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Abstract The present context was aimed to assess the influence of medicinal and aromatic plants supplemented diets on growth performance, digestibility, blood serum constituents, and economic efficiency of rabbits (*Oryctolagus cuniculus* L.) as a model of livestock animals. A total of forty New Zealand White (NZW) male rabbits of 6 weeks of age with an average initial body weight of 837.7 ± 42.4 g were used. Rabbits were distributed into 5 groups (8 rabbits per group). First group served as control (non-supplemented diet), while P1, P2, P3, and P4 groups were supplemented with 1% basil (*Ocimum basilicum* L.), chamomile flower (*Matricaria chamomilla* L.), fennel (*Foeniculum vulgare* Mill.), and ginger (*Zingiber officinale* L.), respectively. The final body weight (13 weeks of age), daily weight gain, daily feed intake, performance index, and feed conversion ratio were increased ($P < 0.05$) in rabbits fed diet supplemented with fennel (i.e., P3). Digestibility and feeding values were higher ($P < 0.05$) for P2 and P3 rabbits. Rabbits fed diets supplemented with P1, P2, and P3 excreted higher (in P3) and lower (in P1 and P2) crude protein in soft and hard feces, respectively. Control and P4 group showed the highest ($P < 0.05$) crude fiber content of soft feces when compared to other groups tested. Most of the carcass traits and blood parameters were significantly ($P < 0.05$) affected by rabbits fed diet supplemented with P3. Results indicated that 1% fennel could be preferably supplemented in growing rabbit's basal diets for their enhanced productive performance, economical efficiency, and other essential livestock parameters.

Keywords Aromatic · Carcass traits · Digestibility · Growth performance · Medicinal plants · Rabbits

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Introduction

Agroforestry systems are complex systems integrating trees or shrubs, crops, and livestock. In agroforestry systems, herbaceous perennials are known to support the agricultural crops as well as animals. Tree leaves, crops, stems, and agro-industry tree by-products have been considered as animal feed to decrease the relay on traditional resources for filling the gap and decreasing feeding costs. Some of tree by-products are rich in crude protein and other nutrients such as minerals and vitamins. Recently, there has been an increasing interest on tree by-products and their bioactive compounds as modifiers. From last few decades, feed additives are used worldwide not only to enhance the growth performance and productivity but also to improve the profitability of animals. Utilization of effective additives tends to cover the requirements of essential nutrients and increases the feed intake as well as feed utilization. A predominant argument in the choice of feed additive is its non-toxicity and lack of side effects towards health status of animals. Moreover, the concern of using feed additives is increasing day by day; therefore, livestock industry is enormously interested in quest of valuable natural alternatives which could be accepted by consumers at wide scale. Probiotics, prebiotics, enzymes, highly available minerals, and herbs can be utilized as suitable and effective alternative feed additives without any cumulative contamination of the environment (Wenk 2003).

At present, exploitation of natural products such as medicinal plants has burgeoned due to their growing applications towards therapeutic usage. Herbal products have wide range of biological properties due to the presence of diverse phytochemicals such as flavonoids, terpenoids, lignins, sulfides, polyphenolics, carotenoids, coumarins, saponins, plant sterols, curcumins, and phthalides (Cross et al. 2007) that may enhance the function of immune system. Along with the stimulating feed intake characteristics, phytoconstituents can protect animals and their products against oxidation too (Wenk 2003). The inclusion of tree by-products in animal diets is limited by higher secondary metabolites concentrations.

A number of dietary herbs, plant extracts, and essential oils have been studied for their growth promoting abilities in mono-gastric animals (Cross et al. 2007). Addition of medicinal plants in broiler diets improved the growth performance, feed conversion efficiency, and meat quality by reducing the feed cost (Huang et al. 1992).

The utilization of medicinal plants as dietary supplementation in rabbits and testing the growth performance of rabbits ration in order to enhance productive performance is a new trend in livestock study. Most importantly, among monogastric animals, non-ruminants are of great interest among veterinarians. As a matter of fact, rabbits are small animals and they are easy to handle for varied parametric studies. It should also be noted that the cost of feed supplied to rabbits are cheaper than that of other non-ruminants. Rabbits are unique animals because they produce highly nutritious, low fat and low cholesterol meat rich in proteins (Cheeke, 1987). Previously, Abd El-hakim et al. (2004) supplemented different forms of black seed in rabbit diets and reported a significant increment in live body weight as well as body weight gain. In another study, Zeweil et al. (2008) showed that rabbits fed 12% *Nigella sativa* L. meal had increased significantly the total weight gain than that of control.

In view of diversiform role of natural products as feed additives in livestock, the present study was aimed to shed light on the effect of some medicinal and aromatic plants such as basil, chamomile flower, fennel, and ginger as natural growth promoters in dietary supplements on growth performance, nutrients digestibility, chemical composition of feces, carcass traits, blood plasma constituents, and economic efficiency of growing New Zealand White (NZW) rabbits from 6 to 13 weeks of age.

