

Research Article

Sun-Dried Versus Blanched Avocado Leaf Meal: Effects on Broiler Chickens' Carcass Traits, Meat Quality, and Sausage Sensory Attributes

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Abstract

This study evaluated the effects of dietary inclusion of sun-dried and blanched avocado (*Persea americana*) leaf meal (ALM) on carcass characteristics, non-carcass components, meat quality parameters, and sensory attributes of fresh meat and processed sausages in broiler chickens. One hundred and eighty broiler chickens were assigned to nine dietary treatments: control (T1), sun-dried ALM at 0.25% (T2), 0.50% (T3), 0.75% (T4), and 1.00% (T5); and blanched ALM at 0.25% (T6), 0.50% (T7), 0.75% (T8), and 1.00% (T9). At 56 days, birds were slaughtered for evaluation of carcass traits, organ weights, meat quality (pH, water-holding capacity, cooking loss, chilling loss), and sensory evaluation of fresh meat and sausages using a 9-point hedonic scale. Results showed significant treatment effects ($p < 0.05$) on live weight, defeathered weight, and breast pH at 0 and 24 hours post-mortem. Live weight ranged from 2.40 kg (T7) to 3.07 kg (T6). Breast pH at 0 h ranged from 7.24 (T1) to 7.55 (T7), while 24 h pH ranged from 6.50 (T2, T7) to 7.51 (T8). Water-holding capacity showed significant variation ($p < 0.001$), ranging from 14.00% (T7) to 42.00% (T5). Non-carcass organ weights showed no significant differences ($p > 0.05$), indicating no pathological organ enlargement. Fresh meat sensory attributes showed no significant differences across treatments ($p > 0.05$). However, sausage samples exhibited significant variations ($p < 0.001$) in all sensory attributes, with T3, T4, T8, and T9 recording the highest overall acceptability scores (9.00). The severe pH elevation (7.51) in T8 at 24 h post-mortem indicated Dark, Firm, and Dry (DFD) meat condition, attributed to pre-slaughter stress from persin toxicity. Dietary inclusion of sun-dried ALM at 0.5-1.0% and blanched ALM at 0.5-0.75% maintained carcass characteristics and fresh meat sensory quality comparable to control, while significantly enhancing water-holding capacity and sausage sensory acceptability. However, 0.75% blanched ALM induced DFD meat condition, warranting caution at this inclusion level. Both processing methods produced nutritionally viable ALM, with sun-dried ALM at 1.0% and blanched ALM at 0.5-0.75% recommended for optimal meat quality and processed product acceptability.

Keywords

Avocado Leaf Meal, Broiler Chickens, Carcass Characteristics, Chicken Sausage, DFD Meat, Meat Quality, Sensory Evaluation

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1. Introduction

The global poultry industry continues to expand in response to increasing consumer demand for high-quality, safe, and affordable animal protein [30]. Broiler chicken production, in particular, has emerged as a key contributor to meeting this demand due to its efficiency in converting feed to meat, short production cycles, and widespread consumer acceptability [41]. However, the industry faces significant challenges, including rising feed costs, consumer concerns about synthetic additives, and increasing demand for products with enhanced nutritional profiles and sensory qualities [3, 4].

In response to these challenges, there has been growing interest in natural feed additives derived from plant sources as alternatives to synthetic growth promoters and antibiotics [35]. These phytogetic feed additives offer multifunctional benefits, including antioxidant, antimicrobial, and immunomodulatory properties that can positively influence animal health, performance, and product quality [5]. Among the promising candidates is avocado (*Persea americana*) leaf meal (ALM), an agro-industrial by-product that is often discarded despite its rich phytochemical profile.

Avocado leaves contain diverse bioactive compounds, including flavonoids, tannins, saponins, and phenolic acids, which have been associated with various biological activities relevant to meat quality enhancement [2, 19]. These compounds possess antioxidant properties that can reduce oxidative stress in muscle tissues, thereby improving oxidative stability, extending shelf life, and preserving sensory attributes such as flavour, colour, and texture [36, 41]. Additionally, the antimicrobial properties of these phytochemicals may contribute to reduced microbial spoilage and improved food safety [49].

Carcass characteristics, including live weight, dressing percentage, and cut-up part yields, are fundamental measures of production efficiency and economic value in broiler operations [13, 33]. These traits are influenced by genetic factors, nutrition, and management practices. Dietary manipulation using phytogetic additives has been shown to affect carcass composition by modulating nutrient utilization, lipid metabolism, and protein deposition [16, 51].

Meat quality encompasses a range of attributes that determine consumer satisfaction and product marketability, including appearance, texture, juiciness, flavor, and water-holding capacity (WHC) [20, 34]. WHC is particularly critical, as it affects product yield during processing and cooking, as well as sensory perception of juiciness and tenderness [11, 21]. Post-mortem pH decline is another major determinant of meat quality, influencing colour, texture, and shelf life [1, 44].

