Egyptian J. Nutrition and Feeds (2023), 26 (2):167-178

SUPPLEMENTAL ESSENTIAL OILS IN GROWING RABBIT DIETS

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(*Received 10/8/2023, accepted 28/8/2023*)

SUMMARY

This study aimed to compare the single effects of commercially available natural essential oils such as garlic oil (*Allium sativum L.*), basil oil (*Ocimum basilicum*), thyme oil (*Thymus vulgaris*), and / or their combinations on growth performance, digestibility coefficients, blood lipid profile and economic efficiency of growing rabbits. One hundred - twenty male growing New Zealand White (NZW) rabbits six weeks old, with an average live body weight of 636.5±7.21g were randomly divided into eight groups (15 rabbits each). Each group was subdivided into three replicates. The 1st group (T1) was fed basal diet (16. 74% CP and 2504 Kcal/ Kg DM) free of additives and served as the control group. The 2nd group (T2) was fed a basal diet supplemented with 1 mg propylene glycol /kg diet, 3rd (T3), 4th (T4), and 5th (T5) groups were fed the basal diet supplemented with garlic oil (GO), Basil oil (BO) and thyme oil (TO) respectively, each at a dose of 400 mg/kg diet, 6th group (T6) was fed a basal diet supplemented with a combination of GO and BO at a dose of 200 mg of each oil /kg diet, 7th group (T7) was fed a basal diet supplemented with a combination of GO and TO at a dose of 200 mg of each oil /kg diet and 8th group (T8) was fed a basal diet supplemented with a combination of GO at a dose of 200 mg/kg diet, BO and TO at a dose of 100 mg of each oil /kg diet. The GO, BO, and TO oils used in this study were sprayed by 400 ml /kg diet v/w on daily pelleted feed intake to avoid loss of some volatile component of oils and to ensure the effect of essential oils in rabbit diets. The duration of the experiment was 8 weeks. The results showed that the rabbits received essential oils and their combinations showed a significant ($P<0.05$) increase in body weight, and daily body weight gain compared with the control group. The feed consumption showed a significant ($P<0.05$) increase in the T4 group compared with the control one. All experimental groups recorded a significantly improve ($P<0.05$) in feed conversion value compared with the control group except the T2 group. The essential oils groups and their combinations did not affect the digestibility of DM, OM, and NFE compared with the control group. The digestibility coefficient for CP, CF, and EE and nutritive values showed significant ($P<0.05$) higher values in T3, T4, and T6 groups compared with the control group. Results indicate that all experimental groups recorded significantly decreased ($p<0.01$) values of triglycerides, total cholesterol, Low-density lipoprotein cholesterol, and very low-density lipoprotein cholesterol concentration except for T2 compared with control group. An opposite effect was noticed regarding high-density lipoprotein cholesterol (HDL-c), where the values had significantly ($P<0.01$) increased compared with the control group. The treatment groups recorded higher values of economic efficiency and relative economic efficiency compared to the control one. Generally, it can be noticed that the findings of this study demonstrated that dietary supplementation of essential oils and their combinations had higher body weight, better feed conversion ratio and the best economic return over the control group.

Keywords: *garlic, basil, thyme oils, performance, blood parameters, growing rabbits*

INTRODUCTION

Rabbit meat stands out for its characteristics and nutritional properties, being low-fat, lean meat (60 % of the total fatty acids are unsaturated), rich in minerals (potassium, phosphorus, and magnesium), proteins and amino acids of high biological value, low in cholesterol and sodium (Cullere and Dalle, 2018). The profitability of rabbit farms is partly depending on the effectiveness of weaned rabbits to grow

