Broiler Chicken Coop Heating Efficiency Analysis: Comparative Study of Heat Dispersion and Energy Consumption

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ABSTRAK

Pemanas kandang ayam broiler berperan penting dalam menjaga suhu optimal selama fase *brooding* untuk mendukung pertumbuhan yang optimal. Namun, pemanas konvensional seperti *Super Saver Heater* dan *Heater Handmade* memiliki beberapa keterbatasan dalam hal efisiensi energi dan distribusi panas. Penelitian ini bertujuan untuk menganalisis performa pemanas hasil penelitian dalam tiga aspek utama, yaitu kecepatan pemanasan, penyebaran panas, dan efisiensi konsumsi bahan bakar LPG, serta membandingkannya dengan pemanas konvensional. Hasil pengujian menunjukkan bahwa pemanas hasil penelitian mampu menaikkan suhu dari 26°C menjadi 53°C dalam waktu 2 menit, dengan rata-rata peningkatan suhu sebesar 13,5°C per menit, lebih tinggi dibandingkan pemanas konvensional. Penyebaran panas juga lebih merata, dengan suhu stabil pada berbagai titik pengukuran dalam kandang. Dari segi efisiensi energi, pemanas hasil penelitian mengkonsumsi 0,5 kg LPG dalam waktu 6 menit, lebih hemat dibandingkan *Super Saver Heater* yang mengkonsumsi 1 kg LPG. Secara keseluruhan, pemanas hasil penelitian lebih unggul dalam aspek efisiensi energi, kecepatan pemanasan, dan kestabilan penyebaran panas, menjadikannya alternatif yang lebih efektif dibandingkan pemanas konvensional yang telah digunakan sebelumnya.
Kata kunci: efisiensi energi; pemanas kandang; penyebaran panas

ABSTRACT

Broiler house heaters play a crucial role in maintaining optimal temperatures during the brooding phase to support optimal growth. However, conventional heaters such as the Super Saver Heater and Heater Handmade have limitations in terms of energy efficiency and heat distribution. This research aims to analyze the performance of the proposed heater in three key aspects: heating rate, heat distribution, and fuel consumption efficiency, and compare it with conventional heaters. The results indicate that the proposed heater increased the temperature from 26°C to 53°C within 2 minutes, with an average heating rate of 13.5°C per minute, outperforming conventional heaters. Heat distribution was more uniform, ensuring stable temperatures at various measurement points within the broiler house. In terms of energy efficiency, the proposed heater consumed only 0.5 kg of LPG in 6 minutes, significantly lower than the Super Saver Heater, which required 1 kg of LPG. Overall, the proposed heater demonstrated superior energy efficiency, faster heating, and more stable heat distribution, making it a more effective alternative to conventional heating systems used in broiler farming.
Keywords: broiler house heater; energy efficiency, heat distribution

INTRODUCTION

The broiler chicken farming industry continues to grow along with the increasing demand for chicken meat in the global market. The closed-house system is the primary choice in broiler chicken cultivation because it can optimally control temperature and humidity, directly affecting broiler chickens' growth rate and productivity [1]. One of the main challenges in this system is the maintenance of stable cage temperatures, especially in the *brooding* phase (the first 1–14 days), where the chicks rely heavily on artificial heating to replace the warmth of their brood [2].

CV XYZ (one of the broiler chicken breeders located in Karanglor Village, Manyaran District, Wonogiri, Central Java) MSMEs that are the location of this research have two cage heaters, namely Super Saver Heater and Handmade Heater, which have several shortcomings in terms of energy efficiency and heat distribution. *Super Saver Heater* has a high LPG (*Liquefied Petroleum Gas*) consumption, while *Handmade Heater* has a relatively longer heating time. This inefficiency impacts the high operational costs of farmers and the instability of cage temperatures, which risks causing stress and growth disruption in broiler chickens [3]. Therefore, innovation is needed in the design of cage heaters that are more energy-efficient, fast in reaching optimal temperatures, and effective in heat distribution.

