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Original Research

Impact of Supplementing a Frankincense-*Melissa officinalis* Mixture to Drinking water on the Performance and Economic Efficiency of Two Commercial Japanese Quail Strains

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Abstract

The purpose of the experiment was to investigate how a Frankincense-*Melissa officinalis* (F-MO) mixture in drinking water affected the growth, carcass traits, sensory meat quality, and economic efficiency of two commercial Japanese quails strains. A total of 120 one-day-old Japanese quails, comprising black quails (n=60) and white quails (n=60), were utilized for the experiment. The experiment commenced when the quails were 14 days old, after a two-week adaptation period. They were randomly divided into two treatment groups, each containing 30 birds, with three replicates of 10 birds in each group. The basic diet plus 2 ml F-MO mixture in drinking water and the basic diet plus drinking water without any supplement (control) were the two treatments used in the experiment over a four-weeks period. The results demonstrated that supplementation with F-MO significantly improved growth traits, dressing-out percentage, sensory meat quality, and economic efficiency compared to the control group. When the strain effect was considered, the white strain outperformed the black strain in terms of growth traits, dressing-out percentage, and economic efficiency.

KEYWORDS
Japanese quails, F-MO mixture, Growth traits, Carcass traits, Sensory meat quality, Economic efficiency.

INTRODUCTION

The global poultry industry is continuously evolving due to the ever-increasing demand for high-quality animal protein. In response to this demand, researchers and stakeholders are exploring innovative strategies to enhance poultry production efficiency and product quality while maintaining sustainable practices. Commercial Japanese quails represent an exceptional avian model for efficient and sustainable meat production. Their rapid growth, remarkable feed conversion efficiency, small size, and low environmental impact make them an ideal choice for farmers aiming to meet the demand for poultry meat while adhering to environmentally responsible practices (Vargas-Sánchez *et al.*, 2019). Quail meat is also gaining popularity as a table delicacy, known for being tender, flavorful, and nutritious. Consuming two quails per day is equivalent to ingesting 125-130 g of pure meat, providing 27-28 g of protein and 11 g of essential amino acids, satisfying 40% of human protein demand (Alagawany *et al.*, 2020). Given their exceptional growth performance and desirable meat qualities, quails continue to play a significant role in advancing meat production systems and addressing the challenges of the modern agricultural landscape.

One approach to enhance the performance and quality attributes of quails is through the utilization of phytogenic feed additives (PFAs), which are natural plant-derived compounds with potential health benefits (Nair *et al.*, 2019). These additives offer a promising alternative to traditional feed supplements (Haque *et al.*, 2020). One such combination of PFAs employed in the study includes Frankincense and *Melissa officinalis*. Frankincense, commonly known as *Boswellia*, is widely utilized in Ayurvedic medicine due to its various therapeutic activities, including anti-inflammatory, antiseptic, analgesic, antibacterial, anticancer, hepatoprotective, hypolipidemic, hypocholesterolemic, immunomodulatory, and antiproliferative actions. These activities are attributed to its favorable chemical composition (Suchita *et al.*, 2021). The therapeutic properties of Frankincense may be utilized in livestock species to achieve positive effects on animal production and well-being (Al-Yasiry *et al.*, 2017). *Melissa officinalis*, commonly known as lemon balm, has garnered particular attention (Travel *et al.*, 2021). This herb is renowned for its rich content of bioactive compounds, including polyphenols, flavonoids, and essential oils, which have been linked to a wide array of health benefits (Chizzola *et al.*, 2018).

Accordingly, the current study aimed to assess the effectiveness of using a mixture of Frankincense and *Melissa officinalis* in quail drinking water. The study focused on evaluating growth performance, carcass traits, sensory meat quality, and economic efficiency.

By elucidating the impacts of this botanical additive on various facets of quail production, this study aimed to contribute to the advancement of sustainable and efficient meat production practices.

MATERIALS AND METHODS

Ethical statement

The collection of samples and care of the birds used in this study followed guidelines for experimental animals established by the Research Ethics Committee, Faculty of Veterinary Medicine, Mansoura University (Code M / 115).

Experimental design

A total of 120 one-day-old Japanese quails from two strains, black quails (n=60) and white quails (n=60), were obtained from a commercial quail farm in Kafr El-Sheikh, Egypt. The quails were randomly divided into two treatment groups for each strain, with each group further subdivided into three replicates, each containing 10 birds.