The processing of raw meat into value-added products such as sausages offers opportunities for product diversification, extended shelf life, and increased profitability [32]. However, sausage quality is influenced by the intrinsic properties of the raw meat, which are in turn shaped by the birds' dietary history [17, 23]. Dietary interventions using phytogetic additives can

indirectly affect processed meat quality by altering muscle lipid composition, antioxidant status, and protein functionality prior to slaughter [15, 50].

The efficacy of ALM as a feed additive is influenced by processing methods. Sun-drying, a traditional and cost-effective method, relies on solar energy to dehydrate plant materials, preserving heat-stable compounds while concentrating anti-nutritional factors [48]. Blanching involves brief heat treatment that leaches water-soluble anti-nutrients while potentially increasing the bioavailability of thermostable compounds [8, 37]. These processing-induced changes in phytochemical profiles may differentially affect meat quality outcomes.

Despite growing interest in phytogetic feed additives, limited information exists on the comparative effects of differently processed ALM on carcass characteristics, meat quality, and sensory attributes of both fresh meat and processed products in broiler chickens. This study was therefore designed to evaluate the effects of graded levels of sun-dried and blanched ALM on carcass traits, non-carcass components, meat quality parameters, and sensory acceptability of fresh meat and chicken sausages, with the aim of identifying optimal processing methods and inclusion levels for enhanced product quality.

2. Materials and Methods

2.1. Study Location and Experimental Design

The experiment was conducted at a dedicated poultry facility located within Ado-Ekiti, Ekiti State, Nigeria (Latitude: 7.623° N, Longitude: 5.221° E; approximate elevation: 455 m above sea level). A total of 200 unsexed day-old broiler chicks were sourced from a certified commercial hatchery and reared under uniform management conditions for the first four weeks, receiving a nutritionally complete commercial broiler starter ration devoid of ALM.

At 28 days post-hatch, the chicks were systematically randomized into nine dietary treatment groups, each replicated three times with seven birds per replicate pen. The experimental dietary treatments comprised: T1 (control, unmodified basal diet), T2 (sun-dried ALM at 0.25%), T3 (sun-dried ALM at 0.50%), T4 (sun-dried ALM at 0.75%), T5 (sun-dried ALM at 1.00%), T6 (blanched ALM at 0.25%), T7 (blanched ALM at 0.50%), T8 (blanched ALM at 0.75%), and T9 (blanched ALM at 1.00%). Birds had continuous access to experimental diets and clean drinking water throughout the trial period (days 28-56).

2.2. Slaughter Procedure and Carcass Evaluation

On the final day of the experiment (day 56), three birds were randomly selected from each replicate group following

an overnight feed withdrawal to standardize gut content [19]. Each bird was weighed individually using a calibrated digital scale prior to slaughter. Slaughtering was performed via cervical dislocation [25], followed by complete exsanguination. The carcasses were subsequently scalded, defeathered, and eviscerated in accordance with standardized poultry processing protocols [27].

The following carcass parameters were recorded: live weight (kg), bled weight (kg), defeathered weight (kg), eviscerated weight (kg), cut-up part weights (g: head, shank, wing, thigh, drumstick, breast, back, neck, ribs). Dressing percentage was calculated as: Dressing Percentage (%) = (Dressed Carcass Weight / Live Weight) × 100.

2.3. Non-Carcass Components

The following non-carcass organs were weighed (g) immediately after evisceration: heart, liver, gizzard, proventriculus, oil gland, and spleen. Organ weights were recorded using a calibrated digital balance.

2.4. Meat Quality Determinations

2.4.1. pH Determination

The pH of raw chicken breast samples was measured to assess post-mortem muscle quality. Approximately 10 g of breast muscle was homogenized at 20°C, and pH was measured using a digital pH meter (Model HI902, Hanna Instruments, Germany) equipped with a penetration electrode. Measurements were taken at room temperature, and the final pH value was calculated as the mean of three independent readings per sample. pH readings were taken at two time points: warm pH (pH₁) measured immediately after evisceration at approximately 37°C, and cold pH (pH₂) measured after freezing samples at -20°C for 24 hours and thawing at room temperature [31].

2.4.2. Water-Holding Capacity (WHC)

WHC was determined using the method of Trout [43]. A 0.5 g sample was placed between two filter papers, which were subsequently sandwiched between two glass sheets. A weight of 4.0 kg was applied for 5 minutes. Moisture released from the sample was absorbed by the filter paper, which was then dried. The wetted area was traced and measured. WHC was calculated as: WHC (%) = (Area of borderline – Area of meat) / Area of borderline × 100.

2.4.3. Chilling Loss

Carcasses were chilled at 4°C for 24 hours after recording warm carcass weights. Chilling loss was calculated as the percentage difference between warm and chilled carcass weights [6]. Chilling Loss (%) = [(Warm carcass weight – Chilled carcass weight) / Warm carcass weight] × 100.

2.4.4. Cooking Loss and Cook Yield

Cooking loss was evaluated following the procedure outlined by Yu et al. [47]. Chicken breast samples were cooked to an internal temperature of 72°C and allowed to cool at room temperature. Cooking loss was expressed as a percentage of weight before cooking [9]: Cooking Loss (%) = [(Raw weight – Cooked weight) / Raw weight] × 100. Cook Yield (%) = (Cooked weight / Raw weight) × 100.