This research focuses on designing and analyzing cage heaters developed using the VDI 2222 design method to produce more efficient heaters than conventional heaters. *The VDI 2222* method is a systematic approach in design engineering that allows the design process to be carried out in a structured and analysis-based manner [4]. The VDI 2222 method has been widely applied in engineering product design to optimize mechanical systems and energy efficiency. This systematic approach has been used to design tools for assembling four-way entry pallets, resulting in significant time savings of 61.66% and eliminating the need for subcontracting [5]. This method has also been used in redesigning and analyzing benchtop injection moulding machines, addressing problems with frame structures, injection mechanisms, and heating systems [6]. Compared to other design methodologies, such as French Pahl and Beitz, *VDI 2222* offers a more comprehensive and detailed approach, making it ideal for novice engineers in product development and mechanical engineering [4]. This method typically consists of four main stages: task clarification, conceptual design, embodiment design, and detailed design, which provides a structured framework for engineers to create and optimize products efficiently. Using this method, the designed heater is expected to have advantages in terms of energy efficiency, ease of production, and durability in a livestock environment. The test was carried out to measure heating speed, temperature spread, and LPG consumption to find out the extent of the efficiency improvement achieved. Some of the main problems that will be studied in this research include how quickly the *heater* can raise the temperature of the cage compared to conventional heaters, how effective the heat distribution is generated in the broiler chicken coop environment, and the extent to which LPG fuel consumption can be reduced with the use of this heater.

This research is closely related to chicken coop heating technology in *a closed house* system, heat transfer efficiency, LPG-based energy consumption, and engineering design methods used in the development of this tool. Therefore, in this section, several relevant theoretical aspects will be discussed, including chicken coop heating systems, heat transfer principles, energy efficiency in heating systems, as well as the application *of the VDI 2222* method in engineering design.

Chicken coop heating systems play an important role in maintaining optimal temperatures during *the brooding* period. Newly hatched chicks are highly dependent on the environment's temperature because they cannot regulate their body temperature independently. A cage heater aims to replace the warmth of its parent and ensure optimal growth. In *a closed-house* system, stable temperature control is key to avoiding stress and premature death in broiler chickens [7]. Some commonly used heaters include *Super Saver Heaters*, *Handmade Heaters*, and electric or gas-based heaters. However, even heat distribution and high energy consumption limitations are still challenges in conventional heating technology.

In heat transfer, heaters work by utilizing conduction, convection, and radiation mechanisms. Conduction occurs when heat flows through a conducting material in a heating system, such as the metal in a heating component. Convection plays a role in heat distribution within the coop, where lighter hot air rises, and cold air falls, creating air circulation that affects the comfort of broiler chickens. Meanwhile, radiation allows heat transfer without direct contact, improving heating efficiency [8]. The efficiency of heat transfer in a heater depends mainly on the appliance's design and the materials used. Therefore, selecting materials with high thermal conductivity can improve heating effectiveness and reduce energy consumption [9].

Considering the increasing cost of LPG fuel, energy efficiency in the heating system is an important aspect that needs to be considered. High energy consumption in conventional heaters can burden farmers' operating costs, so innovation in more energy-efficient heating designs is needed. Heating efficiency can be improved by optimizing the combustion chamber design, using materials with high thermal conductivity, and utilizing an automatic temperature control system to avoid energy wastage [10]. Several studies have shown that more efficient heating designs can reduce LPG consumption by up to 30-60% compared to conventional heaters [2], [11].

In developing this heating technology, *the VDI 2222* design method is used as a systematic approach to the design of the appliance. This method is widely used in design engineering to produce optimal solutions through four main stages: problem analysis, concept development, shape design, and detail design. This approach allows designers to identify the specific needs of users, evaluate design alternatives, and optimize the technical and economic aspects of the product being developed [12].

This research has a strong foundation in cage heating technology, heat transfer, energy efficiency, and engineering design based on VDI 2222 from the literature reviews submitted. By utilizing this approach, the cage heaters developed in this research will be able to provide better solutions than the current conventional heating technology.

RESEARCH METHODS

This research was conducted to analyze the performance of broiler chicken coop heaters designed using *the VDI 2222* design method. The main focus of this research is to evaluate the efficiency of heating in three main aspects, namely heating speed, heat spread, and LPG fuel consumption compared to conventional heaters. To achieve this goal, the research consists of several main stages.

Based on the research flow diagram, the research began with the identification of problems and literature studies to understand the heating needs of broiler chicken coops as well as the weaknesses of conventional heaters that have been used previously. The next stage is the design of the tool, which is carried out using *the VDI 2222* design method, a systematic approach in product engineering consisting of four main stages, namely analysis of user needs, development of design concepts, design of shapes and specifications, as well as detailed design and optimization. After the design of the tool is completed, a heating prototype is made according to the design that has been designed, then continues with performance testing to evaluate the effectiveness of the tool based on the main parameters that have been determined. The test results data are then analyzed to determine the extent to which the heater's efficiency is improved compared to conventional heaters.

