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Ruminants

Evaluation of Oral Supplementation of Black Cumin (*Nigella sativa*) on Growth Performance, Immune Response, Disease Incidence and Mortality Rate of Suckling Zaraibi Goat Kids

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ABSTRACT

The aim of this study was to evaluate the effects of *Nigella sativa* supplementation on the immune response, disease incidence, mortality rate and growth performance of suckling Zaraibi goat kids. Sixty suckling Zaraibi goat kids (33 males and 27 females) with an average body weight of 3.03 ± 0.02 kg were divided into three groups: a control group (G1), which was fed a basal diet and two treatment groups (G2 and G3), which were fed the same diet supplemented with 0.5 g and 1.0 g of *N. sativa* per kid per day, respectively, for 84 days. The data were analysed with a general linear model to assess the differences among dietary treatments, and Duncan's multiple range test was applied for post hoc comparisons. Compared with G1, the body weight of the kids in the treatment groups was significantly higher ($p < 0.05$). Consequently, total weight gain and average daily gain were significantly raised in the G2 and G3 groups compared to the control group ($p < 0.05$). In addition, the feed intake was significantly higher, whereas the feed conversion ratio was significantly lower in G3 compared to G1 ($p < 0.05$). The outputs of weaning weight and the adjusted mortality rate increased significantly ($p < 0.05$), in line with the increasing levels of *N. sativa* in G2 and G3. G3 fed the highest level of *N. sativa* and registered the lowest occurrence of diseases, followed by G2, whereas the control, G1, showed the highest incidence ($p < 0.05$). In particular, the mortality rate decreased significantly ($p < 0.05$) with the inclusion of *N. sativa*, showing a clear dose-dependent effect. The highest mortality rate was observed in G1 (15%), followed by G2 (10%), while G3 exhibited the lowest mortality rate (5%) ($p < 0.05$). The plasma IgG levels were significantly higher in the G2 and G3 groups compared to the control group ($p < 0.05$), with G3 exhibiting increased IgG levels than G2 ($p < 0.05$). These findings suggest that *N. sativa* supplementation can enhance the health and growth performance of suckling Zaraibi goat kids, contributing to sustainable farming practices and potentially reducing antibiotic use in livestock.

1 | Introduction

The increasing concern over antimicrobial resistance (AMR) has underlined the need to reduce the use of antimicrobials in human and veterinary medicine (Caneschi et al. 2023). The World Health Organization (WHO) and other international bodies have called for urgent action to mitigate this growing crisis by encouraging alternative approaches that enhance health while preserving antibiotics as a last resort (WHO 2024).

One promising approach is functional nutrition, which emphasizes the use of bioactive compounds and natural feed additives to support health and immunity in livestock. Functional compounds, such as prebiotics, phytochemicals and plant extracts, can improve gut health, modulate the immune response, and reduce the incidence of infections, thereby lowering the need for antimicrobials (Wang et al. 2024).

By enhancing the overall health of the host through precision nutrition, it is possible to maintain productivity while minimizing the reliance on antibiotics. The use of natural extracts is an important sustainable strategy to revalorize by-products and exploit natural compounds for their beneficial effects. Given the variability in the composition and efficacy of natural extracts, more research on the functional effects of phytochemicals is crucial to fully assess their characteristics and potential applications in livestock nutrition (Ferreira et al. 2022).

Black cumin (*Nigella sativa* L.) is a small flowering plant native to Southwest Asia that is known for its black seeds and has been used for centuries in traditional medicine and as a spice. *N. sativa* is predominantly cultivated in developing countries (Gilani et al. 2004), where more than 90% of the global goat population is concentrated (Galal 2006). *N. sativa* seeds contain hundreds of beneficial compounds and serve as rich sources of essential fatty acids, proteins, carbohydrates, vitamins (A, B1, B2, C and niacin), minerals and carotene.

The nutritional composition of *N. sativa* seeds includes 23.3% crude protein (ranging from 7.5% to 33.1%), 9.67% ether extract (ranging from 4.7% to 12.7%) and 42.7% neutral detergent fibre (ranging from 22.8% to 55.1%) (Zanouny et al. 2013; Sadarman et al. 2021).

