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Navigating Uncertainty: Risk Evaluation in Poultry Farming

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ABSTRACT

This research paper aims to assess and prioritize the risks associated with poultry farming using the Analytic Hierarchy Process (AHP) methodology. Poultry farming is a significant sector of agriculture, facing various risks that can impact production, profitability, and sustainability. The AHP method provides a structured approach to evaluate and rank these risks based on their relative importance and potential impact on poultry farming operations. Through a comprehensive literature review and data collection process, key risk factors such as disease outbreaks, market fluctuations, environmental factors, and operational challenges were identified. These factors were then incorporated into an AHP model to quantify their significance and prioritize mitigation strategies. The findings highlight the critical risks facing poultry farmers and provide insights into effective risk management practices. By understanding and addressing these risks systematically, poultry farmers can enhance their resilience and sustainability in the face of uncertainties. This research contributes to the existing knowledge on poultry farming risk assessment and offers practical implications for stakeholders involved in poultry production and management.

Keywords: Poultry farming risk, Poultry farming industry, Analytical hierarchy process.

1. INTRODUCTION

Poultry farming represents a significant sector within the agriculture industry, providing a vital source of protein for human consumption worldwide [1]. However, like any agricultural endeavour, poultry farming is fraught with various risks that can threaten productivity, profitability, and even the welfare of the birds themselves[2]. Effective risk management strategies are crucial for mitigating these risks and ensuring the sustainability of poultry farming operations.

One powerful tool for evaluating and prioritizing risks in poultry farming is the Analytic Hierarchy Process (AHP). Developed by Thomas L. Saaty in the 1970s [3], AHP is a structured decision-making methodology that allows stakeholders to systematically analyse complex problems with multiple criteria and alternatives [4]. Its ability to incorporate qualitative and quantitative data makes it particularly well-suited for assessing the diverse array of risks inherent in poultry farming.

The objectives of this research paper are twofold. Firstly, we aim to provide an in-depth exploration of the key risk factors faced by poultry farmers, focusing specifically on nutritional

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risk, management risk, and thermal risk. Secondly, we seek to demonstrate the utility of the AHP methodology in quantitatively assessing and prioritizing these risks, thereby offering valuable insights for improving risk management practices within the poultry farming industry. Through this research, we strive to contribute to the broader discourse on agricultural risk management and support the resilience and sustainability of poultry farming operations.

2. LITERATURE REVIEW

Poultry farming, like any agricultural enterprise, faces a myriad of risks that can significantly impact production, profitability, and sustainability [5]. Understanding these risks and implementing effective risk management strategies is essential for the long-term success of poultry operations. In this literature review, we examine existing research on poultry farming risks and various risk assessment methods, with a particular focus on the application of the Analytic Hierarchy Process (AHP) and similar methodologies in agricultural and risk assessment contexts.

2.1 Poultry Farming Risks

Numerous studies have highlighted the diverse array of risks faced by poultry farmers. These risks can be categorized into biological, environmental, financial, operational, and regulatory domains [6], [7], [8], [9]. Biological risks include disease outbreaks such as avian influenza and Newcastle disease, which can lead to significant production losses and pose threats to public health [10], [11]. Environmental risks encompass factors such as climate change, extreme weather events, and pollution, which can impact poultry health and welfare [12]. Financial risks relate to market volatility, input costs, and financial management practices, affecting the profitability of poultry operations[13],[14]. Operational risks involve challenges in production management, biosecurity, and supply chain disruptions [15],[16]. Regulatory risks stem from changes in government regulations and compliance requirements, influencing production practices and market access for poultry products.

2.2 Risk Assessment Methods

Various risk assessment methods have been employed to evaluate and prioritize risks in poultry farming [17], [18]. These methods range from qualitative approaches such as expert opinion surveys and brainstorming sessions to quantitative techniques such as statistical analysis and mathematical modelling. Quantitative risk assessment models, including probabilistic risk assessment (PRA) and fault tree analysis (FTA), offer systematic frameworks for quantifying risks and estimating their likelihood and consequences [19], [20]. Qualitative risk assessment methods, such as risk matrices and risk scoring systems, provide intuitive tools for identifying and ranking risks based on expert judgment and stakeholder feedback.