healthy and to the protection of high mortality rates during the fattening period. Antibiotics have been frequently used in the diets of growing rabbits because the digestive disturbances are the main reason for morbidity and mortality in the rabbit industry (Selim *et al.,* 2021). Also, the cost of feeding is the most significant expensive item in animal production and reaches more than 70% of the total cost. To reduce the rabbit production cost, it is necessary to improve feed efficiency and increase the growth rate (Abedel-Azeem *et al.,* 2012). Feed additives are important materials that can improve the efficiency of feed utilization, animal performance and enhance immune response. The possibility of using new natural additives instead of antibiotics in animals' diets is being recently used. Medical herbal feed additives comprise of a wide variety of herbs, spices, and essential oils have been aspects as alternatives by some researchers (Ceylan *et al.,* 2003). Some of the important aspects associated with herbal additives are the prevention of digestive disturbances improving feed conversion ratio, increasing carcass quality, decreasing the market age of animals, and reducing their rearing cost (Krieg *et al.,* 2009). As a consequence of the European ban on antibiotic growth promoters (AGPs) and increased consumer awareness about the consumption of healthy and safer animal products, researchers and feed companies have been encouraged to seek new animal feeding approaches to substitute AGPs and synthetic antioxidants (Zotte *et al.,* 2016). Recently, aromatic plants and their associated essential oils or extracts are being considered as potential growth promoters. The majority of essential oils involve mixtures of phenolics and polyphenols, terpenoids, saponins, quinine, esters, flavone, flavonoids, tannins, alkaloids, and nonvolatile residues; however, their concentration is variable. These compounds have many beneficial effects as antimicrobial, digestive system, enzyme stimulators antioxidants, and anticoccidial, and for improved utilization of nutrients by enhancing digestion, absorption, and liver function (Ziarlarimi *et al.,* 2011). Garlic has an antibiotic-productive performance when added as a food supplement in broiler diets, stimulates the immune system, causes quantitative changes of blood leukocytes, enhances digestion, is used as a growth promoter, increasing body gain, feed intake, and feed efficiency (Onibi *et al.,* 2009). The garlic extract has been reported to have a critical role as an anti-bacterial agent against multi-drug resistant bacteria (Salih *et al.,* 2016). The Basil oil (*Ocimum basilicum*) exhibits a wide and varying array of chemical compounds, depending on variations in chemotypes, leaf and flower colors, aroma, and origin of the plants (Silva *et al.,* 2003). The chief constituents include chavicol methyl ether or estragole, linalool, and eugenol (Rao *et al.,* 2011). It contains mainly triterpenes and aromatic compounds, and the chemical composition of the essential oils varies with seasonal, geographical, and climatic conditions. Recently there are more research focused on their chemical profiles and their medicinal properties. Due to their antimicrobial, antifungal, insecticidal, larvicidal, and antioxidant properties, they are used as alternatives for synthetic chemical products to reduce costs and side effects. The genus *Ocimum* comprising more than 150 species grows widely throughout the world (Poonkodi, 2016). Volatile oil from thyme (*Thymus vulgaris*) thymol and carvacrol, a major component isolated from the essential oil of the thyme was assessed for antibacterial and antiviral activity as inhibitors of microbial growth (Najafi and Torki, 2010). This study aimed to compare the single effects of commercially available natural essential oils such as garlic oil (*Allium sativum L.*), basil oil (*Ocimum basilicum*), thyme oil (*Thymus vulgaris*), and their mix on growth performance, digestibility coefficients, and economic efficiency of growing rabbits.

MATERIALS AND METHODS

The present study was carried out at Nubaria Experimental Station, by-product Utilization Department, Animal Production Research Institute, Agriculture Research Center, Ministry of Agriculture, Egypt.

Housing and feeding system:

One hundred-twenty male growing New Zealand White (NZW) rabbits six weeks old, with an average live body weight 636.5±7.21 g were randomly divided into eight groups (15 rabbits each). Each group was divided into three replicates, (fiver rabbits each) provided with feeder's automatic drinkers. All rabbits were fed on a basal pelleted diet formulated to meet rabbit's requirements according to NRC (1977). The 1st group (T1) was fed the basal diet (16. 74% CP and 2504Kcal/ Kg DM) free of additives and served as the control group. The 2nd group (T2) was fed a basal diet supplemented with propylene glycol 1 mg/kg diet, while, 3rd (T3), 4th (T4) and 5th (T5)groups were fed the basal diet supplemented with garlic oil (GO), Basil oil (BO) and thyme oil (TO), respectively, each at a dose of 400 mg/kg diet, 6th group (T6) was fed a basal diet supplemented with a combination of GO and BO at a dose of 200 mg of each/kg diet, 7th group (T7) was fed a basal diet supplemented with a combination of GO and TO at a

dose of 200 mg of each/kg diet and 8th group (T8) was fed a basal diet supplemented with a combination of GO at a dose of 200 mg/kg diet, BO and TO at a dose of 100 mg of each/kg diet. The garlic, basil and thyme oils used in this study were sprayed by 400 ml /kg diet v/w on daily pelleted feed intake to avoid loss of some volatile oils and to ensure the effect of essential oils for rabbits. The duration of experiment was 8 weeks (6-14 wk.). Ingredient and chemical composition of experimental diets were shown in Table (1). All rabbits were kept under the same management and hygienic conditions and were individually housed in galvanized wire cages (30 x 35 x 40 cm3). Stainless steel nipples for drinking and feeders allowing the recording of individual feed intake for each rabbit were supplied for each cage. Feed and water were offered *ad libitum*. The samples of pelleted diets were analyzed for crude protein (CP), crude fiber (CF), ether extract (EE), and ash according to A.O.A.C. (2005). The organic matter and nitrogen-free extract (NFE) were calculated. Feed consumption, body weight, body weight gain, and feed conversion ratio were recorded weekly.