Materials and methods

Growth performance

The NZW rabbits (*Oryctolagus cuniculus* L.) of American origin were used in this study. A total of forty weanling NZW male rabbits of 6 weeks of age with an average initial body weight of 837.66 ± 42.4 g were obtained from a local commercial farm. Rabbits were allotted randomly among five experimental groups (eight rabbits in each group) with nearly similar means of live body weight. First group was fed on the control diet, while groups P1, P2, P3, and P4 were fed on control diet supplemented with 1% basil, chamomile, fennel, and ginger, respectively

(99% control diet + 1% of tested materials). The formulation and chemical analysis of control diet are summarized in Table 1. A commercial vitamin and mineral premix were added into all the experimental diets.

Animals were individually caged in metal galvanized cages (50 × 54 × 35 cm) under the same managerial conditions in a well-ventilated block building and fresh air was circulated in the house using exhaust fans. Temperature during the experimental periods varied between 16 and 22 °C employing electrical heaters. Rabbits were kept within a cycle of 16 h light and 8 h dark using artificial light. Experimental diets were offered to rabbits ad libitum in pelleted form. Live body weight (g) and daily feed consumption (g) were individually recorded each week up to 13 weeks of age (marketing age). Feed conversion ratio was calculated as gram feed/g gain. Performance index (PI) and relative growth rate (RGR) were calculated according to the method of North (1981) as given below:

Table 1 Formulation and chemical analysis of the basal diet (control diet)

	%
Ingredients	
Egyptian berseem hay	33.0
Barley grain	16.0
Yellow corn	12.0
Wheat bran	18.0
Soybean meal (44% crude protein)	16.5
Common salt	0.5
Molasses	2.0
Di-calcium phosphate	0.5
Limestone	1.0
Vitamin and mineral premix[a]	0.2
DL-methionine	0.2
Anti-toxicants	0.1
Chemical composition (% on dry matter basis)	
Organic matter	88.72
Crude protein	16.08
Ether extract	2.46
Crude fiber	10.44
Nitrogen free extract	59.74
DE (kcal/kg feed dry matter)[b]	2603.1

[a]Vitamins and mineral premix per kilogram contained: Vit. A 2000,000 Iμ, Vit. D_3 150,000 Iμ, Vit. K 0.33 mg, Vit. B_1 0.33 g, Vit B_2 1.0 g, Vit B_6 0.33 g, Vit. B12 1.7 mg, Pantathonic acid 3.33 g, Biotin 33 mg, Folic acid 0.83 g, Choline chloride 200 mg, Zn 11.7 g, Mn 5.0 g, Fe 12.5 g, Mg 66.7 mg, Se 16.6 mg, Co 1.33 mg, Cu 0.5 g, I 16.6 mg and Antioxidant 10.0 g

[b]DE (kcal/kg feed dry matter) was calculated according to Cheeke (1987)

$$\mathrm{PI} = [\text{Live body weight (kg)}/\text{Feed conversion}] \times 100 \quad (1)$$

$$RGR = \frac{w2 - w1}{1/2(w1 + w2)} \times 100 \quad (2)$$

where $w1$ = initial weight and $w2$ = final body weight. Viability and clinical health status of all rabbits were recorded daily. Viability percentage was calculated as follows:

$$\text{Viability } \% = \frac{\text{Total number of live animals at the end}}{\text{Total number of animals at start}} \times 100. \quad (3)$$

The economic efficiency was calculated by the following equation:

$$\mathrm{Y} = [(\mathrm{A} - \mathrm{B})/\mathrm{B}] \times 100 \quad (4)$$

where A is selling price of obtained gain and B is feeding cost for this gain (Syrucek et al. 2017).

Coefficients of nutrients and nitrogen utilization

Digestibility and nitrogen balance trials were undertaken using a total of twenty rabbits (13 weeks of age; four rabbits/group). Values (%) of total digestible nutrients and digestible crude protein were calculated according to the methods of Cheeke (1987).

Metabolizable energy values were calculated according to the equation described by Kalogen (1985) as follows:

$$\text{Metabolizable energy (kcal/kg dry matter)} = (0.588 + 0.164\mathrm{X})239 \quad (5)$$

where X is dry matter digestion of diet.

Further, rabbits were kept individually in metabolic cages that allow collecting feces and urine separately. Rabbits of each group were offered one of the experimental diets. Trials lasted for 21 days, 14 days as a preliminary period for adaptation to experimental diets followed by 7 days for measurements of actual consumed feed, feces, and urine output. Samples of daily feces (20%) of each rabbit were collected every day, dried at 60−70 °C for 48 h, bulked, mixed, ground, and kept for chemical analysis. Urine was quantitatively collected for each animal and the volume was measured. After that 0.1 ml of concentrated hydrochloric acid was added to 10% sample of the urine before freezing and storing for chemical analysis.