2.3 Application of AHP in Agricultural Risk Assessment

The Analytic Hierarchy Process (AHP) has gained popularity as a decision-making tool in agricultural and risk assessment contexts. AHP enables stakeholders to decompose complex decision problems into a hierarchical structure of criteria and alternatives, facilitating pairwise comparisons and priority ranking based on relative importance weights [21], [22]. Previous studies from [23], [24] have utilized AHP to assess risks in various agricultural sectors, including crop production, livestock farming, and agribusiness management. AHP offers advantages such as transparency, consistency, and flexibility in capturing stakeholders' preferences and value judgments when evaluating risks and selecting mitigation strategies.

2.4 Studies Using AHP in Poultry Farming

While AHP has been widely applied in agricultural risk assessment, its use specifically in poultry farming remains relatively limited [25]. However, a few studies have demonstrated the potential of AHP in prioritizing risks and decision-making in poultry production systems [26], [27]. These studies have focused on evaluating factors influencing poultry farmers' adoption of biosecurity measures, assessing the economic impacts of disease outbreaks on poultry farms, and optimizing feed formulation strategies to minimize production costs and environmental impacts. The application of AHP in poultry farming highlights its utility in addressing complex risk management challenges and informing evidence-based decision-making to enhance the resilience and sustainability of poultry operations.

In summary, the literature review underscores the importance of understanding and managing risks in poultry farming and the diverse methodologies available for risk assessment. While previous research has utilized various approaches, including AHP, in agricultural risk assessment, there is a need for further research exploring the specific application of AHP in poultry farming to address industry-specific challenges and opportunities for risk mitigation and management.

3. METHODOLOGY

The Analytic Hierarchy Process (AHP) is a multi-criteria decision-making technique developed by Thomas Saaty in the 1970s. AHP provides a structured approach to decision-making by decomposing complex problems into a hierarchical structure of criteria and alternatives, facilitating pairwise comparisons and priority ranking based on stakeholders' judgments and preferences.

In this study, we adapted the AHP methodology to assess risks in poultry farming comprehensively. The following steps outline our approach:

3.1 Hierarchical Structure Development

We first identified and developed a hierarchical structure of criteria and alternative relevant to poultry farming risk assessment as shown in Figure 1. The hierarchical structure typically consists of three levels: the goal or objective level, the criteria level, and the alternatives level. At the criteria level, we identified primary risk factors such as nutritional risk, management risk and thermal risk.

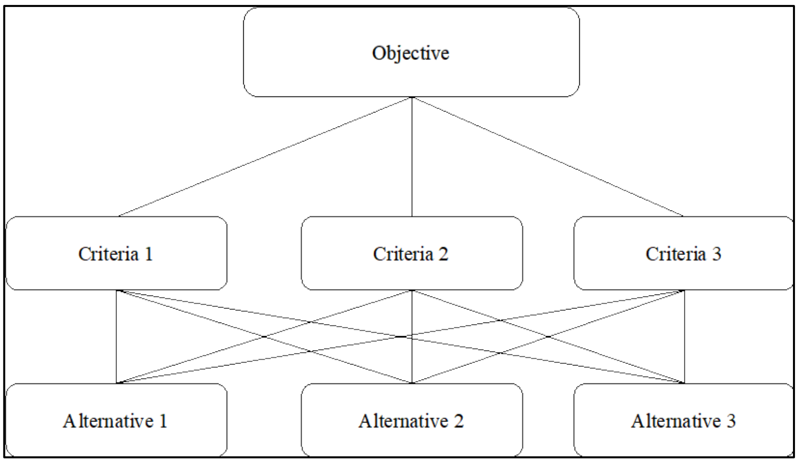

Figure 1: Hierarchy structure of the AHP model.

