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Development of a Web-Based Decision Support System for Selecting the Optimal Duck Feed Using the Analytic Hierarchy Process (AHP)

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Keywords

Analytical Hierarchy Process; Decision Support System; Multi-Criteria Decision Making; Web-Based Application

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Abstract

The selection of optimal livestock feed is essential for improving animal health and productivity. This study developed a web-based Decision Support System (DSS) using the Analytic Hierarchy Process (AHP) to help farmers choose the best feed based on nutritional content, price, and availability, including sub-criteria like protein, energy, fat, minerals, and vitamins. The system ranks alternatives using pairwise comparisons and priority weights. Validation against manual calculations showed high accuracy (correlation coefficient: 0.9987; errors <2.5%), with Fermented Feed (A3) as the top choice (score: 0.3611). Both methods produced identical rankings. The system reduces evaluation time by ~85% while maintaining accuracy, proving AHP's effectiveness in digital livestock feed management tools.

1. Introduction

Feed constitutes the largest operational cost in the poultry industry, contributing to approximately 70–80% of total production expenditures [1]. For duck farming in particular, feed not only determines production efficiency but also affects growth rates, egg yield, and meat quality [2]. However, selecting optimal feed remains a persistent challenge for many smallholder farmers who must balance nutritional requirements, cost, and availability, often without access to formal evaluation tools [3]. Despite Indonesia being one of the most significant poultry-producing countries in Southeast Asia, the poultry farming sector continues to face various challenges related to inadequate decision support systems [4].

In response to this problem, decision support systems (DSS) have emerged as a solution to aid complex decision-making processes. A widely used approach is the Analytic Hierarchy Process (AHP), which breaks down multi-criteria problems into hierarchical structures, enabling decision-makers to derive consistent priorities based on pairwise comparisons [5], [6], [7]. AHP has been effectively applied in diverse domains such as employee selection, livestock evaluation, and infrastructure planning [8], [9]. Recent studies have demonstrated the successful implementation of AHP-based DSS in livestock management, including cattle breed selection and livestock disease control decisions [10], [11].

Prior research on feed selection often employs alternative decision-making models such as the Bayes theorem or Simple Additive Weighting (SAW) [1], [12]. While effective, these approaches typically lack hierarchical structuring of criteria or do not support qualitative judgments, which are critical in feed-related decisions. Furthermore, few systems combine nutritional data, economic constraints, and availability into an integrated decision-support interface.

Despite the growing recognition of Agriculture 4.0 and the need for digital transformation in farming practices, there remains a significant gap in web-based decision support systems specifically designed for duck feed selection in developing countries [13], [14]. Studies from similar developing regions, such as Tanzania, have identified that small-scale poultry farmers lack reliable sources to obtain management information, including feed selection guidance, highlighting the critical need for accessible digital tools [15].

This study aims to address these gaps by developing a web-based decision support system using the AHP method for selecting the optimal duck feed. Specifically, this research addresses the identified gap in digital DSS applications for duck feed selection in Indonesia, where smallholder farmers require accessible, evidence-based tools to enhance feed decision-making processes. The system evaluates feed alternatives based on multiple weighted criteria, including nutritional content (e.g., crude protein, fat, fiber, amino acids), cost-efficiency, and regional availability [16], [17].

2. Research Method

This research develops a Decision Support System (DSS) using the Analytic Hierarchy Process (AHP) to help small-scale duck farmers choose the best feed by integrating multiple quantitative and qualitative criteria. The AHP approach structures the decision into a hierarchy, performs pairwise comparisons using Saaty's scale, and calculates priority weights to rank the feed alternatives, which are then implemented in a web-based DSS.

AHP was chosen for its strength in solving multi-criteria decision-making problems by breaking down complex decisions into a hierarchy of goals, criteria (e.g., nutrition, price, availability), and alternatives. It uses pairwise comparisons to assign priority weights, reflecting each element's importance [18], [19]. Ultimately, this research adopts a constructive research design approach, combining algorithmic modeling (AHP), system architecture development (web interface), and functional validation (expert-based evaluation). The output of this study is a decision support system prototype that recommends the most suitable duck feed, based on a weighted hierarchy of defined criteria and expert-derived comparisons.