Chemical composition of hard and soft feces

In the end of the digestibility trials (16 weeks), excretion of soft feces and hard feces were determined using three rabbits per treatment. Rabbits were kept in individual metabolic wire cages (45 × 45 × 30 cm) that allowed separation of feces and urine. Soft and hard feces were collected during 24 h in triplicate according to the method of Carabaño et al. (1988). The daily feces collected samples were sprayed with 1% boric acid solution to prevent ammonia losses during drying. Feces samples were dried at 70–80 °C for 48 h. Dried feces samples from each rabbit during the collection period were mixed, ground, and kept for chemical analysis. Chemical composition of hard and soft feces samples were analyzed according to AOAC (1990).

Carcass traits and pre-slaughter weight

Effect of dietary supplementation of medicinal and aromatic plants on carcass traits and pre-slaughter weight was estimated according to the method of Blasco et al. (1992). Hot carcass weight was obtained 15 to 30 min after slaughter including liver, kidneys, head, lungs, esophagus, trachea, thymus, and heart.

Dressing percentage (DP) was obtained as follows:

$$DP = \frac{\text{Abdomen fat} + \text{Giblets} + \text{Carcass weight with head}}{\text{Live body weight}} \times 100 \qquad (6)$$

Cold carcass weight was obtained after refrigerating the hot carcass at 4 °C for 24 h. Drip loss percentage was calculated as

$$[(\text{Hot carcass weight} - \text{Cold carcass weight})/\text{Hot carcass weight}] \times 100. \qquad (7)$$

Giblets weight (liver, kidneys, and spleen) and carcass measurements were obtained and their proportion to the live body weight was calculated.

Blood analysis

Blood samples were individually collected at slaughtering in non-heparinized glass tubes (3 samples/treatment group). Serum was separated within an hour after centrifugation at 3000 rpm for 20 min. Serum total protein and albumin were measured according to the method of Armstrong and Carr (1964). Serum globulin was calculated by subtracting serum total protein and albumin. Serum total lipids and cholesterol were measured according to the methods of Chabrol and Charonnat (1973) and Watson (1960), respectively.

Statistical analysis

Data of the experiments were statistically analyzed using analysis of variance (ANOVA) according to Statistical Analysis System (SAS 2004). Duncan's test (1955) was used for the comparison between two means. The following model was assumed to describe an observation of the experiments:

$$Y_{ijk} = \mu + t_i + e_{ij} \qquad (8)$$

where Y_{ijk} = Observation of each traits studied, μ = Overall mean, t_i = Fixed effect of the i-th treatment, e_{ij} = Random error term associated with each observation and assumed independent, normally distributed with mean zero and variance δ2e.

Results

Growth performance

At 13 weeks of age, there were significant differences ($P < 0.01$) observed among the experimental groups with respect to final body weight, total and daily weight gain, daily feed consumption, and performance index in the decreasing order of P3 > P2 > P1 > control > P4.

Dietary supplementation with 1.0% fennel (P3) showed the highest ($P < 0.01$) final body weight, total weight gain, daily weight gain, daily feed consumption, and performance index, while the dietary supplementation with 1% ginger (P4) showed negative impact on the growth performance parameters. Feed conversion data were found to be maximum in P4 rabbits. However, rabbits fed with control or P3 diets showed 100% viability, while those fed diet P2, P1, and P4 recorded 87.5, 75.0, and 62.5% viability, respectively.

Economic efficiency of rabbits was affected by the supplementation of medicinal and aromatic plants tested feed cost/kg gain of P3 was reduced than those of control and other experimental groups. The economic efficiency value in P3 rabbits was the highest than those of control as well as other groups (Table 2).

Digestibility coefficient and nitrogen utilization

The dietary supplementation with P3 followed by P2, affected significantly ($P < 0.05$) all digestion coefficient values of nutrients such as dry matter, organic matter, crude protein, crude fiber, ether extract, and nitrogen free extract. Rabbit diet supplemented with P4 decreased ($P < 0.01$) nutrient digestibility than that of the control diet.

Rabbits of P3 showed maximum N utilization values for urinary-N, N-digested, N-retained, and N-balance. N-intake and fecal-N were found to be increased ($P < 0.01$) for P1 rabbits with maximum values of 3.4 g/day (Table 3).

