JWPR
Journal of World's Poultry Research

2024, Scienceline Publication
J. World Poult. Res. 14(2): 172-180, 2024

Review Paper
DOI: https://dx.doi.org/10.36380/jwpr.2024.18
PII: S2322455X2400018-14

ISSN: 2322-455X

Effects of Breeding Systems on Hen Egg Weight: A Meta-Analysis

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Received: March 30, 2024, Revised: April 23, 2024, Accepted: May 21, 2024, Published: June 30, 2024

ABSTRACT

In the egg production industry, egg weight is a critical parameter influencing economic viability. The objective of the present study was to determine the effect of cage, free-range, and deep litter breeding systems on hen egg weight using meta-analysis. Articles were searched using Google Scholar, PubMed, ScienceDirect, and Web of Science yielding 175 articles of which 22 articles were included in the present study. Methodological quality was assessed using Joanna Briggs Institute guidelines. A model was used to determine the effect of breeding systems on average hen egg weight. Meta-regression analysis was used to examine the effect of the following moderators, publication year, region, chicken age, and breed. The Cochran's Q test and I^2 statistic were performed for h heterogeneity across used studies. According to the obtained results, there was no significant difference between cage and free-range on average hen egg weight (standardized mean difference (SMD) = 0.08, I^2 = 89%, 95%CI 0.19-0.34). The free-range breeding system had heavier hen egg weight than deep litter (SMD = 0.54, I^2 = 88%, 95%CI 0.01-0.08). The findings also revealed that deep litter and free range had no significant difference in average hen egg weight (SMD = -0.05, I^2 = 87%, 95%CI -0.28-0.17). Meta-regression findings showed that the origin of the used articles, the age of the chickens, and the chicken breed were observed as the main reasons for heterogeneity. This meta-analysis revealed that a free-range breeding system increased the average hen egg weight.

Keywords: Breeding system, Cage, Deep litter, Free-range, Meta-analysis

INTRODUCTION

In commercial egg-laying farming enterprises, success depends on the total number and size of eggs produced (Ojedapo, 2013). According to Ahmad et al. (2019), to reduce the use of cage breeding systems for chicken welfare international regulations have been developed. Therefore, the free-range breeding system gained much attention (Rehman et al., 2017). All the breeding systems used for the egg production industry have their advantages and disadvantages (Samiullah et al., 2017). It is well known that egg quality primarily depends on genetic background, rearing system, and management of birds and it is therefore needed to compare many parameters between rearing systems (Ahammed and Ohh, 2013). Several studies have shown that breeding systems affect the egg quality traits of hens in cage and deep litter systems and that hens reared in cages produce heavier eggs (Ojedapo, 2013), while Dahloum et al. (2018) reported that deep litter produces heavier eggs. Although there are studies that discussed the effect of breeding systems on egg quality traits, to the best of the authors' knowledge no meta-analysis study has examined the effect of breeding systems on hen egg weight. To address this gap in knowledge, the current study aimed to provide evidence using a meta-analysis approach based on the influence of breeding systems (cage, deep litter, and free range) on the hen egg weight. The findings of the current review provide valuable insights that can assist poultry farmers in enhancing average egg weight through the

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optimal selection of breeding systems (cage, deep litter, and free range).

MATERIALS AND METHODS

Eligibility criteria

Identification of population, intervention, comparison, and outcomes (PICO) components of the research question as explained by Mattos and Ruellas (2015) was performed before conducting the study. The population was defined as "chicken", with an intervention of "rearing system" or "housing system" or "breeding system", a comparison of "cage and deep litter" or "cage and free-range" or "deep litter and free-range" and outcomes of "egg quality traits" or "egg performance" or "external egg quality traits". A preliminary search of the PICO components was conducted before deciding to conduct the meta-analysis.

Literature search

Google Scholar, PubMed, ScienceDirect, and Web of Science were used for searching the literature.

Inclusion criteria

The eligibility criteria for all acquired articles were defined to include studies that investigated the rearing system (housing or breeding system) along with aspects related to egg quality traits, egg performance, or external egg quality traits.

