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EFFECTS OF SAGE (*Salvia officinalis* L.) INFUSION SUPPLEMENTATION IN DRINKING WATER ON GROWTH PERFORMANCE AND MEAT QUALITY OF QUAIL

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Abstract: The use of phytogenic additives as natural alternatives to antibiotic growth promoters has gained increasing attention in poultry production. This study investigated the effects of sage (*Salvia officinalis* L.) infusion supplementation in drinking water on growth performance, water consumption, slaughter and carcass characteristics, and meat quality of Japanese quail. A total of 160 seven-day-old mixed-sex quail chicks were randomly allocated to four treatment groups with four replicates of 10 birds each. The experimental groups consisted of a control group receiving plain drinking water and three groups receiving sage infusion diluted in drinking water at 25%, 50%, and 75% inclusion levels for 42 days. Growth performance parameters, water consumption, carcass traits, internal organ weights, and meat quality characteristics (pH and color parameters of breast and thigh meat) were evaluated. Sage infusion supplementation did not result in statistically significant differences in growth performance, water consumption, slaughter and carcass characteristics, or meat color parameters compared with the control group (P>0.05). Breast meat pH values were significantly affected by sage infusion supplementation, with lower pH values observed at higher infusion levels (P<0.05), whereas thigh meat pH values were not significantly influenced. In conclusion, sage infusion administered via drinking water did not adversely affect performance or carcass characteristics of Japanese quail and showed a potential positive effect on meat quality by reducing breast meat pH. Water consumption was not influenced by treatment, which may indicate satisfactory palatability and acceptance of the infusion under the present experimental conditions. Overall, these findings suggest that sage infusion may represent a promising phytogenic strategy in quail production; however, further studies are required to determine optimal application levels and elucidate the underlying mechanisms.

Keywords: Quail, Sage, Infusion, Meat quality, Phytogenic additive

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1. Introduction

The increase in the global population has led to a growing demand for animal-derived foods, making sustainable production strategies indispensable (Sözcü and Koyuncu, 2015). Poultry products play a significant role in meeting animal protein requirements due to their high digestibility and economic production advantages (Alabi and Adedokun, 2025). Among alternative poultry species, Japanese quail has attracted considerable attention owing to its short rearing period, low feed consumption, and high production efficiency. Moreover, quail meat is regarded as a valuable food source due to its high protein content and low fat level (Sarıca et al., 2014; Çağlayan and Şeker, 2015; Quaresma et al., 2022).

In intensive poultry production systems, antibiotic growth promoters have long been used to enhance performance. However, concerns related to antimicrobial resistance and drug residues in animal products have resulted in restrictions and bans on their use (Dibner and Richards, 2005; Fonseca et al., 2010; Ganan et al., 2012; Ghimpețeanu et al., 2022). These developments have accelerated research into natural alternatives to antibiotics (Fadlalla et al., 2010; Varmaghany et al., 2015). In this context, phytogenic feed additives have gained increasing attention due to their antimicrobial, antioxidant, antifungal, antiviral, and digestive-stimulatory properties, as well as their potential to be used without inducing resistance (Yörük et al., 2004; Ntsongota et al., 2025).

Sage (*Salvia officinalis* L.) is a medicinal and aromatic plant known for its antioxidant and antimicrobial properties, attributed to its rich content of essential oils and phenolic compounds (Generalić et al., 2012; Mokhtari et al., 2023). In poultry nutrition, sage has primarily been investigated in the form of essential oil, extract, or powder incorporated into feed. While some studies have reported beneficial effects on growth performance, product quality, and oxidative stability, others have indicated limited or inconsistent responses (Çabuk et al., 2006; Karslı and Dönmez, 2007; Küçükyılmaz et al., 2012; Salman, 2018; Farhadi et al., 2020; Çayan and Coşkun, 2025).