Table (1): Ingredient and chemical composition of basal diet.

Ingredients	%	Chemical composition	(%)
Alfalfa hay	30.00	Dry matter	91.06
Soybean meal 44% CP	18.30	Organic matter	93.43
Barley grain	34.00	Crude protein	16.74
Wheat bran	8.90	Crude fiber	13.78
Yellow corn	6.00	Ether extract	3.06
Di calcium phosphate	2.00	Ash	6.57
Sodium chloride	0.40	*NFE	59.85
DL, Methionine	0.10	NDF	37.98
Premix#	0.30	ADF	21.99
Total	100.00	ADL	13.77
		Hemicellulose	15.80
		Cellulose	8.22
		Calcium	1.48
		Phosphorus	0.52
		**DE	2504

*# Vitamins and minerals premix per kilogram diet: Vitamin A 10.000 IU, Zinc 70 mg, Vitamin D3.900 IU, Cupper 0.1 mg, Vitamin E, 50.0 mg, Manganese 8.5 mg, Vitamin K 2.0 mg, Ferrous 75.0 mg, Vitamin B1 2.0 mg, Folic acid 5.0 mg, Vitamin 26.0 mg, Pantothenic acid 20.0 mg, Vitamin B6 2.0 mg, Choline 1200 mg, Vitamin B12 0.01 mg, Niacine 50 mg, Biotin 0.2 mg. *NFE = OM- (Crude protein+ Crude fiber+ Ether Extract)*

***Digestible energy (DE) of the experimental diet was calculated according to the equation described by Cheeke (1987) as follows: DE (Kcal/kg) = 4.36-0.0491×NDF%; NDF% =28.924+0.657× CF%; %ADF= 9.432 + 0.912 (%CF); ADF= cellulose+ lignin and Hemicellulose= %NDF-%ADF.*

Digestibility trials:

At the end of the feeding trial (14 weeks of age), a total number of forty male rabbits were randomly taken after the termination of the fattening period to conduct the digestibility trials to determine the apparent nutrient digestion and nutritive value of experimental diets. Five rabbits within each treatment were randomly housed individually in metabolic cages. The cages were made from stainless wire in such a way that feces were easily collected and separated from urine. Feed intake was daily recorded. The feces of each rabbit were collected every 24 hours in the morning before feeding and dried at 60 ºC for 8 hours using a force draught oven. All collected feces were mixed and sprayed with sulfuric acid (10%) and toluene for each treatment and finely ground and stored for later chemical analysis according to AOAC (2005). The collection period lasted 7 days. The samples of feed and feces were analyzed to calculate nutrients digestion coefficients, the nutritive values, and nitrogen utilization for each dietary treatment as described by Cheeke *et al*. (1982).

Blood serum analysis:

At the end of the experiment, three rabbits from each group were randomly taken and fasted for 12 hrs before slaughtering; individual blood samples from slaughtered rabbits were collected, placed in a plain centrifuge tube, and centrifuged at 3000 rpm for 15 minutes to separate clear serum which stored at -20ºC

until subsequent biochemical analysis. Triglycerides, total cholesterol, High-density lipoprotein (HDL) and low-density lipoprotein (LDL) were estimated in serum using commercial kits provided from Biodiagnostic Company. Serum VLDL cholesterol was measured by dividing serum triglyceride concentration by five (Khaki *et al.,* 2012).

Economic evaluation:

The economic efficiency (EE) of experimental diets was calculated as the ratio between net revenue and cost of feed consumed. The relative economic efficiency % of the experimental groups was calculated relative to that of the control as 100%.

Statistical analyses:

Data observed were statistically analyzed using SAS (2006). The difference between means was tested by Duncan's Multiple Range Test (Duncan, 1955). The used model was as follows: $Y_{ij}= \mu+T_i+e_{ij}$ Where: Y_{ij}= the observation on the 1th treatment. μ= Overall mean. T_i= Effect of the i^{th} treatment. e_{ij} = experimental random error.