2.5. Sensory Evaluation of Fresh Meat

Sensory evaluation of cooked chicken samples was conducted in individual booths within the Sensory Laboratory of the Department of Animal Science, Faculty of Agricultural Sciences, Ekiti State University, Ado-Ekiti, Nigeria. The evaluation employed a 9-point hedonic scale [27]. Ten trained panelists evaluated appearance, juiciness, tenderness, texture, aroma, taste, and overall acceptability. Chicken samples were uniformly cut into rectangular shapes and presented on coded plates labeled with three-digit random numbers for blind testing.

2.6. Chicken Sausage Preparation and Evaluation

2.6.1. Sausage Formulation

Three birds were randomly selected from each dietary treatment for sausage production. After slaughter, defeathering, and evisceration, the breast and thigh muscles were deboned, skinned, cleaned, and weighed. The meat was chopped and blended with ingredients (Table 1). The mixture was placed on parchment paper layered over aluminum foil, formed into candy-shaped cylinders, weighed, and sealed.

2.6.2. Cooking Procedure

Wrapped samples were placed in boiling water maintained at 60°C for 20 minutes. Post-cooking, sausages were cooled to room temperature (approximately 25°C) and sliced into uniform 2 cm rectangular samples for sensory evaluation.

2.6.3. Sensory Evaluation of Sausages

Chicken sausage samples were evaluated using the same 9-point hedonic scale methodology as for fresh meat, assessing appearance, juiciness, tenderness, texture, aroma, taste, and overall acceptability.

Table 1. Formulated Chicken Sausage Composition.

Ingredient	Composition (g/100g)
Coriander Leaves	2.5
Ginger paste	2.5

Ingredient	Composition (g/100g)
Garlic paste	2.5
Cameroon Pepper	2.5
Chili pepper	2.5
Maggi Seasoning	4.5
Thyme	2.5
White pepper	2.5
Curry Powder	2.5
Cinnamon Powder	2.5
Oregano Powder	2.5
Salt	0.5
Egg white	70.0
Total	100

2.7. Statistical Analysis

Data were subjected to one-way analysis of variance (ANOVA) using a completely randomized design. Significant differences between treatment means were separated using Duncan's Multiple Range Test at a 5% significance level. Sen-

sory data were analyzed using one-way ANOVA with panelists as blocks. All statistical analyses were performed using SPSS software (version 25.0, IBM Corp., Armonk, NY, USA). Results are presented as mean \pm standard error of the mean (SEM).

3. Results

3.1. Carcass Characteristics

Table 2 presents the carcass characteristics of broiler chickens fed the experimental diets. Live weight ranged from 2.40 \pm 0.06 kg (T7) to 3.07 \pm 0.23 kg (T6), with significant differences among treatments ($p = 0.038$). T6 (0.25% blanched ALM) and T5 (1.00% sun-dried ALM) recorded the highest live weights, while T7 (0.50% blanched ALM) and T8 (0.75% blanched ALM) had the lowest.

Defeathered weight ranged from 2.20 \pm 0.06 kg (T7) to 2.80 \pm 0.15 kg (T6), with significant differences observed ($p = 0.047$). Breast pH at 0 hours post-mortem ranged from 7.24 \pm 0.06 (T1) to 7.55 \pm 0.04 (T7), with significant differences ($p < 0.001$). Breast pH at 24 hours post-mortem ranged from 6.50 \pm 0.03 (T2) and 6.50 \pm 0.27 (T7) to 7.51 \pm 0.70 (T8), with significant differences ($p < 0.001$). T8 exhibited markedly elevated 24 h pH (7.51) compared to all other treatments, indicating Dark, Firm, and Dry (DFD) meat condition.

Table 2. Carcass Characteristics of Broiler Chickens Fed Experimental Diets.

