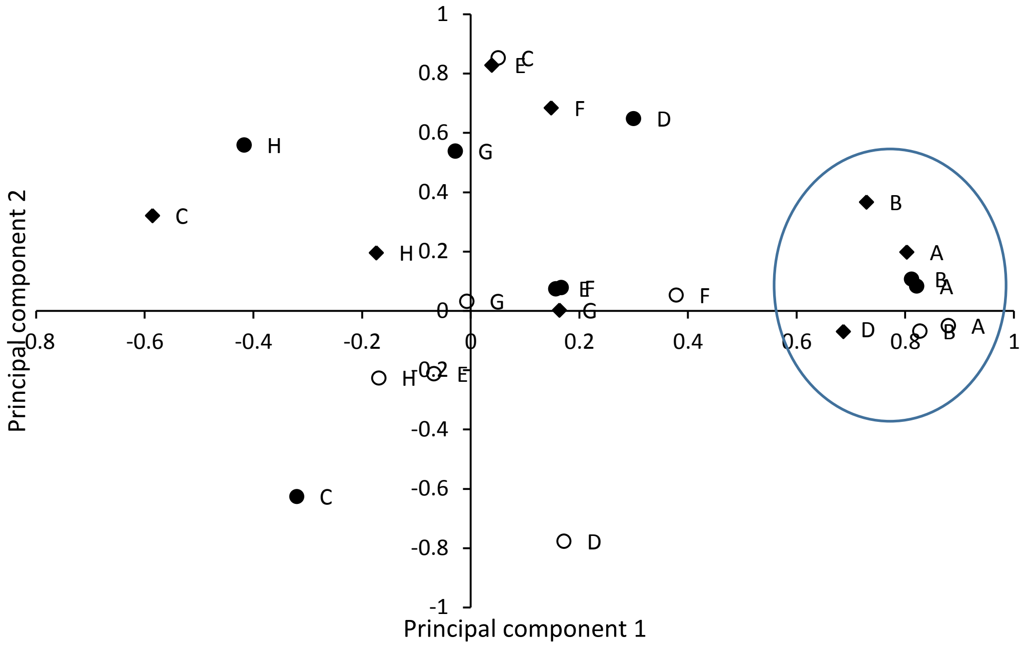

Figure 1 Component patterns (rotated) for principal components 1 and 2

Key: control diet (○), diet with 5% A. angustissima (•) and diet with 10% A. angustissima (♦) A = Taste; B = Overall liking; C = Abnormal flavour intensity; D = flavour; E = Juiciness; F = Tenderness; G = Odour, H = Colour)

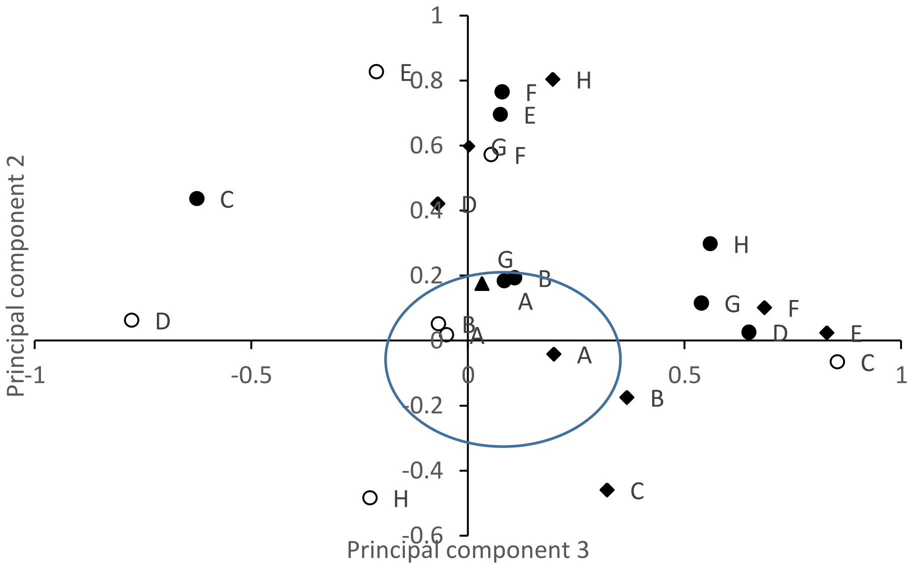

Figure 2 Component patterns (rotated) for principal components 2 and 3

Key: control diet (○), diet with 5% A. angustissima (•) and diet with 10% A. angustissima (♦) A = Taste; B = Overall liking; C = Abnormal flavour intensity; D= flavour; E = Juiciness; F = Tenderness; G = Odour, H = colour