Chemical composition of soft and hard feces

Crude protein content of the soft feces was higher ($P < 0.01$) in rabbits fed diets supplemented with P3,

Table 2 Effect of dietary supplementation with some medicinal and aromatic plants on growth performance, economical efficiency, and viability of growing NZW rabbits

	Control	Experimental diets[1]				
		P1	P2	P3	P4	Significance
No of rabbits	8	8	8	8	8	–
Body weight (g) at:						
6 weeks	855 ± 8.5	870 ± 3.02	861 ± 3.06	847 ± 4.04	850 ± 4.9	NS
13 weeks	1938 ± 9^{d}	1958 ± 9.7^{c}	2046 ± 9.8^{b}	2125 ± 10^{a}	160 ± 10.1^{e}	**
Total weight gain (g)	1084 ± 15.62^{c}	1088 ± 7.27^{c}	1185 ± 8.96^{b}	1278 ± 9.63^{a}	75 ± 6.68^{d}	**
Daily weight gain (g)	22.1 ± 1.23^{c}	22.20 ± 0.64^{c}	24.18 ± 0.28^{b}	26.07 ± 0.37^{a}	15.4 ± 0.95^{d}	**
Daily feed consumption (g)	80.0 ± 2.4^{b}	82.4 ± 3.9^{b}	84.0 ± 4.4^{ab}	89.0 ± 3.9^{a}	73.2 ± 4.33^{c}	**
Feed conversion	3.7 ± 0.03^{b}	3.7 ± 0.03^{b}	3.4 ± 0.04^{c}	3.4 ± 0.03^{c}	4.7 ± 0.04^{a}	**
Performance index (%)	$52.9 \pm 0.\ 63^{c}$	$52.\ 5 \pm 0.61^{c}$	59.9 ± 0.62^{b}	63.5 ± 0.53^{a}	33.7 ± 0.21^{d}	**
Viability (%)	100	75	87.5	100	62.5	–
Total feed cost (L.E.)[2]	11.0	11.73	12.04	12.39	10.5	–
Feed cost/kg gain (L.E.)	10.2	12.762	10.164	9.695	14.0	–
Economic efficiency (%)[3]	136.1	122.61	136.14	151.79	72.1	–
Relative economic efficiency	100	90.1	100.1	134.4	52.9	–

NS not significant

$*P < 0.05$; $**P < 0.01$

[a–d]Means in the same row bearing different letters differ significantly ($P < 0.05$)

[1]Experimental diets P1, P2, P3, and P4 supplemented with 1% basil, chamomile, fennel, and ginger, respectively

[2]Total feed cost (L.E.) = feed price/kg (L.E.) × total feed intake (kg)

[3]Economical efficiency based on that the price of 100 kg of diet control, P1, P2, P3, and P4 was 274.5, 290.5, 295.5, 284.5, and 292.5 Egyptian pound (L.E.) respectively and the price of 1 kg of live body weight at selling time was 24 L.E.

Table 3 Effect of dietary supplementation with some medicinal and aromatic plants on coefficients of nutrients, nutritive values, and nitrogen utilization of growing NZW rabbits

	Control	Experimental diets[1]				
		P1	P2	P3	P4	Significance
Nutrients appearance digestibility						
Dry matter	68.6 ± 0.85^{b}	68.5 ± 0.55^{b}	70.5 ± 0.38^{a}	71.9 ± 1.25^{a}	65.0 ± 0.29^{c}	**
Organic matter	68.7 ± 0.84^{ab}	68.5 ± 0.90^{b}	71.1 ± 0.68^{ab}	72.1 ± 1.21^{a}	64.1 ± 1.70^{c}	**
Crude protein	68.3 ± 0.87^{b}	67.9 ± 0.84^{b}	71.0 ± 0.28^{a}	72.3 ± 0.87^{a}	64.6 ± 0.98^{c}	**
Crude fiber	75.5 ± 0.67^{a}	75.3 ± 0.56^{a}	76.3 ± 0.38^{a}	76.7 ± 0.58^{a}	68.1 ± 1.33^{b}	**
Ether extract	39.0 ± 0.48^{ab}	37.9 ± 0.56^{b}	40.7 ± 0.91^{a}	41.4 ± 1.02^{a}	35.2 ± 0.79^{c}	**
Nitrogen free extract	76.1 ± 1.20^{ab}	76.0 ± 1.18^{ab}	78.5 ± 0.67^{a}	80.2 ± 1.75^{a}	72.0 ± 1.69^{b}	**
Nutritive value						
Total digestible nutrients	64.8 ± 0.97^{ab}	$64.2 \pm 0.8\ 2^{b}$	66.6 ± 0.65^{ab}	67.5 ± 1.04^{a}	60.5 ± 1.31^{c}	**
Digestible crude protein	10.8 ± 0.14^{b}	10.7 ± 0.14^{b}	11.2 ± 0.12^{a}	11.4 ± 0.13^{a}	10.2 ± 0.15^{c}	*
ME (kcal/kg dry matter)[2]	2831 ± 17.6^{b}	2824 ± 31.8^{b}	2902 ± 9.4^{ab}	2958 ± 16.4^{a}	2686 ± 14.3^{c}	*
Nitrogen utilization						
N-intake (g/day)	2.98 ± 0.04^{d}	3.42 ± 0.04^{a}	3.15 ± 0.02^{c}	3.31 ± 0.02^{b}	2.74 ± 0.02^{e}	**
Fecal-N (g/day	0.94 ± 0.01^{bc}	1.10 ± 0.02^{a}	$0.91 \pm .02^{c}$	0.91 ± 0.02^{bc}	0.97 ± 0.02^{b}	**
Urinary-N (g/day)	1.12 ± 0.04	1.11 ± 0.05	1.10 ± 0.05	1.14 ± 0.07	0.96 ± 0.06	NS
N-digested (g/day)	2.03 ± 0.05^{c}	2.32 ± 0.05^{ab}	2.23 ± 0.03^{b}	2.39 ± 0.04^{a}	1.77 ± 0.04^{d}	**
N-retained (g/day)	0.91 ± 0.01^{c}	1.21 ± 0.01^{ab}	1.135 ± 0.03^{b}	1.25 ± 0.04^{a}	0.80 ± 0.03^{d}	**
N-balance (% of N-intake)	30.54 ± 0.46^{b}	35.46 ± 0.68^{a}	36.01 ± 1.15^{a}	37.83 ± 1.56^{a}	29.42 ± 1.5^{b}	**

