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# Meta-Analysis: Effect of Transport Distance on Physiological Conditions, Pre-Slaughter, and Broiler Meat Quality

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## ABSTRACT

Meta-analysis study of the effect of transportation distance on physiological conditions, pre-slaughter, and broiler meat quality was carried out to examine the magnitude of the effect and calculate the publication bias of the effect of transportation distance on physiological conditions, pre-slaughter, and broiler meat quality. The material s obtained from 1123 studies, and 622 relevant studies were selected from 62 journals for further analysis. Parameters related to physiological conditions consist of blood glucose levels, corticosterone levels, and body temperature. Parameters of pre-slaughter conditions on arrival were observed from weight loss and mortality. Meat quality parameters were observed from the drip loss percentage, pH, and meat color. Transportation distances are categorized into various moderator individual and combined distances, namely <60 km, 60-180 km, >180 km, and combined distances (a collection of distances <60 km, 60-180 km, and >180 km). The data obtained were tabulated and analyzed using CMA 3.7 software. The results showed a negative effect of transportation distances on physiological conditions, pre-slaughter, and broiler meat quality with a moderate level of determination (est. 0.3-0.5) to strong on the parameters of physiological conditions, pre-slaughter, and broiler meat quality. (est. 0.5-1.0). Publication bias was found in several parameters, such as corticosterone levels and color (redness) did not show a significant egger's test result (p>0.05), potentially having interference with the interpretation of the study results. However, the significant results of the Rosenthal analysis (p<0.05)) mean that the intervention did not change the overall interpretation of the data. It concluded that transportation distance harmed physiological conditions, pre-slaughter, and broiler meat quality with a moderate to strong effect and the consistency of publication results.

**Keywords:** Broiler, glucose, corticosterone, body temperature, weight loss, mortality, drip loss, pH, yellowness, redness, lightness, transportation distance, meta-analysis

## INTRODUCTION

Research using the meta-analysis method is a form of research based on other relevant research data, both published and unpublished. The meta-analysis is a systematic and statistical analysis approach for identifying, assessing, and combining research results to obtain better conclusions. Based on the literature studies that have been conducted regarding research results and reviews of the effect of transportation distance on broilers, there are at least 456 literature studies that found inconsistent results and differences in conclusions. For example, in the study of Xing *et al* . (2017), the *P-value is* <0.001, and the result is significant, while in the study of Gou *et al* . (2021), the P -value is <0.423, so the result is not significant.

The advantages of meta-analysis include that it is less subjective, the results are more representative (Lee, 2019), there is an opportunity to combine the results of various previous studies with the same research problem and theme (Schroeder, 2018), various insignificant results can be accumulated, and disparities in results from various studies can be answered (Lee and Song, 2021). Thus, meta-analysis can summarize activities from various studies in an integrative manner, and conclusions can be drawn more precisely and in-depth. Various research results can be summarized through a meta-analysis method which aims to examine the magnitude of the impact of transportation on broiler chickens in an integrative manner.

Based on the general literature, the impact of transportation distance can be identified from three parameter aspects: physiological conditions, pre-slaughter period, and meat quality. Pre-slaughter is the entire step after the rearing phase on the farm until the slaughter of the chickens, and this period is relatively shorter than the rearing phase (Benincasa et al., 2020). The pre-slaughter phase, such as transportation activities, can impact stress on broilers due to the capture and loading of chickens for transportation (Tamzil et al., 2022), density ratio, distance, and duration of transportation to the slaughterhouse, and changes in microclimate during transportation (Wang *et al.*, 2017).

## MATERIALS AND METHODS

### Material

The material used is accredited journals, both national and international, research data that the Poultry Production Laboratory - Faculty of Animal and Agricultural Sciences, Diponegoro University, has carried out by searching the study literature as many as 1123 studies which are expected to contain data on one or every aspect of the study (parameter physiological conditions, *pre-slaughter,* and meat quality), and found 62 related studies that could be included. A summary of the journals used as a study is presented in appendix 1. The tools used consist of a PDF application for screening journals for which research data will be used and a data processing application in the form of Microsoft Excel Software JASP version 0.16 and CMA version 3.7. to interpret the data results obtained from the journal.

### Method

The method used in this study is a quantitative method with a meta-analytic study design. Studies included in the meta-analysis should be pre-selected based on explicit inclusion and exclusion criteria. Inclusion and exclusion criteria were based on the evaluation of abstracts and full texts, including the presentation of data in each related article. The keywords used in the search were a combination of keywords related to the influence of transportation distance, physiology, slaughter, pre-slaughter, and meat quality. The articles used are in Indonesian and English, and the time of publication is from 2000-2022. The entire study was extracted separately from the study based on the appropriate treatment distance. In addition, increasing the accuracy of the meta-analysis research related to the distance of the study moderator represented by separate data lines can be developed into four moderator databases. The transport moderator distances were categorized into <60 km, 60-180 km, >180 km, and combined distances (collection of <60 km, 60-180 km, and >180 km).