Exclusion criteria

Exclusion criteria were applied to remove duplicate records found across different databases and studies that did not assess the impact of cage, deep litter, and free-range breeding systems on egg quality traits.

Data extraction

The extracted data from the articles included the name of the first author, year of publication, country, species, chicken breed, and sample size.

Statistical analysis

R software version 4.3.1 (The R Foundation for Statistical Computing) using the meta package was used for analysis. The effects of different breeding systems (cage, deep litter, and free-range) on hen egg weight were examined using a random effects model. The Cochran-Q and I^2 statistics were used to test heterogeneity among studies. Forest plots were performed for overall evaluation.

RESULTS

Characterization of included studies

The studies included in the meta-analysis were 22 as indicated in Figure 1. The search findings indicated that one author published two articles in different years (Table 1; Samiullah et al., 2014; 2017). The majority of the studies (n = 13) included in the review focused on exotic chicken breeds, accounting for 59.09% of the total, followed by crossbreeds at 22.73%, indigenous chickens at 13.64%, and studies involving both indigenous chickens and cross breeds at 4.55% (Choudhuri et al., 2014). The chickens ranged from 26 to 78 weeks in terms of age. The sample size used ranged from a minimum of 40 to 4320 eggs. Breeding systems investigated in this study were cages, deep litter, and free-range.

Publication by country

The results indicated that 22 studies were published in different countries worldwide (Figure 2). The majority of the studies originated from Türkiye, with five studies (22.73%), followed by three studies each from India (13.64%) and Pakistan (13.64%). Two studies each were conducted in Poland (9.09%) and Australia (9.09%). Additionally, there was one study each from the Czech Republic (4.55%), Nigeria (4.55%), the Republic of Korea (4.55%), China (4.55%), Algeria (4.55%), Bulgaria (4.55%), and Spain (4.55%).

Publication by year

The findings indicated that all published studies were from 2000 to 2023 (Figure 3). According to the obtained results, According to results, four articles were published in 2009 (18.18%), three in 2018 (13.64%), and two each in 2013, 2014, 2017, and 2020 (each accounting for 9.09%).

The effect of cage and free-range systems on hen egg weight

A total of 13 experiments from 11 studies that compared cage and free-range breeding systems for egg weight were included in the meta-analysis, with cage data used as the experimental group and free-range data as the control group (Figure 4). The results demonstrated no significant difference in egg weight between the cage and free-range systems (Figure 4A). Meta-regression results indicated that the country of the article, the age of the chickens, and the chicken breed were the reasons for heterogeneity (Table 2). Figure 4B shows the publication biases.

The effect of deep litter and free-range on hen egg weight

A total of 13 experiments from 8 studies (Krawczyk and Gornowicz, 2010; Lewko and Gornowicz, 2011; Choudhuri et al., 2014; Samiullah et al., 2017; Ahmad et al., 2019; Popova et al., 2020; Champati et al., 2020; Nayak et al., 2020) were included in the meta-analysis assessing the effect of deep litter and free-range breeding systems on egg weight (Figure 5). The results indicated high heterogeneity, favoring the free-range system. A funnel plot (Figure 5B) was used to evaluate publication bias.

The effect of cage and deep litter on hen egg weight

A total of 15 experiments from 11 studies (Basmacioğlu and Ergül, 2005; Özbey and Esen, 2007; Lichovníková and Zeman, 2008; Roll et al., 2009; Lewko and Gornowicz, 2011; Ahammed and Ohh, 2013; Ojedapo, 2013; Samiullah et al., 2017; Dahloum et al., 2018; Ahmad et al., 2019; Nayak et al., 2020) were used for meta-analysis addressing the effect of cage and deep litter on egg weight (Figure 6). The results indicated no significant difference between the cage and deep litter (Figure 6A). A funnel plot (Figure 6B) was used to predict the publication biases of used articles.