Parameter	T1	T2	T3	T4	T5	T6	T7	T8	T9	p-value
Live wt (kg)	2.63 \pm 0.12 ^a	2.83 \pm 0.17 ^a	2.87 \pm 0.13 ^a	2.50 \pm 0.15 ^b	3.00 \pm 0.15 ^a	3.07 \pm 0.23 ^a	2.40 \pm 0.06 ^b	2.43 \pm 0.03 ^b	2.60 \pm 0.19 ^a	0.038
Bled (kg)	2.37 \pm 0.28	2.53 \pm 0.19	2.67 \pm 0.13	2.43 \pm 0.23	2.63 \pm 0.09	2.87 \pm 0.18	2.30 \pm 0.06	2.30 \pm 0.06	2.50 \pm 0.10	0.302
Defeathered (kg)	2.37 \pm 0.09 ^{ab}	2.57 \pm 0.15 ^{ab}	2.47 \pm 0.13 ^{ab}	2.30 \pm 0.15 ^b	2.73 \pm 0.12 ^{ab}	2.80 \pm 0.15 ^a	2.20 \pm 0.06 ^c	2.23 \pm 0.03 ^c	2.37 \pm 0.22 ^{ab}	0.047
Eviscerated (kg)	2.03 \pm 0.17	2.03 \pm 0.22	1.90 \pm 0.21	1.67 \pm 0.07	1.80 \pm 0.21	1.80 \pm 0.12	2.00 \pm 0.00	1.97 \pm 0.35	1.92 \pm 0.06	0.645
Breast pH (0 h)	7.24 \pm 0.06 ^b	7.47 \pm 0.02 ^a	7.40 \pm 0.06 ^a	7.42 \pm 0.08 ^a	7.50 \pm 0.06 ^a	7.49 \pm 0.01 ^a	7.55 \pm 0.04 ^a	7.41 \pm 0.08 ^{a^b}	7.37 \pm 0.04 ^{a^b}	<0.001
Breast pH (24 h)	6.73 \pm 0.01 ^b	6.50 \pm 0.03 ^b	6.79 \pm 0.10 ^b	6.59 \pm 0.05 ^b	6.68 \pm 0.07 ^b	6.57 \pm 0.06 ^b	6.50 \pm 0.27 ^b	7.51 \pm 0.70 ^a	6.69 \pm 0.01 ^{ab}	<0.001

a,b,c: means within a row with different superscripts differ significantly ($p < 0.05$)

3.2. Non-Carcass Characteristics

Table 3 presents the non-carcass characteristics of broiler chickens. Heart weight ranged from 0.20 \pm 0.00 g (T7) to 0.33 \pm 0.07 g (T4), with no significant differences ($p = 0.750$). Liver weight ranged from 1.03 \pm 0.03 g (T2) to 1.40 \pm 0.21 g

(T6), approaching significance ($p = 0.093$). Gizzard weight ranged from 1.37 \pm 0.07 g (T7) to 1.77 \pm 0.17 g (T4), with no significant differences ($p = 0.104$). Proventriculus, oil gland, and spleen weights showed no significant differences across treatments ($p > 0.05$).

3.3. Meat Quality Parameters

Table 4 presents the meat quality parameters of broilers under different dietary treatments. Cooking loss ranged from $4.00 \pm 0.00\%$ (T4, T8) to $5.33 \pm 0.67\%$ (T2) and $5.33 \pm 0.33\%$ (T6), with no significant differences ($p = 0.483$). Chilling loss ranged from $8.00 \pm 0.00\%$ (T8) to $10.33 \pm 0.67\%$ (T3) and $10.33 \pm 0.88\%$ (T6), with no significant differences ($p = 0.527$). Water-holding capacity (WHC) showed considerable and significant variation ($p < 0.001$), ranging from $14.00 \pm$

0.00% (T7) to $42.00 \pm 0.58\%$ (T5). T2 (41.67%), T3 (41.67%), and T5 (42.00%) recorded the highest WHC values, which were significantly higher than T1 (16.33%), T6 (16.83%), T7 (14.00%), T8 (24.67%), and T9 (17.00%). T4 (27.67%) and T8 (24.67%) showed intermediate values. Initial pH (pH_i) ranged from 7.00 ± 0.00 (T1) to 8.00 ± 0.00 (T7), with no significant differences ($p = 0.406$). Final pH (pH₂) ranged from 6.33 ± 0.33 (T4) to 6.90 ± 0.10 (T8, T9), with no significant differences ($p = 0.837$).

Table 3. Non-Carcass Characteristics of Broiler Chickens Fed Experimental Diets.

Parameter	T1	T2	T3	T4	T5	T6	T7	T8	T9	p-value
Heart	0.20±0.06	0.27±0.03	0.30±0.06	0.33±0.07	0.30±0.00	0.27±0.07	0.20±0.00	0.30±0.10	0.30±0.06	0.750
Liver	1.13±0.13	1.03±0.03	1.07±0.12	1.10±0.10	1.13±0.09	1.40±0.21	1.17±0.09	1.10±0.15	1.37±0.15	0.093
Gizzard	1.37±0.18	1.47±0.07	1.67±0.17	1.77±0.17	1.67±0.09	1.53±0.03	1.37±0.07	1.63±0.20	1.47±0.20	0.104
Proventriculus	0.30±0.10	0.20±0.06	0.30±0.06	0.20±0.06	0.30±0.06	0.30±0.06	0.30±0.06	0.27±0.03	0.33±0.03	0.574
Oil Gland	0.30±0.10	0.33±0.07	0.40±0.00	0.40±0.06	0.53±0.19	0.43±0.03	0.50±0.06	0.43±0.09	0.47±0.03	0.092
Spleen	1.13±0.22	1.29±0.21	1.01±0.34	1.48±0.03	1.30±0.72	1.60±0.20	1.51±0.23	1.42±0.65	1.51±0.46	0.362

a,b,c: means within a row with different superscripts differ significantly ($p < 0.05$)

Table 4. Meat Quality Parameters of Broilers under Different Dietary Treatments.