N. sativa seeds have recently gained attention as a feed supplement because of their high oil content and bioactive compounds (Ahmad et al. 2021; Cherif et al. 2018). The primary beneficial component of *N. sativa* is thymoquinone (Sahak et al. 2016), alongside notable concentrations of polyphenols and essential oils such as p-cymene, α-thujene, carvacrol and β-pinene (Odhaib et al. 2018; Kabir et al. 2020). The phytochemicals in black cumin seeds are known to positively influence ruminant productivity by modulating rumen metabolism, thereby improving growth performance (Rahmy et al. 2024). A recent review from Majid et al. (2018) highlighted the multiple biological properties of *N. sativa*, including antioxidant, antidiabetic, antimicrobial, anticancer, hepatoprotective, neuroprotective, anti-inflammatory, gastroprotective, immunomodulatory, analgesic, spasmolytic and bronchodilator activities (Longato et al. 2015; Kooti et al. 2016; Ahmad et al. 2021).

There is significant interest in the use of *N. sativa*, both in its seed form and derived oils, as a supplement in animal feed to increase growth performance and overall health (Singh et al. 2022). Meta-analyses indicate that essential oils derived from *N. sativa* can effectively improve growth performance and nutrient digestibility in cattle, small ruminants (Khiaosa-Ard and Zebeli 2013; Torres et al. 2020), and broiler chickens while also successfully replacing antibiotics as growth promoters (Irawan et al. 2021).

N. sativa seeds are highly valued for their nutritional composition, including monosaccharides, non-starch polysaccharides (providing dietary fibre) and high contents of unsaturated and essential fatty acids that cannot be synthesized by the body and must be obtained through the diet. The seeds contain 15 amino acids, including eight of the nine essential amino acids (Sh et al. 2024). Although both sheep and goats are ruminants, their digestive physiology and feeding behaviours differ significantly (Krone et al. 2024).

This study hypothesized that increasing levels of *N. sativa* seed supplementation would lead to a dose-dependent improvement in growth performance and health status and enhance economic efficiency in suckling Zaraibi kids. Different levels of supplementation have been evaluated in ruminants and kids in the literature (El-Saadany et al. 2008; Habeeb and El-Tarabany 2012; El-Basiony et al. 2015; Singh et al. 2022; Mohammed and Al-Suwaiegh 2023). In this study, intermediate levels were selected to achieve a balance between cost-effectiveness, dietary adequacy and functional activity, ensuring the optimal efficiency of black cumin seeds inclusion.

Therefore, the aim of this study was to investigate the effects of *N. sativa* seeds supplementation on the growth performance, feed intake and conversion, immune response, health status, mortality rate and economic efficiency of suckling Zaraibi kids.

2 | Materials and Methods

The experimental trial was carried out at the Sakha Animal Production Research Station belonging to the Animal Production Research Institute (APRI), Agricultural Research Center, Ministry of Agriculture. The experiments were performed according to the guidelines of a local ethical committee for animal care and welfare (Number of ethical approval: 06/2024 EC).

2.1 | *N. sativa* Seed Bromatological Characterization

Black cumin seeds were analysed according to official methods for the content of crude protein (AOAC 932.06), crude fat (AOAC 923.03), ash (AOAC 925.09), fibre (AOAC 985.29) and oven-drying method for moisture determination (AOAC 930.15), as documented in the Official Methods of Analysis (AOAC 2023). Carbohydrates are calculated according to Gbenga-Fabusiwa et al. (2018) as the difference between the mean values [100 − (proteins + lipids + ash + moisture)]. The amino acid content was determined via an amino acid autoanalyzer according to Babayan et al. (1978). The mineral content was determined through a Perkin Elmer atomic absorption spectrophotometer (Plasma 400) according to Karrar et al. (2019). Volatile compounds were determined according to the method described by Karrar et al. (2019). The fatty acid composition of the cumin seed oil was determined following the method described by Karrar et al. (2019).