RESULTS AND DISCUSSION

Rabbits performance:

Data of body weight, feed consumption and feed conversion of growing New Zealand rabbits during the experimental period are tabulated in Table (2). The results showed that the rabbits that received essential oils and their combinations showed a significant ($P<0.05$) increase in body weight, and daily body weight gain compared with the control group. The feed consumption showed a significant ($P<0.05$) increase in the T4 group compared with the control one. All experimental groups recorded a significantly improve in ($P<0.05$) feed conversion value compared with the control group except the T2 group. There were no significant differences between T2 group and control one. The present results agreed with those of Abedo et al. (2015) who found that, garlic oil supplementations improved daily weight gain and feed conversion ratio for growing rabbits. Also, the positive effect of the phytogenic additives supplementation may also be due to the provision of some compounds that increase the digestion and absorption of certain nutrients in the diets, which may be attributed to the bioactive ingredients (curcuminoids and allicin) present in garlic that cause greater efficiency and also in enhanced growth (El-Nomearyet al.2020). Sidiropoulou et al. (2020) found that the essential oils from plant sources play vital biological roles in the metabolism and physiology of humans, animals and organisms. A manipulation of gut function and microbial habitat of domestic animal with feed additives has been recognized as an important tool for improving growth performance and feed efficiency (Collington *et al.,* 1990). Zucca et al. (2019) reported that garlic is enriched with sulfur- containing compounds and utilized in nutraceuticals for the prevention of certain disease states. Garlic (*Allium sativum*) is a medicinal herb for prevention and treatment of many diseases (Adibmoradi *et al.,* 2006). Furthermore, the decrease of feed intake in the essential oils supplemented treatment (like garlic) may be attributed to the tastes and odours emanated by the active substances contained in the plants, which inhibit intake by animals, consequently, some herbs may be barely appetizing (Jugl-Chizzola *et al.,* 2006).Volatile oil from thyme (*Thymus vulgaris*) thymol and carvacrol, a major component isolated from essential oil of the thyme was assessed for antibacterial and antiviral activity as inhibitors of microbial growth (Najafi and Torki, 2010). Yasser et al. (2014) showed that, thymol and carvacrol from (thyme) and allicin from (garlic) are active material in these plants, which are considered as appetizer and stimulating of digestion, in addition to their antimicrobial activity against intestinal bacteria resulting in enhancing health status and growth improvement. Abedo et al. (2020) reported that, the utilization of herbal plants as nutritional supplements in rabbits and the evaluation of increased performance of rabbit diets to improve productive performance is a new direction in the study of livestock. Alatrony et al (2022) concluded that, it could be stated that adding up to thyme, moringa and licorice leaves extract to growing rabbit diets can improve growth performance. Herbal feed additives have been found to improve the average daily gain (ADG) and feed conversion ratio (FCR), reduce the mortality and increase the viability of rabbits (Zeweil *et al.,* 2013).

Table (2): Growth performance of growing rabbits fed diets supplemented with essential oils.

Item	Experimental diets								SEM	P-value
	T1	T2	T3	T4	T5	T6	T7	T8		
Body weight, g										
IBW	635	637	639	629	639	640	633	640	7.211	0.998
FBW	2054^{d}	2052^{d}	2388^{a}	2365^{a}	2328^{ab}	2367^{a}	2235^{c}	2285^{bc}	14.281	0.002
Live body weight gain, g										
BWG	1419^{d}	1415^{d}	1749^{a}	1736^{a}	1689^{ab}	1727^{a}	1602^{c}	1645^{bc}	14.951	0.039
Feed consumption, (g) and feed conversion ratio										
TFC	5524^{cd}	5520^{cd}	5509^{d}	5621^{a}	5567^{bc}	5574^{b}	5567^{bc}	5608^{ab}	7. 799	0.050
FCR	3.89^{a}	3.90^{a}	3.15^{d}	3.24^{cd}	3.30^{cd}	3.23^{cd}	3.48^{b}	3.41^{bc}	0.035	0.012

$^{a, b, c, d}$ means in the same row having different superscripts differ significantly. SEM: standard error of means
T1: Control; T2: Control+1 mg/kg diet of propylene glycol; T3: Control + 400 mg/kg diet of garlic oil; T4: Control + 400 mg/kg diet of basil oil; T5: Control + 400 mg/kg diet of thyme oil; T6: Control + 200 mg/kg diet of garlic oil. +200 mg/kg diet of basil oil; T7: Control + 200 mg/kg diet of garlic oil. +200 mg/kg diet of thyme oil. T8:200 mg/kg diet of garlic oil +100 mg/kg diet of basil oil+100 mg/kg diet of thyme oil. IBW: initial body weight; FBW: final body weight; BWG: body weight gain; TFC: total feed consumption.