Parameter	T1	T2	T3	T4	T5	T6	T7	T8	T9	p-value
Cooking Loss (%)	5.00±1.00	5.33±0.67	5.00±0.58	4.00±0.00	4.33±0.67	5.33±0.33	4.67±0.33	4.00±0.00	4.33±0.33	0.483
Chilling Loss (%)	8.67±0.67	9.67±1.45	10.33±0.67	8.33±0.33	9.67±1.45	10.33±0.88	9.00±0.58	8.00±0.00	9.33±0.67	0.527
WHC (%)	16.33±0.67 ^c	41.67±0.88 ^a	41.67±0.67 ^a	27.67±0.88 ^b	42.00±0.58 ^a	16.83±0.17 ^c	14.00±0.00 ^c	24.67±0.33 ^b	17.00±0.00 ^c	0.000
pH _i	7.00±0.00	7.33±0.33	7.33±0.33	7.33±0.33	7.33±0.33	7.33±0.17	8.00±0.00	7.43±0.30	7.23±0.12	0.406
pH ₂	6.67±0.33	6.67±0.33	6.47±0.29	6.33±0.33	6.50±0.29	6.47±0.29	6.53±0.29	6.90±0.10	6.90±0.10	0.837

a,b,c: means within a row with different superscripts differ significantly ($p < 0.05$)

WHC = Water-holding capacity; pH_i = Initial pH; pH₂ = Final pH

3.4. Sensory Attributes of Fresh Broiler Chicken Meat

Table 5 presents the sensory evaluation scores of fresh meat samples across treatments. Aroma scores ranged from 3.40 ± 0.65 (T8) to 6.30 ± 0.75 (T1) and 6.11 ± 1.05 (T9), with no significant differences ($p = 0.197$). Flavor scores ranged from 4.00 ± 0.62 (T5) to 5.75 ± 0.90 (T9), with no significant differences ($p = 0.894$). Color scores ranged from 3.78 ± 0.57

(T6) to 5.30 ± 0.79 (T7), with no significant differences ($p = 0.735$). Texture, thickness, creaminess, sourness, saltiness, and overall acceptability showed no significant differences across treatments ($p > 0.05$).

3.5. Sensory Attributes of Broiler Chicken Sausages

Table 6 presents the sensory evaluation scores of chicken sausage samples. In contrast to fresh meat, sausage samples

exhibited significant differences ($p < 0.001$) across all sensory attributes.

Aroma scores ranged from 3.44 ± 0.44 (T5) to 8.00 ± 0.00 (T3, T8). T3 and T8 recorded the highest aroma scores, significantly higher than all other treatments. T1, T2, T4, and T7 showed intermediate scores (7.00), while T5 (3.44) and T6 (4.22) had the lowest. Flavour scores ranged from 3.00 ± 0.00 (T7) to 9.00 ± 0.00 (T2). T2 had significantly higher flavor score than all other treatments. T3, T4, and T9 recorded intermediate scores (7.00), while T1 and T8 scored 6.00, and T5,

T6, and T7 had the lowest scores. Color scores ranged from 4.00 ± 0.00 (T1, T4, T9) to 7.00 ± 0.00 (T2, T3, T7, T8). T2, T3, T7, and T8 recorded the highest color scores, significantly higher than other treatments. Texture scores ranged from 1.00 ± 0.00 (T1) to 8.00 ± 0.00 (T3). T3 had the highest texture score, followed by T4 (7.00). T1 had the lowest texture score (1.00). Overall acceptability scores ranged from 6.00 ± 0.00 (T2) to 9.00 ± 0.00 (T3, T4, T8, T9). T3, T4, T8, and T9 recorded the highest overall acceptability scores, significantly higher than other treatments.

Table 5. Fresh Meat Sensory Attributes of Broilers under Different Dietary Treatments.

Parameter	T1	T2	T3	T4	T5	T6	T7	T8	T9	p-value
Aroma	6.30±0.75	4.30±0.47	4.00±0.72	4.90±0.96	4.00±0.78	4.30±0.91	5.10±0.96	3.40±0.65	6.11±1.05	0.197
Flavor	5.10±0.81	4.80±0.51	4.70±0.83	5.30±0.62	4.00±0.62	5.11±0.75	5.10±0.88	4.70±0.47	5.75±0.90	0.894
Color	4.00±0.63	4.40±0.40	4.30±0.67	3.90±0.46	4.90±0.59	3.78±0.57	5.30±0.79	4.33±0.62	4.22±0.64	0.735
Texture	5.00±0.62	5.00±0.70	6.30±0.60	4.50±0.37	4.70±0.54	4.67±0.44	6.00±0.44	5.60±0.50	4.67±0.82	0.262
Overall Acceptability	5.70±0.70	5.40±0.73	6.00±0.52	5.20±0.74	5.50±0.54	6.22±0.52	4.70±0.73	7.20±0.25	5.11±0.81	0.233

a,b,c: means within a row with different superscripts differ significantly ($p < 0.05$)

WHC = Water-holding capacity; pH₁ = Initial pH; pH₂ = Final pH

Table 6. Sensory Attributes of Chicken Sausages as Influenced by Experimental Treatments.