The journal that has been obtained in illustration 1. is then tabulated into the MS table. Excel before being analyzed into JASP version 0.16 and CMA version 3.7. to interpret the results of the data obtained from the journal.

The database compiled is related research in the form of publications in international and national web journals and from research that has not been published. The results of the research article selection process are described through the journal inclusion stages based on PRISMA, which are presented in illustration 1. as follows:

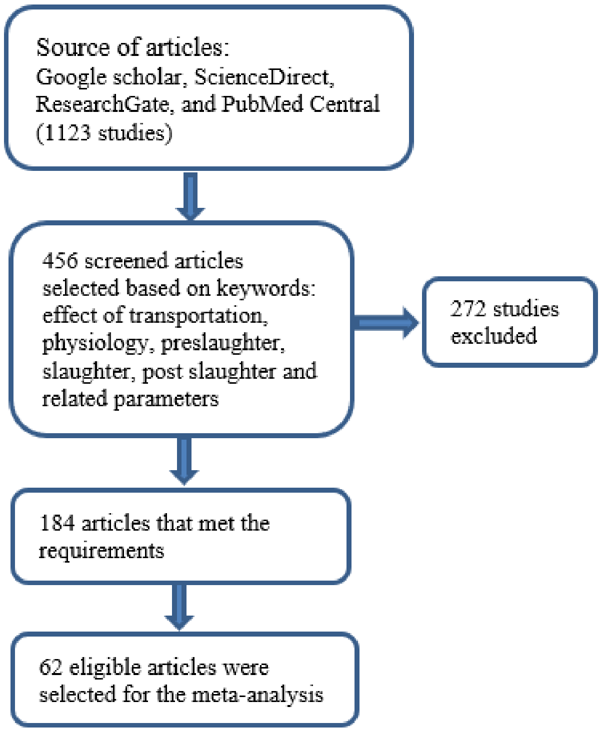


Illustration. The article selection and evaluation process used the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analysis ) method.

### Data analysis

The random effect model is seen through the presence of heterogeneity in research. The random effect model assumes that the actual effect may vary from study to study due to differences (heterogeneity) between studies. If the study allowed for an infinite number of studies, the effect estimates from all studies would follow a normal distribution. The estimates collected will be the average effect. In-study effect sizes were performed and assumed to represent a random sample of all possible effect sizes. Random effect model investigations use the plural (effect) because multiple actual effects exist in different research studies. The random effect model considers sources that contribute to variance; in addition to intra-study variability, it also considers the inter-study variability that arises from each study and the variance between studies.

Meta-analysis was carried out by measuring the effect size of group contrast studies, namely the results of studies presented in the analysis of variance, and by comparing the experimental group with the control group. The ultimate goal of a meta-analysis is to estimate the effect size to determine the summary effect of the research. The results of the summary effect are used to determine the magnitude of the effect of transportation distance on physiological conditions, pre-slaughter, and broiler meat quality. There are three categories based on Cohen's (1988) criteria, usually used in summary effect measurements. These categories are defined as follows, high category if the value is ≥ 0.5, medium category if the value is 0.5-0.3, and low category if the value is 0.3-0.1.

Biased is a data distortion that can mislead the results of meta-analytic research. In the presence of bias, the results of meta-analytic studies may be in contrast to studies of larger samples and higher quality, thereby compromising the validity of meta-analytic studies. The existence of publication bias in meta-analytic studies can be identified using funnel plots and Egger's tests. The funnel plot estimates the effect of a study of some size per study. Funnel plots present effect sizes plotted against their standard errors or precisions. Intuitively assessing publication bias is done by examining the funnel plot asymmetry. If the funnel plot results produce an asymmetrical distribution of articles, publication bias will occur in the study. However, visual examination is usually subjective. So testing for publication bias using Egger's test needs to be done to ensure the presence of publication bias if the presence of publication bias is difficult to detect through funnel plot testing.

## RESULTS AND DISCUSSION

Based on the results of a meta-analysis of the effect of transportation distance on physiological conditions, pre-slaughter and meat quality of broiler chickens are presented in Tables 1, 2, and 3. Data in Tables 1, 2, and 3 present heterogeneity, Summary Effect, p-Value of the effect of transportation distance, and the Egger test used to determine the effect of transportation distance on physiological conditions, pre-slaughter, and broiler meat quality.

### Glucose

The data table 1 results show that the summary effect of the negative effect of transportation distance on glucose levels at distances <60 km, 60-180 km, >180 km, and the combined distance is -0.617, -0.529, -0.342, and -0.428. The summary effect number means that there is an effect of transportation distance of 62%, 53%, 34%, and 43% on the decrease in glucose levels during the transportation process. The Summary Effect value included in the Confidence Interval range indicates the effect of transportation distance on glucose levels categorized in the moderate category at transportation distances >180 km and the combined distance. In contrast, strong categories were found at transportation distances <60 km and 60-180 km. It shows that transportation distance between <60 km and 60-180 km have a more substantial effect on changes in glucose levels compared to transportation distances of >180 km and the combined distance. Our results regarding broiler blood glucose levels at various transportation distances (combined, <60 km, 60-180 km, and >180 km) have a Confidence Interval (CI) value that does not involve 0 (zero). CI values that do not involve 0 are evidence that transportation distance has a different effect on changes in glucose levels.