Nutrients digestibility coefficients:

The nutrients digestibility of different experimental diets is presented in Table (3). The essential oils groups and their combinations did not affect the digestibility of DM, OM, and NFE compared with the control group. The digestibility coefficient for CP, CF, and EE showed significant ($P<0.05$) higher values in T3, T4, and T6 groups compared with the control group. There is no significant difference between T2 and control group. The present results agreed with those of El-Nomeary *et al.* (2020) who showed that, EOs supplementation affected the digestibility of CP and CF especially with garlic oil supplemented diet due to increased amounts of protein available at the cellular level for deposition in the body tissues. These results were supported by the findings of CF digestibility which agrees with Shehata *et al.* (2003) and Hernandez *et al.* (2004) who indicated that the great improvement in CP and CF digestibility resulted from adding garlic at different levels. The results also, showed an improvement in the complete digestion of nutrients, especially CP, as a result of consuming garlic extract. The herbal effects of garlic powder on improving digestibility are due to the decrease in the number of harmful microbes, especially the number of bacteria such as *E. coli*, *Clostridium spp*. and *Enterococci*. Many authors have suggested that dietary essential oils improve the performance of birds, because these substances stimulate the secretion of internal digestive enzymes, which increases the digestion of nutrients or the rate of gut passage or feed intake (Muhl and Liebert, 2007). The Herbal growth promoters serve as appetizers, digestive stimulants, antibacterial, antiviral, anthelmintic, anti-inflammatory and also possess immune-stimulation properties (Platel *et al.*, 2002). These results probably because EOs are a mixture of substances that have the ability to stimulate the secretion (bile and saliva) and enhance the activity of enzymes such as trypsin and amylase in part by increasing the ability of epithelial tissues to increase the retention time of the stomach for feed, which leads to increase digestion and absorption (Platel and Srinivasan, 2004). Also, probably due to that the mixture of EOs able to return a significant protein that increments glutathione enzymes in the liver that conserve damaged cells and improve organ function (Shehata *et al.*, 2003) or may be because the ability of some EOs to boost the S-transferase enzyme system as ally sulfides in garlic (Kyo *et al*., 1998). In other words, or because of its characteristics as antimicrobial as in the rumen, or it may be that the mixture of EOs can manipulate the process of metabolism of ceacum and inhibit the formation of methanogenesis selectively (Boadi *et al.,* 2004). Hernandez et al (2004) concluded that the blend of carvacrol (thyme oil) cinnamaldehyde, and capsaicin improved the digestibility of the feeds for broilers. The effect of different additives on digestibility improved the performance slightly, but this effect was statistically non-significant. Also, Sabrin *et al.* (2019) reported that, the widespread use of EOs from peppermint and basil in traditional medicines and their abundant beneficial effects on the mammalian digestive and immune systems inspired us to explore their potential biological activities in rabbits. These results are consistent with those presented by Khempaka *et al.* (2013), who showed that experimental diets containing 0.5–2.0% dried peppermint had no adverse effects on the DM, OM and CF digestibility and the nitrogen retention in comparison with the control diet. In contrast, Emami *et al.* (2012) found that the CP digestibility increased significantly ($P \leq 0.01$) by supplementation with the peppermint oil at a dose of 400 mg/kg in a broiler diet. However, information concerning the effects of basil on the nutrient

digestibility and the nitrogen balance is rare. Alatrony *et al.* (2022), showed that the addition of moringa, thyme and licorice leaves extract had significant affect (P<0.05) on all parameters of the digestion coefficients DM, OM, NFE, CP, CF, and EE. Moringa, thyme and licorice leaves extract are power antioxidant that can help the boost of the secretion of pancreatic juice as gallbladder secrete bile and boost the secretion of pancreatic juice, which contain enzymes like lipase, amylase and protease that help with carbohydrate, fat, and protein digestion (Abo El-Fadl *et al.*, 2020).

Table (3): Digestibility coefficients and nutritive values of the experimental diets.