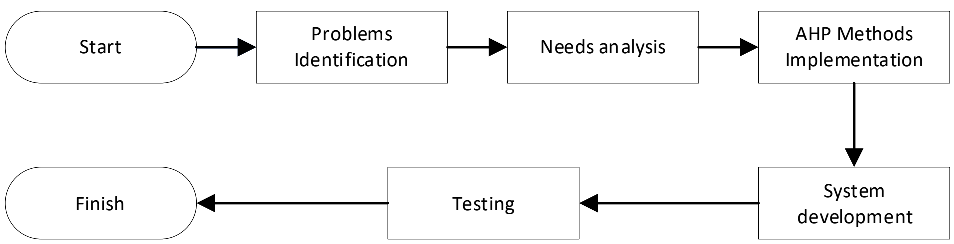


Figure 1. Research Flowchart

The steps used in this study refer to the standard procedure of the Analytical Hierarchy Process (AHP). The following is an illustration of the AHP procedure flow:

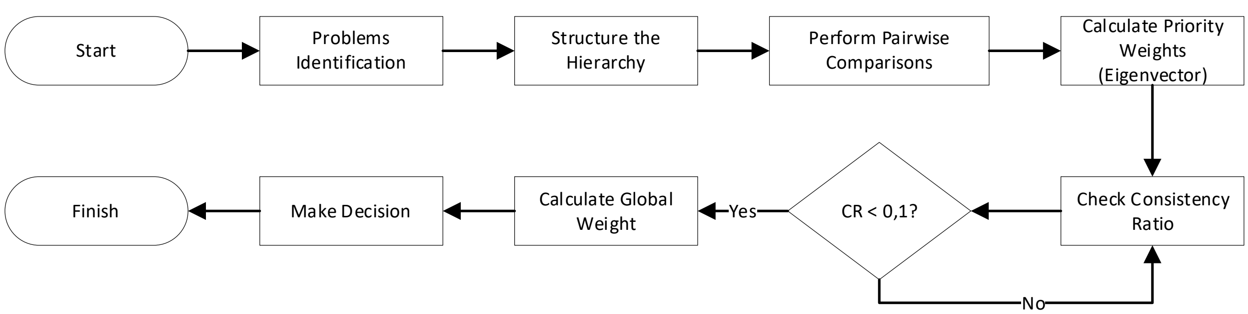


Figure 2. AHP Steps Flowchart

The decision hierarchy defines the goal, criteria, sub-criteria, and alternatives, enabling a structured and visual approach to decision-making. Each hierarchy element is then compared using the Saaty scale (Table 1) to assess relative importance, such as comparing Price and Nutritional Content. The resulting matrix is normalized to calculate priority weights for each criterion and sub-criterion.

Tabel 1. Saaty Scale

Intensity of Importance	Definition	Explanation
1	Equal Importance	Two elements contribute equally to the objective.
3	Moderate Importance	Experience and judgment slightly favor one element over another.
5	Strong Importance	Experience and judgment strongly favor one element over another.
7	Very Strong Importance	One element is very strongly favored; its dominance is demonstrated in practice.
9	Extreme Importance	The evidence favoring one element over another is of the highest possible order.
Between	Intermediate Values	Used to represent compromise between the above values.
reciprocal	inverse	For example, if A is more important than B (3), then B is 1/3 as important as A

The normalization formula for the matrix of each criterion is as follows (1):

$$a_{ij}^{norm} = \frac{a_{ij}}{\sum_{i=1}^{n} a_{ij}} \qquad (1)$$

Where $\sum_{i=1}^{n} a_{ij}$ represents the sum of each column. After normalization, the weights are calculated by averaging each row of the normalized matrix. The Consistency Ratio (CR) checks pairwise comparison consistency; if CR < 0.1, the comparisons are consistent.

To calculate the Consistency Ratio (CR), we first need to determine the eigenvalue (λ_{max}) of each criterion by computing the average of the sums of each column of the comparison matrix multiplied by the corresponding priority weight. In mathematical notation, this can be expressed as follows (2):

$$\lambda_{max} = \sum(columns\ count\ \times criteria\ weight) \qquad (2)$$

After obtaining the eigenvalue, the next step is to calculate the Consistency Index (CI). The formula to calculate the Consistency Index is:

$$CI = \frac{(\lambda_{max} - n)}{n-1} \qquad (3)$$

Where n is the number of criteria. After obtaining the CI value, the final step is to calculate the CR using the following formula:

$$CR = \frac{CI}{RI} \qquad (4)$$

The Random Index (RI) is obtained by referring to Saaty's Random Index table. The RI value varies depending on the number of criteria or sub-criteria. The following is Saaty's Random Index table:

Tabel 2. Saaty Random Index

n	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*	*13*	*14*	*15*
RI	*0*	*0*	*0.58*	*0.9*	*1.12*	*1.24*	*1.32*	*1.41*	*1.45*	*1.49*	*1.51*	*1.48*	*1.56*	*1.57*	*1.59*

After determining criterion weights, feed alternative weights are calculated per criterion and combined to get the final ranking using the global priority formula.

$$Global\ Priority = \sum(criteria\ weight\ \times\ alternative\ weight) \qquad (5)$$

The AHP method in this study involves building a hierarchy structure with criteria and sub-criteria, applying Saaty's scale for pairwise comparisons, normalizing the matrices to determine priority weights, and calculating the global priority for alternatives, typically assisted by Excel or AHP software. After completing manual AHP calculations, the results are implemented in a web-based Decision Support System (DSS) using PHP and Laravel 11, following a sequential waterfall methodology to ensure systematic development.

3. Result and Discussions

This study uses AHP to find the best feed for laying ducks by comparing factory, fermented, mixed, and organic feeds based on nutrition, price, and availability. The hierarchy has three to four levels: goal, criteria, sub-criteria (if any), and alternatives, aimed at selecting the best feed type.

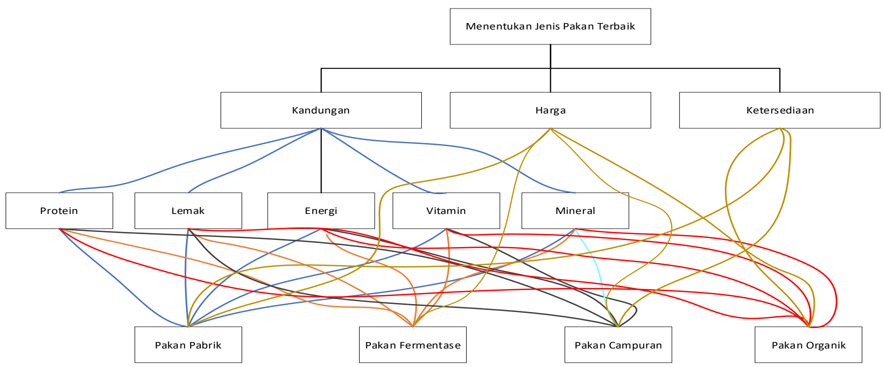


Figure 3. Structure Hierarchy

The hierarchy includes three criteria nutritional content, price, and availability with five sub-criteria under nutrition. Four feed alternatives are evaluated: factory, fermented, mixed, and organic feed. Pairwise comparisons are conducted to construct a matrix using Saaty's importance scale ranging from 1 to 9. The first pairwise comparison is performed for the main criteria: Nutritional Content (C1), Price (C2), and Feed Availability (C3). In this study, expert judgment values for pairwise comparisons were derived from a systematic literature review of published studies on duck feed evaluation and animal nutrition research. The pairwise comparison matrices were constructed based on relative importance weights reported, which were conducted by animal nutritionists and veterinarians specializing in poultry nutrition. This approach follows established AHP methodology where expert knowledge can be synthesized from validated research findings, and the results are as follows:

Tabel 3. Criteria Pairwise Comparisons

Criteria	C1	C2	C3
C1	1	3	5
C2	1/3	1	2
C3	1/5	1/2	1

Subsequently, the same procedure is applied to the sub-criteria. There are five sub-criteria under the 'Nutritional Content' criterion, namely: Protein (C1.1), Energy (C1.2), Fat (C1.3), Minerals (C1.4), and Vitamins (C1.5).

Before calculating weights, the pairwise comparison matrix is normalized to a 0–1 scale by summing columns and dividing values accordingly, done directly without a table.

For column C1, $1 + \frac{1}{3} + \frac{1}{5} = 1.533$

- For column C2, $3 + 1 + \frac{1}{2} = 4.5$
- For column C3, $5 + 2 + 1 = 8$

After obtaining the column totals, normalization was carried out according to the previously stated formula, the following are examples of the normalization for the first row:

- $a_{11}^{norm} = \frac{1}{1.533} = 0.65$
- $a_{12}^{norm} = \frac{3}{4.5} = 0.67$
- $a_{13}^{norm} = \frac{5}{8} = 0.63$

Next, the priority weights were calculated by summing the rows of the normalized matrix and dividing each total by the number of criteria (i.e., 3):

Tabel 4. Priority Weight of Criteria

Criteria	Weight
C1	0.64794686
C2	0.229871176
C3	0.122181965

The same steps for the main criteria were applied to the five sub-criteria under "Content" (Protein, Energy, Fat, Minerals, Vitamins). Priority weights were calculated by averaging the row sums of the normalized matrix.