3.2 Pairwise Comparisons

Stakeholders involved in poultry farming, including farmers, veterinarians, industry experts, and policymakers, were invited to participate in pairwise comparisons to assess the relative importance of criteria and sub-criteria. Participants were asked to compare each pair of criteria and alternative based on their judgment of which factor is more important in influencing poultry farming risks. Pairwise comparisons were conducted using a scale developed by Saaty, ranging from 1 (equal importance) to 9 (extremely more important).

Table 1: Ranking Scale for criteria and alternative.

Preference Level	Quantitative Value
Equal important	1
Moderate important	3
Strong important	5
Very strong important	7
Extremely important	9
Intermediate values between two adjacent judgements	2, 4, 6, 8,

In AHP, the Saaty rating scale shown in Table 1 will be used to compare the same hierarchy alternatives using pairwise comparison in same level, expressing the importance of each alternative over other alternatives. The average value for each alternative to criteria that computed in the Excel will be used in the pairwise comparison. The relative priority of the alternatives to each criterion will be calculated by the weighting process. The comparison will be made for all alternatives in the same level with every criterion in the level above. The pairwise comparison matrix of the alternatives to criteria is shown in Table 2 below.

Table 2: Pairwise comparison of the alternatives to criteria.

Criteria, C_n	C_1	C_2	C_3	C_4	C_5
C_1	$C_{1.1}$	$C_{1.2}$	$C_{1.3}$	$C_{1.4}$	$C_{1.5}$
C_2	$\frac{1}{C_{1.2}}$	$C_{2.2}$	$C_{2.3}$	$C_{2.4}$	$C_{2.5}$
C_3	$\frac{1}{C_{1.3}}$	$\frac{1}{C_{2.3}}$	$C_{3.3}$	$C_{3.4}$	$C_{3.5}$
C_4	$\frac{1}{C_{1.4}}$	$\frac{1}{C_{2.4}}$	$\frac{1}{C_{3.4}}$	$C_{4.4}$	$C_{4.5}$
C_5	$\frac{1}{C_{1.5}}$	$\frac{1}{C_{2.5}}$	$\frac{1}{C_{3.5}}$	$\frac{1}{C_{4.5}}$	$C_{5.5}$

In a similar manner, the Saaty rating scale will also be employed to conduct pairwise comparisons of the criteria within the same hierarchy level. The relative importance of the criteria will be determined based on the average value computed in Excel, which will be utilized in the pairwise comparison process. Table 3 presents the pairwise comparison of the criteria.

Table 3: Pairwise comparison of the criteria.

	Criteria				
Alternative, A_n	A_1	A_2	A_3	A_4	A_5
A_1	$A_{1,1}$	$A_{1,2}$	$A_{1,3}$	$A_{1,4}$	$A_{1,5}$
A_2	$\frac{1}{A_{1,2}}$	$A_{2,2}$	$A_{2,3}$	$A_{2,4}$	$A_{2,5}$
A_3	$\frac{1}{A_{1,3}}$	$\frac{1}{A_{2,3}}$	$A_{3,3}$	$A_{3,4}$	$A_{3,5}$
A_4	$\frac{1}{A_{1,4}}$	$\frac{1}{A_{2,4}}$	$\frac{1}{A_{3,4}}$	$A_{4,4}$	$A_{4,5}$
A_5	$\frac{1}{A_{1,5}}$	$\frac{1}{A_{2,5}}$	$\frac{1}{A_{3,5}}$	$\frac{1}{A_{4,5}}$	$A_{5,5}$

3.3 Normalization

After constructing both the pairwise comparison of the alternative to criteria and criteria, it is necessary to normalize the values in the table. Normalization is a crucial step in the AHP process as it converts the values into comparable numerical data that can be rated and ranked. This is achieved by dividing each value by the total value of its respective column. In order to determine the relative priority, it is important to normalize both pairwise comparison matrices such that the sum is equal to 1.