The administration of medicinal and aromatic plants via drinking water using the infusion technique allows for the practical delivery of water-soluble bioactive compounds (Piljac Žegarac et al., 2013; Malongane et al., 2017). Although several studies have evaluated the effects of infusions derived from different plants on poultry growth performance, immune responses, and selected quality traits (Durrani et al., 2008; Sadeghi et al., 2012; Rafeeq et al., 2016; Erener et al., 2023; Mikael et al., 2024), data regarding the use of sage infusion administered through drinking water in quail are extremely limited. Therefore, the present study aimed to evaluate the effects of sage infusion supplementation in the drinking water of Japanese quail on growth performance and meat quality characteristics. The findings of this study are expected to fill an important gap in the literature regarding alternative application methods of sage and to contribute to the use of phytogenic additives as natural alternatives to antibiotics in poultry production.

2. Materials and Methods

2.1. Experimental Design and Animal Management

A total of 160 mixed-sex Japanese quail chicks aged 7 days were used in the experiment. The birds were randomly allocated to four dietary treatment groups, each consisting of four replicates with 10 birds per replicate (n=40 per treatment). Prior to the start of the trial, all chicks were individually weighed, and allocation to experimental groups was performed based on body weight uniformity.

The experimental design consisted of one control group receiving plain drinking water and three treatment groups receiving sage (*Salvia officinalis* L.) infusion diluted in drinking water at different inclusion levels: 25%, 50%, and 75%. The experimental groups were as follows: control (0% infusion), 25% infusion + 75% drinking water, 50% infusion + 50% drinking water, and 75% infusion + 25% drinking water.

All birds were fed according to the NRC (1994) with the turkey grower diet obtained from a commercial company. The feed was characterized by 21% content of crude protein (CP) and 3100 kcal/kg of metabolic energy (ME). The birds were housed in 16 floor pens (70 × 90 cm), corresponding to four replicates per treatment. A near-continuous lighting program (23 h light:1 h dark) was applied. Ambient temperature was set at 33 ± 1 °C during the first week and then progressively decreased to 24 ± 1 °C for the remainder of the experiment. Relative humidity was maintained at levels exceeding 60% throughout the study period. During the starter period, feed was offered using tray feeders, while hanging bucket feeders were used from the third week onward. Drinking water was provided *ad libitum* using floor-type drinkers throughout the experiment. All birds were fed a standard basal diet formulated to meet nutrient requirements, and feed and water were provided *ad libitum*.

2.2. Preparation and Administration of Sage Infusion

Sage leaves were prepared using the infusion method described by Rafeeq et al. (2016). Dried sage leaves were obtained from the Agricultural Application and Research Center of Kırşehir Ahi Evran University. The leaves were cleaned, ground, and passed through a 1-mm sieve. For infusion preparation, 50 g of ground sage leaves (5%, w/v) were placed into a glass container, and 1 L of boiling water (100 °C) was added. The mixture was allowed to steep for 6 h at room temperature, then filtered and stored at +4 °C until use.

The prepared sage infusion was diluted daily with drinking water to obtain 25%, 50%, and 75% infusion concentrations. Infusions were freshly prepared each day and supplied to the birds. A total of 3 L of infusion was prepared daily and equally distributed among the three treatment groups, with 500 mL provided per replicate.

2.3. Chemical Analyses

Dry matter, crude ash, and crude protein contents of the basal diet and sage leaves were determined according to AOAC (1998) methods. Acid detergent fiber (ADF), neutral detergent fiber (NDF), and crude cellulose analyses were performed using the ANKOM fiber analysis method at the Feed Biotechnology Laboratory, Department of Agricultural Biotechnology, Faculty of Agriculture, Kırşehir Ahi Evran University. The nutrient composition of the basal diet and sage leaves used in the experiment is presented in Table 1.