Housing and management

Quails were housed in separate wire battery cages (150 cm x 50 cm x 30 cm) within a conventional poultry house (13 m x 6 m) with a raised elevation of 60 cm. The cages were thoughtfully filled with nesting material and layered with sawdust and corrugated paper to safeguard their comfort and foot health. Bell feeders and drinkers were available to provide ad libitum access to a standard diet and supplemented drinking water. Rigorous hygiene was maintained through regular cage cleaning. The ambient temperature was maintained at 35°C during the first 3 days and gradually decreased to 29°C until the end of the experimental period. The quails were exposed to a continuous 24-hour light cycle during the entire experiment. Regardless of treatment or strain, all quails received uniform care, hygienic standards, and temperature and lighting controls throughout the study, assuring optimal housing conditions and unbiased results.

Diet and supplementation

All quails were fed a standard diet formulated according to the guidelines of the National Research Council (NRC, 1994), as shown in Table 1. On the 14th day of the experiment, quail chicks were administered a drinking water solution enriched with 2 ml of the Frankincense-*Melissa officinalis* (F-MO) mixture, utilizing bell drinkers as the delivery method. The procurement of Frankincense and *Melissa officinalis* involved acquisition from a reputable spice supplier.

The preparation of the mixture entailed the blending of 1 g of Frankincense powder / L of drinking water, allowing for dissolution over a 12-hour duration. The extraction protocol for *Melissa oficinalis* was executed in accordance with the methodology delineated by Poorghasemi *et al.* (2017). Specifically, 200 g of dried *Melissa officinalis* herb underwent infusion with 1 L of boiling water for a duration of 10 minutes. Subsequent to infusion, the resulting mixture was cooled to 40°C and meticulously strained to obtain a clear extract. After that, 1 ml of the extracted *Melissa officinalis* solution was carefully incorporated into the Frankincense-water mixture, yielding a homogenous 50/50 amalgam of F-MO. Subsequently, a dosage of 2 ml of the F-MO mixture / L of drinking water was administered to the quail chicks via the bell drinkers.

Studied traits

Growth traits

In the current experiment, the quail's growth traits were evaluated. the initial body weight (BW) of the quails was recorded before the experiment commencing at 14 days of age. The final BW of the quails was measured at the end of the 6-week experimentation to assess the impact of 2 ml of F-MO mixture supplementation on their growth. The difference between the final initial BW was calculated to determine body weight gain (BWG) as described by Safalaoh (2006). The amount of feed consumed by each quail in each cage was recorded weekly to evaluate feed intake (FI) according to Fernandez *et al.* (2018). The total feed intake (TFI) for each quail was then calculated throughout the entire duration of the experiment. According to Huang *et al.* (2022), feed conversion ratio (FCR) was determined as the ratio of TFI to total BWG which provides insight into the efficiency of converting feed into BWG.

Table 1. Ingredients of basic quail diet fed during the experimental period.

Feed ingredients %	Amount (kg)
Yellow corn	52.2
Soyabean meal (44%CP)	39.1
Corn gluten	4
Mixed oil	0.58
Limestone	1.75
Di-calcium phosphate	1.3
Salt	0.3
Vit &min premix[1]	0.3
Lysine	0.18
DL- methionine	0.16
Energy enzyme[2]	0.03
Phytase enzyme[3]	0.01
Antitoxin	0.1
Total	100

[1]Vitamin and mineral premix (Vita Care): Each 3 kg of the premix contains the following: vitamin A = 2,500,000 IU, vitamin D3 = 2,500,000 IU, vitamin E = 5,000 mg, zinc sulfate = 50 g, copper sulfate = 15 g, ferric sulfate = 30 g, cobalt sulfate = 200 mg, potassium iodide = 600 mg, sodium selenite = 220 mg, magnesium sulfate = 20 g, manganese sulfate = 50 g.
[2]Energy enzyme supplement (Natozyme Mix): Each 1 g of the supplement contains the following: xylanase = 15,000 U, ß-mannanase = 2,000 U, α-galactosidase = 500 U, α-amylase = 800 U, acid protease = 6,000 U, neutral protease = 6,000 U, cellulase = 1,000 U, glucose oxidase = 1,500 U, pectinase = 500 U. The carrier is corn starch, which is added up to 1 g.
[3]Phytase enzyme supplement (PHYTASE_5000): Each 1 g of the supplement contains phytase (from E. coli) at a dosage of 5,000 units. The carrier is calcium carbonate, which is added up to 1 g.