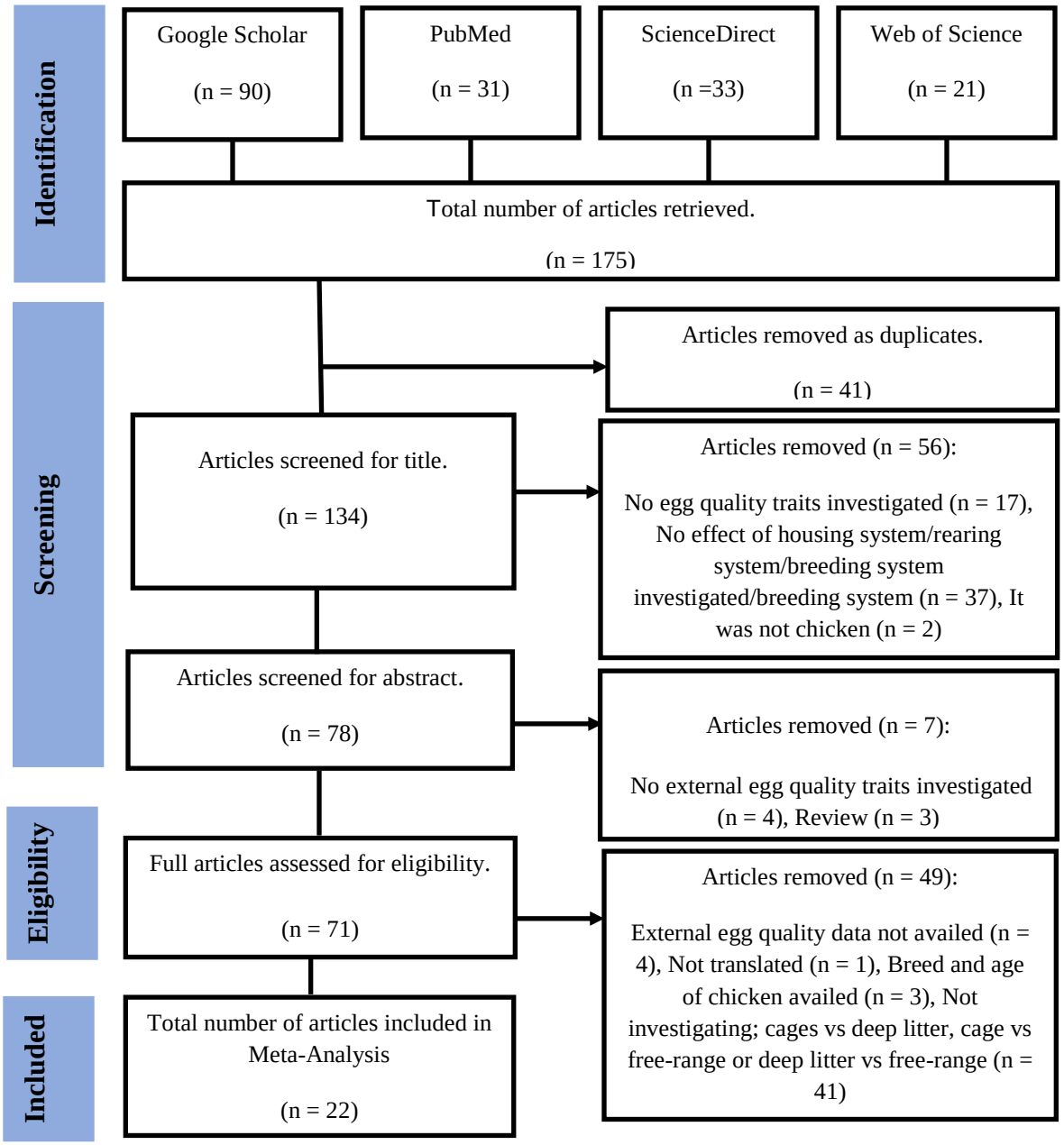

Figure 1. Preferred reporting items for systematic reviews and meta-analyses. The chart detailing the workflow of the selection process of 22 studies about the effects of breeding systems on hen egg weight

Table 1. Characterizations of the selected published articles included in the present study