NS not significant

*$P < 0.05$; **$P < 0.01$

[a–d]Means in the same row bearing different letters differ significantly ($P < 0.05$)

[1]Experimental diets P1, P2, P3, and P4 supplemented with 1% basil, chamomile, fennel, and ginger, respectively

[2]Metabolizable energy (ME, kcal/kg dry matter) = (0.588 + 0.164 X) 239, where X is the dry matter digestion of the offered diet

P2, and P1 by 16.86, 10.69, and 9.49%, respectively, while, values decreased ($P < 0.01$) in the hard feces by 11.7, 6.8, and 10.8%, respectively, when compared to the control group. The CF content of the soft feces in group fed diet P3 was lowered ($P < 0.05$) by 19.1%, comparing with those fed the control diet (Table 4).

Carcass parameters and internal organs

The hot carcass weight was increased ($P < 0.01$) in P3 and P2 rabbits by 15.8 and 9.9%, respectively versus control. The supplementation of 1% ginger increased ($P < 0.01$) the alimentary tract weight (full and empty) than those of control and other experimental groups. The giblets weight (%) was not affected by the medicinal and aromatic plants supplementation, except the liver weight, which was found to be increased ($P < 0.05$) with 1% dietary ginger (Table 5).

Blood biochemical constituents

Plasma albumen, globulin, aspartate transaminase (GOT o AST), alanine transaminase (GPT o ALT), total lipids, and cholesterol concentrations were affected ($P < 0.01$) in P1, P2, P3, and P4 rabbits. The plasma total protein, urea, and creatinine not differed between the control and other experimental groups. Serum albumin in rabbits fed P3 and P1 diets was increased ($P < 0.05$) by 14.1 and 8.1%, respectively, than control rabbits. The highest serum globulin was obtained ($P < 0.05$) in P2 rabbits. Rabbits fed P3 (1.0% fennel) represents the lowest ($P < 0.01$) GOT and the highest GPT. Plasma total lipids and

Table 4 Effect of dietary supplementation with some medicinal and aromatic plants on chemical composition of hard and soft feces of growing NZW rabbits

Chemical composition (%)	Control	Experimental diets[1]				
		P1	P2	P3	P4	Significance
Soft feces						
Dry matter	35.0 ± 2.02	36.2 ± 1.26	36.0 ± 0.83	35.7 ± 0.86	35.2 ± 0.85	NS
Crude protein	28.2 ± 1.22[c]	30.9 ± 0.91[ab]	31.7 ± 1.20[ab]	33.0 ± 0.57[a]	26.1 ± 0.82[c]	**
Ether extract	2.8 ± 0.21	2.6 ± 0.07	2.5 ± 0.15	2.8 ± 0.37	2.7 ± 0.17	NS
Crude fiber	16.6 ± 1.24[ab]	13.9 ± 0.69[bc]	14. 8 ± 0.89[b]	13.4 ± 0.70[c]	18.3 ± 0.84[a]	*
Ash	8.5 ± 0.21	7.7 ± 0.33	8.2 ± 0.38	8.1 ± 0.58	7.3 ± 0.40	NS
Hard feces						
Dry matter	62.6 ± 1.79[a]	60.22 ± 1.76[ab]	59.1 ± 1.58[c]	59.5 ± 1.58[bc]	58.7 ± 1.81[c]	**
Crude protein	13.7 ± 0.15	12.18 ± 0.51	12.7 ± 0.80	12.1 ± 0.21	14.3 ± 0.93	NS
Ether extract	3.3 ± 0.23	3.09 ± 0.1	3.5 ± 0.32	3.1 ± .014	3.5 ± 0.26	NS
Crude fiber	23.6 ± 0.24	21.64 ± 0.82	23.1 ± 0.85	22.8 ± 0.93	24.2 ± 1.25	NS
Ash	10.2 ± 0.43	10.7 ± 1.25	11.0 ± 0.40	11.3 ± 0.42	11.8 ± 0.38	NS