2.2 | Experimental Animals, Treatments and Management

Sixty suckling Zaraibi goat kids (33 males and 27 females) at 7 days after birth with an average body weight of 3.03 ± 0.02 kg were allocated into three groups (11 males and 9 females in each group) balanced for weight. The dams were hormonally treated to synchronize estrus over a 2-week period, ensuring that births occurred within the same timeframe. This hormonal synchronization allowed for kids' parity balance (from the 2nd to the 4th) in both groups and better coordination in managing the experimental groups. The kids were born over a one-week period and were then allocated to the experimental treatments on the basis of weight and sex, ensuring similarity across the groups. All kids were housed in semi-shaded open yards for each group and kept under the same managerial and hygienic experimental conditions. All kids naturally suckled their dams. The control group did not receive *N. sativa* supplementation (G1), whereas the treatment groups were orally supplemented with 0.5 and 1.0 g *N. sativa*/kid/day (G2 and G3, respectively). This dosage was selected on the basis of previously obtained data, although an optimum *N. sativa* level for suckling kids has not been definitively established, studies in small ruminants suggest effective inclusion rates of roughly 10–20 g/kg of diet (≈0.25 g/kg body weight/day), with reported benefits for growth, feed efficiency and overall health (Singh et al. 2022; Mohammed and Al-Suwaiegh 2023). In particular, *N. sativa* seeds were ground and administered orally to the kids. The experiment started at 7 days after birth and continued until weaning at 90 days, for a total of 84 days.

2.3 | Zootechnical Performance and Diseases Incidence

The kids were individually weighed biweekly, and total weight gain and average daily gain were calculated for each kid. The number of kids that were affected by diseases such as diarrhoea, respiratory disease, septicaemia, navel and general weakness, as well as mortality, was recorded during the experimental period. Specifically, the diagnosis of diarrhoea, respiratory issues, septicaemia, navel and general weakness was performed through close monitoring of the kids, which was conducted by the same trained operator to ensure consistency and repeatability. Symptoms of septicaemia were identified on the basis of rapid onset of clinical signs: chills, fever, tachycardia and tachypnoea.

2.4 | Blood Samples and Immunoenzymatic Analyses

Blood samples were collected during the last week of the trial from the jugular vein of each kid in tubes containing heparin as an anticoagulant. The samples were subsequently centrifuged for 15 min at 4000 rpm to obtain the plasma. The quantification of immunoglobulins in plasma was performed using goat IgG, IgA and IgM ELISA kits (Goat IgG ELISA no. A80040, Goat IgA ELISA Kit no. A80214, Goat IgM ELISA Kit no. A80215, Bethyl Laboratories, Montgomery, Texas, USA) according to Rodríguez et al. (2009).

2.5 | Statistical Analysis

The sample size was estimated a priori via GPower software by setting the significance level (α) at 0.05 and the statistical power (1-β) at 0.80 for an ANOVA test considering fixed effects. Specifically, the total sample size was calculated to detect a significant difference for an effect size of 0.45 (Cohen's d).

The normal distribution of the data was analysed with explore procedure in SPSS. The data, including the mortality rates, were analysed with a general linear model (GLM) procedure in IBM SPSS Statistics (Version 22), with one-way ANOVA employed to assess the differences among dietary treatments. A linear effect of supplementation level was tested to evaluate the dose–dependent relationship across treatments. Post hoc comparisons of significant mean differences were conducted using the Duncan's multiple range test, with the significance level set at $p < 0.05$. The raw and adjusted weaning weight outputs of kids in the different experimental groups were analysed. The price of 1 kg of live weight was set at 200 LE on the basis of 2024 market prices. To account for mortality, the adjusted weaning weight was calculated according to Gaafar (2024) through the following formula:

$$\text{AdjustedOutput} = \text{RawOutput} \times (100 - \text{MortalityRate})/100.$$

This adjustment ensured that the weaning weight reflected the loss due to mortality in the experimental groups.

Figures were prepared with GraphPad Prism 9.0 software.