Table 1. The results of the meta-analysis of the effect of transportation distance on the physiological conditions of broiler chickens

| Parameters | Distance (km) | Test of Residual Heterogeneity | | | Estimation | SE | z | p-Value | 95% Confidence Intervals | | Egger test |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Q | df | p-Value | | | | | Lower | Upper | p-Value |
| Glucose | Combined | 575,781 | 75 | < .001 | -0.428 | 0.089 | -4,829 | 0.000 | -0.602 | -0.254 | < .001 |
| | <60 | 43.201 | 8 | < .001 | -0.617 | 0.233 | -2,645 | 0.008 | -1.074 | -0.160 | < .001 |
| | 60 – 180 | 105,281 | 16 | < .001 | -0.529 | 0.181 | -2,919 | 0.004 | -0.884 | -0.174 | 0.001 |
| | >180 | 409,934 | 49 | < .001 | -0.342 | 0.114 | -3,008 | 0.003 | -0.564 | -0.119 | < .001 |
| Cortico-sterone | Combined | 358,951 | 41 | < .001 | 0.433 | 0.090 | 4,837 | 0.000 | 0.258 | 0.609 | 0.006 |
| | <60 | 50,33 | 10 | < .001 | 0.508 | 0.260 | 1,956 | 0.050 | -0.001 | 1.018 | 0.554 |
| | 60 – 180 | 64,431 | 10 | < .001 | 0.376 | 0.182 | 2,071 | 0.038 | 0.020 | 0.732 | < .001 |
| | >180 | 143,183 | 20 | < .001 | 0.438 | 0.122 | 3,601 | 0.000 | 0.200 | 0.677 | < .001 |
| Body temperature | Combined | 90,394 2 | 45 | < .001 | 0.707 | 0.107 | 6,577 | 0.000 | 0.496 | 0.917 | < .001 |
| | <60 | 34,595 | 5 | < .001 | 0.947 | 0.245 | 3,86 | 0.000 | 0.466 | 1.428 | 0.014 |
| | 60 – 180 | 23,276 | 10 | < .001 | 0.888 | 0.242 | 3,668 | 0.000 | 0.414 | 1,362 | < .001 |
| | >180 | 65,182 | 19 | < .001 | 0.573 | 0.137 | 4,168 | 0.000 | 0.303 | 0.842 | < .001 |

The negative impact of transportation distance in the form of a decrease in blood glucose levels in several studies was caused by stress originating from the effects of the transportation process, causing an increase in glycolytic activity and a decrease in blood glucose levels. Sarkar et al. (2013) believe stress due to the transportation process causes an increase in muscle glycogen breakdown for use in glycolysis and a decrease in glucose levels. Restrictions on drinking and feed consumption can also cause a decrease in glucose levels. According to Gou et al. (2021), a decrease in glucose in the blood of chickens occurs a few hours after feed withdrawal; broiler chickens will experience transportation stress, especially due to long-term transportation, resulting in reduced liver glycogen and causing hypoglycemia. In addition, oxidative stress through the excessive accumulation of iron during the transport process can affect the decrease in glucose levels. It is the opinion of Liu et al. (2022) that oxidative stress can increase iron accumulation and affect blood glucose levels by interfering with collagen turnover and causing increased levels of lipids in the blood, so glucose levels decrease.

Other causes of decreased blood glucose levels can be caused by the nervous, hormonal, and neurogenic systems that are activated by releasing catecholamine hormones and norepinephrine. Ibrahim and Aziz (2021) believe the transportation process activates glycogenesis enzymes. During stress, the main function of norepinephrine is to enact non-shivering thermogenesis, which provides energy to skeletal muscle from adipose tissue. Chronic heat exposure can motivate the sympathetic-adrenal medullary axis and increase noradrenaline which stimulates broiler energy metabolism to cope with dramatic changes in environmental conditions. Heat exposure during transport increases serum levels of noradrenaline and two citrate cycle intermediates (succinic acid and L-malic acid). Ranjbar et al. (2014) believe that broiler chickens suffering from heat stress can strengthen their energy metabolism by regulating the nervous system to reduce the impact of heat stress during transportation. It is in line with the opinion of Alobaidy et al. (2020) that reduced oxidation of fatty acids under chronic heat stress made broiler chickens increasingly dependent on glucose to meet energy requirements and reduce blood glucose levels.