Authors	Country	Breed	Age (weeks)	Sample size (eggs)	Breeding systems
Ahammed and Ohh (2013)	Republic of Korea	Brown laying pullet (Shaver 579)	30	120	Cage, deep litter
Ahmad et al. (2019)	Pakistan	Rhode Island Red × Naked Neck (RNN), Black Australorp × Naked Neck (BNN) and Naked Neck × Naked Neck (NN)	46	45	Cage, deep litter, free-range
Basmacioğlu and Ergül (2005)	Türkiye	white layers (Babcock-300) and brown layers (IsaBrown)	47	4 320	Cage, deep litter
Baykalir and Simsek (2018)	Türkiye	Bovans White	60	360	Cage, free-range
Champati et al. (2020)	India	Hansli males x Colour synthetic male line (CSML) females	40	50	Deep litter, free-range
Choudhuri et al. (2014)	India	Nicobari and crosses (Nicorock and Nishibari)	50	90	Deep litter, free-range
Dahloum et al. (2018)	Algeria	Adult indigenous Naked neck layers (White layers (WL); Brown layers (BrL) and Black layers (BL))	35	592	Cage, deep litter
Denli et al. (2016)	Türkiye	Lohmann Brown	50	60	Cage, free-range
Islam et al. (2021)	Pakistan	Rhode Island Red (RIR) × Fyoumi (F)	38	800	Cage, free-range
Krawczyk and Gornowicz (2010)	Poland	Polish hybrid layers Messa 45, originating from German “Meister Hybriden” breed	56	240	Deep litter, free-range
Lewko and Gornowicz (2011)	Poland	KA-62, KA-42, KA-68 and KA-48 hybrids derived from crossing strains K-66, K-44 (Rhode Island Red), A-88 and A-22 (Rhode Island White)	34	300	Cage, deep litter, free-range
Lichovníková and Zeman (2008)	Czech Republic	ISA Brown	66	336	Cage, deep litter
Nayak et al. (2020)	India	Vanaraja	26	60	Cage, deep litter, free-range
Ojedapo (2013)	Nigeria	Nera Brown	38	125	Cage, deep litter
Özbey and Esen (2007)	Türkiye	Partridge	38	60	Cage, deep litter
Petek et al. (2009)	Türkiye	Super Nick	36	640	Cage, free-range
Popova et al. (2020)	Bulgaria	Lohmann- Brown Classic	34	40	Deep litter, free-range
Rehman et al. (2017)	Pakistan	Aseel	30	72	Cage, free-range
Roll et al. (2009)	Spain	Isa Brown	78	780	Cage, deep litter
Samiullah et al. (2014)	Australia	Hy-Line Brown	75	540	Cage, free-range
Samiullah et al. (2017)	Australia	Hy-Line Brown	73	180	Cage, deep litter, free-range
Wang et al. (2009)	China	Blue-Shelled	50	120	Cage, free-range