Parameter	T1	T2	T3	T4	T5	T6	T7	T8	T9	p-value
Aroma	7.00±0.00 ^b	7.00±0.00 ^b	8.00±0.00 ^a	7.00±0.00 ^b	3.44±0.44 ^d	4.22±0.22 ^c	7.00±0.00 ^b	8.00±0.00 ^a	6.00±0.00 ^c	<0.001
Flavor	6.00±0.00 ^c	9.00±0.00 ^a	7.00±0.00 ^b	7.00±0.00 ^b	4.22±0.22 ^d	6.56±0.44 ^c	3.00±0.00 ^c	6.00±0.00 ^c	7.00±0.00 ^b	<0.001
Color	4.00±0.00 ^c	7.00±0.00 ^a	7.00±0.00 ^b	4.00±0.00 ^b	6.78±0.22 ^b	6.22±0.22 ^b	7.00±0.00 ^a	7.00±0.00 ^a	4.00±0.00 ^c	<0.001
Texture	1.00±0.00 ^c	6.00±0.00 ^a	8.00±0.00 ^a	7.00±0.00 ^b	6.89±0.11 ^b	6.67±0.33 ^{bc}	6.56±0.44 ^c	4.00±0.00 ^d	6.00±0.00 ^c	<0.001
Overall Acceptability	8.00±0.00 ^b	6.00±0.00 ^c	9.00±0.00 ^a	9.00±0.00 ^a	7.67±0.47 ^b	8.33±0.67 ^{ab}	8.00±0.00 ^{ab}	9.00±0.00 ^a	9.01±0.00 ^a	<0.001

a,b,c,d: means within a row with different superscripts differ significantly ($p < 0.05$)

4. Discussion

The significant variation in live weight across treatments, with T6 (0.25% blanched ALM) and T5 (1.00% sun-dried ALM) recording the highest values, indicated that ALM inclusion at optimized levels could support or even enhance growth performance. This finding was consistent with [16], who reported that avocado leaf powder supplementation maintained carcass traits in broilers without adverse effects. However, the significantly lower live weights in T7 (0.50% blanched ALM)

and T8 (0.75% blanched ALM) suggested potential growth-impairing effects at those specific inclusion levels.

The significant reduction in defeathered weight for T7 and T8, despite comparable eviscerated weights, suggested that these treatments might have affected feathering characteristics or skin moisture content rather than muscle mass. This observation aligned with [16], who noted that ALM supplementation did not significantly affect carcass or organ weights, indicating systemic rather than localized effects.

Despite variations in live weight, the lack of significant differences in cut-up part weights, including the economically valuable breast muscle, indicated that ALM inclusion did not

alter the proportional allocation of nutrients to muscle tissues. This finding was consistent with [16], who observed sTable carcass characteristics alongside signs of oxidative stress, suggesting that bioactive components in ALM might affect metabolic rates or nutrient absorption efficiency without directly hindering muscle development.

The severe elevation of ultimate pH (pHu = 7.51) in the T8 group (0.75% blanched ALM) was a critical finding, representing a hallmark of Dark, Firm, and Dry (DFD) meat. DFD meat arose when muscle glycogen was depleted before slaughter, providing inadequate substrate for post-mortem lactic acid production [1]. Consequently, the high pHu caused darker meat colour, firmer texture, and shorter shelf life due to heightened bacterial susceptibility.

The presence of DFD meat in T8 indicated that birds likely endured pre-slaughter stress and metabolic exhaustion. This may have been attributed to persin, a lipid-soluble toxin in avocado leaves known to trigger stress responses. Although blanching effectively reduced water-soluble anti-nutrients such as oxalates and phytates [8], it did not remove lipid-soluble compounds like persin. Consequently, even blanched ALM included at 0.75% may still have delivered a biologically active dose of persin, potentially depleting glycogen reserves and compromising meat quality.

This result was consistent with research on plant toxins that acted as metabolic stressors and degraded meat quality [28]. Notably, the effect was absent in the 1.00% blanched ALM group (T9), implying a potential threshold effect, natural variation in persin levels, or induction of compensatory physiological mechanisms. These observations highlighted the necessity for further research into the pharmacokinetics and dose-response relationship of persin in poultry.

The conventional pHu range observed across all other dietary groups, including the highest concentration of sun-dried ALM (T5: 1.00%), implied that the interaction between ALM processing technique, inclusion rate, and physiological effect was intricate and not linear. Sun-drying and blanching processes differentially affected the bioavailability of various compounds, an effect previously documented during processing of other leaf meals [14].

The lack of significant variation in relative organ weights was a critical safety indicator, demonstrating that dietary inclusion of ALM, regardless of processing method or level, did not result in adverse physiological effects on internal organs. This demonstrated that, at the tested durations and inclusion levels, both sun-dried and blanched ALM did not induce obvious pathological enlargement or reduction of essential organs. This implied that concentrations of persin and other anti-nutritional factors remained below the threshold required to cause overt structural damage to organs such as the liver and heart, which were established targets for toxins from avocado [10].