3 | Results and Discussion

3.1 | *N. sativa* Seed Composition

N. sativa seeds were purchased from a local Egyptian producer. Proximate analysis of *N. sativa* seeds revealed a composition of 20.85% protein, 38.20% fat, 4.64% moisture, 4.37% ash, 7.94% crude fibre and 31.94% total carbohydrates. The total amino acid content was 15.5 g/100 g, the total essential amino acid content was 5.40 g/100 g and the total nonessential amino acid content was 10.1 g/100 g. The major amino acid was glutamic acid (4.10 g/100 g), followed by aspartic acid (1.59 g/100 g), arginine (1.40 g/100 g) and leucine (0.93 g/100 g). The levels of linoleic acid (57.71%), oleic acid (24.46%), palmitic acid (12.17%), eicosadienoic acid (2.52%) and stearic acid (2.31%) were measured. Saturated fatty acids 15% and unsaturated fatty acids 85%. The minerals (mg/100 g) used were 810 calcium, 358 phosphorus, 276 magnesium, 28 sodium, 716 potassium, 0.95 iron, 0.25 copper and 0.43 zinc. The volatile components are thymoquinone (21.01%), o-cymene (18.23%), β-thujene (17.22%), cis-4-methoxythujane (7.04%), longifolene (6.43%), β-pinene (5.08%), D-limonene (3.46%), (E)-longipinene (2.19%) and phenol, 2-methyl-5-(1-methylethyl) (2.07%). The composition of the *N. sativa* seeds used in this study aligns with findings from previous studies conducted in Egypt. However, the ether extract concentration, fatty acid profile, and fibre content can significantly vary depending on the specific variety of black cumin seeds and whether they have undergone decortication (El-Saadany et al. 2008; Habeeb and El-Tarabany 2012; El-Basiony

TABLE 1 | Growth performance of suckling kids not supplemented (G1) or supplemented with 0.5 or 1.0 g/kid/day *N. sativa* (G2 or G3, respectively) over 84 days of the trial.

	Experimental groups				
Item	**G1**	**G2**	**G3**	**SE**	***p* value**
Initial weight (7 days old), kg	2.35	2.36	2.34	0.01	0.876
Final weight (90 days old), kg	10.60^{c}	11.05^{b}	11.60^{a}	0.16	0.004
Total weight gain, kg	8.25^{c}	8.69^{b}	9.26^{a}	0.15	0.001
Average daily gain, g/day	91.67^{c}	96.56^{b}	102.89^{a}	1.72	0.001
Feed intake, g/day	130^{b}	134^{ab}	139^{a}	1	0.017
Feed conversion ratio, kg/kg gain	1.42^{a}	1.39^{ab}	1.36^{b}	0.01	0.030

Note: Values in the same row with different superscripts (a, b, c) differ significantly at $p < 0.05$.

et al. 2015; Singh et al. 2022; Mohammed and Al-Suwaiegh 2023). *N. sativa* seeds, also known as black cumin seeds, have a complex composition including fixed oil, volatile oil, proteins, carbohydrates, fibre, alkaloids, tannins, saponins, minerals and vitamins. Key components include unsaturated fatty acids like linoleic and oleic acids, and saturated fatty acids like palmitic acid. They also contain various amino acids, with glutamic acid, aspartic acid and arginine being prominent (Majid 2018).

3.2 | Growth Performance

No significant differences were observed in the initial body weights of the kids among the groups (p = 0.876, Table 1). However, at weaning, kids in the G2 and G3 groups presented significantly higher final weights than those in the control group ($p < 0.05$), with G3 being the heaviest ($p < 0.05$). Specifically, the final weights were 11.60 kg for G3, 11.05 kg for G2 and 10.60 kg for G1. The total weight gain and average daily gain were also significantly ($p < 0.05$) increased in the *N. sativa*-supplemented groups compared to the control group, with G3 showing the highest values for both parameters. The total weight gain was 9.26 kg in G3, 8.69 kg in G2 and 8.25 kg in G1. Similarly, the average daily gain was 102.89 g in G3, 96.56 g in G2 and 91.67 g in G1. The weaning weights of kids in G2 and G3 were approximately 4.25% and 9.43% raised than those in the control group, respectively. Additionally, the total weight gain and average daily gain in G2 and G3 increased by approximately 5.33% and 12.24%, respectively, compared with those in the control group. These results are consistent with findings from previous studies by Mahmoud and Bendary (2014), who reported improved live body weight in lambs and calves fed *N. sativa* seed meal. Similarly, Mohsen et al. (2017) and Ahmed et al. (2022) reported significant increases in live body weight, total weight gain, and average daily gain in animals supplemented with *N. sativa*. Growth performance, feed intake and digestibility increase were more prominent when *N. sativa* seeds were fed at the rate of 10 g/head/day in male Beetal goats (Ahmed et al. 2022). *N. sativa* seeds, also known as black cumin seeds, can positively impact the growth of growing goats when included in their diet. Studies have shown that supplementation with *N. sativa* can improve nutrient digestion, increase feed intake and enhance overall growth performance in goats. Additionally, it may offer benefits related to immunity and gut health (Elfaki and Elkhair 2024). The dry matter intake

