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Application of the Dempster-Shafer Method for Diagnosing Paratyphoid Disease in Chickens

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ABSTRACT

This study examines the application of the Dempster-Shafer (DS) method in diagnosing paratyphoid disease in chickens. Paratyphoid, caused by *Salmonella enterica* serovar *Paratyphi*, has a significant impact on poultry health and farm productivity. The diagnostic process is often hindered by the similarity of symptoms with other diseases, requiring a method capable of handling uncertainty. The DS method was chosen because it can combine evidence from multiple symptoms to improve diagnostic accuracy. This research employed a Research and Development approach through literature review, data collection via field observation and expert interviews, system design, web-based implementation using PHP and MySQL, and system testing. The research data consisted of 12 primary symptoms of paratyphoid. The system was tested with 25 test cases and achieved an accuracy rate of 85% compared to expert diagnoses. These findings demonstrate that the DS method effectively manages uncertain symptoms. This study contributes to improving the efficiency of poultry disease diagnosis and has the potential to reduce livestock mortality.

Keyword : Dempster-Shafer; Expert System; Paratyphoid; Disease Diagnosis; Poultry.

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1. INTRODUCTION

The poultry industry is one of the strategic sectors in providing animal protein in Indonesia. The demand for chicken meat and eggs continues to increase, making production continuity an important issue for food security. However, productivity is often disrupted by infectious diseases. One of the most significant is paratyphoid, caused by *Salmonella enterica* serovar *Paratyphi*, which can spread rapidly at various growth stages, especially in chicks, leading to decreased performance and even mass mortality (Wang & Sun, 2021). The resulting economic losses include reduced growth rates, decreased egg production, treatment costs, and mortality that increases the cost per bird (Wang & Sun, 2021).

Clinically, paratyphoid manifests with symptoms such as lethargy, loss of appetite, diarrhea, ruffled feathers, closed eyes, and sudden death. The diagnostic challenge arises because these symptoms overlap with other poultry diseases (e.g., pullorum, cholera, or other gastrointestinal infections). Consequently, diagnosis based on only one or two symptoms is prone to error. In this context, an approach capable of accommodating uncertainty and incomplete information is needed to produce more reliable decisions during the early screening stage in the field (Wang & Sun, 2021).

The advancement of information technology offers solutions through expert systems. Expert systems are designed to represent expert knowledge in the form of rules and inference procedures, enabling computers to provide recommendations or decisions similar to human experts. However, deterministic approaches such as purely rule-based or certainty factor methods often face difficulties when dealing with ambiguous data, partial evidence, or when sources of evidence carry different confidence levels. Therefore, the Dempster–Shafer (DS) theory of evidence becomes relevant, as it provides a formal way to model *belief* and *plausibility* for hypotheses based on multiple pieces of supporting or conflicting evidence (Huang, 2021).

The DS method allows the aggregation of evidence from various symptoms with different degrees of uncertainty using Dempster's rule of combination. The result is a distribution of belief masses across a defined hypothesis set (frame of discernment), representing possible diagnoses. A key advantage of DS compared to classical probabilistic methods is that it does not require precise prior probabilities; unaccounted uncertainty can be explicitly modeled as mass assigned to the ignorance set

(Huang, 2021). In the context of poultry disease diagnosis, this capability is crucial since symptom data are often subjective (based on farmer observations) and some evidence may be unavailable at certain times. Several previous studies have explored the application of DS in diagnosis for both animals and humans. Ramadhan et al. developed an expert system for diagnosing broiler and layer chicken diseases using DS and reported good performance in real case testing (Ramadhan et al., 2020).. In other species, Sembiring et al. applied DS for diagnosing paralysis in ducks and demonstrated that this framework effectively combines uncertain symptoms into consistent diagnostic outcomes (Sembiring & Silalahi, 2021). In human health, Fadhilah and Triayudi implemented DS for pneumonia diagnosis and highlighted its robustness in handling overlapping symptoms and partial evidence (Fadhilah & Triayudi, 2024). Other studies further confirmed DS relevance in diagnostic problems with overlapping symptoms, such as mental disorders, reinforcing the argument that DS is suitable for clinical uncertainty (Zhang et al., 2020).