Carcass Traits

At 42 days of age, three quails from each replicate of the two strains (9 birds per treatment) were selected randomly for slaughter. Prior to the slaughtering process, the quails underwent a 6-hour fasting period, and their individual weights were accurately measured. The slaughter process was carried out humanely and in strict adherence to established ethical guidelines and industry practices. After the slaughter, all internal organs, including the intestines, heart, liver, gizzard, and kidneys, were carefully and completely removed. The resulting dressed carcass, which was devoid of internal organs, was then weighed. To assess the efficiency of converting live weight into dressed carcass weight, the dressing out percentage was calculated according to the formula of Brake *et al.* (1993): Dressing out percentage = (Hot carcass weight) / (Live weight) × 100. Furthermore, to evaluate the proportional weights of specific internal organs relative to the live body weight, a precise digital weight balance was employed to record the individual weights of the heart, gizzard, liver, and spleen to the nearest mg, with the calculation of their percentages in relation to the live BW.

Sensory meat quality

Meat samples were prepared in accordance with ISO (2023) guidelines for sensory analysis, assessing attributes perceptible to the five senses: color, odor, taste, touch, and texture. Three representative quail breast cuts from each treatment group were individually cooked on an ordinary kitchen stove without spices, adding only salt for taste improvement. Each sample was cooked at 85°C and allowed to cool to 50°C before being cut into uniform pieces and served to panelists in covered dishes with random codes. Twelve panelists from the Department of Food Safety, Faculty of Veterinary Medicine, Mansoura University, evaluated the meat's acceptability based on six attributes: meat color, aroma, taste, tenderness, juiciness, and overall acceptability. The assessment relied on a 1–9-point hedonic scoring scale as described by Ruiz-Capillas *et al.* (2021), where 9 represented "like extremely" and 1 represented "dislike extremely".

Economic efficiency

The economic evaluation of the experimental groups was determined by the calculation of production costs and returns.

Production costs were classified into total fixed cost (TFC), total variable cost (TVC), and total cost (TC). TFC included the price of purchased quails, building rent values, equipment depreciation costs, veterinary management costs, labor, litter, water, electricity, and other miscellaneous costs as described by Kamel *et al.* (2020). The TVC included the TFI cost for each quail in each experimental group during the experimental period, as well as the cost of the F-MO mixture as outlined by Kamel *et al.* (2016). The TFI cost is calculated by multiplying the FI per bird by the cost of 1 kg of diet. Total Return (TR) was calculated by the summation of the litter selling return and the quail selling return according to El-Sheikh *et al.* (2013). The quail selling return was estimated by multiplying the final BW / gram × selling price / gram. Net profit (NP) was calculated according to Hamad and Kareem (2019) by subtracting TC from TR.

Statistical analysis

The current experiment's data were analyzed using the General Linear Model (GLM) procedures of the SPSS statistical software, version 21. The statistical model included the fixed effects of the strain of Japanese quail (black and white), the treatments (F-MO mixture and control), and their interaction. Duncan's multiple range was applied to compare the means among treatment groups (Duncan, 1955). The results are presented as least squares means ± standard error, which provides a measure of the variability in the data.

RESULTS

Growth traits

The outcomes of the evaluation of growth traits in commercial Japanese quails after supplementation with the F-MO mixture are presented in Table 2. It is noteworthy that the inclusion of the F-MO mixture led to a significant ($P \leq 0.01$) enhancement in final BW, total BWG, and improved FCR when compared to the control group. However, no significant differences were noted among the treatments in terms of TFI. Furthermore, the experiment also revealed noteworthy and statistically significant ($P \leq 0.01$) variations in the response to the treatment across different quail strains. Specifically, the white strain demonstrated considerable enhancements in final BW, total BWG, TFI, and a significant ($P \leq 0.05$) improvement in FCR when juxtaposed with the black strain. It is worth noting that no interaction between the treatments and strains were shown to have any impact in the current experiment.