## Corticosterone

The data table 1 results show that the summary effect of the negative effect of transportation distance on corticosterone levels at distances <60 km, 60-180 km, and>180 km, and the combined distance is 0.508, 0.376, 0.438, and 0.433. The summary effect number means that there is an effect of transportation distance of 51%, 38%, 44%, and 43% on the increase in corticosterone during the transportation process. The Summary Effect value included in the Confidence Interval range indicates that the effect of transportation distance on corticosterone is included in the moderate category at transportation distances of 60-180 km, >180 km, and combined distances and is included in the strong category at transportation distances <60 km. It shows that the effect of the transportation distance of <60 km is stronger than the transportation distance of 60-180 km, >180 km, and the combined distance. The results we obtained related to the broiler corticosterone level parameter have a CI range that does not involve zero (0) except for transportation distances <60 km, which has a CI value involving a value of 0. CI values that do not involve 0 are evidence that transportation distance has a different effect on changes in Corticosterone levels. In contrast, CI values involving a value of 0 indicate that the transportation distance <60 km does not affect corticosterone levels.

In several studies, the negative impact of increased corticosterone due to transportation stress is associated with tissue mobilization to maintain body functions. The provision of energy to maintain body functions by increasing corticosterone concentration in the blood indicates broiler stress during transportation. According to Ondrasovicová et al . (2008), corticosterone and glucagon in the blood will increase the level of glucose which aims to fight stress during transportation. Established metabolic relationships between insulin (anabolic) and corticosteroids (catabolic) have opposite effects on each other under high temperatures. Perai et al. (2015) stated that the high ambient temperature increased corticosterone concentrations but decreased insulin in broiler chickens.

In the parameter of corticosterone levels, the results of the Egger's Test were found to be insignificant (p>0.05); this indicates publication bias, which could interfere with the interpretation of research results. However, based on the results of the Rosenthal follow-up test, it was significant ($p < 0.05$) that the intervention did not change the overall interpretation of the data.

Some literacy biases and research results are generally expressed as a decrease in corticosterone caused by the transport process before transportation. We suspect several variations of moderator variables, such as differences in season or climate, modes of transportation, duration, and speed of transportation, as well as other factors that can be an additional source of stressors for broilers resulting in variations in concentrations and results of corticosterone studies. Research by Vosmerova et al. (2010) showed that corticosterone concentrations increased significantly before transportation (after capture) and decreased after transportation with distances (0, 10, 70, and 130 km) both in summer and winter. However, in this study, there was no explanation for the decrease in corticosterone after processing.

In some cases, rest after transportation may contribute to the decrease in plasma corticosterone. According to Zhang *et al.* (2009), broiler chickens stored for 4 hours in a dark and quiet place after transportation showed a reduced stress response, as indicated by lower corticosterone levels. The addition of guanidine acetic acid can also help reduce corticosterone concentrations. Research by Zhang *et al.* (2022)demonstrated that adding guanidine acetic acid may reduce corticosterone as an adverse effect caused by transport stress.

## Body temperature

The data table 1 results show that the summary effect of the negative effect of transportation distance on body temperature at distances <60 km, 60-180 km, >180 km, and the combined distance is 0.947, 0.888, 0.573, and 0.707. The summary effect number means that there is an effect of transportation distance of 95%, 89%, 57%, and 71% on the increase in body temperature during the transportation process. The Summary Effect value included in the Confidence Interval range indicates the effect of transportation distance on body temperature. Broiler chickens are included in the medium category at transportation distances > 180 km and the strong category at transportation distances < 60 km, 60-180 km, and combined distances.

The negative impact of increased metabolism during the transportation is known to contribute to an increase in body temperature. According to Hussnain *et al.* (2020), the increase in body temperature comes from high metabolic processes, so it produces more metabolic heat when transportation takes place; this metabolic heat affects the increase in body temperature of chickens. This condition can be exacerbated by poor air circulation during transportation in trucks. According to Langer et al. (2010), controlling the layout during the loading process of broiler chickens placed in the middle of the vehicle experienced an increase in body temperature of around 10°C during 2 hours of transportation compared to the side of the vehicle due to differences in air circulation between the sides of the vehicle and the middle of the vehicle.

## Weight loss

The data table 2 results show that the summary effect of the negative effect of transportation distance on broiler weight loss at distances <60 km, 60-180 km, and>180 km, and the combined distance is 0.367, 0.409, 0.514, and 0.471. The summary effect figure means that there is an effect of transportation distance of 37%, 41%, 51%, and 47% on the increase in weight loss during the transportation process. The *Summary Effect* value included in the *Confidence Interval range* indicates the effect of transportation distance on weight loss, including in the moderate category at transportation distances <60 km, 60-180 km, and combined distances, and is included in the strong category at transportation distances,> 180 km.

The negative impact of effect of transportation distance on the increase in broiler weight loss is caused by the emptying of the digestive tract, the duration of feed withdrawal, and glucose metabolism through the mechanisms of glycolysis, glycogenolysis, and gluconeogenesis (Bianchi et al., 2005; Vosmerova et al., 2010; Castellini et al., 2016). Taylor et al. research. (2001) showed that the average weight loss during transportation in the United States reached 0.285 kg annually, it consisted of 4.2% due to decreased live body weight, and 1.8% came from feces. This situation was exacerbated due to the incorrect implementation of a recall program that did not allow a minimum feed withdrawal period of 8 hours. According to Bianchi et al. (2005), feed withdrawal for less than 8 hours affects incomplete cleaning of the digestive tract and increases the possibility of carcass contamination.