2.4. Growth Performance Measurements

Body weights of individual birds were recorded weekly, starting from day 7 until the end of the experiment (day 42), using a digital scale with 0.1 g precision. A total of six body weight measurements were conducted at weekly intervals. Feed intake was recorded weekly by measuring the amount of feed offered and the residual feed remaining at the end of each week. Weekly feed intake was calculated as the difference between feed supplied and feed refused. Feed conversion ratio was calculated using the equation 1:

$$FCR = \text{Total feed intake} / \text{Body weight gain} \quad (1)$$

Table 1. Nutrient composition of the experimental basal diet and sage leaves used in the experiment (%)

	DM	CP	EE	CA	Starch	ADF	NDF
Basal diet	94	20.25	3.03	10.11	44.91	16.63	4.48
Sage leaf	92	22.8	14.31	9.92	15.84	21.35	23.95

DM= dry matter (%), CA= crude ash (% of DM), CP= crude protein (% of DM), EE= ether extract (% of DM), NDF= neutral detergent fiber (% of DM), ADF= acid detergent fiber (% of DM).

2.5. Slaughter Procedure and Meat Quality Analysis

At the end of the experiment (day 42), all birds were weighed to determine final body weights. From each treatment group, eight birds (two birds per replicate), with body weights close to the group average, were selected for slaughter, resulting in a total of 32 birds for carcass and meat quality analyses.

Following slaughter, the digestive tract of each selected bird was carefully removed, and the total length of the gastrointestinal tract was measured using a measuring tape. Subsequently, internal organs including the heart, gizzard (with contents removed), liver, proventriculus, and bursa of Fabricius were excised and individually weighed using a digital balance with 0.01 g precision. Organ weights were recorded for each bird and used for subsequent evaluation.

Post-slaughter pH measurements were conducted on breast and thigh muscles. Muscle pH was measured at three different points on the left breast and thigh muscles using a digital pH meter equipped with a penetration electrode (Testo 205).

Meat color parameters (L*, a*, b*) of the breast and thigh muscles were determined using a Minolta CR-410 Chroma Meter (Minolta Camera Co., Osaka, Japan), calibrated with a white standard plate (Y = 92.6, x = 0.3136, y = 0.3196). Measurements were taken at three different points on the skinless surface of each muscle sample.

2.6. Statistical Analysis

The data obtained from the experiment were analyzed using a completely randomized design. One-way analysis of variance (ANOVA) was performed to evaluate the effects of the experimental treatments. Differences among treatment means were determined using Duncan's multiple range test. All statistical analyses were conducted using the SPSS statistical software package (SPSS 25.0 for Windows, Evaluation version).

3. Results

The results of the present study evaluating the effects of different inclusion levels of sage (*Salvia officinalis* L.) infusion in the drinking water of Japanese quail on growth performance, slaughter and carcass characteristics, and meat quality traits are presented below.

3.1. Growth Performance

At the end of the 42-day experimental period, the effects of different inclusion levels of sage infusion in the drinking water on initial body weight, final body weight, body weight gain, feed intake, and feed conversion ratio of Japanese quail are presented in Table 2.

At the end of the 42-day experimental period, supplementation of sage (*Salvia officinalis* L.) infusion in the drinking water at different inclusion levels did not result in significant differences in growth performance parameters of Japanese quail (P>0.05). Initial body weight, final body weight, body weight gain, feed intake, feed conversion ratio, and water consumption were not significantly affected by sage infusion supplementation compared with the control group. Although no statistically significant differences were detected, numerically higher final body weight (approximately 3.35%) and body weight gain were observed in the sage infusion–supplemented groups compared with the control group (Table 2). In addition, feed conversion ratio values were numerically lower in the groups receiving sage infusion, indicating a tendency toward more efficient feed utilization. However, these numerical improvements did not reach statistical significance (P>0.05).

At the end of the 42-day experimental period, supplementation of sage infusion in the drinking water did not significantly affect water consumption of Japanese quail compared with the control group (P>0.05). Although minor numerical differences were observed among treatment groups, these variations were not statistically significant

3.2. Slaughter and Carcass Characteristics

At the end of the 42-day experimental period, the effects of different inclusion levels of sage infusion in the drinking water on slaughter and carcass characteristics of Japanese quail are presented in Table 3.