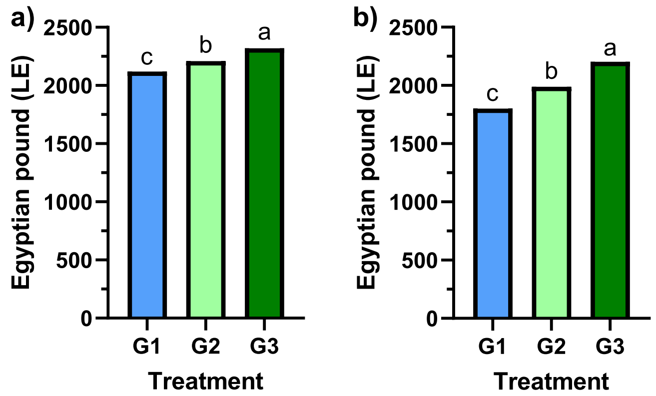

FIGURE 1 | Outputs of raw and adjusted weaning weights of kids in the different experimental groups. The price of 1 kg live weight was 200 LE according to the price of 2024. (a) Raw output of the weaning weight of kids; (b) Adjusted output of the weaning weight for the mortality rate of kids in different groups. Adjusted output = output × (100 − mortality rate)/100. Different lowercase letters (a, b, c) indicate significant differences among groups ($p < 0.05$).

was significantly higher in G3 (139 g/head/day) than in G1 (130 g/head/day), but it did not differ significantly from G2 group (134 g/head/day) ($p = 0.017$). However, the feed conversion ratio expressed as kg dry matter intake per kg weight gain was significantly lower in G3 (1.36) than in G1 (1.42) ($p = 0.030$). These results are in line with the findings of Ahmed et al. (2022), who reported that *N. sativa* seeds supplementation in the diets of male Beetal goats increased feed intake and improved feed efficiency. Mohsen et al. (2017) reported that *N. sativa* seeds supplemented at the level of 10 g/head/day in Friesian calves during suckling and postweaning improved feed intake and the feed conversion ratio. *N. sativa* seed supplementation can positively influence dry matter intake (DMI) in growing goats, potentially leading to improved growth performance. Studies have shown that adding *N. sativa* seeds to goat diets can increase DMI, along with other beneficial effects on nutrient intake and digestibility (Singh et al. 2022).

The output weaning weights of kids in Egyptian pounds (LE) are shown in Figure 1a. Compared with those in the control group, the values in the G2 and G3 groups increased linearly with increasing *N. sativa* concentrations ($p < 0.05$). Specifically, the

TABLE 2 | Disease occurrence of suckling kids in the different experimental groups.

Item	Experimental groups			SE	p value
	G1	G2	G3		
Diarrhea, %	21.38[a]	13.59[b]	6.46[c]	2.16	0.002
Respiratory, %	15.74[a]	10.66[b]	5.38[c]	1.50	0.004
Septicaemia, %	12.42[a]	8.25[b]	4.07[c]	1.21	0.003
Navel, %	9.02[a]	5.98[b]	3.53[c]	0.79	0.006
General weakness, %	7.94[a]	5.49[b]	3.23[c]	0.68	0.005

Note: Values in the same row with different superscripts (a, b, c) differ significantly at $p < 0.05$.

output of weaning weight increased by 90 LE (4.25%) in G2 and by 200 LE (9.43%) in G3 compared with the control group (G1). Moreover, the adjusted output of weaning weight for the mortality rate at Egyptian pound (LE) is shown in Figure 1b. Compared with the control, the *N. sativa* additive significantly increased ($p < 0.05$) the adjusted output of weaning weight, with the best results occurring in G3. Compared with that of the control group (G1), the output of weaning weight increased by 187 LE (10.38%) in G2 and 402 LE (22.31%) in G3. These results align with those of Mahmoud and Bendary (2014), who reported that *N. sativa* seed meal can improve the total economic value of growing lambs and calves. Similarly, Mohsen et al. (2017) reported a significant increase in income from growing Holstein calves after black cumin supplementation. *N. sativa* seeds, also known as black cumin seeds, can positively impact the economic efficiency of growing goats by improving growth performance, feed efficiency, and potentially reducing the need for antibiotics. This can lead to increased profitability for goat farmers (Singh et al. 2022).