Carcass traits

The impact of the F-MO mixture on the carcass traits in two distinct strains of commercial Japanese quails is detailed in Table 3. Our analysis illuminated a significant influence of the F-MO mixture on dressing-out percentage ($P \leq 0.05$). Likewise, the influence of quail strain on carcass traits was also discerned to be highly significant ($P \leq 0.01$), with the white strain exhibiting a notably higher dressing-out percentage compared to the black strain. In regarding interaction, currently experiment analyzed the interactions of treatments and quail strains on carcass traits

Table 2. Effect of the Frankincense–*Melissa officinalis* mixture on growth traits of two different strains of commercial Japanese quails.

Parameters (g/bird)	Growth traits			
	Final BW	Total BWG	TFI	FCR
	Least Squares Means ± Standard Error			
	Treatment Effect (T)			
F- MOE mixture	255.82^{a}±2.34	198.35^{a}±2.41	599.00^{a}±2.72	3.02^{b}±0.03
Control	235.48^{b}±1.77	178.00^{b}±1.76	602.75^{a}±2.62	3.39^{a}±0.03
	Strain Effect (S)			
Black	241.71^{b}±4.09	184.19^{b}±4.06	596.25^{b}±2.04	3.25^{a}±0.08
White	249.59^{a}±5.21	192.16^{a}±5.24	605.50^{a}±1.72	3.16^{b}±0.09
	Treatments Strain Interaction (T*S)			
Black-F-MO mixture	250.76±0.99	193.15±1.05	595.17±3.94	3.08±0.03
Black Control	232.66±0.85	175.22±0.88	597.33±2.05	3.41±0.02
White-F-MO mixture	260.89±0.90	203.54±0.98	602.83±2.62	2.96±0.03
White Control	238.29±2.65	180.79±2.65	608.17±0.88	3.36±0.05
	P-value			
T	<0.001	<0.001	0.19	<0.001
S	0.00	0.00	0.01	0.04
T*S	0.18	0.16	0.56	0.32

Means within the same column of each sample carrying different subscripted letters are significantly different ($p \leq 0.05$); F-MO: Frankincense-*Melissa officinalis*, BW: Body weight, BWG: Body weight gain, TFI: Total feed intake, FCR: Feed conversion ratio.

in order to understand more about their combined impacts. No significant differences were identified within these interactions (P>0.05), Indicating that the addition of the F-MO mixture resulted in similar effects on carcass traits for both the white and black strains of Japanese quails.

Sensory meat quality

The sensory evaluation of meat samples provided insightful perspectives into the impact of F-MO mixture supplementation on meat quality attributes. As displayed in Table 4, incorporating the F-MO mixture into the quails' drinking water yielded highly significant improvements (P≤0.01) across various sensory aspects, including aroma, juiciness, tenderness, overall acceptability, and notably (P≤0.05) in color and taste when compared to the control group. In terms of strain impact, no significant differences were observed between the black and white quail meat samples. There were no significant variations (P>0.05) in the sensory meat quality when the interaction of the treatments and strains were analyzed. This finding highlights how F-MO mixture supplementation consistently affects sensory meat traits, whether black or white quail strains were examined.

Economic efficiency

The economic assessment findings, presented in Table 5, provide insight into the financial implications of supplementing the F-MO mixture in the drinking water of commercial Japanese

Table 3. Effect of the Frankincense–*Melissa officinalis* mixture on carcass traits of two different strains of commercial Japanese quails.

Parameters %	Carcass traits				
	Dressing -out	Liver	Gizzard	Heart	Spleen
Least Squares Means ± Standard Error.					
Treatment Effect (T)					
F-MO mixture	84.82^{a}±2.15	2.55±0.24	1.76±0.05	0.91±0.07	0.07±0.01
Control	80.01^{b}±1.34	2.16±0.46	1.74±0.07	0.91±0.05	0.05±0.00
Strain Effect (S)					
Black	79.53^{b}±1.31	2.34±0.53	1.79±0.07	0.85±0.06	0.06±0.01
White	85.29^{a}±1.93	2.37±0.08	1.71±0.05	0.97±0.05	0.06±0.00
Treatments Strain Interaction (T*S)					
Black-F-MO mixture	80.91±2.45	2.89±0.41	1.75±0.11	0.78±0.05	0.08±0.02
Black Control	78.15±0.81	1.78±0.96	1.82±0.10	0.92±0.09	0.05±0.01
White-F-MO mixture	88.73±1.37	2.21±0.03	1.76±0.01	1.05±0.08	0.06±0.01
White Control	81.86±2.21	2.53±0.08	1.65±0.10	0.90±0.05	0.05±0.01
P-value					
T	0.03	0.48	0.84	0.96	0.13
S	0.01	0.95	0.40	0.11	0.52
T*S	0.30	0.21	0.33	0.07	0.34

Means within the same column of each sample carrying different subscripted letters are significantly different (p ≤ 0.05); F-MO: Frankincense-*Melissa officinalis*.