Supplementation of sage infusion in the drinking water did not result in statistically significant differences in slaughter and carcass characteristics of Japanese quail at the end of the 42-day experimental period (P > 0.05). Small intestine length, heart weight, liver weight, and proventriculus weight were not significantly affected by sage infusion supplementation compared with the control group. Although gizzard weight tended to be numerically higher in the sage infusion–supplemented groups, particularly at the 50% and 75% inclusion levels, this difference did not reach statistical significance (P=0.056).

3.3. Meat Quality Traits

At the end of the 42-day experimental period, the effects of different inclusion levels of sage infusion in the drinking water on post-slaughter pH values and color parameters of breast and thigh meat are presented in Table 4.

Sage infusion supplementation in the drinking water did not significantly affect breast or thigh meat color parameters (L*, a*, b*) of Japanese quail at the end of the 42-day experimental period (P>0.05). In contrast, breast meat pH values were significantly influenced by sage infusion supplementation (P<0.05). The lowest breast meat pH value was observed in the 75% sage infusion group, whereas the control group exhibited the highest pH value. However, thigh meat pH values were not significantly affected by the treatments (P>0.05).

Table 2. Effects of sage infusion on growth performance in Japanese quail

Parameters	Sage Infusion Levels, %				SEM	P value
	Control	25	50	75		
IBW	34.30	34.25	34.25	34.33	0.026	0.689
FBW	209.35	216.83	215.82	214.40	2.710	0.794
BWG	175.05	182.58	181.57	180.07	2.709	0.790
FI	696.52	700.68	694.96	708.40	6.039	0.907
FCR	3.98	3.85	3.83	3.93	0.048	0.697
WI	1415.12	1451.15	1459.18	1471.33	12.264	0.448

IBW= initial body weight (g), FBW= final body weight (g), BWG= body weight gain (g), FI= feed intake (g), FCR= feed conversion ratio (g/g), WI= water intake (L), SEM= standard error of mean.

Table 3. Effects of sage infusion on slaughter and carcass characteristics of Japanese quail

Parameters	Sage Infusion Levels, %				SEM	P value
	Control	25	50	75		
DTL	72.62	71.66	71.87	68.66	0.985	0.562
Gizzard	4.33	4.61	5.20	4.79	0.123	0.056
Hearth	1.76	1.85	1.84	1.95	0.053	0.686
Liver	4.37	5.40	5.01	5.34	0.222	0.341
Proventriculus	0.76	0.88	0.83	0.82	0.020	0.226
EIO	10.48	11.88	12.05	12.09	0.310	0.196

DTL= digestive tract length (cm), EIO= edible inner organs (g), SEM= standard error of mean.

Table 4. Meat color and pH of quail supplemented with sage infusion in drinking water

Parameters	Sage Infusion Levels, %				SEM	P value
	Control	25	50	75		
Breast meat						
L*	52.18	55.93	60.55	63.29	2.701	0.504
a*	46.99	50.41	47.56	46.64	1.397	0.793
b*	18.96	20.10	21.68	20.70	0.425	0.144
pH	5.69^{a}	5.67^{ab}	5.58^{bc}	5.56^{c}	0.019	0.028
Thigh meat						
L*	51.58	53.19	57.40	57.06	1.845	0.639
a*	48.08	51.89	49.57	49.27	1.047	0.658
b*	18.38	20.14	21.45	20.16	0.430	0.082
pH	6.42	6.39	6.31	6.41	0.046	0.863

$^{a-c}$ there is a statistical difference between the averages shown with different letters (P<0.05), L*= lightness, a*= redness, b*= yellowness, SEM= standard error of means.

4. Discussion

In the present study, supplementation of sage (*Salvia officinalis* L.) infusion in the drinking water of Japanese quail did not result in statistically significant differences in growth performance parameters. This finding is in line with the limited number of studies investigating the use of sage infusion in poultry nutrition, as well as with previous studies evaluating other medicinal plant infusions administered via drinking water. In this regard, studies conducted with cypress leaf infusion, olive leaf tea, neem leaf infusion, and drinking water–infused cinnamon, thyme, turmeric, and their mixtures in broiler chickens reported no significant effects on growth performance parameters (Sadeghi et al., 2012; Egbeyale et al., 2021; Erener et al., 2023; Mikael et al., 2024). The similarity between these findings and the results of the present study suggests that infusion-based applications may not consistently induce marked improvements in performance under standard rearing conditions.