3.4 Preferences Calculation

After normalization, the subsequent step is to rank the alternatives of each criterion and the criteria themselves. The preferences will be ascertained by computing an average of the normalized values for each row in both pairwise comparisons discussed in sections i and ii The alternative with the highest priority score will be considered the most preferred for each criterion's alternative, as well as the criteria itself, based on the respondents' perspectives.

3.5 Model Evaluation:

It is not advisable to solely depend on the data analysis results without evaluating the model. In the case of selecting an internship company, any inconsistency in the evaluation process can result in significant problems due to erroneous decisions made by the model. For instance, farmer may end up selecting main risk in poultry farming based on their preference and expectations, leading to unsatisfactory outcomes.

3.5.1 Consistency Check

To ensure the reliability of pairwise comparisons, consistency checks were performed using the consistency ratio (CR). If the CR exceeded a predefined threshold (e.g., 0.1), participants were asked to review and revise their judgments to improve consistency. The following formula gives the calculation of the consistency ratio (C.R.):

$$CR = \frac{CI}{\text{Random Index}} \tag{1}$$

The RI value is fixed and is based on the number of criteria, as shown in Table 4.

Table 4: Random Consistency Index.

Size of Matrix	Random Index
1	0.00
2	0.00
3	0.58
4	0.90
5	1.12
6	1.24
7	1.32
8	1.41
9	1.45
10	1.49

To compute the CR, we need to first determine the confidence index (C.I.) value. This value is obtained by multiplying each value in the first column (Eigen vector) of the pairwise comparison matrix of criteria by its relative priority (Eigen value). We then repeat this process until the last row of the pairwise comparison of criteria is calculated. Finally, we divide the sum of these values by each priority for each criterion. The values from the previous process will be computed by averaging the value namely λmax. The following formula gives the calculation of the consistency index (CI):

$$CI = \frac{\lambda_{max} - n}{n - 1} \quad (2)$$

3.5.2 Overall Ranking

In our analysis, we considered a range of criteria and factors relevant to poultry farming risks, including disease prevalence, market demand and price fluctuations, climate variability, input costs, biosecurity measures, production efficiency, and regulatory compliance. These factors were carefully selected based on their potential impact on poultry farming operations and their significance to stakeholders in the poultry industry.

By employing the Analytic Hierarchy Process methodology, we aimed to provide a systematic and transparent approach to assessing risks in poultry farming, enabling stakeholders to prioritize risk management strategies and allocate resources effectively to mitigate the identified risks.

4. RESULTS AND DISCUSSION

Figure 2 illustrates the progression of the AHP model. It demonstrates how the task of identifying the primary risk in a poultry farm is broken down into a hierarchical structure. Within this hierarchy, the research objective, comprising three criteria and three alternatives, is further categorized into high, medium, and low levels.

The collected data has been analyse using MS excel which analysed the pairwise comparison, normalization and efficiency. For the part of pairwise comparisons between alternatives for each criterion, as presented through Table 5 to Table 12. Additionally, in Table 3, displays the pairwise comparisons among the criteria.

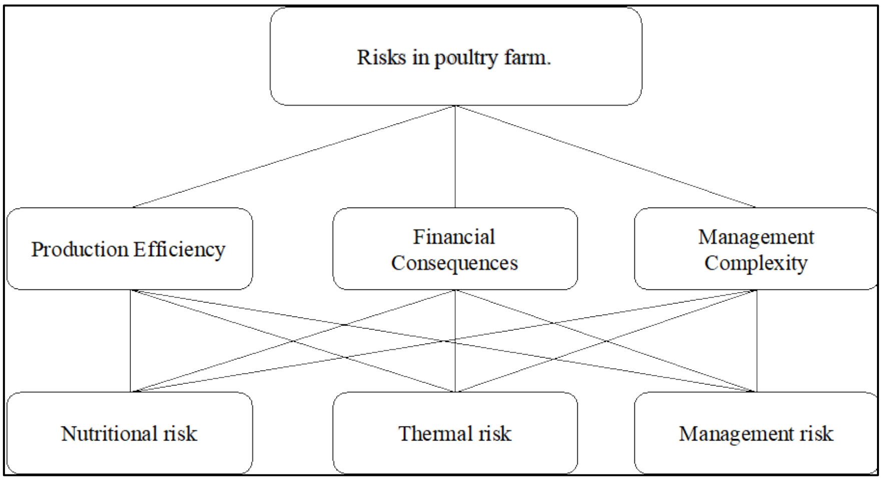

Figure 2: Hierarchy Structure of AHP Model.