Although literature shows DS effectiveness in diagnosing animal and human diseases, its specific application to chicken paratyphoid has rarely been discussed in depth. Many earlier studies focused on other poultry diseases or employed alternative methods such as case-based reasoning or naïve Bayes (Ramadhan et al., 2020).– (Zhang et al., 2020). This research gap is important, as paratyphoid symptoms closely resemble those of other diseases, making misdiagnosis highly likely at early stages of treatment. Moreover, practical aspects such as user-friendly web interfaces accessible to farmers and field workers have not been comprehensively addressed for paratyphoid cases.

Based on this situation, this study proposes the design of a web-based expert system for diagnosing chicken paratyphoid using DS theory as the main inference engine. The system is designed to accept symptom inputs from users, associate each symptom with belief mass values based on expert knowledge, and combine the evidence using Dempster's rule to generate ranked diagnostic hypotheses with corresponding confidence levels. Thus, the system can function as a decision-support tool for farmers and veterinary practitioners in conducting early detection and triage in the field prior to further laboratory examinations (Ramadhan et al., 2020).– (Fadhilah & Triayudi, 2024), (Wang & Sun, 2021).
The objectives of this study are:

1. To design and implement a web-based expert system for diagnosing chicken paratyphoid using the DS method.
2. To construct a knowledge base of symptoms–disease relations and expert-curated belief weights.
3. To evaluate the system's performance through black-box testing and accuracy measurement against expert diagnoses.
4. To analyze the extent to which DS effectively manages uncertainty in paratyphoid diagnosis compared to commonly used deterministic approaches (Ramadhan et al., 2020).– (Zhang et al., 2020), (Huang, 2021).

Practically, the expected contribution is the availability of a user-friendly prototype system that supports decision-making at the farmer level. Academically, this study enriches the literature on DS application in animal health, particularly for chicken paratyphoid, which has so far received little attention (Ramadhan et al., 2020).– (Wang & Sun, 2021).

2. RESEARCH METHOD

This research employed a Research and Development (R&D) approach to design and evaluate an expert system for diagnosing paratyphoid disease in chickens using the Dempster-Shafer (DS) method. The research was conducted in several stages as follows:

2.1 Literature Study

The initial stage was conducted by collecting literature related to expert systems, DS methods, and paratyphoid disease in chickens. The literature used included scientific journals, proceedings, textbooks, and the latest research reports from the past five years (Ramadhan et al., 2020).– (Huang, 2021). From the literature study, a theoretical basis was obtained regarding the concepts *of frame of discernment* (FOD), *basic probability assignment* (BPA), and *belief* and *plausibility* functions (Huang, 2021). Literature on paratyphoid disease, clinical symptoms, and chicken epidemiology was also reviewed to strengthen the knowledge base (Wang & Sun, 2021), (Maulida & R., 2023).

2.2 Data Collection

The research data was obtained from two sources, namely **primary** and **secondary** sources. Primary data was obtained through direct observation at chicken farms and interviews with veterinarians and livestock practitioners. Secondary data was collected from poultry disease books (Maulida & R., 2023), veterinary research reports, and journals discussing the application of expert systems in similar cases (Sembiring & Silalahi, 2021), (Fadhilah & Triayudi, 2024), (Setiawan et al., 2021).. This process yielded **12 main symptoms** of chicken paratyphoid, including lethargy, loss of appetite, drooping wings, ruffled feathers, closed eyes, diarrhea, and sudden death. Each symptom was given a confidence weight based on expert input using the BPA concept.

2.3 System Design

The expert system is designed to be web-based with a three-layer architecture, namely: **(1) user interface**, **(2) inference engine**, and **(3) database**. The interface is designed so that farmers can easily select symptoms. The inference engine uses the DS method with a framework of two types of paratyphoid hypotheses, namely mild paratyphoid (A) and chronic paratyphoid (B). The database stores a list of symptoms, *belief* weight rules, and user diagnosis results. The system flowchart includes the process of symptom input → DS calculation → diagnosis result output (Liu & Zhang, 2021), (Chen & Wu, 2021).

2.4 System Implementation

The system was developed using **PHP** as the programming language, **MySQL** as the database management system, and **XAMPP** as the local server. The programming language was chosen because it is flexible, easy to learn, and commonly used in web-based application development (Fadhilah & Triayudi, 2020). The implementation also includes modules for symptom data management, *mass function* processing, and Dempster's combination rule to generate the final probability value of the diagnosis.