Nonetheless, the numerical increases in liver weight observed in T6 (blanched ALM at 0.25%) and spleen weight in

T7 (blanched ALM at 0.50%), although not statistically significant, could have held biological importance. As the main detoxification organ, the liver could undergo enlargement (hepatomegaly) as an adaptive mechanism to a heightened metabolic burden from toxins [45]. In a similar vein, an increase in spleen size could indicate an immune system reaction or extramedullary haemopoiesis. These numerical patterns highlighted the need for subsequent histological analysis of these tissues to exclude the possibility of sub-clinical cellular damage that might have occurred before changes in organ weight became apparent.

The significant variation in water-holding capacity (WHC) across treatments represented one of the most important findings of this study. WHC was a critical quality attribute that affected product yield during processing and cooking, as well as sensory perception of juiciness and tenderness [11, 21]. The dramatically higher WHC values in T2 (41.67%), T3 (41.67%), and T5 (42.00%) compared to control (16.33%) indicated that sun-dried ALM supplementation at moderate to high levels significantly enhanced the meat's ability to retain moisture. This improvement in WHC was attributed to the antioxidant properties of phytochemicals in ALM, particularly flavonoids and phenolic acids, which protected muscle proteins from oxidative damage and preserved their water-binding capacity [39]. Antioxidants helped maintain cellular integrity by preventing oxidative damage to muscle proteins, which in turn supported better WHC [12]. The flavonoids and tannins in avocado leaves might have stabilized muscle membranes and reduced drip loss, resulting in more succulent meat.

The low WHC values in T7 (14.00%) and T9 (17.00%) suggested that at specific inclusion levels, particularly with blanched ALM, the balance between beneficial antioxidant effects and anti-nutritional factors might have been disrupted. Plant phenolics exhibited a biphasic effect: at low to moderate levels, they acted as antioxidants protecting membranes and improving WHC, while at high levels, particularly condensed tannins, they might have impaired protein functionality and nutrient availability through protein-phenol interactions that reduced protein solubility [7, 38].

The absence of significant differences in all sensory attributes of fresh meat across treatments was a practically important finding. This indicated that dietary inclusion of ALM, regardless of processing method and inclusion level up to 1.0%, did not adversely alter consumer-perceived sensory characteristics compared to control. This outcome suggested that volatile compounds associated with avocado leaf phytochemicals were either present at concentrations below sensory detection thresholds or were effectively masked within the meat matrix. Previous studies had reported that avocado leaves contained bioactive compounds that could influence aroma when included at high concentrations [22, 24]. However, the non-significant aroma scores observed in this study suggested that inclusion levels up to 1.00% were not sufficient to induce perceptible aromatic changes, particularly following processing treatments that reduced volatile and thermolabile

compounds [40]. The comparable flavour perception across treatments was particularly noteworthy, as it indicated that bitter-tasting tannins and alkaloids did not negatively influence palatability at the tested inclusion rates. Blanching, in particular, had been shown to significantly reduce bitterness and astringency by leaching water-soluble anti-nutritional factors [26]. The consistent colour scores indicated that ALM inclusion did not result in visually detectable pigmentation changes, despite the chlorophyll and carotenoid content typically associated with leaf meals [18].

In contrast to fresh meat, sausage samples exhibited significant differences across all sensory attributes, demonstrating that dietary-induced changes in raw meat quality could be amplified during processing into value-added products. Sausage manufacture involved extensive mincing, emulsification, and heat treatment, processes that intensified oxidative reactions and exposed underlying differences in meat stability [15]. The significantly higher overall acceptability scores in T3, T4, T8, and T9 (9.00) indicated that ALM supplementation, particularly at moderate to high inclusion levels with both processing methods, could enhance consumer preference for processed poultry products. This finding had important commercial implications, as overall acceptability integrated all individual sensory attributes and served as a major determinant of product marketability. The superior aroma and flavour scores in T3 and T8 (sun-dried ALM at 0.50% and blanched ALM at 0.75%) suggested that these specific treatment combinations optimized the balance of volatile compounds and flavor precursors in the meat. Plant-derived phenolics and flavonoids had been shown to delay oxidative rancidity and reduce formation of off-flavour compounds during meat processing and storage [17, 50]. The method of avocado leaf processing appeared central to explaining these sensory trends, with sun-drying preserving higher concentrations of heat-stable phytochemicals that may have contributed antioxidant protection, while blanching reduced anti-nutritional factors and volatile compounds while retaining sufficient antioxidant activity [23].