4.1 Pairwise Comparisons Between Alternative to Criteria

Table 5 to Table 7 below illustrates the pairwise comparison of risk in poultry farm alternatives with respect to the criteria of production efficiency, financial consequence and management complexity respectively. The values within the table represent the average values derived from the data collected via Google Forms and subsequently processed using Excel. These values indicate the relative weights of the comparisons between each alternative based on the perspectives of the respondents.

Table 5: Pairwise Comparison of Alternatives to Production Efficiency。

Production Efficiency			
	Nutritional	**Management risk**	**Thermal risk**
Nutritional	1.0000	6.0000	7.1429
Management risk	1/6.0000	1.0000	1.1429
Thermal risk	1/7.142857	1/1.42857	1.0000

Table 6: Pairwise Comparison of Alternatives to Financial Consequence.

Financial Consequences			
	Nutritional	**Management risk**	**Thermal risk**
Nutritional	1	7.428571	7.142857
Management risk	1/7.428571	1	1.428571
Thermal risk	1/7.142857	1/1.428571	1

Table 7: Pairwise Comparison of Alternatives to Management Complexity.

Management Complexity			
	Nutritional	**Management risk**	**Thermal risk**
Nutritional	1	7.000000	6.857143
Management risk	1/7.000000	1	2.142857
Thermal risk	1/6.000000	1/2.142857	1

4.2 Pairwise Comparisons Between Criteria

Table 8 shows the pairwise comparison of criteria. The value within the table is the average value from the collected data through the google form and transformed using Excel. These values show the relative weight of the comparison of criteria to each criterion based on respondent's perspectives.

Table 8: Pairwise Comparison of Criteria.

	Criteria		
	Production Efficiency	**Financial Consequences**	**Management Complexity**
Production Efficiency	1	3.857143	4.428571
Financial Consequences	1/3.857143	1	3.857143
Management Complexity	1/4.428571	1/3.857143	1

4.3 Normalization

Table 9 to Table 12 show the normalization of the pairwise comparison of risk in poultry farm alternatives with respect to the criteria of production efficiency, financial consequence and management complexity respectively. Table 12 shows the normalization of criteria. Each column value is summed and divided by the column's total. To determine the relative priority, this pairwise comparison is normalized into sum equal to 1 to make its values in the table to be comparable.

Table 9: Normalization of Pairwise Comparison of Alternative to Production Efficiency.

	Production Efficiency			
	Nutritional	**Thermal risk**	**Management risk**	**Priority**
Nutritional	0.7653	0.7619	0.7692	0.765480551
Management risk	0.1276	0.1270	0.1231	0.12587069
Thermal risk	0.1071	0.1111	0.1077	0.108648759
Sum	1.0000	1.0000	1.0000	1.0000

Table 10: Normalization of Pairwise Comparison of Alternative to Financial Consequences.

	Financial Consequences			
	Nutritional	**Management risk**	**Thermal risk**	**Priority**
Nutritional	0.784550	0.813772	0.746269	0.781530
Management risk	0.105613	0.109546	0.149254	0.121471
Thermal risk	0.109837	0.076682	0.104478	0.096999
Sum	1.000000	1.000000	1.000000	1.000000

Table 11: Normalization of Pairwise Comparison of Alternative to Management Complexity.

	Management Complexity			
	Nutritional	**Management risk**	**Thermal risk**	**Priority**
Nutritional	0.775982	0.826772	0.685714	0.762822
Management risk	0.110855	0.118110	0.214286	0.147750
Thermal risk	0.113164	0.055118	0.100000	0.089427
Sum	1.000000	1.000000	1.000000	1.000000

Table 12: Normalization of Pairwise Comparison of Criteria.