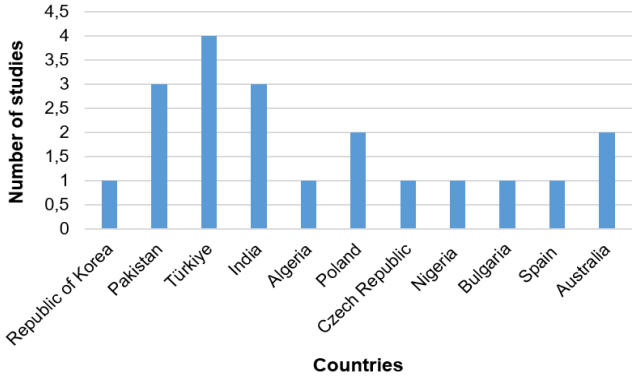

Figure 2. Countries included their published articles

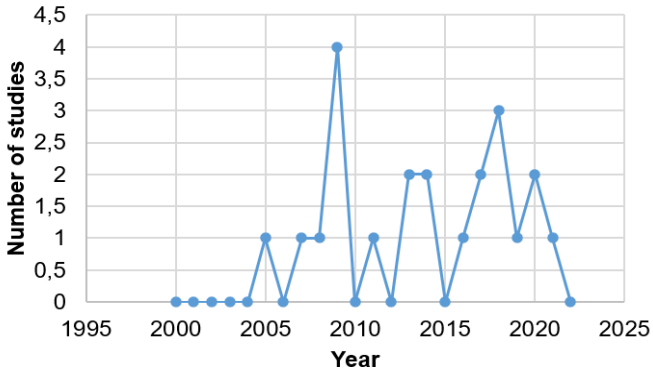

Figure 3. Years of included published studies

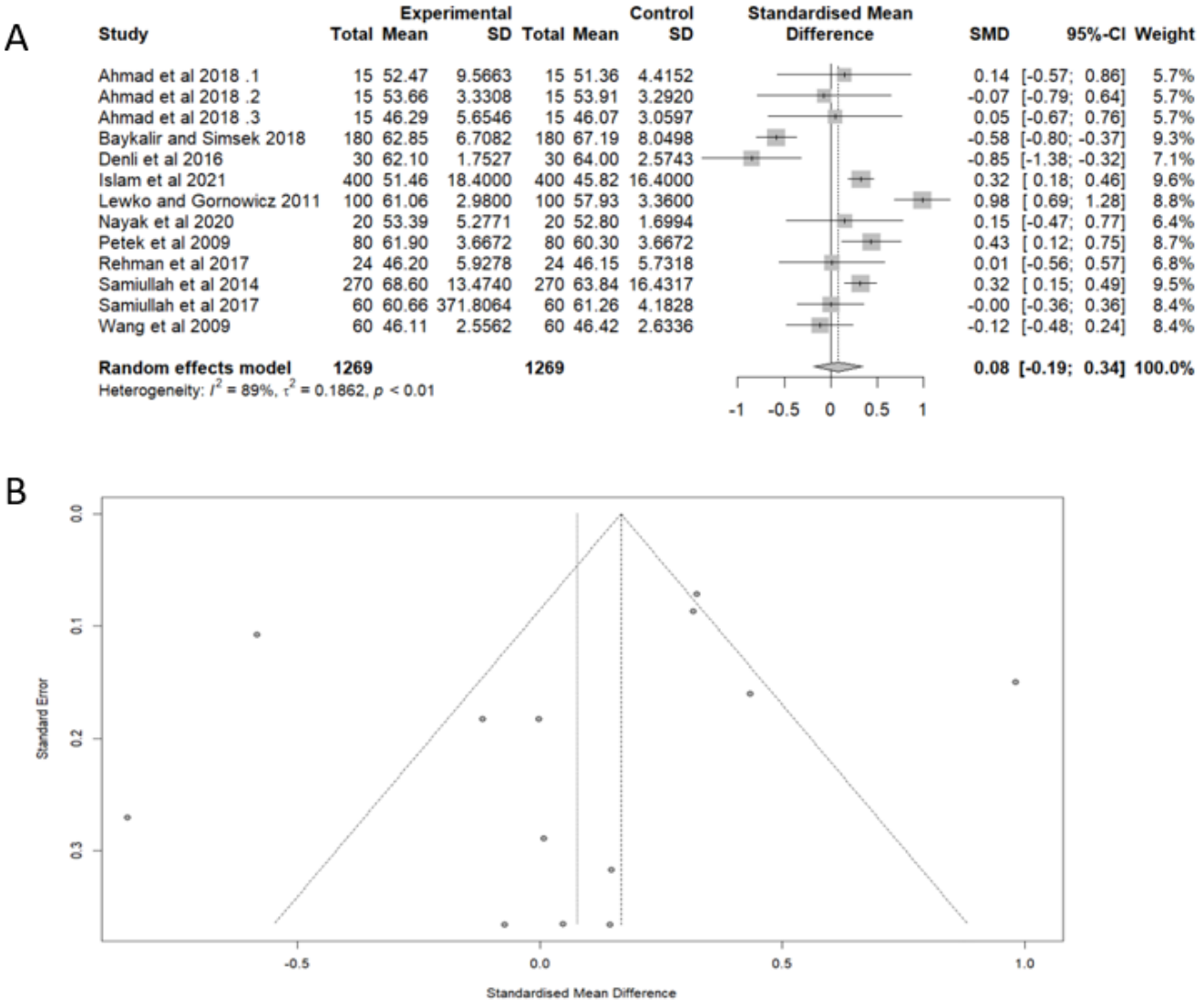

Figure 4. Effects of cage and free-range breeding systems on hen egg weight. **A**: Forest plot. **B**: Funnel plot