Table 2. The results of the meta-analysis of the effect of transportation distance on the pre-slaughter condition of broiler chickens

| Parameters | Distance (km) | Test of Residual Heterogeneity | | | Estimation | SE | z | p-Value | 95% Confidence Intervals | | Egger test |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Q | df | p-Value | | | | | Lower | Upper | p-Value |
| Weight loss | combined | 390,394 | 66 | < .001 | 0.471 | 0.076 | 6,231 | 0.000 | 0.323 | 0.620 | < .001 |
| | <60 | 42,183 | 11 | < .001 | 0.367 | 0.174 | 2,111 | 0.035 | 0.026 | 0.708 | 0.014 |
| | 60 – 180 | 38,371 | 10 | < .001 | 0.409 | 0.200 | 2,049 | 0.040 | 0.018 | 0.800 | < .001 |
| | >180 | 219,767 | 36 | < .001 | 0.514 | 0.093 | 5,553 | 0.000 | 0.333 | 0.696 | < .001 |
| Mortality | combined | 255,859 | 36 | < .001 | 0.668 | 0.097 | 6,872 | 0.000 | 0.477 | 0.858 | < .001 |
| | <60 | 42,183 | 11 | < .001 | 0.595 | 0.162 | 3,674 | 0.000 | 0.277 | 0.912 | < .001 |
| | 60 – 180 | 34,821 | 7 | < .001 | 0.484 | 0.206 | 2,354 | 0.019 | 0.081 | 0.887 | < .001 |
| | >180 | 145,511 | 16 | < .001 | 0.850 | 0.175 | 4,863 | 0.000 | 0.508 | 1.193 | < .001 |

Such changes between day and night result in increased weight loss. According to Widyasari et al. (2021), transportation that occurs during the day and continues into the night can increase the stress on the chickens so that the reshuffling of glucose occurs and reduces the weight of the chickens. The highest decrease in body weight was also seen in transportation during winter in January, February, March, and April. It is the opinion of Vecerek et al. (2006). During winter transportation, broiler chickens face icy environmental conditions and lose body weight to maintain their body temperature.

Loss of body weight can also occur due to broiler chickens' metabolic system, which continues without feeding and drinking during transportation. Therefore, the metabolism continues to run so that the energy needed is still met by overhauling the energy stored in the body's tissues. According to Dadgar et al. (2010), the leading energy used for muscle contraction comes from glucose and fatty acids in the blood. Energy reserves (glycogen) in the form of intramuscular carbohydrates (muscle glycogen) and extra muscle carbohydrates (liver glycogen) will be broken down in the muscles when the reserves of glucose and fatty acids in the blood have been used up. An increase in the concentration of the hormone corticosterone in the blood triggers an excessive increase in metabolism and weight loss. Sara et al. (2019) opinions are that the energy requirement during transportation stress becomes very high due to the influence of the hormone corticosterone, which activates gluconeogenesis. The gluconeogenesis process uses protein and fat components as energy sources. It has an impact on reducing muscle mass which mainly contains protein.

## Mortality

The data table 2 results show that the summary effect of the negative effect of transportation distance on broiler mortality at distances <60 km, 60-180 km, and>180 km, and the combined distance is 0.595, 0.484, 0.850, and 0.668. The summary effect number means that there is an effect of transportation distance of 60%, 48%, 85%, and 67% on the mortality rate during the transportation process. The Summary Effect value included in the Confidence Interval range indicates the effect of transportation distance on broiler mortality in the moderate category at a transportation distance of 60-180 km and in the strong category at a transportation distance of <60 km, >180 km, and combined distances.

Factors can influence the negative impact in the form of increased mortality in broiler chickens before transportation, including injury to broiler chickens due to loading, microclimatic conditions, and transportation density. According to Di Martino et al. (2017), Factors such as mortality on the farm and the fishing system have also been identified as factors increasing mortality for broiler chickens in France; mechanized capture is associated with higher mortality than manual capture. The larger quantity of broiler chickens means it causes an increase in catching time which is longer, and can affect the ability of workers to catch broiler chickens according to the procedure. Research by Petracci et al. (2006) showed that related to the size of slaughterhouses, the preslaughter mortality rate found in smaller slaughterhouses can reduce the mortality rate in the pre-slaughter process compared to larger slaughterhouses. Restrictions on feed and water consumption can also cause high mortality during transportation, resulting in fatigue and increased broiler mortality.

According to Bianchi *et al.* (2005), restriction of feed and water consumption during transportation causes fatigue and causes death in broiler chickens. Seasonal conditions are known to have an impact on broiler mortality. According to Beˇno *et al.* (2021), the transportation process during hot and cold seasons significantly affects the mortality of broiler chickens when the temperature is too low and high during transportation can cause erratic poultry temperatures and increase mortality during transportation.