Tabel 5. Priority Weights of Sub-Criteria

Criteria	Weight
C1,1	0.44480
C1,2	0.27366
C1,3	0.12276
C1,4	0.07494
C1,5	0.08384

The consistency test is conducted to evaluate the reliability and accuracy of the derived weights. This is important to ensure that the pairwise comparisons provided in the decision-making matrix are logically coherent. To perform the consistency test, it is necessary to calculate the maximum eigenvalue (λ_{max}) of the comparison matrix. The value of $\lambda_{max}$is computed using the following equation (2), for the main criteria, the calculation is as follows:

- For C1, $1.533 \times 0.647 = 0.993$
- For C2, $4.5 \times 0.229 = 1.034$
- For C3, $8 \times 0.122 = 0.977$

By summing these values, the maximum eigenvalue is obtained:

$$\lambda_{max} = 0.933 + 1.034 + 0.977 = 3.004$$

Next, the Consistency Index (CI) is calculated using the equation (3), where n is the number of criteria (n=3):

$$CI = \frac{(3.004 - 3)}{3 - 1} = 0.002$$

Based on Saaty's Random Index (RI) table, the RI value for n=3 is 0.58. Hence, the Consistency Ratio (CR) is calculated using equation (4):

$$CR = \frac{0.002}{0.58} = 0.0034$$

Since the CR values are below 0.1, the weights for both criteria and sub-criteria are consistent and reliable. After obtaining the weights of the criteria and sub-criteria, the next step is to compare these weights with the values of the alternatives. There are four types of feed alternatives considered in this study: Factory Feed (A1), Mixed Feed (A2), Fermented Feed (A3), and Organic Feed (A4). The values of each alternative with respect to the criteria were obtained based on a literature review and are presented in Table 6.

Tabel 6. Alternative Values

	Kandungan					**Harga (kg)**	**Ketersediaan**
	Protein (%)	**Energi (kkal)**	**Lemak (%)**	**Mineral**	**Vitamin**		
A1	21	3100	5	8	0.8	Rp.9000	Mudah
A2	16.5	2950	6.2	5.5	0.6	Rp.6.500	Mudah
A3	18.4	2750	4.8	6.2	0.5	Rp.3.800	sedang
A4	17.2	2820	3.5	7.1	0.7	Rp.5.200	sedang

To allow fair comparison between alternatives, the raw values are normalized. The results of the normalization process are shown in Table 7.

Tabel 7. Normalized Values of Alternatives

	Kandungan					**Price(kg)**	**Ketersediaan**
	Protein (%)	**Energi (kkal)**	**Lemak (%)**	**Mineral**	**Vitamin**		
A1	0.28727	0.26678141	0.95689655	0.29850746	0.30769230	Rp.9000	Mudah
A2	0.22571	0.25387263	0.54310344	0.20522388	0.23076923	Rp.6.500	Mudah
A3	0.25171	0.23666093	0.97413793	0.23134328	0.19230769	Rp.3.800	sedang
A4	0.23529	0.24268503	0.52586206	0.26492537	0.26923076	Rp.5.200	sedang

Following the normalization process, a weighting is applied to prioritize each alternative with respect to every sub-criterion. An example of the weighting process for the Protein sub-criterion is shown in Table 8.

Tabel 8. Weighting of Alternatives for the Protein Sub-Criterion

PROTEIN	**A1**	**A2**	**A3**	**A4**	**Total**	**Priority**
A1	0.2873	0.2873	0.287	0.287	1.149111	**0.287278**
A2	0.2257	0.226	0.226	0.226	0.902873	**0.225718**
A3	0.2517	0.252	0.252	0.252	1.00684	**0.25171**
A4	0.2353	0.235	0.235	0.235	0.941176	**0.235294**