The improved texture scores in ALM-supplemented groups, particularly T3 (8.00), were attributed to enhanced protein functionality. Protein functionality was a critical determinant of sausage texture, as myofibrillar proteins were responsible for fat emulsification and gel formation during cooking [42]. Diets that supported optimal muscle protein integrity prior to processing were more likely to yield sausages with desirable textural properties. The antioxidant protection afforded by ALM phytochemicals may have preserved protein structure and function, leading to improved emulsification and gelation during sausage manufacture. The colour scores, with T2, T3, T7, and T8 recording the highest values (7.00), indicated that ALM supplementation enhanced visual appeal of sausages. Colour perception in poultry sausages was closely associated with oxidative stability of pigments and lipids during thermal processing. Dietary antioxidants had been shown to enhance colour stability by limiting pigment oxidation and maintaining visual uniformity in processed meat products [15, 23].

The distinct impacts of sun-dried and blanched ALM on meat and sausage quality stemmed from their differing phytochemical profiles. Blanching reduced water-soluble anti-nutrients like tannins and oxalates, thereby improving protein digestibility and mineral bioavailability, which helped preserve muscle cell integrity and proteolytic activity [29]. In contrast, sun-drying concentrated heat-stable phenolics and tannins, potentially increasing protein-phenol interactions that might have affected protein functionality [38]. The superior WHC observed with sun-dried ALM (T2, T3, T5) suggested that the higher concentration of phenolic compounds preserved through sun-drying may have provided enhanced antioxidant protection to muscle proteins. However, the DFD meat condition observed with 0.75% blanched ALM (T8) indicated that blanching, while reducing water-soluble anti-nutrients, might have increased the bioavailability of lipid-soluble toxins like persin, leading to stress responses that depleted glycogen reserves and compromised meat quality.

The exceptional sausage sensory scores achieved with both processing methods at specific inclusion levels (T3: 0.50% sun-dried; T4: 0.75% sun-dried; T8: 0.75% blanched; T9: 1.00% blanched) suggested that both processing approaches could produce meat suitable for value-added processing, provided inclusion levels were optimized. This finding aligned with the concept that nutritional strategies applied at the production stage could meaningfully influence the sensory performance of processed poultry products.

The findings of this study had several important implications for commercial poultry production and meat processing. First, the significant enhancement of water-holding capacity in sun-dried ALM treatments (up to 42% compared to 16% in control) offered substantial economic benefits through reduced processing losses and improved product yield. This improvement in WHC would have translated to higher cooked product weights, reduced drip loss during storage, and enhanced consumer satisfaction through improved juiciness.

Second, the occurrence of DFD meat in the 0.75% blanched ALM treatment (T8) highlighted the importance of precise inclusion level control when using processed avocado leaves. The absence of this defect in the 1.00% blanched ALM treatment (T9) suggested a complex, non-linear dose-response relationship that required further investigation. Poultry producers should exercise caution when including blanched ALM at levels approaching 0.75% and consider implementation of pre-slaughter stress reduction protocols if this inclusion level was used.

Third, the superior sensory quality of sausages produced from ALM-supplemented birds demonstrated that phytochemical feed additives could enhance the value of processed poultry products. This finding supported the integration of ALM into production systems targeting further processing markets, where product differentiation and premium pricing might offset any additional production costs [46].

Fourth, the comparable fresh meat sensory attributes

across all treatments indicated that ALM supplementation did not compromise consumer acceptability of whole muscle products. This was critical for market acceptance, as consumers were increasingly discerning about meat quality and might reject products with perceived off-flavors or abnormal appearances.

Dietary avocado leaf meal (ALM) significantly influenced broiler performance and product quality. Sun-dried ALM (0.25-1.00%) enhanced live weight and dramatically improved water-holding capacity (42% vs. 16% control), while blanched ALM at 0.25% supported growth. However, 0.75% blanched ALM induced DFD meat (pHu 7.51) from persin-induced stress. Crucially, ALM did not affect organ weights or fresh meat sensory acceptability, confirming safety. Notably, ALM significantly improved processed sausage quality, with four treatments achieving superior overall acceptability. It is therefore recommended to utilize sun-dried ALM at 0.5-1.0% to enhance water-holding capacity and sausage quality without DFD risk and use blanched ALM at 0.5% but strictly avoid 0.75% due to meat quality defects.

Abbreviations

ALM	Avocado (<i>Persea americana</i>) Leaf Meal
DFD	Dark, Firm, and Dry
WHC	Water Holding Capacity
pH1	Initial pH (warm pH Measured Immediately After Evisceration)
pH2	Final pH (cold pH Measured After Freezing and Thawing)
pHu	Ultimate pH
ANOVA	Analysis of Variance
SEM	Standard Error of the Mean
SPSS	SPSS Statistical Package

Author Contributions

Oluwatoyin Folake Alamuoye: Conceptualization, Methodology, Project administration, Supervision, Validation, Writing – review & editing

Roseline Feyisayo Olafalayi: Data curation, Formal Analysis, Investigation, Software, Visualization, Writing – original draft

Conflicts of Interest

Oluwatoyin Folake Alamuoye, as the supervisor, and Roseline Feyisayo Olafalayi, as the corresponding author and PhD student, affirmed that the research was carried out solely for academic purposes. No funding bodies, commercial entities, or personal relationships influenced the design, execution, analysis, or reporting of this study.

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