Table 4. Effect of the Frankincense–*Melissa officinalis* mixture on the sensory meat quality of two different strains of commercial Japanese quails.

Sensory Meat Quality						
Parameters	Color	Aroma	juiciness	Tenderness	Taste	Overall acceptability
Least Squares Means ± Standard Error						
Treatment Effect (T)						
F-MO mixture	8.25^{a}±0.11	8.42^{a}±0.12	8.70^{a}±0.16	8.87^{a}±0.05	8.45^{a}±0.13	8.42^{a}±0.11
Control	7.05^{b}±0.38	7.02^{b}±0.27	7.45^{b}±0.18	7.20^{b}±0.18	7.61^{b}±0.27	7.51^{b}±0.14
Strain Effect (S)						
Black	7.55±0.40	7.48±0.45	8.17±0.29	7.97±0.44	8.10±0.28	8.05±0.20
White	7.75±0.38	7.95±0.24	7.98±0.35	8.10±0.35	7.97±0.29	7.88±0.27
Treatments Strain Interaction (T*S)						
Black-F-MO mixture	8.07±0.07	8.43±0.23	8.80±0.15	8.90±0.06	8.37±0.20	8.47±0.09
Black Control	7.03±0.72	6.53±0.23	7.53±0.09	7.03±0.27	7.82±0.51	7.62±0.13
White-F-MO mixture	8.43±0.15	8.40±0.15	8.60±0.31	8.83±0.09	8.53±0.20	8.37±0.23
White Control	7.07±0.47	7.50±0.25	7.37±0.38	7.37±0.23	7.40±0.23	7.40±0.26
P-value						
T	0.03	<0.001	0.00	<0.001	0.03	0.00
S	0.66	0.07	0.50	0.50	0.70	0.43
S*T	0.71	0.05	0.95	0.32	0.38	0.76

Means within the same column of each sample carrying different subscripted letters are significantly different (p ≤0.05). F-MO: Frankincense-*Melissa officinalis*.

quails. Regarding the treatment impact, notable disparities were observed in F-MO mixture cost, TVC, and TC, with highly significant differences (P≤0.01) evident when comparing the F-MO mixture-supplemented group to the control group. Conversely, no significant differences (P>0.05) were discerned in TFI cost and TFC among the various treatments. Noteworthy, quails receiving water supplemented with the F-MO mixture exhibited significantly higher quail selling return, TR, and NP values (15.35, 15.57, and 3.98 E£/quail, respectively) in contrast to the control group (14.13, 14.35, and 3.17 E£/quail, respectively). Regarding the strain impact, highly significant (P≤0.01) differences emerged in TFI cost, TVC, TC, quail selling return, TR, and NP between the white and black strains. Notably, the white quails displayed highest values in these economic parameters than the black strain. However, no significant differences (P>0.05) were detected between both strains in terms of F-MO mixture cost and TFC values. Furthermore, upon examining the interactions between treatments and strains, no significant effects (P<0.05) on the economic efficiency were observed.

DISCUSSION

The current experiment aimed to compare the responses of two strains of commercial Japanese quails, the black strain and the white strain, to drinking water supplemented with a F-MO mixture.

The use of the F-MO mixture, according to our findings, considerably enhance growth traits. Significant improvements were recorded in the final BW, total BWG, and FCR. This positive effect can be attributed to the synergistic interplay between Frankincense (*Boswellia*) and *Melissa officinalis* (lemon balm). This synergism likely contributes to the observed improvements in growth metrics.

Our findings are consistent with earlier studies that have investigated the individual effects of each herb within the mixture. Particularly, Al-Yasiry and Kiczorowska *et al.* (2016); Al-Yasiry *et al.* (2017) demonstrated favorable impacts on body weight, weight gain, and FCR in broiler chickens through the incorporation of *Boswellia* into their diets. This alignment in outcomes is paralleled by Ismail *et al.* (2019), they reported analogous results in rabbit diets, thus providing additional support for our present findings. In a similar way, Kwiecień *et al.* (2014) recorded elevated body weights among chickens receiving a 2% lemon balm. Moreover, Kasapidou *et al.* (2014) identified heightened final weights in chickens supplemented with feed containing 5 g/kg of lemon balm.