NS not significant

*$P < 0.05$; **$P < 0.01$

[a–d]Means in the same row bearing different letters differ significantly ($P < 0.05$)

[1]Experimental diets P1, P2, P3, and P4 supplemented with 1% basil, chamomile, fennel, and ginger, respectively

Table 5 Effect of dietary supplementation with some medicinal and aromatic plants on carcass traits and internal organs relative to pre-slaughter weight of growing NZW rabbits

	Control	Experimental diets[1]				
		P1	P2	P3	P4	Significance
Pre-slaughter weight (g)	1947 ± 11.27[c]	1966 ± 19.47[c]	2065 ± 12.5[b]	2147 ± 14.3[a]	1626 ± 12.5[d]	**
Hot carcass weight (g)	11,380 ± 21.12[c]	1161 ± 23.41[c]	1251 ± 6.57[ab]	1318 ± 4.41[a]	915 ± 19.18[c]	**
Dressing (%)	58.5 ± 1.87[b]	59.1 ± 1.52[b]	59.1 ± 2.35[b]	61.4 ± 1.35[a]	56.2 ± 1.37[c]	**
Cold carcass weight (g)	1122 ± 15.8[c]	1142 ± 19.6[c]	1232 ± 11.9[b]	1299 ± 13.8[a]	900 ± 12.4[d]	**
Carcass drip loss (%)	1.40 ± 0.23	1.60 ± 0.14	1.55 ± 0.28	1.42 ± 0.26	1.61 ± 0.18	NS
Alimentary tract full (g)	279.5 ± 7.8[ab]	287.5 ± 8.7[a]	292.4 ± 6.4[a]	299.7 ± 6.4[a]	262.3 ± 4.9[b]	*
Alimentary tract as % of body weight						
Full	14.35 ± 0.4[b]	14.62 ± 0.41[b]	14.17 ± 0.39[b]	13.96 ± 0.21[b]	16.13 ± 0.22[a]	**
Empty	0.94 ± 0.04[ab]	0.95 ± 0.04[ab]	0.93 ± 0.02[ab]	0.85 ± 0.03[b]	1.03 ± 0.014[a]	*
Giblets weight (%) of body weight						
Liver (%)	2.21 ± 0.09[b]	2.42 ± 0.12[ab]	2.56 ± 0.14[ab]	2.67 ± 0.13[a]	2.77 ± 0.11[a]	*
Kidneys (%)	0.55 ± 0.02	0.57 ± 0.009	0.56 ± 0.02	0.54 ± 0.02	0.54 ± 0.02	NS
Spleen (%)	0.03 ± 0.004	0.028 ± 0.001	0.029 ± 0.002	0.029 ± 0.003	0.03 ± 0.002	NS

NS not significant

*$P < 0.05$; **$P < 0.01$

[a–d]Means in the same row bearing different letters differ significantly ($P < 0.05$)

[1]Experimental diets P1, P2, P3, and P4 supplemented with 1% basil, chamomile, fennel, and ginger, respectively

cholesterol values were lower ($P < 0.05$) in P4 and P3 rabbits than control rabbits (Table 6).

Discussion

Among livestock animals, rabbit's meat constitutes the highest crude protein content and the lowest fat, cholesterol, and energy contents. Rabbits are known to be the best converter of herbs into meat and play a paramount role in intensive production system due to their high reproductive efficacy, ease feeding, inexpensive production costs, long productivity, and high economic return (Abdelhamid and Saleh 2015).

Feed additives are the nutritious and non-nutritious components which contribute towards the improvement of efficiency of feed utilization. Over the last few years, the use of chemical products and antibiotics as growth promoters and additives in animal feeds has been prohibited due to increasing concerns about the presence of residues in meat and milk, emergence of antibiotic resistant bacteria, and their side effects on both livestock as well as human health. In the past decade, medicinal plants derived feed additives have replaced the traditional feed additives and received a considerable attention among researchers due to their non-toxicity, productive performance, and health improving characteristics.