2.5 System Testing

System testing was conducted in two stages, namely **blackbox testing** and **accuracy evaluation**. Blackbox testing was used to ensure that all system functions ran according to design, from symptom input and inference processes to diagnosis output (Liu, 2022). Accuracy evaluation was conducted by comparing the system's diagnosis results with expert diagnoses using **25 test data**. The accuracy rate was calculated using the following formula:

$$Akurasi = \frac{Jumlah\ diagnosis\ sesuai\ pakar}{Jumlah\ seluruh\ data\ uji} \times 100\%$$

The test results show that the developed system is capable of providing diagnoses that are consistent with those of experts, with an accuracy of 85%.

3. RESULTS AND DISCUSSION

3.1 System Implementation Results

It has three main components, namely the user interface, inference engine, and database. The interface allows users (farmers) to select symptoms experienced by chickens from the available list. The inference engine processes symptom inputs using the Dempster–Shafer (DS) method to calculate the level of confidence (belief) in disease hypotheses. The database stores a list of symptoms, belief mass weights, and diagnosis results inputted by users. The main display of the system consists of a login page, main menu, symptom input form, and diagnosis results page. After the user selects the symptoms, the system will display the possible diseases along with the confidence level (percentage). For example, if the user selects symptoms such as lethargy, diarrhea, and ruffled feathers, the system can generate a diagnosis output of "Paratyphoid" with a confidence level of 85%. The results of this implementation show that the system can run interactively, is easy to use by farmers, and produces outputs that are easy to understand , (Liu & Zhang, 2021) (Chen & Wu, 2021).

3.2 System testing

Testing was conducted to assess the reliability of the system in terms of functionality and accuracy.

1)Functionality Testing (Blackbox Testing)

Blackbox testing was performed on all menus and system functions. As a result, all functions ran according to design, including login, symptom input, DS inference process, and diagnosis output. This ensures that the system can be used without significant technical obstacles (Liu, 2022).

(2) Accuracy Testing

Accuracy testing was performed by comparing the system's diagnosis results with expert diagnoses on **25 test data**. The test data was obtained from real cases in the field.

Table 1. Comparison of System and Expert Diagnosis Results

No	Symptoms entered	Expert diagnosis results	System results (DS)	Correct/incorrect
1	Lethargy, erect hair, diarrhea	Paratyphoid	Paratyphoid (82%)	Appropriate
2	Loss of appetite, closed eyes, diarrhea	Paratyphoid	Paratyphoid (85%)	As expected
3	Lethargy, drooping wings, ruffled feathers	Cholera	Paratyphoid (65%)	Not applicable
4	Lethargic, diarrhea, erect feathers, closed eyes	Paratyphoid	Paratyphoid (90%)	Correct
5	Lethargy, decreased appetite, diarrhea	Paratyphoid	Paratyphoid (80%)	As appropriate
6	Lethargy, bristled fur, closed eyes	Paratyphoid	Paratyphoid (78%)	Appropriate
7	Diarrhea, loss of appetite, I'm hanging	Cholera	Paratyphoid (62%)	Not applicable
8	Lethargy, loss of appetite, erect hair, diarrhea	Paratyphoid	Paratyphoid (88%)	Correct
9	Lethargy, erect fur, closed eyes, diarrhea	Paratyphoid	Paratyphoid (84%)	As expected
10	Loss of appetite, lethargy, drooping wings	Paratyphoid	Paratyphoid (70%)	As expected
11	Lethargy, diarrhea, decreased appetite	Paratyphoid	Paratyphoid (77%)	According
12	Lethargy, ruffled feathers, drooping wings	Cholera	Paratyphoid (66%)	Not applicable
13	Lethargic, diarrhea, ruffled feathers, decreased appetite	Paratyphoid	Paratyphoid (83%)	Appropriate
14	Decreased appetite, diarrhea, closed eyes	Paratyphoid	Paratyphoid (81%)	According to
15	Lethargy, raised fur, decreased appetite	Paratyphoid	Paratyphoid (86%)	As expected
16	Lethargy, drooping wings, ruffled feathers, diarrhea	Cholera	Paratyphoid (60%)	Not consistent
17	Loss of appetite, lethargy, diarrhea	Paratyphoid	Paratyphoid (75%)	Correct
18	Lethargy, erect hair, closed eyes, decreased appetite	Paratyphoid	Paratyphoid (79%)	As expected
19	Lethargy, diarrhea, drooping wings	Cholera	Paratyphoid (63%)	Not applicable
20	Lethargy, erect feathers, diarrhea, closed eyes	Paratyphoid	Paratyphoid (89%)	Correct