3.3 | Health Status

The percentages of disease occurrence in suckling kids are reported in Table 2. The percentages of diarrhoea, respiratory disease, septicaemia, navel infections and general weakness in kids significantly decreased ($p < 0.05$) with the addition of *N. sativa* to their diet, and further reductions were observed with increasing levels of the additive. Notably, the group receiving the highest black cumin level (G3, 1 g/head/day) presented the lowest percentage of disease incidence, followed by G2 (0.5 g/head/day), whereas the control group (G1) presented the highest percentage ($p < 0.05$). These improvements may be attributed to the higher concentrations of immunoglobulins in the plasma of kids receiving *N. sativa* additive, which could enhance their overall health status. Similarly, Abdel-Raouf et al. (2018) reported that *N. sativa* supplementation significantly reduced the incidence of diarrhoea in Friesian calves during the suckling and first postweaning periods. Additionally, Singh et al. (2022) reported that *N. sativa* improved the gut health of small ruminants. *N. sativa* seeds can positively impact the health and growth of young goats. Thymoquinone, the major bioactive quinone in *N. sativa* seeds, together with other secondary metabolites (e.g., p-cymene), confers antioxidant, antimicrobial and immunomodulatory effects that may reduce pathogen load, modulate inflammation, and enhance the immune system in young ruminants (Mohammed and Al-Suwaiegh 2023, Alberts et al. 2024). Studies have shown that supplementing goat diets with *N. sativa* can improve nutrient digestion, increase weight gain, enhance immune responses and improve blood parameters. Specifically, it can lead to better feed utilization, increased red blood cell and haemoglobin levels, and improved immune responses in growing goats (Singh et al. 2022). *N. sativa* may be a promising natural alternative to antibiotics for promoting growth and improving health in goats (Sadarman et al. 2021) supplementing goat diets with *N. sativa* seeds can improve immunity, reduce disease incidence, and enhance overall growth performance.

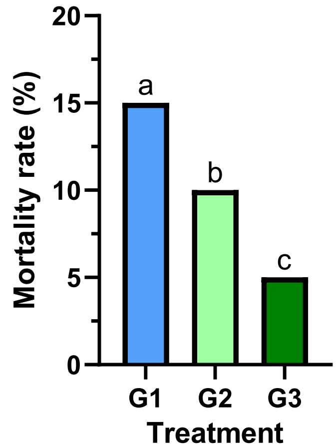

FIGURE 2 | Mortality rates of suckling kids in the different experimental groups. Different lowercase letters (a, b, c) indicate significant differences among groups ($p < 0.05$).

3.4 | Mortality Rate

The mortality rate of suckling kids, as influenced by the *N. sativa* additive, is presented in Figure 2. The mortality rate followed a similar trend to that of disease infection, decreasing significantly ($p < 0.05$) with the inclusion of *N. sativa* and with higher levels of the additive. The control group (G1) presented the highest mortality rate at 15% (3 out of 20), followed by G2 at 10% (2 out of 20), whereas G3 presented the lowest rate at 5% (1 out of 20) ($p < 0.05$). Several studies have investigated the potential of the use of natural additives such as medicinal herbs, including *N. sativa*, in animal feed to reduce mortality rates in offspring (El-Hosseiny et al. 2000; Shehata et al. 2007). When used as a dietary supplement in growing goats, *N. sativa* seeds can positively influence several aspects of health and growth, including a potential reduction in mortality rates (Elsayed et al. 2025). The registered mortality reduction is biologically plausible since *N. sativa* seeds contain thymoquinone, a major bioactive quinone with broad antibacterial and antibiofilm activity, quorum-sensing/virulence interference, and demonstrated ability to improve survival in experimental infection models (Chaieb et al. 2011; Wang et al. 2021; Al-Rabia et al. 2024). These properties can help limit the establishment of enteric and respiratory pathogens in newborns, thereby reducing morbidity and mortality rates. Moreover, *N. sativa* supplementation has been associated with improved haematological and metabolic status, immune stimulation, and better overall physiological resilience in goats and other small ruminants, factors that would be expected to lower case-fatality

TABLE 3 | Plasma antibody titres of suckling kids in the different experimental groups.