Consistent with these observations, previous studies evaluating different forms of sage supplementation in quail, including extracts and essential oils, have also reported limited or no significant effects on growth performance (Bulbul et al., 2015; Seifi et al., 2018; Salman, 2018; Kaplan and Koksal, 2021). These results indicate that the growth-promoting potential of sage may vary depending on its form, dosage, and route of administration.

Despite the absence of statistically significant differences, numerically higher final body weight and body weight gain, along with a numerically lower feed conversion ratio, were observed in the sage infusion–supplemented groups compared with the control group. Such numerical trends have also been reported in studies involving phytogenic additives and may reflect subtle physiological effects that are not always detectable as significant differences within the experimental period (Çabuk et al., 2006; Farhadi et al., 2020).

In the present study, sage infusion supplementation in drinking water did not significantly influence water consumption of Japanese quail. This finding is consistent with previous studies reporting that the inclusion of phytogenic additives or plant infusions in drinking water does not necessarily alter water intake in poultry (Sadeghi et al., 2012; Egbeyale et al., 2021; Erener et al., 2023). The absence of significant changes in water consumption suggests that sage infusion did not adversely affect water palatability and was readily accepted by the birds.

Water intake is an important parameter reflecting both animal welfare and the acceptability of drinking water additives. The unchanged water consumption observed in the present study indicates that the infusion levels applied did not induce aversive effects related to taste or aroma. Similar findings have been reported in studies evaluating herbal infusions administered via drinking water, where water consumption remained stable despite the presence of bioactive plant compounds (Mikael et al., 2024).

Sage leaves are known to contain several bioactive compounds, including α- and β-thujone, 1,8-cineole, and camphor, which are associated with antimicrobial, antioxidant, and appetite-stimulating properties (Miljanović et al., 2023). These bioactive constituents may contribute to improved gut environment and feed utilization efficiency, which could explain the numerically higher body weight gain and lower feed conversion ratio observed in the infusion-supplemented groups. In addition, the potential anabolic or muscle-supportive effects of sage bioactives may have contributed to proportional increases in carcass and breast meat weights, thereby indirectly influencing live weight gain.

The results of the present study indicated that sage infusion supplementation in drinking water had no significant effect on slaughter and carcass characteristics of Japanese quail, including small intestine length and the weights of internal organs. These findings are in agreement with previous studies reporting that phytogenic additives, including sage and other aromatic plants, do not consistently alter carcass traits in poultry (Küçükyılmaz et al., 2012; Abdelati et al., 2021).

A numerical increase in gizzard weight was observed in the sage infusion–supplemented groups, particularly at higher inclusion levels, although this difference did not reach statistical significance. This tendency may be associated with the potential stimulatory effects of phytogenic compounds on digestive activity and mechanical digestion; however, the absence of statistical significance suggests that the observed variation may also be attributable to biological variability among birds. Similar tendencies have been reported in studies evaluating herbal additives administered via drinking water, where changes in digestive organ weights were modest and inconsistent (Rafeeq et al., 2016; Erener et al., 2023).

In the present study, sage infusion supplementation did not significantly affect breast or thigh meat color parameters (L*, a*, b*), indicating that the infusion had no detrimental effect on meat appearance. A review of the literature indicates that studies directly investigating the effects of sage leaf on meat color and pH in poultry are very limited. Therefore, the results of the present study were discussed in comparison with studies conducted using different phytogenic feed additives. In the current study, the absence of significant effects of sage infusion supplementation on breast and thigh meat color parameters (L*, a*, b*) is consistent with the findings of Salman (2018), who reported that dietary supplementation of sage, thyme, and mint essential oils did not significantly affect breast meat color values in broiler chickens.