Dietary supplementation with 1.0% fennel (P3) showed the highest ($P < 0.01$) final body weight, total weight gain, daily weight gain, daily feed consumption, and performance index. However, growth performance parameters were reduced due to diet supplemented with 1% ginger (P4). The study favors strongly the findings of Omer et al. (2013) who reported that dietary treatments with fennel seeds improved ($P < 0.05$) the final weight, body weight gain, and average daily gain of rabbits. More or less similar observations were reported by Skomorucha and Sosnowka-Czajka (2013) who demonstrated that body weight gain and feed consumption of growing rabbits were improved by 1.0% fennel or 0.75% chamomile dietary supplementation. Additionally, outcomes of the present study were in complete agreement with the findings of Nammi et al. (2009) who found that ethanolic extract of ginger showed remarkable protection from the high-fat diet and induced metabolic disturbances by strongly suppressing the body weight gain, protection from hyper

Table 6 Effect of dietary supplementation with some medicinal and aromatic plants on some blood serum constituents of growing NZW rabbits

	Control	Experimental diets[1]				
		P1	P2	P3	P4	Significance
Serum constituents						
Total protein (g/dl)	6.37 ± 0.27	5.95 ± 0.16	7.87 ± 0.78	6.39 ± 0.48	6.39 ± 0.47	NS
Albumen (g/dl)	3.97 ± 0.10^{b}	4.29 ± 0.09^{a}	4.04 ± 0.12^{b}	4.53 ± 0.09^{a}	4.05 ± 0.19^{ab}	*
Globulin (g/dl)	2.39 ± 0.3^{b}	1.68 ± 0.23^{b}	3.83 ± 0.66^{a}	1.86 ± 0.45^{b}	2.34 ± 0.38^{b}	*
Urea	59.97 ± 0.94	58.32 ± 1.56	65.58 ± 4.39	63.82 ± 6.35	69.34 ± 3	NS
Creatinine	0.91 ± 0.03	1.027 ± 0.09	0.93 ± 0.13	0.79 ± 0.07	1.12 ± 0.15	NS
GOT (AST)[2]	66.99 ± 1.6^{c}	77.30 ± 5.76^{ab}	80.87 ± 5.63^{a}	65.56 ± 1.89^{c}	85.49 ± 1.64^{a}	**
GPT (ALT)[3]	74.9 ± 2.17^{ab}	69.61 ± 2.25^{b}	70.97 ± 3.48^{b}	78.05 ± 2.01^{a}	75.37 ± 4.5^{ab}	*
Total lipids (mg/dl)	86.4 ± 2.03^{a}	88.05 ± 2.05^{a}	95.34 ± 4.79^{a}	50.80 ± 2.11^{b}	49.95 ± 3.1^{b}	**
Cholesterol (mg/dl)	62.9 ± 1.77^{a}	64.43 ± 2.26^{a}	62.65 ± 2.31^{a}	43.79 ± 2.53^{b}	46.5 ± 1.91^{b}	*

NS not significant

$^{*}P < 0.05$; $^{**}P < 0.01$

$^{a–d}$Means in the same row bearing different letters differ significantly ($P < 0.05$)

[1]Experimental diets P1, P2, P3, and P4 supplemented with 1% basil, chamomile, fennel, and ginger, respectively

[2]Aspartate transaminase

[3]Alanine transaminase

glycaemic, hyper lipidaemic, and insulin-resistant conditions.

Rabbits fed with control or P3 diets showed 100% viability and highest economic efficiency. Increasing the mortality rate in group fed diet containing 1% ginger (P4) may be due to the lowering abdomen fat among these rabbits which led to the reduction in daily body weight gain and final live body weight. Ademola et al. (2009) showed that ginger addition increased the mortality rate in broiler chickens. El-Hosseiny et al. (2000) reported that addition of chamomile in diets (60 mg/kg body weight) reduced mortality rate to zero during the suckling period. This suggests that chamomile may have a role in improving immunity and performance. Pinheiro et al. (2004) mentioned that fennel and caraway seeds might have essential roles in reducing the mortality rate by modifying the pH of rabbit digestive tract, promoting useful bacteria, and inhibiting the harmful ones. Omer et al. (2013) reported that addition of 0.5% fennel seeds significantly decreased the mortality rate of growing rabbits.

Group P1 and P4 decreased the economic efficiency than that of control group. These results favored the findings of Radwan and Khalill (2002) and Hanna et al. (2008). However, outcomes of this investigation were in contrast with those of Abaza et al. (2003) who reported that the best relative economic efficiency was recorded with the group P2 fed diet. Groups P2 and P3 diets improved ($P < 0.05$) both the feed intake as well as performance index up to 13 weeks old. In contrary to our results, Omage et al. (2007) reported that addition of ginger waste meal (10, 20, 30, and 40%) after extraction increased the average daily feed intake of growing rabbits. Abbas (2010) reported that addition of 3 g of basil/kg diet in broiler diets increased the live body weight, feed efficiency, and feed intake.

Rabbits fed diet P4 showed the highest ($P < 0.01$) feed conversion versus control and other experimental groups. The higher feed conversion ratio and lower performance index observed in group fed diet containing 1.0% ginger in this context might be due to the lower live body weight and higher feed consumption obtained in this group.