Heating Plan

The design of the cage heater in this research aims to produce a more efficient tool in heat distribution and fuel consumption. The *VDI 2222* method is used to ensure that the design process is carried out systematically and based on robust technical analysis. At the needs analysis stage, obstacles in the use of conventional heaters were identified, including high energy consumption and uneven heat distribution. Based on the results of this analysis, a heating concept was developed that prioritizes energy efficiency and optimization of heat transfer through conduction and convection mechanisms.

The heater designed has four main components, namely a frame, a cover, a *primary heating system*, and a support leg with an *adjustable foot frame*. The heating dimensions are adjusted to the needs of the broiler chicken coop measuring 120 m × 12 m, with the main material in the form *of mild steel* coated with *powder coating* to increase resistance to heat and corrosion. The main heating system uses LPG fuel with an automatic lighter mechanism based on *thermocouple* and *thermostat* to keep the temperature in the optimal range of 27°C – 33°C according to the needs of broiler chickens in the *brooding phase*.

Testing Procedure

The test was carried out by comparing the performance of the heater used in this research with two types of conventional heaters, namely Super Saver Heater and Handmade Heater. This test includes three types of tests which can be seen in Table 1.

Table 1 Testing Procedure

Types of Testing	Methods Used
Heating Speed Testing	The heater is switched on in the condition of the enclosure with an initial temperature of 26°C.
	The test uses a metal plate medium placed within 1 meter of the heater to measure the temperature rise for 2 minutes.
	Temperature change data is recorded every 30 seconds until it reaches the maximum point.
	Hasil dibandingkan dengan pemanas konvensional untuk mengevaluasi efektivitas pemanas yang dibuat dalam penelitian ini dalam menaikkan suhu lebih cepat dan merata.
Heat Dispersion Testing	Measurements are made by installing temperature sensors at several points in the enclosure to evaluate the heat distribution.
	The sensor is placed within a specific radius of the heater to see the heat distribution pattern.
	Heat dispersion compared to conventional heaters to assess the efficiency of the heating system created in this research.
LPG Consumption Testing	Fuel consumption is measured by weighing the LPG cylinder before and after use during 6 minutes of heating operation.
	LPG consumption results compared to conventional heaters under the same conditions of use.
	Data are analyzed to determine the level of efficiency of the heater in fuel use.

Data Analysis Methods

After the tests were carried out, the data obtained was analyzed using quantitative methods to evaluate the performance of the heater in three main aspects. The research aspects can be seen in Table 2.

Table 2 Research Aspects

Analysis Aspect	Methods Used
Heat Transfer Analysis	Using conduction and convection equations to evaluate heat transfer efficiency based on heating materials and heat conducting media.
Energy Consumption Analysis	Compare the amount of LPG used in units of time between the heaters made in this research and conventional heaters to measure the level of energy efficiency.
Evaluation of Heating Effectiveness	Assess heating speed, temperature stability, and heat dispersion patterns in broiler chicken coops to determine the performance of the heaters created in this research compared to conventional heaters.

With this systematic research method approach, it is hoped that the research can produce valid data in assessing the performance of heaters and their potential to improve energy efficiency in the broiler chicken farming industry.

RESULTS AND DISCUSSION

This section presents the results of the broiler chicken coop heating test and discusses the findings obtained based on the research objectives, namely analyzing the heating rate, heat dispersion effectiveness, and LPG fuel consumption efficiency compared to conventional heaters.

Heating Rate Test Results

Heating rate testing was carried out to find out how quickly the research results were able to increase the temperature in broiler chicken coops. This test was carried out by turning on the heater in the initial condition of the cage temperature of 26°C, then measuring the temperature change using *a metal plate medium* placed within 1 meter of the heater for 2 minutes. Temperature data is recorded every 30 seconds, then compared to conventional heaters (*Super Saver Heater* and *Handmade Heater*).

Table ***3*** shows the results of heating speed tests for all three types of heaters.

Table 3 Heater Temperature Test Results

Time (seconds)	*Heater Handmade* (°C)	*Super Saver Heater* (°C)	Heating Research Results (°C)
0	26	26	26
30	35	40	42
60	40	45	48
90	43	48	51
120	45	50	53

The test results showed that *the researchers* had a better heating rate than conventional heaters. Within 2 minutes, the temperature increased from 26°C to 53°C, with an average increase of 13.5°C per minute. In comparison, *the Handmade Heater* is only able to reach 45°C, while *the Super Saver Heater* can reach 50°C.