Item	Experimental diets								SEM	P - value
	T1	T2	T3	T4	T5	T6	T7	T8		
Digestibility coefficients										
DM	68.96	68.53	74.87	74.31	72.79	71.98	72.29	73.64	0.779	0.374
OM	70.77	70.63	73.95	73.37	71.98	71.77	71.56	72.45	0.594	0.337
CP	70.50^{c}	70.41^{c}	77.61^{a}	77.13^{a}	74.94^{b}	77.78^{a}	75.83^{b}	76.92^{ab}	0.753	0.05
CF	37.34^{c}	37.28^{c}	44.82^{a}	44.78^{a}	42.74^{ab}	44.79^{a}	42.68^{ab}	43.14^{b}	0.032	0.007
EE	71.78^{c}	71.98^{c}	79.74^{a}	77.22^{ab}	75.68^{b}	77.83^{ab}	77.92^{ab}	75.55^{b}	0.780	0.004
NFE	74.77	75.67	79.10	79.12	75.24	74.24	76.35	77.61	0.749	0.470
Nutritive values										
TDN	53.80^{b}	53.40^{b}	57.81^{a}	56.04^{ab}	55.98^{ab}	57.51^{a}	55.55^{ab}	54.12^{b}	0.201	0.041
DCP	10.59^{c}	10.42^{c}	14.73^{a}	13.33^{ab}	13.46^{ab}	13.99^{ab}	13.38^{ab}	12.65^{ab}	0.482	0.041
DE	2383.4^{b}	2365.6^{b}	2560.9^{a}	2482.5^{ab}	2479.9^{ab}	2547.6^{a}	2460.8^{ab}	2397.5^{b}	9.253	0.050

$^{a, b, c}$ means in the same row having different superscripts differ significantly. SEM: standard error of means
T1: Control; T2: Control+1 mg/kg diet of propylene glycol; T3: Control + 400 mg/kg diet of garlic oil; T4: Control + 400 mg/kg diet of basil oil. ; T5: Control + 400 mg/kg diet of thyme oil; T6: Control + 200 mg/kg diet of garlic oil. +200 mg/kg diet of basil oil; T7: Control + 200 mg/kg diet of garlic oil. +200 mg/kg diet of thyme oil. T8:200 mg/kg diet of garlic oil +100 mg/kg diet of basil oil+100 mg/kg diet of thyme oil.
TDN= Total digestible energy. DCP= Digestible crude protein
DE= Digestible energy DE (Kcal/kg DM) was calculated according to Schneider and flat, 1975), DE = TDN × 44.3

The nutritive values of the experimental diets are shown in Table (3). The nutritive values of total digestible nutrients (TDN), digestible crude protein (DCP) and digestible energy (DE) showed a significant (P< 0.05) increase in the essential oils diets and their combinations compared with control and T2 groups, where T3 supplemented with 400 mg/kg of garlic oil had the highest values of TDN (57.81%), DCP (14.73)& DE (2560.9, kcal/kg DM) followed by T6 supplemented with 200 of garlic oil plus 200 mg/kg of basil oil (TDN 57.51% , DCP 13.99% and DE 2547.6, kcal/kg DM), respectively. There was no significant deference between control group and T2 group. These improvements tend to that garlic, basil, thyme oils or their mixtures stimulate and activate the digestive system by improving the diet palatability and enhancing appetite. Shehata *et al.* (2003) reported that the addition of garlic improved DCP and TDN significantly (P<0.05). These results might be due to the retrieval of important protein which increases glutathione enzymes in the liver which safeguard the cells from oxidative damage and play a vital role in detoxification, better organs function and immunity and inhibits lipid per-oxidation. Abedo *et al.* (2020) showed that the addition of garlic plus cinnamon significantly decreased the DCP compared to the control group. These results declared that the addition of garlic did not impact DCP. El-Nomeary *et al.* (2020) stated that addition of cinnamon, garlic and juniper EOs did not affect on the total digestible of nutrients (TDN). While, the addition of juniper EO significantly (P<0.05) decreased DCP. In addition, Sabrin *et al.* (2019) reported that, basil oil did not have deleterious effects on the nutrient digestibility and the nutritive values of growing rabbits. Alatrony *et al.* (2022), showed that, the addition of moringa, thyme and licorice leaves extract significantly (P<0.05) improved total digestible nutrients (TDN) and digestible crude protein (DCP) of experimental diets fed to growing rabbits. The herbal supplements secondary compounds, such as essential oils (EOs), saponins, and tannins, have become a primary source of feed additives and antioxidants to enhance general health conditions in humans and animals. Moreover, herbal feed additives have been found to improve digestion of nutrients and reduce the mortality and increase the viability of rabbit. (Zeweil *et al.*, 2013). EOs can improve the digestion, exclude intestine pathogenic bacteria, stimulate haemostasis and improve antioxidant and immune status (Zeng *et al.*, 2015). The combination of EOs has beneficial effects on the ecosystem of the intestinal microflora by relieving oxidative stress induced by them, controlling potential pathogens and stabilizing intestinal microbes (Zeng *et al.*, 2015). The mixture of EOs appears to stimulate beneficial microbes such as Lactobacillus spp and suppress growth of harmful microorganisms. The reason for the improvement in nutrient