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Table 2. Effect of the year of publication, the origin of the article, chicken age, and chicken breed on included studies on the effect of breeding systems on hen egg weight

Factor	Estimate	Significance
Intercept	- 0.0563	***
Year of publication	- 0.1827	ns
Origin region of publication	0.4460	***
Age of the chicken	- 0.3871	***
Chicken breed	0.4082	***

Significant *** = 0.001, ns = not significant.

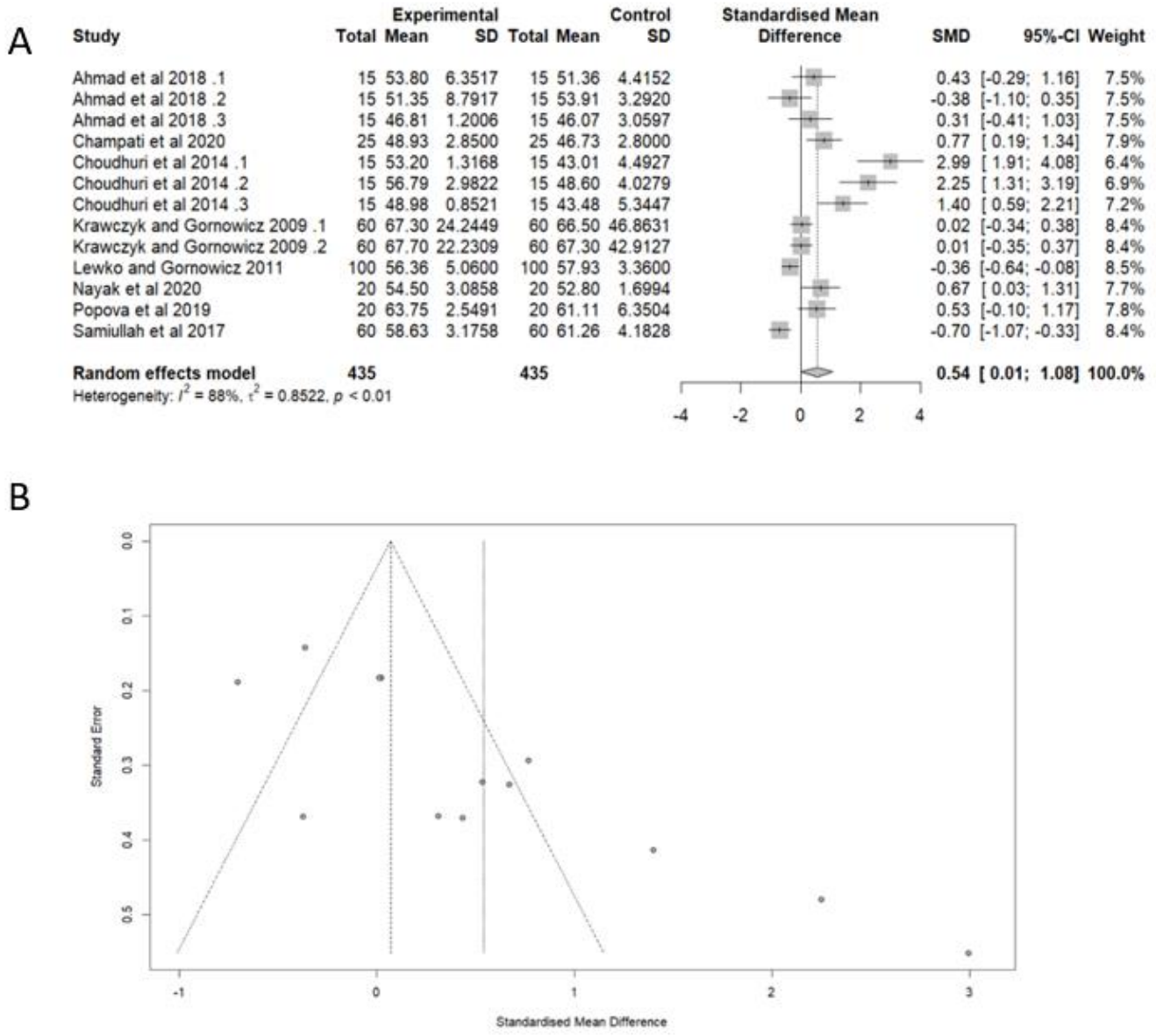

Figure 5. Effects of deep litter and free-range breeding systems on hen egg weight. **A**: Forest plot. **B**: Funnel plot