	Criteria			
	Production Efficiency	**Financial Consequences**	**Management Complexity**	**Priority**
Production Efficiency	0.673371	0.753878	0.476923	0.634724
Financial Consequences	0.174578	0.195450	0.415385	0.261804
Management Complexity	0.152051	0.050672	0.107692	0.103472
Sum	1.000000	1.000000	1.000000	1.000000

4.4 Preference Calculation

After normalization, the priority score can be calculated by averaging each row's normalized value for both the pairwise comparison of alternative to each criterion and criteria. The highest value of the average number will be the priority based on respondent's perspective. Figure 3 below shows the preferences calculation for alternatives to each criterion and the criteria.

Production Efficiency	
Alternative	Priority
Nutritional	0.765480551
Management risk	0.12587069
Thermal risk	0.108648759

Financial Consequences	
Alternative	Priority
Nutritional	0.781530
Management risk	0.121471
Thermal risk	0.096999

Management Complexity	
Alternative	Priority
Nutritional	0.762822
Management risk	0.147750
Thermal risk	0.089427

Criteria	
	Priority
Production Efficiency	0.634724
Financial Consequences	0.261804
Management Complexity	0.103472

Figure 3: Results of Preferences Calculation.

According to the findings depicted in Figure 3, most farmers favoured Nutritional as having the highest reputation ranking among the various alternatives. Regarding production efficiency, Nutritional emerges as the primary risk selected among other alternatives, holding the highest priority at 0.76548. Following this, management risk takes the second spot, trailed by Thermal risk, with priorities of 0.125871 and 0.108649 respectively.

In the realm of financial consequences, most respondents believe that nutritional poses higher risks compared to other alternatives, holding the highest priority of 0. 0.781530. Following Nutritional, Management risk, Thermal risk, follow with priorities of 0.121471 and 0.09699899 respectively. The prioritization of Nutritional as the primary concern in production costs aligns with its significant impact beyond the expensive price of food. Nutritional factors substantially influence production expenses due to their intricate relationship with output quality, efficiency, and resource utilization. Therefore, respondents likely emphasize Nutritional as a critical risk factor due to its considerable potential to affect the overall cost structure beyond the initial expense of the food itself.

Regarding management complexity, the majority of participants perceived nutritional as the primary concern among other options due to the direct impact of nutrition on workforce health and productivity or the intricate management required for nutritional programs or initiatives within the labour framework. Nutritional holds the highest priority at 0.762822, with management risk, thermal risk following at priorities of 0.147750 and 0.089427, respectively.

The priorities assigned to the criteria for assessing management risk in poultry farming reveal valuable insights into stakeholders' perceptions of risk factors within this domain. Production efficiency emerges as the most significant criterion, with a priority score of 0.634724, underscoring the importance placed on optimizing output while minimizing resource inputs. Financial consequences, assigned a priority score of 0.261804, follow closely behind, indicating stakeholders' recognition of the economic impacts of risks on poultry farming operations. However, management complexity receives the lowest priority score of 0.103472, suggesting that while acknowledged, factors such as biosecurity protocols, workforce management challenges, and regulatory compliance requirements are perceived as relatively less influential in assessing and managing risks compared to production efficiency and financial considerations. These findings offer crucial insights for stakeholders in prioritizing resources and implementing effective risk management strategies to enhance overall farm performance and sustainability.

