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Merit Analysis for Animal Products and By-Products

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Abstract: Merit analysis serves as an effective tool for determining the optimum value of animal products and by-products. This study utilizes findings from various animal products and by-products research initiatives to evaluate optimum value through simple arithmetic merit analysis. The results consistently demonstrated distinct optimum values for each evaluated products and by-products. Consequently, the adaption of merit analysis within the animal products sector is highly recommended, as it provides clear, quantifiable insight into a product's maximum value.

Keywords: *Merit Analysis, Animal Products, By-Products and Value Optimization,*

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I. INTRODUCTION

The livestock and animal processing industries face increasing pressure to maximize the quality, safety and economic yield of animal products and by-products. Traditional assessment methods often rely heavily on subjective parameters or single-variable metrics, which can fail to capture the multi-dimensional value of the final commodity (Schroeder et. al., 1998). To address this limitation, mathematical optimization frameworks, such as arithmetic merit analysis, have emerged as vital tools for synthesized decision-making (Toldra et. al., 2016).

By assigning quantitative scores across multiple intersecting variables-such as proximate composition, sensory properties and financial yield-merit analysis allows researchers and processors to objectively determine the absolute optimum value of a product (Triantaphyllou, 2000). Consequently, standardizing this analytical frame work is essential for advancing quality control and economic viability across the animal product supply chain.

Due to inherent diversity, animal products and by-products present expansive avenues for empirical investigation within the field of animal science. However, existing literature frequently fails to explicitly articulate comprehensive optimum yields. Furthermore, current research often lacks the frameworks necessary to isolate the significance of individual parameters over others, or to deduce definitive conclusions and recommendations based upon such hierarchies. As a result, the holistic optimum value of these products and by-products remains inadequately documented in contemporary studies. To address these specific limitations, a simple arithmetic merit analysis framework was developed to systematically evaluate the optimum outcomes of animal products and by-products. Merit analysis in this context serves as an objective evaluation process, effectively quantifying products based on their intrinsic value, structural strengths, quality parameters, and economic benefits.

II. MATERIALS AND METHODS

Empirical data compiled from various research initiatives on animal products (meat, milk and egg) and by-products (hide and skins) were utilized to validate the framework. To determine the optimum outcomes across these datasets, an arithmetic merit analysis was applied. This was achieved by establishing a standardize scoring system across a set of defined variables ($^{a, b, c \text{ and } d}$).

Scores were assigned on an ordinal scale based on statistical performance: a maximum score of four (4) was allocated to subclasses exhibiting significantly higher mean values (^{a}), whereas a minimum score of one (1) was assigned to counterparts exhibiting lower mean values (^{d}), with intermediate scores scaled relative to the total number of evaluation criteria.

To determine overall merit, the assigned scores were aggregated for each treatment group. The groups were then ranked in descending order based on their cumulative scores, where the treatment achieving the highest total score

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was ranked first (1st), followed sequentially by the second highest (2nd), and so forth.

➢ *Animal Products*

* *Meat*

Data from Mazur et al. (2021) were utilized to determine the optimum hardness, cohesiveness, springiness, chewiness, and gumminess during Texture Profile Analysis (TPA) of homogenized meat products (HMP). These parameters had been evaluated using a Zwick/Roell Z010 testing machine (Zwick Testing Machines Ltd., Leominster, Herefordshire, UK). Slices of HMP (10–15 mm thick) at day 0 were compressed twice to 50% of their original height. The crosshead speed was set at 60 mm/min with a relaxation time of 30 s, as outlined in Table 1.

Table 1 Texture Profile Analysis (TPA)

	Cohesiveness [-]	Springiness [mm]	Hardness [N]	Gumminess [Nm]	Chewiness [N]
A	$0.55^{a} \pm 0.05$	$0.82^{a} \pm 0.25$	$30.06^{a} \pm 2.4$	$19.31^{a} \pm 1.83$	$25.22^{a} \pm 2.66$
B	$0.42^{b} \pm 0.15$	$0.76^{a} \pm 0.21$	$28.0^{b} \pm 6.26$	$11.06^{b} \pm 5.83$	$19.68^{b} \pm 2.27$
C	$0.34^{c} \pm 0.11$	$0.61^{c} \pm 0.17$	$31.0^{a} \pm 0.84$	$5.59^{c} \pm 1.35$	$8.06^{c} \pm 2.74$
D	$0.4^{b} \pm 0.05$	$0.68^{c} \pm 0.07$	$29.4^{a} \pm 3.21$	$10.13^{d} \pm 2.74$	$16.53^{d} \pm 2.07$

A—control sample, B, C, D samples produced with 0.05, 0.1, 0.15 g/100 g of GRFP, respectively, n = 10; Day 0, a,b,c—different letters indicate significant differences at $p \leq 0.05$ between values.