absorption may be partly explained due to stimulation in secretions of saliva, bile and enhanced enzyme activity (Jang *et al.,* 2007). Due to the wide variety of phytochemicals present in plant herbs, they can stimulate digestive secretions and regulate feed intake, but affect digestion processes differently (Frankič *et al.,* 2009). The beneficial effects of nutritional inclusion of phytogenics on digestion of nutrients, gut health, growth performance and intestinal integrity have been reported earlier Brenes and Roura (2010). Such as the results reported by Amad *et al.* (2011) who found that herbal feed additives enhanced the apparent digestibility of the nutrients of broiler chickens at 21, 35 and 42 days of age. The beneficial effects of herbal plants and their extracts in animal nutrition include stimulation of appetite, activation of the immune response, improving digestive enzyme secretion, antiviral, antibacterial and antioxidant actions that may affect the digestive tracts physiological and chemical function (Rahimi and Ardekani, 2013).

Blood serum lipid profile:

Blood serum lipid profile of rabbits is presented in Table (4). The serum triglycerides, total cholesterol, high density lipoprotein cholesterol (HDL-c), Low density lipoprotein cholesterol (LDL-c) and very low-density lipoprotein cholesterol (VLDL-c) were significantly ($P<0.05$) decreased in groups fed diet supplemented with essential oils and their combinations compared with T2 and control groups. There were no significant differences between the experimental group T2 and control group. The results obtained in this study are in match with findings of El-Nomeary *et al.* (2020) who reported, regarding the liver enzymes that Eos decreased value of serum GOT, this indicated the improvement of lipid profile due to the hepato-protection effect of essential oils on liver function and lipid metabolism as it reduces cholesterol biosynthesis. El-Gogary *et al.* (2018) showed that, there was no significant effect of garlic levels (0.25 and 0.75 g/kg) on plasma cholesterol, triglycerides and LDL in all groups during the experimental period whereas, rabbit fed the 0.5 g/kg garlic oil diet had significantly higher HDL level than other groups. The reduction of serum cholesterol observed could be returned to the lowering of synthetic enzyme efficiency as suggested by Chowdhury *et al.* (2002). Alagawany *et al.* (2016) reported that garlic reduced the lipid profile in blood and enhanced the immunity responses, lipid peroxidation in the liver and increased hepatic antioxidant effectiveness in treated rabbits. Iyad *et al.* (2015) scientific studies indicate the presence of many important compounds in basil oil, as alpha – terpinene.

Table (4): Blood lipid profile of growing rabbits fed diets supplemented with essential oils.

Item	Experimental diets								SEM	P value
	T1	T2	T3	T4	T5	T6	T7	T8		
Triglycerides (mg/dl)	147.42^{a}	147.06^{a}	126.91^{b}	124.97^{c}	127.91^{b}	127.23^{b}	127.73^{b}	126.30^{bc}	1.433	<0.0001
Total Cholesterol (mg/dl)	178.11^{a}	180.07^{a}	155.87^{b}	154.12^{b}	155.67^{b}	154.85^{b}	155.29^{b}	155.30^{b}	1.694	<0.0001
HDL (mg/dl)	41.89^{b}	42.23^{b}	47.87^{a}	47.68^{a}	47.30^{a}	47.54^{a}	46.51^{a}	46.29^{a}	0.430	<0.0001
LDL (mg/dl)	33.52^{a}	32.98 ^{a}	28.36^{b}	27.48^{b}	28.47^{b}	26.86^{b}	27.16^{b}	26.60^{b}	0.465	<0.0001
VLDL (mg/dl)	29.48^{a}	29.41^{a}	25.38^{b}	24.99^{c}	25.58^{b}	25.45^{b}	25.55^{b}	25.26^{bc}	0.651	<0.0001

$^{a, b, c}$ means in the same row having different superscripts differ significantly. SEM: standard error of means
T1: Control; T2: Control+1 mg/kg diet of propylene glycol; T3: Control + 400 mg/kg diet of garlic oil; T4: Control + 400 mg/kg diet of basil oil. ; T5: Control + 400 mg/kg diet of thyme oil; T6: Control + 200 mg/kg diet of garlic oil. +200 mg/kg diet of basil oil; T7: Control + 200 mg/kg diet of garlic oil. +200 mg/kg diet of thyme oil. T8:200 mg/kg diet of garlic oil +100 mg/kg diet of basil oil+100 mg/kg diet of thyme oil.