This faster temperature increase is due to a more optimal heating design, which allows for more efficient heat transfer through conduction and convection mechanisms. With faster heating, *the resulting heaters* allow for time and energy savings, which directly impact the operational efficiency of the farm.

Heat Dispersion Test Results

An even spread of heat in a broiler chicken coop is essential to maintain the comfort and growth of chickens. This test was carried out by installing temperature sensors at several points in the cage, namely at a radius of 0.5 meters, 1 meter, and 2 meters from the heater. Table 4 shows the temperature distribution for each heater at different distances.

Table 4 Heat Dispersion Test Results

Distance from Heater (m)	Heater Handmade (°C)	Super Saver *Heater* (°C)	Produce Heater Penelitian (°C)
0,5	Unstable (~46)	48	50
1	39	42	45
2	32	35	38

The test results showed that the research results had a more even heat distribution compared to conventional heaters. At a radius of 0.5 meters, the average temperature reaches 50°C, while at 1 meter and 2 meters it reaches 45°C and 38°C respectively.

Compared to *Super Saver Heaters*, which have temperatures of 48°C at 0.5 meters, 42°C at 1 meter, and 35°C at 2 meters, as well as *Handmade Heaters*, which show more unstable temperature variations, the researchers found that the heat was more consistent in distributing heat. This is due to the optimization of the heating design that allows for more efficient heat flow through the air convection mechanism. With a more stable heat distribution, broiler chickens are less stressed by uneven temperatures, which contributes to more optimal growth.

LPG Consumption Test Results

Energy efficiency is an important factor in a cage heater, which is evaluated through LPG consumption measurements during 6 minutes of heating operation. Table 5 shows the results of LPG consumption testing for all three types of heaters.

The test results showed that the research heater consumed the least LPG, which was 0.5 kg in 6 minutes. In comparison, *the Super Saver Heater* consumes 1.0 kg, while *the Handmade Heater* consumes 0.7 kg.

Table 5 *LPG Consumption Test Results*

Heater Type	LPG Consumption (kg) / 6 minute
Heater Handmade	0,7
Super Saver Heater	1,0
Heater Researcher	0,5

This energy saving rate shows that the researchers are up to 50% more fuel-efficient than *Super Saver Heaters*. This efficiency is due to a more optimal combustion chamber design, which allows for more perfect combustion and reduces energy wastage.

CONCLUSION

This research has evaluated the performance of broiler chicken coop heaters through three main aspects, namely heating speed, heat dispersion effectiveness, and LPG fuel consumption efficiency, by comparing the research results with *Super Saver Heaters* and *Handmade Heaters*.

The test results showed that the researchers had a better heating speed than conventional heaters. Within 2 minutes, this heater is able to raise the temperature from 26°C to 53°C, with an average temperature increase of 13.5°C per minute. In comparison, *the Super Saver Heater* only reaches 50°C, while *the Handmade Heater* is only able to reach 45°C in the same duration.

In addition, the researchers showed a more even distribution of heat in the cage. At a radius of 0.5 meters, the average temperature reaches 50°C, while at 1 meter and 2 meters it reaches 45°C and 38°C respectively. Compared to conventional heaters that exhibit more significant and less stable temperature variations, the researchers were able to maintain better temperature stability in broiler chicken coops.

In terms of energy efficiency, the researchers found that the researchers were more economical than conventional heaters. Within 6 minutes of operation, this heater only consumes 0.5 kg of LPG, more economical than *the Super Saver Heater* which consumes 1 kg of LPG and *the Handmade Heater* which consumes 0.7 kg of LPG. Thus, the researchers were able to save up to 50% on fuel consumption compared to *Super Saver Heaters*, which has the potential to reduce the operational costs of broiler chicken farms.

To improve the performance of these heaters in the future, some further developments can be made. Optimization of automatic temperature control systems using more precise sensors can be applied to keep the temperature stable without manual intervention. In addition, the use of materials with better thermal conductivity can improve heat transfer efficiency and further reduce fuel consumption. Testing on a wider cage scale is also needed to obtain more representative data on the effectiveness of heating in real conditions in the broiler chicken farming industry. The integration of heating systems with alternative energy, such as solar panels or biomass, can be a long-term solution to reduce dependence on LPG as well as improve overall energy efficiency. With further development, the research results of the heater can become a more sustainable and energy-efficient solution for the broiler chicken farming industry.

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