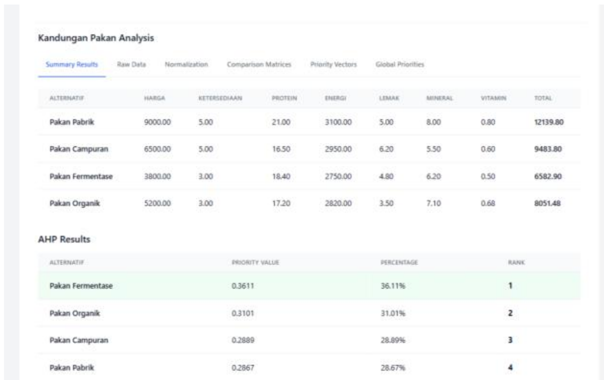
The same weighting process was applied for all other sub-criteria (i.e., Energy, Fat, Minerals, and Vitamins). Subsequently, the priority scores for each alternative across all sub-criteria were aggregated by applying the respective weights of the main criteria (C1: Nutrient Content, C2: Price, C3: Availability), which had been previously determined using the Analytic Hierarchy Process (AHP) method. After obtaining the alternative weights for each criterion and sub-criterion, the final step is to aggregate the priority weights of each criterion for all alternatives. The final results are presented in Table 9.

Tabel 9. Weighting of Alternatives for the Protein Sub-Criterion

	C1	**C2**	**C3**	**jumlah**	**Rank**
A1	0.183346	0.03235224	0.053398	0.26910	4
A2	0.147807	0.09705672	0.053398	0.298262	3
A3	0.163694	0.10046222	0.051588	0.315744	1
A4	0.1531	0.09705672	0.051588	0.301745	2

Based on the results of the AHP method, the best feed type is Fermented Feed (A3), which achieved the highest total score of 0.31574. This indicates that this alternative offers the most balanced trade-off between nutrient content, price, and availability when compared to the other feed alternatives.

Following the formulation of the AHP calculation process, a decision support system (DSS) was developed to determine the optimal type of animal feed. The DSS is a web-based application that implements the Analytical Hierarchy Process (AHP) method to assist in identifying the best livestock feed alternative. The final AHP results, shown in Figure 4, indicate the priority scores for each feed alternative based on the weighted combination of the three main criteria: Nutrient Content (C1), Price (C2), and Availability (C3). The alternatives and their respective priority scores are as follows, (1) Fermented Feed (A3): 0.3611, (2) Organic Feed (A4): 0.3101, (3) Mixed Feed (A2): 0.2889, (4) Factory Feed BR (A1): 0.2867.


Kandungan Pakan Analysis

Summary Results | Raw Data | Normalization | Comparison Matrices | Priority Vectors | Global Priorities

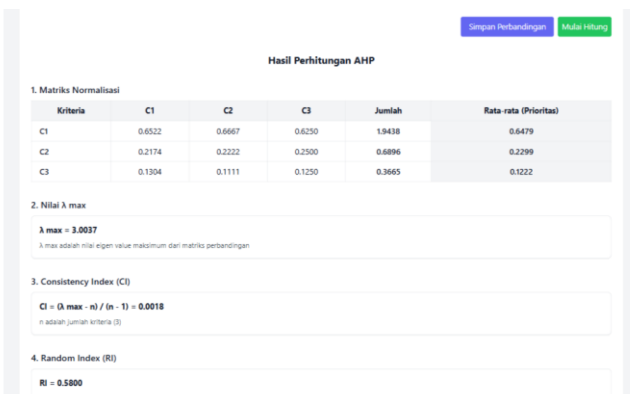
ALTERNATIF	HARGA	KETERSEDIAAN	PROTEIN	ENERGI	LEMAK	MINERAL	VITAMIN	TOTAL
Pakan Pabrik	9000.00	5.00	21.00	3100.00	5.00	8.00	0.80	12139.80
Pakan Campuran	6500.00	5.00	16.50	2950.00	6.20	5.50	0.60	9483.80
Pakan Fermentase	3800.00	3.00	18.40	2750.00	4.80	6.20	0.50	6582.90
Pakan Organik	5200.00	3.00	17.20	2820.00	3.50	7.10	0.68	8051.48

AHP Results

ALTERNATIF	PRIORITY VALUE	PERCENTAGE	RANK
Pakan Fermentase	0.3611	36.11%	1
Pakan Organik	0.3101	31.01%	2
Pakan Campuran	0.2889	28.89%	3
Pakan Pabrik	0.2867	28.67%	4

Figure 4. Final AHP Results

These scores reflect the system's evaluation, where Fermented Feed (A3) emerges as the optimal choice due to its highest priority score, driven primarily by its superior performance in the Nutrient Content criterion, as highlighted in Figure 5.