Franz et al. (2010) reported an enhancement in the digestion, resulting in reduced methanogenesis and nitrogen excretion using aromatic herbs as feed additives. The improvement in digestibility coefficients caused elevation in nutritive values of group supplemented with fennel (P3). In this study, the highest ($P < 0.05$) nutrient digestibility, urinary-N, N-digested, N-retained, and N-balance values were obtained in fennel group. However, rabbits fed P4 diet (ginger) showed the lowest digestibility coefficients and nutritive values among the other experimental groups. The beneficial effect of chamomile (P2) and fennel (P3) supplementation on nutrients digestibility and thus on nutritive values as digestible crude protein, total digestible nutrients, and metabolizable energy were investigated earlier (Omer et al. 2013). Hernandez et al. (2004) reported that flavonoids, terpenoids, lignans, sulfides, polyphenolics, carotenoids, coumarins, saponins, plant sterols, coumarins, phthalides etc. are the major phytoconstituents present in medicinal plants and herbs that stimulate the function of animal digestive systems by increasing the production of digestive enzymes. The positive impact of fennel on rabbit's digestive system might be due to the presence of bioactive compounds such as benzene, 1-methoxy-4-(1-propenyl), D-Limonene, estragole, 3-carene, and 1, 6-octadien-3-ol, 3,7-dimethyl (Renjie et al. 2010). Ali et al. (2008) reported that ginger addition decreased the digestibility of crude protein and crude fat due to negative impacts of its compounds such as polyphenolics which significantly decreased the live body weight of growing rabbits.

Results obtained related to the chemical composition of soft feces indicated that dietary supplementation with 1.0% fennel (P3), chamomile (P2), and basil (P1) activated the useful microorganisms in cecum and colon, producing high crude protein content in soft feces and improving the nutrients digestibility, especially for crude fibre. Our results were against the findings of Omer et al. (2013) who observed no significant effect of treatments on chemical analysis of feces.

In the present context, most of the carcass traits and internal organs as a percentage of pre-slaughter weight were found to be affected by the supplementation of medicinal and aromatic plants into diet. In the line of our reports, Ibrahim et al. (2000) had already demonstrated that sweet basil or oregano at the level of 0.5% significantly increased dressing and giblets. Our findings and previous reports were also in general agreement with Radwan and Khalill (2002) and Hassan et al. (2004) who found that carcass data differed between treatment upon feeding diets with medicinal and aromatic plants. In another observation reported by Omer et al. (2013), dietary treatment had no significant effect ($P > 0.05$) on slaughter weight, full and empty content of digestive tract, carcass weight, dressing percentages, carcass cuts, and other parameters of giblets.

Results of this study illustrated that the concentration of plasma albumen, globulin, GOT, GPT, total lipids, and cholesterol were affected ($P < 0.01$) in groups fed P1, P2, P3, and P4 diets. Omer et al. (2013) reported no significant effect of dietary supplements on plasma albumen, globulin, GOT, and GPT. In another report, Hanna et al. (2008) observed that supplementation of fennel seeds to rabbit diets reduced plasma total protein and globulin concentrations. Ademola et al. (2009) reported that ginger addition decreased the abdomen fat and serum total protein, total lipids, and cholesterol of broiler chickens which may lead to lower body weight gain. Hanna et al. (2008) also reported that supplementation of diets with fennel or ginger had significant effects on lowering the level of serum total lipids and cholesterol of either chickens or rabbits and this effect was positively related to its level in the diets. Furthermore, Ali et al. (2008), and Hanna et al. (2008) reported that blood parameters were significantly differed by the supplementation of medicinal and aromatic plants. In line of previous reports, we also observed that rabbits fed P4 and P3 diets had significant effect on lowering the total lipids and cholesterol, respectively. The reduction in cholesterol level with the supplementation of herbs may be due to the inactivation of hepatic 3-hydroxy-3-methy glutaryl coenzyme A (HMG-CoA), a key regulatory enzyme in cholesterol synthesis (Crowell 1999).

Conclusion

Natural feed additives of plant origin are considered to be safe, inexpensive, and non-toxic. In a nutshell, under these conditions of present investigation, it is concluded that the supplementation of growing rabbit diets with aromatic and medicinal plants, especially fennel caused relatively considerable improvement in the growth and productive performance without negative effects on carcass characteristics and constituents of blood plasma. Meanwhile, 1% fennel supplementation in growing rabbit diets resulted in the best economic efficiency. Our data suggested that medicinal and aromatic plants can be utilized as growth promoters in order to improve the utilization of diet effectively. Further study needs to be investigated on the utilization of these medicinal plants as alternative feed additives in a concentration dependent manner towards the welfare of livestock health.

Compliance with ethical standards

Conflict of interest All authors declare that they have no conflicts of interest.

Informed consent Consent was obtained from all participants included in this study.

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