* *Milk*

Data regarding feed intake, milk yield, and milk total solids of Red Sokoto goats fed graded levels of dried tigernut (*Cyperus esculentus* L.) byproducts were adapted from Onyemaechi et al. (2024). The basal diet was formulated using brewer's dried grains, palm kernel cake, molasses, bone meal, and common salt. Sundried tigernut meal was used to replace cassava peel at 0%, 10%, 20%, and 30% (w/w) in diets A, B, C, and D, respectively, with Diet A serving as the control. The cassava peels were sourced from local *garri* processing sites and sundried for 6–8 days prior to dietary incorporation.

Table 2 Intake, Milk Yield and Composition of Goats Fed Graded Levels of Tigernut Meal

Parameter	A	B	C	D	SEM
Feed intake (g/day)	497.68^{b}	609.64^{a}	593.93^{a}	456.43^{b}	31.78
Feed intake($Wkg^{0.75}$)	104.34^{b}	122.48^{a}	120.28^{a}	98.20^{b}	5.09
Milk yield (g/day)	48.74^{b}	66.51^{a}	67.05^{a}	51.10^{b}	5.04
Total solids (%)	15.70	14.89	15.77	16.38	0.61

ab means on the same row with the same superscripts are not significantly different (P>0.05)

* *Egg*

Akinbola et al. (2023) investigated the growth performance traits and egg quality of indigenous Yoruba ecotype chickens crossbred with Lohmann Brown cocks. The measured egg quality parameters included egg weight (g), egg length (cm), egg breadth (cm), shell weight (g), shell thickness (mm), egg color, albumen height (mm), albumen weight (g), yolk length (cm), yolk index, yolk height (cm), and yolk weight (g). A weighing scale, vernier caliper, micrometer screw gauge, spherometer, and other appropriate instruments were used to evaluate these parameters in accordance with the procedures described by Amao and Olugbemiga (2016). Egg quality assessments were conducted once weekly for a duration of 12 weeks from the onset of lay, as indicated in Tables 3 and 4.

Table 3 External Egg Quality Parameters of Indigenous Chicken and their F1 and F2 Crosses

Parameters	Indigenous eggs	F_1 eggs	F_2 eggs
Egg weight (g)	29.4 ± 10.29^{c}	35.71 ± 0.44^{b}	43.09 ± 0.61^{a}
Egg length (cm)	4.47 ± 0.03^{c}	4.84 ± 0.03^{b}	5.06 ± 0.03^{a}
Egg breadth (cm)	3.30 ± 0.02^{c}	3.66 ± 0.02^{b}	3.96 ± 0.02^{a}
Shell weight(g)	4.02 ± 0.08^{c}	4.74 ± 0.06^{b}	5.27 ± 0.12^{a}
Shell thickness(mm)	0.24 ± 0.01^{a}	0.19 ± 0.00^{c}	0.22 ± 0.01^{b}
Egg colour	White	Brown	Tinted brown

abcMeans along the same row with different superscripts are significantly ($p < 0.05$) different. F_1 = First filial generation, F_2 = Second filial generation.

Table 4 Internal Egg Quality Parameters of Indigenous Chicken and their F1 and F2 Crosses

Parameters	Indigenous eggs	F_1 eggs	F_2 eggs
Albumen height (mm)	6.41 ± 0.18^b	6.53 ± 0.11^b	6.96 ± 0.12^a
Albumen weight(g)	16.30 ± 0.29^c	20.75 ± 0.33^b	26.82 ± 0.51^a
Yolk length(cm)	3.43 ± 0.04^b	3.51 ± 0.03^b	3.73 ± 0.05^a
Yolk index(mm)	0.41 ± 0.01^c	0.39 ± 0.01^a	0.34 ± 0.02^b
Yolk height(cm)	1.39 ± 0.03^a	1.37 ± 0.02^a	1.26 ± 0.07^b
Yolk weight (g)	9.23 ± 0.09^c	10.21 ± 0.15^b	11.09 ± 0.22^a

^{abc}Means along the same row with different superscripts are significantly ($p < 0.05$) different. F_1 = First filial generation, F_2 = Second filial generation.

➢ *Animal By-Products*

- *Skin/ Leather*

Data on skin thickness characteristics across different breeds were obtained from Adamu (2021). Measurements were recorded for overall skin thickness, as well as the epidermal, papillary, reticular, and dermis layers, using an optical microscope equipped with an Amscope 3.7 digital camera under x4, x10, and x40 objective lenses (Table 5).