## Drip losses

The data in table 3 show that the summary effect of the negative effect of transportation distance on broiler drip loss at distances <60 km, 60-180 km, and>180 km, and the combined distance is 0.517, 0.342, 0.411, and 0.414. The summary effect number means that there is an effect of transportation distance of 52%, 34%, 41%, and 41% on the increase in meat drip loss during the transportation process. The Summary Effect value included in the Confidence Interval range indicates the effect of transportation distance on drip loss is included in the moderate category at transportation distances of 60-180 km, >180 km, and combined distances and is included in the strong category at transportation distances <60 km.

An increase in drip loss in broiler meat due to transportation distance is caused by damage to meat tissue due to free radicals, acids, and antioxidant imbalances. According to Xing et al. (2017), free radicals and acids produced due to transport stress can cause damage to the protein structure and reduce its hydrophilicity, damage cell membranes, cause exosmosis of cell contents and increase drip loss in chicken meat. It is supported by Lan et al. (2021) opinion that the imbalance of antioxidants causes the oxidation of lipids and proteins, followed by damage to muscle tissue. Damage to the muscle tissue increases the drip loss in the meat.

Another opinion relates to the increased drip loss caused by decreased pH and devaluation of ketone bodies that occur in chickens during transportation. In the opinion of Yalcin and Gutler (2012), when the pH decreases, it will reduce the space available for water in the cells, thereby increasing drip loss in broiler chicken meat. It is in line with the opinion of Zhang et al. (2017) that the decrease in muscle glycogen content decreased the meat's pH during transportation. Devaluation Ketone bodies that occur during transport stress can discolor meat and increase drip loss. According to Fu et al. (2022), s transport stress can devalue ketone bodies which are reflected by increased drip loss.

Table 3. The results of the meta-analysis of the effect of transportation distance on the meat quality of broiler chickens

| Parameters | Distance (km) | Test of Residual Heterogeneity | | | Estimation | SE | z | p-Value | 95% Confidence Intervals | | Egger test |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Q | df | p-Value | | | | | Lower | Upper | p-Value |
| Drip losses | combined | 382,192 | 66 | < .001 | 0.414 | 0.073 | 5,71 | 0.000 | 0.272 | 0.557 | < .001 |
| | <60 | 57,852 | 10 | < .001 | 0.517 | 0.182 | 2,848 | 0.004 | 0.161 | 0.873 | < .001 |
| | 60 – 180 | 56,683 | 13 | < .001 | 0.342 | 0.164 | 2,084 | 0.037 | 0.020 | 0.663 | < .001 |
| | >180 | 263,921 | 41 | < .001 | 0.411 | 0.090 | 4,547 | 0.000 | 0.234 | 0.588 | < .001 |
| pH | combined | 575,781 | 75 | < .001 | -0.518 | 0.072 | -7,234 | 0.000 | -0.658 | -0.377 | < .001 |
| | <60 | 43.201 | 8 | < .001 | -0.525 | 0.238 | -2,203 | 0.028 | -0.992 | -0.058 | < .001 |
| | 60 – 180 | 105,281 | 16 | < .001 | -0.495 | 0.187 | -2,65 | 0.008 | -0.861 | -0.129 | 0.001 |
| | >180 | 409,934 | 49 | < .001 | -0.526 | 0.084 | -6,261 | 0.000 | -0.690 | -0.361 | < .001 |
| Yellowness | combined | 441,993 | 80 | < .001 | 0.447 | 0.078 | 5,748 | 0.000 | 0.294 | 0.599 | < .001 |
| | <60 | 50,33 | 9 | < .001 | 0.588 | 0.192 | 3,06 | 0.002 | 0.211 | 0.965 | < .001 |
| | 60 – 180 | 79,137 | 25 | < .001 | 0.622 | 0.190 | 3,268 | 0.001 | 0.249 | 0.994 | 0.012 |
| | >180 | 305,659 | 44 | < .001 | 0.321 | 0.086 | 3,75 | 0.000 | 0.153 | 0.488 | 0.050 |
| Redness | combined | 533,824 | 83 | < .001 | -0.469 | 0.098 | -4,806 | 0.000 | -0.660 | -0.278 | < .001 |
| | <60 | 73,44 | 11 | < .001 | -0.904 | 0.249 | -3,623 | 0.000 | -1.393 | -0.415 | 0.268 |
| | 60 – 180 | 83,422 | 24 | < .001 | -0.959 | 0.262 | -3,662 | 0.000 | -1.472 | -0.446 | 0.004 |
| | >180 | 371,278 | 46 | < .001 | -0.380 | 0.083 | -2.168 | 0.030 | -0.343 | -0.017 | 0.004 |
| Lightness | combined | 465,147 | 82 | < .001 | 0.453 | 0.098 | 4,627 | 0.000 | 0.261 | 0.645 | < .001 |
| | <60 | 52,477 | 9 | < .001 | 0.557 | 0.193 | 2,884 | 0.004 | 0.178 | 0.935 | < .001 |
| | 60 – 180 | 73,162 | 23 | < .001 | 0.472 | 0.161 | 2,939 | 0.003 | 0.157 | 0.786 | 0.001 |
| | >180 | 338,474 | 48 | < .001 | 0.404 | 0.142 | 2,839 | 0.005 | 0.125 | 0.682 | < .001 |

## pH

The results in the data table 3 show that the summary effect of the negative effect of transportation distance on the pH of broiler meat at a distance of <60 km, 60-180 km, >180 km, and the combined distance is -0.525, -0.495, -0.526 and -0.518. The summary effect number means that there is an effect of the transportation distance of 53%, 50%, 53%, and 52% on the decrease in the pH of the meat during the transportation process. The *Summary Effect* value included in the *Confidence Interval range* indicates the effect of transportation distance on pH is included in the medium category at <60 km transportation distance and is included in the strong category at 60-180 km transportation distance, > 180 km, and combined distances.