Further analysis of the organoleptic scores indicated that treatment had an effect on the degree of consumer preference in all organoleptic characteristics (P <0.05) (Table 9). The preference for meat colour, juiciness and tenderness declined with increasing levels of leaf meal (P <0.05). The intensity of the abnormal broiler flavour increased with increasing leaf meal content in the diet (*P* <0.05). The significant decline in the scores for aroma, flavour and taste with increasing leaf meal content (*P* <0.05) indicated increased preference with increasing levels of the leaf meal. Juiciness, tenderness and overall liking scores for the control and 5% diets did not differ (*P* >0.05), but were better than those from the 10% group (*P* <0.05).

Table 9 Average organoleptic scores for birds fed graded levels of *Acacia angustissima* leaf meal

Organoleptic characteristic	Average treatment scores		
	Control	5% Leaf meal	10% Leaf meal
Colour	1.48^{a}	2.18^{b}	3.43^{c}
Aroma	3.38^{a}	2.35^{b}	1.89^{c}
Flavour	3.78^{a}	2.71^{b}	2.02^{c}
Abnormal flavour intensity	4.18^{a}	3.38^{b}	2.32^{c}
Taste	3.19^{b}	2.60^{a}	2.38^{a}
Juiciness	2.79^{a}	2.93^{a}	3.45^{b}
Tenderness	2.50^{a}	2.55^{a}	3.19^{b}
Overall liking	2.24^{a}	2.42^{a}	2.97^{b}

^{abc} Within a row, means without a common superscript differ (*P* <0.05)

The decline in the aroma, flavour and taste scores indicates a possible enhancement of those organoleptic attributes with increasing levels of the leaf meal in the diet. It was interesting that the consumers noted an increase in intensity of abnormal flavour with increasing leaf meal, but still rated flavour better as the level of leaf meal in the diet increased. The increase in the abnormal flavour seems to explain the enhanced flavour from broilers fed the leaf meal-based diets. According to Melton (1983), feeding of forages to animals can alter meat flavour as a result of changes in the fatty acid composition (Nuernberg *et al*., 2005). Because an increase in *A. angustissima* levels improved the taste scores, the leaf meal could play a role in improving the acceptability of broiler meat. Taste was also the most important sensory attribute influencing overall liking of meat.

The increase in the intensity of abnormal chicken flavour on inclusion of *A. angustissima* in broiler diets was expected to have a negative effect on the flavour rating of the meat. However, the opposite was true in this study, possibly implying preference towards the detected abnormal flavour. This preference might be related to the gamey taste of meat from animals fed plant-based diets. Consistent with this study, Jang *et al.* (2008) reported enhancement of flavour after feeding a mixture of herbal tree extracts to broilers. Aderinola *et al.* (2013) also reported enhanced taste, aroma and flavour of *M. oleifera*-fed broilers. While taste was enhanced, even at 10% inclusion of the leaf meal, it is possible that the reported increase in cooking loss resulted in inferior overall liking scores of the 10% group. According to Michalczuk *et al*. (2014), high meat cooking loss has an adverse effect on sensory perception as it reduces juiciness.

Conclusion

For optimum yield of parts of economic importance, chemical, physical and organoleptic characteristics in broiler meat, up to 5% *A. Angustissima* leaf meal should be included in broiler diets. At 10% inclusion, breast meat percentage declined. As dietary leaf meal addition increased, the meat grew tougher and cooking losses increased. The study concluded that up to 5% *A. angustissima* leaf meal inclusion had no negative effects on performance yield of carcass parts and meat quality characteristics of broilers.

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Authors' Contributions

SN did the initial study design, collected all data and drafted first draft, which was reviewed by THE, EVIC and PTS. TEH and PTS also helped in the designing of the study. TEH and EVIC analysed and interpreted the data

Conflict of Interest Declaration

There are no conflicts of interest.

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