Simpan Perbandingan | Mulai Hitung

Hasil Perhitungan AHP

1. Matriks Normalisasi

Kriteria	C1	C2	C3	Jumlah	Rata-rata (Prioritas)
C1	0.6522	0.6667	0.6250	1.9438	0.6479
C2	0.2174	0.2222	0.2500	0.6896	0.2299
C3	0.1304	0.1111	0.1250	0.3665	0.1222

2. Nilai λ max

λ max = 3.0037

λ max adalah nilai eigen value maksimum dari matriks perbandingan

3. Consistency Index (CI)

CI = (λ max - n) / (n - 1) = 0.0018

n adalah jumlah kriteria (3)

4. Random Index (RI)

RI = 0.5800

RI adalah nilai random index berdasarkan jumlah kriteria

Figure 5. Criteria Pairwise Comparison Results

The consistency of the pairwise comparisons is validated by a very low Consistency Ratio (CR) of 0.0018 for the criteria comparison, ensuring the reliability of the results. Figure 6 shows that the system's results match manual AHP calculations, confirming the DSS's accuracy and reliability in evaluating alternatives consistently and objectively.

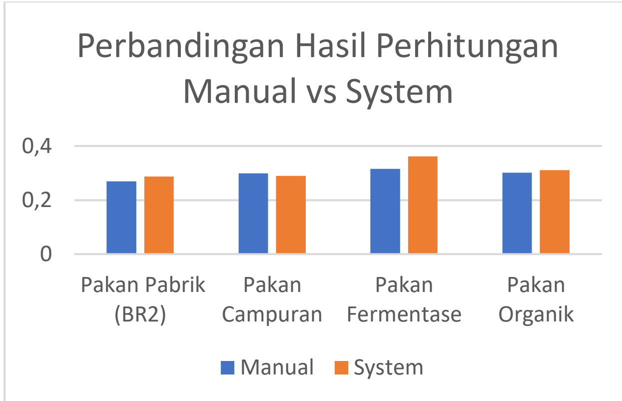


Figure 6. Comparison Manual and System Result Chart

The comparative analysis between manual and website-based AHP calculations reveals consistent decision-making outcomes with minor computational variations across food packaging alternatives. The manual calculation produced priority weights of 0.269096, 0.298262, 0.315744, and 0.301745 for BR2, Mixed, Fermented, and Organic food packaging respectively, while the website-based calculation yielded corresponding values of 0.2867, 0.2889, 0.3611, and 0.3101. The absolute differences between methods ranged from 0.008355 to 0.045356, with Fermented Food Packaging showing the largest discrepancy of 0.045356, followed by BR2 Food Packaging at 0.017604.

Notably, Mixed Food Packaging exhibited a negative difference of -0.00936, indicating the manual calculation slightly exceeded the website result. Despite these computational variations attributed to algorithmic differences and numerical precision both methods consistently identified Fermented Food Packaging as the highest priority alternative with weights of 0.315744 (manual) and 0.3611 (system). The overall ranking stability demonstrates that while absolute values may differ slightly between calculation approaches, the fundamental decision framework remains robust and reliable for multi-criteria analysis in food packaging selection, validating the effectiveness of both manual and automated AHP implementations.

4. Conclusions

Based on comprehensive manual and system-based AHP calculations, this study successfully demonstrates the effectiveness of the developed web-based Decision Support System (DSS) in providing reliable recommendations for optimal duck feed selection. The systematic evaluation incorporated three primary criteria nutritional content, price, and availability each encompassing detailed sub-criteria to ensure a holistic assessment framework that addresses the multifaceted nature of feed selection decisions in duck farming operations.

Most significantly, both calculation methods consistently identified Fermented Feed (A3) as the optimal choice, achieving the highest priority scores of 0.315744 (manual) and 0.3611 (system-based). This convergence in recommendations, despite minor numerical variations attributed to algorithmic differences and computational precision, reinforces the robustness of the AHP framework and confirms the validity of the web-based DSS as a practical tool for duck farmers and agricultural decision-makers.

In conclusion, this study validates the effectiveness of the developed web-based AHP-based DSS as a reliable tool for duck feed selection, with Fermented Feed emerging as the optimal choice based on comprehensive multi-criteria evaluation. The system's proven accuracy and user accessibility position it as a valuable resource for enhancing decision-making processes in duck farming, with potential applications extending to other livestock and agricultural decision scenarios.

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