As the transportation distance increases, the meat tends to experience a lower pH due to the negative effect of the transportation distance. The transport-induced increase in glycolysis suggests an increase in energy metabolism in muscle concomitant with a decrease in pH. According to Zheng *et al*. (2020), the lower meat pH may be a consequence of the increased rate of muscle glycolytic metabolism immediately after slaughter, and the glycolysis process will be accelerated when the birds experience transport stress resulting in lactate accumulation and a decreased in pH (Savenije et al., 2002). Another effect of lowering the pH can come from enzyme activity. The activity of the enzyme lactate dehydrogenase is crucial for anaerobic glycolysis in muscle. According to Lan *et al.* (2021), the activity of the enzyme lactate dehydrogenase resulted in a decrease in glycogen content, an increase in lactate content, and a further decrease in pH and meat quality.

The high speed of transportation, density, ambient temperature, and restrictions on feed and water are common causes of disturbance of broiler homeostasis and unwanted changes in meat quality. According to Al Abdullatif *et al.* (2021), lower meat pH values were associated with poor water-holding capacity; there was a 2.32% decrease in the more extended transported group in water-holding capacity. According to Zhang *et al* . (2021), exposure to cold temperatures during transport causes glycogen depletion in poultry muscles due to increased energy consumption to maintain average body temperature under these conditions. As a result, broiler chickens have fewer muscle glycogen stores at slaughter to convert to lactic acid and reduce the pH of the meat. The accumulation of H+ ions also results in a lower pH in the meat. It is the opinion of Wang *et al.* (2017) that accumulated protons from fast anaerobic glycolysis induced by transport stress cannot be removed promptly by postmortem meat, which may explain why the pH at 24 h postmortem in meat three h post-transportation is still lower than before transportation.

## Yellowness

The results in the data table 3 show that the summary effect of the negative effect of transportation distance on the *yellowness* of broiler meat at a distance of <60 km, 60-180 km, >180 km, and the combined distance is 0.588, 0.622, 0.321 and 0.447. The summary effect number means that there is an effect of transportation distance of 59%, 62%, 32%, and 45% on the increase in the *yellowness* of the meat during the transportation process. The *Summary Effect* value included in the *Confidence Interval range* indicates the effect of transportation distance on *yellowness which is* included in the moderate category at transportation distances > 180 km and combined distances and is included in the strong category at transportation distances <60 km and 60-180 km.

The increase in the degree of *yellowness* in broiler meat is caused by a decrease in muscle glycogen content due to the negative effect of transportation distance. According to Widyasari *et al.* (2021), transport stress decreases muscle glycogen content during anaerobic glycolysis. It is accompanied by decreased muscle glycogen and increased muscle lactate content. Lactate can lower muscle pH and meat quality further. If the muscle pH decreases, it will increase the damage to the integrity of muscle cells. According to Pan *et al.* (2018), damage to muscle cells due to decreased pH can increase drip loss and oxidation, which changes the color of the meat. It is in line with He et al. (2022) opinion that lower meat pH causes actin and myosin in muscles to condense and contract into granules, destroys a spatial structure, reduces water-holding capacity, and has a direct impact on meat color. Therefore, oxidation which changes the condition of the red meat pigment to yellowish, can occur. According to Arif *et al.* (2022), transportation will significantly increase the value of *yellowness* of muscle meat accompanied by a decrease in the redness value which indicates the oxidation of red myoglobin to metmyoglobin which is a yellow pigment in meat.

Enzyme and hormone activity can also increase *the yellowness* of broiler chicken meat. Research by Doctors and Połtowicz (2009) showed an indication of a positive relationship between corticosterone and meat color, an increase in corticosterone concentration was associated with a higher color value in *yellowness* and a decrease in red pigment. The activity of the lactate dehydrogenase enzyme results in a decrease in glycogen content and an increase in lactate content and yellowness in the meat. According to Lan *et al.* (2021), the enzyme lactate dehydrogenase is the main enzyme in anaerobic glycolysis in muscle; this enzyme will increase the lactate content and further decrease the pH and quality of the meat.