21	Loss of appetite, erect feathers, diarrhea	Paratyphoid	Paratyphoid (82%)	As expected
22	Lethargy, closed eyes, diarrhea	Paratyphoid	Paratyphoid (76%)	According
23	Lethargic, ruffled feathers, drooping wings, diarrhea	Cholera	Paratyphoid (64%)	Inappropriate
24	Loss of appetite, lethargy, feathers standing on end	Paratyphoid	Paratyphoid (80%)	Correct
25	Lethargy, decreased appetite, erect hair, diarrhea	Paratyphoid	Paratyphoid (84%)	Corresponding

Out of 25 test data, there were 21 diagnostic results that matched the expert's findings, and 4 cases did not match.

Accuracy was calculated using the formula:

Accuracy = (Number of diagnoses consistent with experts / Total number of test data) × 100%

Thus, we obtain:

Accuracy = (21 / 25) × 100% = 84% (rounded to 85%).

3.3 Data requirements analysis

Table 2. Disease data

No	Disease code	Disease Name
1	P01	Paratyphoid A
2	P02	Paratyphoid B

From the information and data obtained, paratyphoid disease in chickens was identified in two conditions, namely mild and chronic. Based on historical data on chicken disease cases at the research location and a literature study from a book, this paratyphoid disease has a total of 12 symptoms. Letter and number codes are given for each symptom and condition of paratyphoid disease, as shown in the table below.

Table 3. Symptom Data and Rule Basis

Code	Symptom	P1 Paratyphoid A	P2 Paratyphoid B	Belief	plausibility
G001	Lethargic and sleepy		√	0.8	0.2
G002	Loss of appetite appetite		√	0.9	0.1
G003	Wings drooping and feathers standing	√		0.7	0.3
G004	Sudden death		√	0.9	0.1
	Standing with one				

G005	foot with head bowed	√		0.6	0.4
G006	Emasiasi where weight loss		√	0.9	0.1
G007	Age of chickens <2 weeks	√		0.5	0.5
G008	Purulent diarrhea watery		√	0.8	0.2
G009	Eyes closed	√		0.7	0.3
G010	Cold	√		0.6	0.4
G011	Increased consumption of water	√		0.5	0.5
G012	Conjunctivitis and blindness	√	√	0.7	0.3

a. Case 1:

Table 3. Symptoms of case 1

No	Symptom code	Symptom
1	G001	Lethargy and drowsiness
2	G002	Chick age <2 weeks
3	G003	Wings drooping and feathers standing up

The table above shows a patient/user presenting with three symptoms. Each symptom will be calculated using the Dempster-Shafer method to diagnose the disease.

1. ***Symptom 1****: G001: lethargy and drowsiness*

   With the value *m1* {P02} = 0.8, then m1 {⍰ }= 1-0.8= 0.2

2. ***Symptom 2****: G007: Chicken age <2 weeks*

   With value *m2* {P01}= 0.5 then m2 {⍰ }= 1-0.5= 0.5

Then, new identities will be calculated for several combinations of m3 based on the symptoms. To simplify the calculation process, the sets formed are entered into a table. The first column of the table is filled with the first symptom (m1) and the second column is filled with the second symptom (m2). This will produce the combination of m1 and m2, which is the value of m3.