Concerning FI, our experiment demonstrated that the F-MO mixture had no effect on FI. Similar results were reported for *Boswellia serrata* resin by Kiczorowska *et al.* (2016) in broiler chicken diets, *Melissa officinalis* by Poorghasemi *et al.* (2017) in broiler chicken diets and other herbal extracts by Skomorucha and SosnówkarCzajka (2017) in broiler chicken drinking water.

The combined findings underscore the potential synergistic effects of the F-MO mixture observed in our experiment, which translate into improvement in growth parameters such final BW, total BWG, and FCR. These effects are in line with outcomes derived from individual herb supplementation studies, further solidifying the efficacy of our novel mixture in enhancing growth performance.

Enhancements in growth traits can be related firstly to the F-MO mixture's antioxidant properties as documented by Mohammadi *et al.* (2020); Mohamed *et al.* (2021), which play a vital role in counteracting harmful free radicals and reducing oxidative stress, thereby promoting optimal cellular function and contributing to improved growth. Secondly, the immunostimulant properties of Frankincense and *Melissa officinalis* Poorghasemi *et al.* (2017); Amer *et al.* (2023) may have assisted in enhancing growth by strengthening the quails' immune responses. The advancement in disease resistance and overall health is most likely responsible for the observed growth improvements.

The differences in growth traits between the white and black quail strains observed highlight the impact of genetic diversity on growth performance. This finding is consistent with previous studies Bagh *et al.* (2016) ; Kamel *et al.* (2021) that reported significant variations in final body weight among different quail strains. The observed variation in growth-related traits is inevitably influenced by these genetic factors.

In relation to carcass traits, the incorporation of the F-MO mixture led to a notable increase in the dressing-out percentage. Our findings resonate with similar research outcomes, as indicated by Al-Yasiry *et al.* (2017). They demonstrated that supple-

Table 5. Effect of the Frankincense–*Melissa officinalis* mixture on the economic efficiency of two different strains of commercial Japanese quails.

Parameters (E£/ quail)	Economic efficiency							
	TFI cost	F-MO Cost	TVC	TFC	TC	Quail selling return	TR	NP
Least Squares Means ± Standard Error								
Treatment Effect (T)								
F-MO mixture	5.98±0.03	0.45^a±0.00	6.43^a±0.03	5.16±0.00	11.59^a±0.03	15.35^a±0.14	15.57^a±0.14	3.98^a±0.14
Control	6.02±0.03	0.00^b±0.00	6.02^b±0.03	5.16±0.00	11.18^b±0.03	14.13^b±0.11	14.35^b±0.11	3.17^b±0.09
Strain Effect (S)								
Black	5.95^b±0.02	0.23±0.10	6.17^b±0.10	5.16±0.00	11.33^b±0.10	14.50^b±0.24	14.72^b±0.24	3.39^b±0.15
White	6.05^a±0.02	0.23±0.10	6.27^a±0.08	5.16±0.00	11.43^a±0.08	14.98^a±0.31	15.20^a±0.31	3.76^a±0.23
Treatments Strain Interaction (T*S)								
Black-F-MO mixture	5.95±0.05	0.45±0.00	6.40±0.05	5.16±0.00	11.56±0.05	15.04±0.06	15.26±0.06	3.71±0.09
Black Control	5.94±0.01	0.00±0.00	5.94±0.01	5.16±0.00	11.10±0.01	13.96±0.05	14.18±0.05	3.07±0.05
White-F-MO mixture	6.01±0.03	0.45±0.00	6.46±0.03	5.16±0.00	11.62±0.03	15.65±0.05	15.87±0.05	4.25±0.09
White Control	6.09±0.01	0.00±0.00	6.09±0.01	5.16±0.00	11.25±0.01	14.30±0.16	14.52±0.16	3.27±0.16
P-value								
T	0.23	<0.001	<0.001	NS	<0.001	<0.001	<0.001	<0.001
S	0.01	1	0.01	NS	0.01	0.00	0.00	0.01
S*T	0.20	1	0.20	NS	0.20	0.18	0.18	0.14

Means within the same column of each sample carrying different subscripted letters are significantly different (p ≤ 0.05). F-MO: Frankincense-*Melissa officinalis*, E£: Egyptian pound's, TFI: total feed intake, TVC: total variable cost, TFC: total fixed cost, TC: total cost, TR: total return, NP: net profit, NS: non-significant.

menting broiler chicken diets with *Boswellia serrata* resin alone resulted in a linear elevation in the percentage of total muscle per carcass. Furthermore, the findings of Kasapidou *et al*. (2014) on organically produced broilers revealed that supplementation with *Melissa officinalis* alone contributed to significantly higher values for both slaughter and carcass weight when compared to the control group. Similarly, Kwiecień *et al*. (2014) showed that adding 2% *Melissa officinalis* into feed mixes increased slaughter yield and improved carcass traits when compared to the control group of chickens.