Item	Experimental groups G1	G2	G3	SE	*p* value
IgG, g/L	29.28[c]	35.71[b]	41.95[a]	1.84	0.002
IgM, g/L	3.98[c]	4.37[b]	4.66[a]	0.10	0.003
IgA, g/L	2.65[c]	2.92[b]	3.14[a]	0.07	0.004

Note: Values in the same row with different superscripts (a, b, c) differ significantly at $p < 0.05$.

risk when diseases occur (Sadarman et al. 2021; Mohammed and Al-Suwaiegh 2023).

3.5 | Immune Status

Table 3 shows the significant effects of black cumin seeds on the concentrations of different types of serum immunoglobulins (IgG, IgM and IgA) in the plasma of kids at weaning. The results indicated that all types of plasma immunoglobulins were significantly ($p < 0.05$) increased in the *N. sativa* treatment groups (G2 and G3) compared with those in the control group (G1). The group with the highest *N. sativa* level (G3) presented significantly ($p < 0.05$) higher values than the lower-level group G2. These findings align with previous studies on pre- and postweaning calves, where black cumin was used at levels of 5 and 10 g/head/day, significantly increased the concentrations of IgG, IgM and IgA in plasma at 3 and 6 months of age. These findings suggest that the *N. sativa* dietary supplementation may enhance the immune status of small ruminants (Abdel-Raouf et al. 2018; Singh et al. 2022). Black cumin seeds, when supplemented in the diet of growing goats, can positively impact their immune status. Studies have shown that these seeds can enhance immune responses, potentially by increasing levels of immunoglobulins like IgA and IgG. This can lead to improved overall health and resistance to diseases in growing goats (Singh et al. 2022). *N. sativa* contains thymoquinone, a compound with antioxidant and immunomodulatory properties. Previous data obtained by our research group, which analysed the content of thymoquinone content of the tested *N. Sativa* seeds, indicated a concentration of 0.19 mg/g of seeds (Abdel-Razek et al. 2024). Supplementation with black cumin seeds can lead to increased levels of immune-related proteins in the blood, suggesting a boosted immune response (Wei et al. 2022). *N. sativa* supplementation can increase the concentration of immunoglobulins (as shown in Table 3), specifically IgA and IgG, in the blood of small ruminants, including goats and these immunoglobulins play a crucial role in the host's defence against pathogens (El-Basiony et al. 2015).

4 | Conclusion

The findings of this study indicate that the inclusion of *N. sativa* as an additive at a level of 1 g/kid/day for suckling Zaraibi goat kids significantly enhances their immune responses. Moreover, this dietary intervention was associated with a marked reduction in disease incidence and mortality rates. Positive effects of *N. sativa* supplementation were also observed in terms of higher weaning weight, total weight gain and average daily gain. Collectively, these results suggest that *N. sativa* is a valuable dietary additive for optimizing the health and growth performance of suckling Zaraibi goat kids, thereby promoting both animal welfare and overall productivity.

Author Contributions

Hamed Mohamed Gaafar: conceptualization, methodology, investigation, data curation, visualization, writing – original draft preparation, writing – review and editing. **Matteo Dell'Anno**: visualization, writing – original draft preparation, writing – review and editing. **Mostafa Mohamed El-Nahrawy**: methodology, investigation, data curation. **Ali Ahmed Abdou**: methodology, investigation. **Mohamed Fekry Elkersh**: methodology, investigation. **Reda Abdel-Bary Mesbah**: methodology, investigation. **Luciana Rossi**: writing – original draft preparation, writing – review and editing. **Ghada Slah El-Esawy**: supervision.

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The authors have nothing to report.

Ethics Statement

The experiments were performed according to the guidelines of the local ethical committee for animal care and welfare (Number of ethical approval: 08/2016 EC).

Conflicts of Interest

The authors declare no conflicts of interest.

Data Availability Statement

The data are available within the manuscript.

Peer Review

The peer review history for this article is available at https://doi.org/10.1002/vms3.70774.

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