Table 5 Skin Thickness Characteristics According to Breed

Factor	Overall Skin Thickness (µm)	Epidermis (µm)	Papillary (µm)	Reticular (µm)	Dermis (µm)
Overall	1.27	0.08	0.78	0.41	1.19
Breed of Goat					
Sahelian	1.22^b	0.09^{ab}	0.74^b	0.39^b	1.13^b
Sokoto Red	1.48^a	0.04^b	0.85^a	0.59^a	1.44^a
WAD	1.21^b	0.13^a	0.62^c	0.46^b	1.08^b
SE	0.07	0.02	0.05	0.03	0.04

ab = means bearing different superscripts along the same column within a subset differ ($P<0.05$)

Chemical properties—including volatile matter, water-soluble organic matter, water-soluble inorganic matter, sulphated total ash, sulphated water-insoluble ash, water-soluble magnesium salts (Epsom salt), nitrogen, hide substances, and pH values—were determined. These analyses were carried out according to the standard procedures described in ISO 4098 (2006) and ISO 4045 (2008).

Table 6 Effect of Tanning Agent on Chemical Properties of Goat Leather

	Tanning Agent			
Chemical Properties	Chrome	Acacia	t value	LS
Volatile Matter	11.92^b	12.13^a	1.450	*
Water Soluble Org.	19.28^b	26.17^a	3.162	*
Water Soluble In Org	11.17^a	6.89^b	2.611	*
Hide Substances	6.71	8.85	1.776	ns
pH Value	5.36	3.65	24.783	ns
Water Soluble Mag.	29.23	25.65	2.739	ns
Sulphated Total Ash	1.80	1.47	3.201	ns
Water Insoluble Ash	1.74	1.45	3.078	ns

* = $P<0.05$, (significant), ns = not significant, LS= Level of significant

III. RESULTS AND DISCUSSION

➢ *Animal Products and By-products*

The data compiled for animal products (meat, milk, and eggs) were adapted from peer-reviewed national and international journals, whereas the data for animal by-products (skin and leather) were synthesized from published literature and an unpublished doctoral thesis.

- *Meat*

Texture Profile Analysis (TPA) rankings for the homogenized meat products (HMP) demonstrated a clear hierarchy of treatment preferences, following the order of Treatment A > Treatment B > Treatment C > Treatment D (Table 7). Treatment A achieved the maximum possible evaluation score of 20, establishing it as the most optimal formulation across all evaluated textural dimensions: cohesiveness, springiness, hardness, gumminess, and chewiness.

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Table 7 Ranking for Texture Profile Analysis (TPA) of homogenized Meat Products

	A (Scores)	B (Scores)	C (Scores)	D (Scores)
Cohesiveness	4	3	2	3
Springiness	4	4	2	2
Hardness	4	3	4	4
Gumminess	4	3	2	1
Chewiness	4	3	2	1
Total	**20**	**16**	**12**	**11**
Rank	**1st**	**2nd**	**3rd**	**4th**

Source: Mazur *et. al.* (2021).

The superior textural performance of Treatment A suggests that its specific structural formulation optimally preserves the myofibrillar protein matrix responsible for gelation and water-binding capacity in homogenized meats. As noted by Bourne (2002), variations in TPA scores typically reflect differences in moisture-to-protein ratios and fat emulsification efficiency. The progressive decline in gumminess and chewiness scores from Treatment B through Treatment D suggests that higher substitution levels or processing deviations disrupted the stable protein network, leading to a softer, less cohesive structural profile, consistent with findings by Herrero et al. (2007) on structural degradation in processed meats.

- *Milk*

The evaluation of goats fed graded levels of tigernut meal showed a non-linear response, adhering to the general pattern of Diet A < Diet B = Diet C < Diet D across cumulative parameters (Table 8). Both average daily feed intake (g/day) and metabolic feed intake (Wkg$^{0.75}$) were significantly higher ($P < 0.05$) for Diets B (10% tigernut) and C (20% tigernut) compared to the control diet (Diet A) and the highest substitution level (Diet D, 30% tigernut). Average milk yield (g/day) mirrored this consumption pattern, increasing markedly in the intermediate tigernut-containing diets (B and C). However, the milk yield of goats under Diet D dropped back to a level statistically similar to the control group.

Table 8 Intake, Milk Yield and Composition of Goats Fed Graded Levels of Tigernut Meal

	A	B	C	D
Feed intake (g/day)	497.68^{b}	609.64^{a}	593.93^{a}	456.43^{b}
Feed intake (Wkg$^{0.75}$)	104.34^{b}	122.48^{a}	120.28^{a}	98.20^{b}
Milk yield (g/day)	48.74^{b}	66.51^{a}	67.05^{a}	51.10^{b}
Total solid (%)	15.70	14.89	15.77	16.38
Total	**3**	**6**	**6**	**3**
Rank	**2nd**	**1st**	**1st**	**2nd**

Source: Onyemaechi *et. al.* (2024).