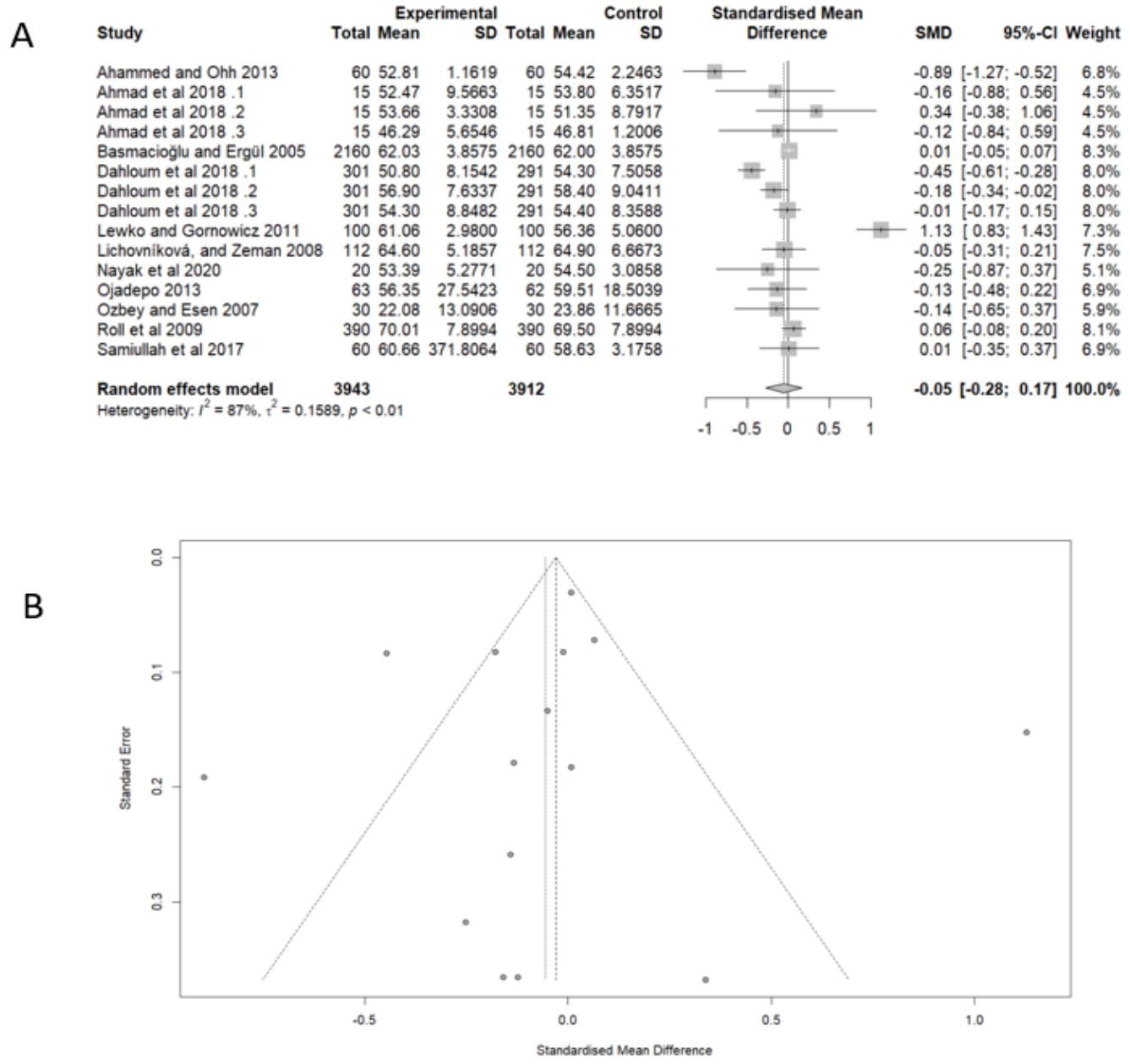

Figure 6. Effects of cage and deep litter breeding systems on hen egg weight. **A**: Forest plot. **B**: Funnel plot

DISCUSSION

Egg weight is one of the vital traits in the egg production industry (Nayak et al., 2020). The study was conducted to determine the effect of breeding systems, such as cage, deep litter, and free-range on hen egg weight using a meta-analysis approach. The results were obtained based on 22 published studies included in the meta-analysis, with the majority of them from Türkiye, Pakistan, and India. The reason might be related to the continent's call for studying the effect of the breeding systems on hen egg weight since Asia is one of the leading continents in egg production (Nayak et al., 2020). The results revealed that there was no significant difference in egg weight between chickens kept in cages and those kept in deep litter and free-range breeding systems. However, a significant difference was found when comparing deep litter and free-range systems, with free-range systems producing heavier eggs. This difference might be because free-range chickens can move freely to scavenge, supplementing their diet beyond the

provided feed. The random effects model applied for comparing the hen egg weight of chickens kept in deep litter and free-range indicated a high heterogeneity and significant difference in hen egg weight. More than 80% of local chickens are kept under the free-range breeding system in rural areas (Msoffe, 2002). According to Nonga et al. (2010), egg weight was largely affected by feeding, age, environmental factors, chicken ecotype, live body weight, and genetic makeup. Ahmad et al. (2019) emphasize that breeding systems influence egg quality traits. Egg weight from the free-range breeding system was influenced by both nutritional factors and ambient microclimate (Sekeroglu et al., 2008). As far as the authors are concerned, this meta-analysis study was the first to compare breeding systems (cage, deep litter, and free range) on hen egg weight. Hence, there were no similar