In contrast, breast meat pH values were significantly influenced by sage infusion supplementation in the present study, with a decreasing trend observed as the infusion level increased. Salman (2018) also reported that breast meat pH decreased over time post-slaughter, and similar findings were observed in the present study. Likewise, Gümüş and Küçükersan (2017) demonstrated that dietary supplementation of α-tocopherol, grape seed extract, and green tea extract had no significant effect on meat pH in broiler chickens, indicating that the effects of phytogenic additives on meat pH may vary depending on the type and form of the additive used. The differential pH response between breast and thigh muscles may be attributed to their distinct fiber-type composition and metabolic properties. In poultry, the breast muscle predominantly consists of fast-twitch glycolytic fibers, which are more susceptible to post-mortem glycolysis and pH fluctuations. In contrast, the thigh muscle contains a higher proportion of oxidative fibers, which may confer greater metabolic stability. This physiological difference may explain why sage infusion affected breast muscle pH but not thigh muscle pH (Lilburn et al., 2019).

The observed reduction in the pH values of breast and thigh meat with increasing levels of infused sage tea supports previous findings reporting that the administration of phytogenic additives via drinking water may contribute to lower meat pH values in poultry (Ahmed et al., 2015; Puvača et al., 2016; Yang et al., 2020). A lower meat pH is considered an important quality attribute, as elevated pH values and increased microbial counts are commonly associated with meat spoilage. Therefore, maintaining a lower pH is critical for improving meat shelf life (Yang et al., 2020).

Differences among studies may be attributed to several factors, including the plant species used, basal diet composition, applied dose, method and duration of supplementation, environmental conditions, rearing systems, and feed ingredient composition. In particular, in the present study, sage was prepared using the infusion technique and administered to quail via drinking water for 42 days, representing a distinct application strategy compared with many previous studies. This methodological difference should be considered when interpreting the observed effects on meat quality parameters.

5. Conclusion

In conclusion, supplementation of sage (*Salvia officinalis* L.) infusion at different inclusion levels in the drinking water of Japanese quail did not result in statistically significant effects on growth performance, water consumption, slaughter and carcass characteristics, or meat color parameters. Nevertheless, numerically higher final body weight and body weight gain, together with a numerically lower feed conversion ratio in the sage infusion–supplemented groups, suggest a potential tendency toward improved feed utilization efficiency.

The absence of significant differences in water consumption among treatment groups indicates that sage infusion did not negatively affect water palatability and was well accepted by the birds. This finding also suggests that the applied infusion levels did not compromise hydration status or animal welfare.

Sage infusion supplementation did not adversely affect carcass traits or internal organ parameters, demonstrating that the infusion levels used in this study were safe. Moreover, the significant reduction in breast meat pH observed with increasing sage infusion levels suggests a potential beneficial effect on meat quality, particularly in relation to post-mortem biochemical processes and shelf-life stability.

Overall, the results of this study indicate that sage infusion administered via drinking water can be considered a promising phytogenic strategy in quail production, particularly with respect to meat quality attributes, without causing negative effects on performance, water intake, or carcass characteristics. However, further research is needed to determine the optimal infusion concentration, elucidate the underlying mechanisms of action, and evaluate long-term effects under different rearing conditions.

Author Contributions

The percentages of the authors' contributions are presented below. All authors reviewed and approved the final version of the manuscript.

	Y.A.	H.Ç.
C	50	50
D	40	60
S	20	80
DCP	60	40
DAI	40	60
L	70	30
W	50	50
CR	30	70
SR	30	70
PM	20	80
FA	20	80

C= concept, D= design, S= supervision, DCP= data collection and/or processing, DAI= data analysis and/or interpretation, L= literature search, W= writing, CR= critical review, SR= submission and revision, PM= project management, FA= funding acquisition.

Conflict of Interest

The authors declared that there is no conflict of interest.

Ethical Consideration

All the birds and the experimental protocol used in this study were approved by the Institution Animal Care and Use Committee of Kırsehir Ahi Evran University (approval date: 30/03/2022, protocol code: 68429034/12).

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