The increased feed consumption observed in Diets B and C suggests that the inclusion of tigernut meal at low-to-moderate levels (10% to 20%) improves dietary palatability and ruminal passage rates. This surge in nutrient intake directly fueled the higher milk yields, confirming the well-documented correlation between dry matter intake and energy available for lactogenesis (NRC, 2007). Conversely, the decline in feed intake and subsequent milk production at the 30% inclusion level (Diet D) may be attributed to a high lipid content or elevated fiber fractions inherent to tigernut by-products, which can induce negative feedback mechanisms in the rumen and suppress appetite (Copani et al., 2014).

- *Egg*

The phenotypic indices for growth performance and egg quality traits among the chicken cohorts followed a distinct genetic progression: F2 Progenies > F1 Progenies > Indigenous Breed (Table 9). The F2 generation demonstrated comprehensive improvements over both the F1 generation and the purebred indigenous Yoruba ecotype, highlighting the cumulative benefits of selective crossbreeding.

Table 9 Egg Quality Traits of Indigenous, F1 and F2 Bird Eggs

	Indigenous Eggs	F1 Eggs	F2 Eggs
Egg weight (g)	1	2	3
Egg length (cm)	1	2	3
Egg breadth (cm)	1	2	3
Shell weight (g)	1	2	3
Shell thickness (mm)	3	1	2
Albumen height (mm)	2	2	3
Albumen weight (g)	1	2	3
Yolk length (cm)	2	2	3

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Yolk index (mm)	1	3	2
Yolk height (cm)	3	3	2
Yolk weight (g)	1	2	3
Total	**17**	**23**	**30**
Rank	**3rd**	**2nd**	**1st**

Source: Akinbola *et. al.* (2023)

The continuous advancement of internal and external egg quality traits from the indigenous lines through the F2 crosses reveals a clear additive genetic variance and heterosis resulting from the introduction of the Lohmann Brown commercial paternal strain. These outcomes align with standard quantitative genetic theories applied to poultry breeding, where crossing low-performing, highly resilient indigenous ecotypes with high-yielding commercial strains improves egg weight and egg components without entirely compromising native adaptability (Gueye, 1998). The minor trade-offs, such as shifts in shell thickness and yolk height across generations, typically reflect resource allocation adjustments within the reproductive tract as total egg mass increases, a phenomenon corroborated by commercial layer development reviews (Nys and Guyot, 2011).

➢ *Animal By-Products*

- *Skin/ Leather*

Merit analysis of physical skin layers established that skins obtained from the Sokoto Red goat breed were comprehensively thicker than those from the Sahelian and West African Dwarf (WAD) goat breeds, yielding a top-ranked total merit score of 18 (Table 10).

Table 10 Skin Layer Thickness of Nigerian Goat Breeds

	Sahelian	Sokoto Red	WAD
Overall Skin thickness (µm	2	4	2
Epidermis (µm)	3	2	4
Papillary (µm)	2	4	1
Reticular (µm)	2	4	2
Dermis (µm)	2	4	2
Total	**11**	**18**	**11**
Rank	**2nd**	**1st**	**2nd**

Source: Adamu (2021

The physical superiority of the Sokoto Red goat skin layers, particularly the dermis and reticular layers, provides a stronger structural blueprint for downstream leather processing. Thicker reticular and dermal zones heavily correlate with heightened tensile strength and tear resistance in finished leather commodities (Passman, 2005). These breed-dependent variations are deeply rooted in genetic traits, physiological adaptations to geographical niches, and hormonal influences on collagen fiber deposition within the extracellular matrix of the skin (Jacinto et al., 2011).

Furthermore, the comparative merit evaluation of tanning agents (Table 11) demonstrated that the vegetable tanning agent (*Acacia* extract) outperformed the conventional chemical chrome tanning agent in overall analytical merit.

Table 11 Effect of Tanning Agent on Chemical Properties of Goat Leather

	Tanning Agent	
	Chrome	**Acacia**
Volatile Matter	1	2
Water Soluble Org.	1	2
Water Soluble In-Org	2	1
Hide Substances	0	0
pH Value	0	0
Water Soluble Mag.	0	0
Sulphated Total Ash	0	0
Water Insoluble Ash	0	0
Total	**4**	**5**
Rank	**2nd**	**1st**

Source: Labaran *et. al.* (2021).

The higher ranking of the *Acacia*-based vegetable tanning process points toward a highly efficient cross-linking mechanism between vegetable tannins (polyphenols) and the collagen fibers of the skin matrix. Vegetable tanning agents have been consistently shown to yield structural stability while minimizing the accumulation of volatile matter and undesirable inorganic salts commonly leftover from mineral/chrome tanning synthetics (Covington, 2009).

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This supports the industrial viability of organic, plant-derived vegetable tannins as ecologically sound and physically competent alternatives to standard chromium-heavy chemical agents, echoing a global shift towards green leather manufacturing practices (Nashy et al., 2012).

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