## Redness

The data table 3 shows the summary effect of transportation distance's negative effect on broiler chicken's redness at a distance of <60 km, 60-180 km, and>180 km, and the combined distance is -0.904, -0.959, -0.380, and -0.469. The summary effect number means that there is an effect of transportation distance of 90%, 96%, 38%, and 47% on reducing meat *redness* during the transportation process. The *Summary Effect* value included in the *Confidence Interval range* indicates the effect of transportation distance on *redness* which is included in the moderate category at transportation distances > 180 km and combined distances and is included in the strong category at transportation distances <60 km and 60-180 km.

The decrease in the degree of *redness* in broiler chicken meat is due to myoglobin oxidation, which decreases redness. Myoglobin oxidation results from damage to the integrity of the cell nucleus membrane. This damage will eliminate the content and form of myoglobin pigment so that the red color fades and turns yellow. According to Zhang *et al.* (2014), transport stress causes an imbalance of the oxidation-antioxidant defense system, which causes the oxidation of red oxymyoglobin to brown metmyoglobin. Another opinion is that a decrease in the pH value can also affect the color of the meat. According to Castellini *et al* . (2016), when the pH decreases, it will reduce the space available for water in the cells, thereby increasing *drip loss* in broiler chicken meat. The activity of the enzyme lactate dehydrogenase results in a decrease in glycogen content, an increase in lactate content, and reduce redness in meat. According to Lan *et al.* (2021), the enzyme lactate dehydrogenase is the main enzyme in anaerobic glycolysis in muscle; this enzyme will increase the lactate content and further decrease the pH and quality of the meat.

In the parameter of corticosterone levels, the results of the Egger's Test were found to be insignificant (p>0.05); this indicates publication bias, which could interfere with the interpretation of research results. However, based on the results of the Rosenthal follow-up test, it was significant (p <0.05) that the intervention did not change the overall interpretation of the data.

Publication bias in the form of an increase in the degree of *redness* was found in several research results using the addition of nutrients to feed in the form of resveratrol, creatine monohydrate, and L-theanine, which are effective in reducing the harmful effects of transportation and increasing *redness*. We suspect that there are several variations of the moderator variables of transportation conditions, such as differences in season or climate, mode of transportation, duration, and speed of transportation, as well as other factors that can be an additional source of stressors for broilers so that they have an impact on variations in redness conditions. According to Zhang *et al*. (2014; 2017; and 2019), supplementation of resveratrol, creatine monohydrate, and L-theanine in drinking water increases the capacity Water Holding Capacity of chicken meat which increases the intracellular volume of cells through the uptake of water in the muscles and a load of creatine phosphate in the muscles which is the primary source of energy for muscle fiber contraction during intense physical activity, thus reducing the *redness reduction* in broiler meat.

In other studies, an increase in the degree of redness can also occur due to recovery in the resting phase for a long time after transportation to improve the quality of the meat by increasing the redness value. According to Zhang *et al* . (2009), rest after transportation can prevent protein denaturation and changes in muscle structure, especially in actin and myosin, and reduce the decrease in redness in chicken meat.

## Lightness

The results in the data table 3 show that the summary effect of the negative effect of transportation distance on the degree of *lightness* of broiler meat at a distance of <60 km, 60-180 km, >180 km, and the combined distance is 0.557, 0.472, 0.404 and 0.453. The summary effect number means that there is an effect of transportation distance of 56%, 47%, 40%, and 45% on the increase in the *lightness* of the meat during the transportation process. The Summary Effect value included in the Confidence Interval range indicates the effect of transportation distance on lightness which is included in the moderate category at transportation distances of 60-180 km, >180 km, and combined distances and is included in the strong category at transportation distances <60 km.

The increase in the degree of lightness in broiler chicken meat is caused by damage to the structure of cell membrane proteins and a decrease in cell hydrophilicity due to transport stress. Jacobs et al.(2016) believe that cell membrane damage causes cell exosmosis and increases lightness in chicken meat. Damage to actin and myosin reduces water binding to the meat by muscle proteins. If the water content in the meat is reduced, it will increase the lightness. According to Gou et al. (2021), protein denaturation during the transportation process damages and changes the structure of muscle proteins, especially in actin and myosin, causing an increase in lightness.

Myofibrillar reflection contributes to the difference in light scattering between PSE and dark, firm, and dry; this is related to pH, which significantly impacts the clarity of light on the chicken breast and causes the meat to appear pale in parts with a lower pH. Under He et al. (2022) opinion, lightness increases with a decrease in the pH value.

Phosphoric acid can damage the sensitive muscle cell membranes and result in the infiltration of myoglobin into the blood and increased lightness. According to Zhang et al. (2022), damage to muscle cell membranes caused by phosphoric acid makes myoglobin infiltrate into the blood and increases lightness. Indications of a relationship between corticosterone and meat color were found in research. Increased corticosterone concentration was associated with higher color values in lightness and yellowness and a decrease in redness. According to Doktor and Połtowicz (2009), high levels of corticosterone concentrations are associated with stress resulting in a decrease in meat quality.

## CONCLUSION

It was concluded that overall the transportation distance negatively affecting physiological conditions, pre-slaughter, and broiler meat quality with a moderate to strong influence, and so does the consistency of the published results.

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