studies for the comparison of the findings. The current study indicated that producers in the egg industry focusing on improving egg weight should look more into production using the free-range breeding system as it produces heavier eggs than cages and deep litter systems. As a benefit of the present findings, this meta-analysis brings conclusive information about the effect of the breeding systems on hen egg weight and selecting the best breeding system when coming to egg production for producing heavier eggs. However, there were some limitations, such as the data synthesis was focused on hen egg weight and outcomes may not be generalized to other egg quality traits, there were disparities in the number of hens, number of eggs, duration of the experiment, and finally the significant heterogeneity was found in the endpoints that may have been caused by different breeds.

CONCLUSION

The results indicated nonsignificant differences in hen egg weight between the cage and deep litter systems and between the cage and free-range breeding systems. However, there were significant differences in average hen egg weight between the deep litter and free-range breeding systems. Specifically, the free-range breeding systems produced heavier eggs compared to both the cage and deep litter systems.

DECLARATIONS

Acknowledgments

The authors acknowledge the University of Limpopo for their financial support.

Authors' contributions

The authors have contributed equally in planning, analyzing, and writing of this review article.

Competing interests

The authors certify that there is no conflict of interest.

Ethical considerations

The ethical issues, such as double publication and submission, data fabrication, plagiarism, redundancy, misconduct and consent to publish have been checked by both authors before publication in this journal.

Availability of data and materials

Data is available by request from the corresponding author.

Funding

The authors acknowledge the University of Limpopo for their financial support.

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