4.5 Model Evaluation:

4.5.1 Consistency Check

Sum the value to get the weighted sum:

$$0.6347239 \begin{bmatrix} 1 \\ 0.259259 \\ 0.225806 \end{bmatrix} + 0.261804 \begin{bmatrix} 3.857143 \\ 1 \\ 0.259259 \end{bmatrix} +$$

$$0.116381035 \begin{bmatrix} 4.428571 \\ 3.857143 \\ 1 \end{bmatrix} = \begin{bmatrix} 2.102773 \\ 0.719453 \\ 0.314672 \end{bmatrix}$$

Divide the weighted sum with the priority of each criterion:

$$\begin{bmatrix}2.102773\\0.719453\\0.314672\end{bmatrix} \div \begin{bmatrix}0.634724\\0.261804\\0.103472\end{bmatrix} = \begin{bmatrix}3.312893\\2.748058\\3.041130\end{bmatrix}$$

Average the value to get the Eigenvalue (λ_{max}):

$$\lambda_{max} = 3.034027$$

Calculate the consistency index using Eigenvalue, number of criteria (3):

$$\text{Consistency Index (CI)} = \frac{3.034027-3}{3-1} = 0.017014$$

Compute the consistency ratio using the CI, random index (0.58):

$$\text{Consistency Ratio (CR)} = \frac{0.017014}{0.58} = 0.029334$$

To evaluate the AHP model, the relative weight in Table 7. will be recorded in a matrix. The matrix is then multiplied by itself several times with the relative priority of the criteria which showed in Figure 3. From the calculation above, the weighted sum will be used to divide by the relative priority of the criteria and the average value of it is the Eigenvalue (λ_{max}). The λ_{max} is 3.034027 and will be used to compute the Confidence Index (CI) according to the number of criteria. The calculated CI is 0.017014 and will be used to compute the Consistency Ratio (CR). According to Table 4, if number of the criteria is 3, the random index will be 0.58. The calculated CR is 0.029334 which less than 0.1, hence, it can be concluded that this AHP model is acceptable.

4.5.2 Overall Ranking:

Priority of nutritional:

$$(0.765481 \times 0.634724) + (0.781530 \times 0.261804) + (0.762822 \times 0.103472) = 0.769407$$

Priority of management risk:

$$(0.125871 \times 0.634724) + (0.121471 \times 0.261804) + (0.147750 \times 0.103472) = 0.126983$$

Priority of thermal risk:

$$(0.108649 \times 0.634724) + (0.096999 \times 0.261804) + (0.089427 \times 0.103472) = 0.103610$$

Table 12: Overall Ranking of the Alternatives.

Alternative	Priority
Nutritional	0.769407
Management risk	0.126983
Thermal risk	0.103610

Table 12 shows the overall ranking of the alternative, the calculated result showed that nutritional is main risk to be selected with the highest priority of 0.769407, followed by the management risk and thermal risk with the priority of 0.126983 and 0.103610 respectively.

5. CONCLUSION

In this study, the Analytic Hierarchy Process (AHP) was employed to assess and prioritize risks in poultry farming, focusing on nutritional risk, management risk, and thermal risk. The results of the analysis revealed that among the alternatives considered, nutritional risk ranked highest, followed by management risk and thermal risk. Furthermore, when evaluating criteria, production efficiency emerged as the most significant factor, followed by financial consequences and management complexity. These findings underscore the multifaceted nature of risk management in poultry farming and highlight the need for a comprehensive approach to address diverse challenges.

The importance of risk management in poultry farming cannot be overstated. Effective risk management strategies are essential for mitigating potential threats to poultry health, welfare, and productivity, as well as ensuring the financial viability and sustainability of farming operations. By systematically identifying and prioritizing risks using methodologies like AHP, poultry farmers and industry stakeholders can make informed decisions and allocate resources efficiently to minimize the impact of adverse events and maximize overall farm performance.

The AHP analysis conducted in this research has made significant contributions to understanding and prioritizing nutritional risk, management risk, and thermal risk in poultry farming. By providing a structured framework for evaluating and comparing risk factors based on their relative importance, AHP enables stakeholders to identify key areas of concern and allocate resources effectively to mitigate risks. This research contributes to the broader body of knowledge on agricultural risk management and provides valuable insights for improving risk management practices within the poultry farming industry. Moving forward, continued research and innovation in risk assessment methodologies will be essential to address emerging challenges and ensure the long-term sustainability of poultry farming operations.

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