Our experiment revealed distinct effects depending on strain variations with the white strain exhibited a higher dressing-out percentage than the black strain. This disparity could be attributed to the genetic factors inherent in each strain.

The improvements observed across various sensory evaluation parameters, including color, aroma, juiciness, tenderness, taste, and overall acceptability, provide compelling evidence that the supplementation of the F-MO mixture positively contributed to the sensory quality of the meat. Significantly, the absence of negative effects on sensory attributes highlights the potential of the F-MO mixture to maintain the sensory appeal of quail meat. The sensory enhancements noted in the quail meat treated with the F-MO mixture are consistent with previous research, particularly in the context of the bioactive compounds present in *Melissa officinalis*. The presence of flavonoids and other bioactive compounds has been reported to enhance sensory attributes and subsequently influence consumer preferences for the poultry products, as defined by Kamboh *et al*. (2019). This finding corresponds with Sheikhsamani *et al*. (2022), where the incorporation of herbal mixtures in Japanese quail diets improved the physiochemical properties of the meat. The potential mechanism underlying the observed sensory enhancements can be attributed to the antioxidant properties inherent in the bioactive compounds present within the Frankincense and *Melissa officinalis,* according to Mohammadi *et al*. (2020) and Mohamed *et al*. (2021). Antioxidants play a crucial role in preventing lipid oxidation and the emergence of undesirable flavors and odors. F-MO mixture supplementation likely contributed to the observed advancements in color, aroma, juiciness, tenderness, taste, and overall acceptability by mitigating oxidative stress and preserving lipid quality within the meat.

In terms of economic efficiency, the consistency in overall feed consumption costs can be attributed to the uniform feed intake observed across the treatment groups. This coherence aligns with the stability of TFC, encompassing factors such as chick price, labor, electricity, building rent, and equipment depreciation. These remained constant across all groups, leading to minimal variation in TFC. Despite the slightly higher production expenses associated with the F-MO mixture, the treatments involving F-MO exhibited significantly elevated quail selling returns, total returns, and net profits compared to the control group. This finding implies that the somewhat higher production costs are better offset than covered by the potential advantages of F-MO mixture supplementation, including higher quail performance and improved product quality. It emphasizes the practicality of the F-MO mixture as a potentially cost-effective choice for quail farmers. Although none of the previous studies have specifically examined the economic implications of F-MO mixture supplementation in poultry diets, existing research on herbal additives in poultry production reveals positive economic outcomes.

Experiments by Omar *et al*. (2016); Kuralkar and Kuralkar (2021) showcased that herbal additive incorporated into broiler diets resulted in lower production costs and higher economic efficiency. These findings illustrate the potential of herbal additives, particularly the F-MO mixture, as cost-effective growth enhancers, ultimately enhancing overall poultry performance and the cost-to-revenue ratio.

Turning to the strain effect, substantial distinctions emerged in TFI costs, TVC, TC, quail selling returns, TR, and NP, with the white strain surpassing the black strain. These divergences can be attributed to variations in both TFI and slaughter BW between the two strains, which are controlled by inherent genetic factors.

CONCLUSION

The current experiment clarifies the significant beneficial effects of administering the F-MO mixture on growth traits, dressing-out percentage, sensory meat quality, and economic viability of Japanese quails. However, in terms of growth-related traits, the white strain responded significantly better to this mixture than the black strain.

These compelling findings underline the potential of the F-MO mixture as a natural and effective option for enhancing quail production and improving meat quality. Furthermore, the integration of this herbal extract addresses growing concerns about the use of antibiotics in the livestock feed industry, providing a sustainable and safer alternative to promoting healthier poultry growth within farming practices.

CONFLICT OF INTEREST

The authors declare that they have no conflict of interest.

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