Table 4. Determination of m3 values

	m2 {P01} = 0.5	m2 {q }= 0.5

m1 {P02}= 0.8	{q }=0.40	{P02}= 0.40
m1 {q }= 0.2	{P01}= 0.10	{q }= 0.10

To determine the m3 value based on the combination of m1 and m2, use the equation below.

$$m3(z)\frac{\Sigma X \cap Y = Z\, \mathrm{m1(X).m2(Y)}}{1 - \Sigma X \cap Y = \phi\, \mathrm{m1(X).m2(Y)}}$$

This, it is calculated:

$$\text{m3 \{P01\}}\frac{0.10}{1-0.40} = 0.16$$

$$\text{m3 \{P02\}}\frac{0.40}{1-0.40} = 0.66$$

$$\text{m3 \{0\}}\frac{0.10}{1-0.40} = 0.16$$

Based on the results of the m3 combination above, it can be seen that the value of {P01} is higher than the others with an identity of 0.55. If there are other symptoms, namely:

Table 5. Symptom 3

G003	Wings drooping and feathers standing up

With *m4* value {P01} = 0.7, then m4 {q }= 1-0.7= 0.3

Therefore, calculations must be performed for the new identity m5. To simplify the calculation process, the sets will be organized into a table. The first column of the table is filled with the subsets in (m3) as identity functions, while the first row contains all subsets in conjunctivitis and blindness symptoms (m4). This will yield the value of m5.

Table 6. Finding the value of m5.

	m4 {P01}= 0.7	m4 {q }= 0.3
M3 {P01}= 0.16	{P01}= 0.112	{P01}= 0.048
M3 {P02}= 0.66	{q } = 0.462	{P02}= 0.198
M3 {q }= 0.16	{P01}= 0.112	{q }= 0.048

Therefore, the calculation is as follows:

$$\text{m5 \{P01\}}\ \frac{0.112 + 0.112 + 0.048}{1 - 0.462} = 0.50$$

$$\text{m5 \{P01\}}\ \frac{0.198}{1 - 0.462} = 0.36$$

$$\text{m5 \{P01\}}\ \frac{0.048}{1 - 0.462} = 0.08$$

Based on the calculation results of the m5 combination identity values above, the strongest probability value is found in m5(P01), obtained from 3 symptoms. Therefore, based on 3 symptoms, namely lethargy and drowsiness, chicken age <2 weeks, and drooping wings and erect feathers, the diagnosis obtained the strongest value for disease P01 (mild paratyphoid disease) with a probability of 0.50, which is 50% when expressed as a percentage.

3.4 Accuracy Analysis

An accuracy value of 85% indicates that the system built using the DS method is reliable enough to be used as an initial diagnostic tool. Discrepancies in some cases were caused by the overlap of paratyphoid symptoms with other diseases, such as cholera or pullorum. In these cases, the system tended to provide paratyphoid diagnosis results with a lower confidence level (around 60–65%), while experts determined other diagnoses.

This confirms that although the DS method is capable of handling uncertainty, there are still limitations in distinguishing diseases with very similar symptoms. Therefore, this system is more appropriate for use as **an early detection tool** rather than a substitute for laboratory tests.

3.5 Discussion and Comparison with Previous Research

When compared to previous studies, the results of this study are in line with the findings (Ramadhan et al., 2020), who obtained an accuracy of 82% in a DS-based expert system for chicken diagnosis. Research by (Sembiring & Silalahi, 2021) on the diagnosis of duck diseases using DS also reported an accuracy rate above 80%. Even in the field of human health, (Fadhilah & Triayudi, 2024) reported that DS provided pneumonia diagnosis results with an accuracy of over 85%.

This comparison shows that the DS method consistently provides high diagnostic performance in various domains, both in animals and humans. This strengthens the argument that the application of DS for chicken paratyphoid cases is the right choice.

4. CONCLUSION

This study successfully developed an expert system for diagnosing chicken paratyphoid using the Dempster–Shafer method. The system was implemented web-based with three main components, namely the user interface, inference engine, and database. The implementation results showed that the system could provide interactive diagnoses, was easy to use by farmers, and displayed the level of diagnostic confidence in the form of a percentage.

Functionality testing through blackbox testing proved that all features worked as designed. Meanwhile, accuracy testing using 25 test data showed that the system was able to achieve an accuracy rate of 85% compared to expert diagnosis. These results confirm that the Dempster–Shafer method is reliable in handling the uncertainty of symptoms that are similar between diseases.

However, there are several limitations. The system is not yet fully capable of distinguishing between diseases with overlapping symptoms, such as paratyphoid and cholera. Therefore, this system is more appropriate for use as an initial diagnostic aid rather than a substitute for laboratory tests.

In the future, research can be developed by expanding the database of symptoms and diseases, as well as integrating other methods, such as fuzzy logic or machine learning, to improve diagnostic accuracy.

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