Terpenes are the components of the volatile oils in aromatic plants that contain compounds with chemical formulas that include multiples of five zymes. These terpenes are widespread in the plant kingdom and differ in their structural composition according to the natural source. Examples are: sclareol, isocarnosol and theosifene. The triterpenes consist of six isomer units, which are solids such as amerin and lobel. Some of the triterpenes have activity against microbes and insects, and some have biological significance. Experiments have shown that ursolic acid derivatives decrease both blood cholesterol and the concentration of phospholipids. Alatrony *et al.* (2022) revaluated that, adding dietary supplements to growing rabbit diets as thyme, moringa and licorice leaves extracts reduced total cholesterol concentration in blood serum compared with control. Juniper EO significantly decreased triglycerides by 18.4%, total cholesterol by 12.4% and LDL- cholesterol by 4% (non-significant) as well as significantly

increased the HDL- cholesterol by 30.5%, respectively compared to the control group. Similar results showed that juniper has a greater hypolipidemic effect (Ju *et al.,* 2008). It has been reported that cinnamaldehyde may stimulate lipolysis via activation of adenosine monophosphate-activated protein kinase (AMPK) which is involved in the maintenance of lipid and cholesterol homeostasis (Shen *et al.,* 2014).

Economic efficiency:

Data presented in Table (5) showed that the experimental group's recorded higher values of economic efficiency and relative economic efficiency compared to control one. T3 (Control + 400 mg/kg diet of garlic oil) achieved the values 0.677 and 121% respectively, of economic efficiency and relative economic efficiency followed by T6 (200 mg/kg diet of garlic oil. +200 mg/kg diet of basil oil), T4 (Control + 400 mg/kg diet of basil oil) and T5 (Control + 400 mg/kg diet of thyme oil) 0.637, 0.631 and 0.612 for economic efficiency and 113, 112% and 109% for relative economic efficiency, respectively. Generally, it can be noticed that, the findings of this study demonstrated that dietary supplementation of essential oils as garlic oil, basil oil or thyme oil at 400 mg/kg diet level and dietary supplementation of200 mg/kg diet of garlic oil plus 200 mg/kg diet of basil oil had the best economic return over the control group. This improvement based on the higher body weight and better feed conversion ratio. The result of performance index (PI) indicated that the experimental groups received diets with essential oils as garlic oil, basil oil or thyme oil at 400 mg/kg diet level and dietary supplementation of 200 mg/kg diet of garlic oil plus 200 mg/kg diet of basil oil gave better values especially T3 which had the highest value (75.81) followed by 73.28, 72.99 and 70.55 for T6, T4, T5 and 67.01 & 64.22 for T8 and T7 compared to control group. Abdelnour *et al.* (2022) determined the modulatory role of thyme essential oil (TEO) in improving the blood metabolites, antioxidant status, immunological response, ovarian activity, reproductive traits and fecundity of rabbit does kept under high environmental stress. Herbal growth promoters serve as appetizers, digestive stimulants, antibacterial, antiviral, anthelmintic, anti-inflammatory and also possess immune-stimulation properties (Platel *et al.,* 2002). New additives derived from plants including aromatic plant extracts have been studied. They have several advantages over antibiotics because they are residue free, also may has an effect on greater efficiency to the utilization of feed, resulting in enhanced growth and economic efficiency (Franz *et al.,* 2010).

Table (5): Effect of dietary treatments on economic efficiency of growing rabbits.

Item	Experimental diets							
	T1	**T2**	**T3**	**T4**	**T5**	**T6**	**T7**	**T8**
Total average weight gain (g)	1419	1415	1749	1736	1689	1727	1602	1645
Price of 1kg body weight	45	45	45	45	45	45	45	45
Selling price/rabbit (LE) (A)	63.86	63.68	78.71	78.12	76.01	77.72	72.09	74.03
Total feed intake (g)	5524	5520	5509	5621	5567	5574	5567	5608
Price/kg feed (LE)	7.40	8.40	8.52	8.52	8.47	8.52	8.50	8.50
Total feed cost/ rabbit (LE) (B)	40.88	46.37	46.94	47.89	47.15	47.49	47.32	47.67
Net revenue (LE)[1]	22.98	17.31	31.77	30.23	28.86	30.23	24.77	26.36
Economic efficiency[2]	0.562	0.373	0.677	0.631	0.612	0.637	0.523	0.553
Relative Economic efficiency[3]	100	66	121	112	109	113	93	98
Performance index.%[4]	52.80.	52.62	75.81	72.99	70.55	73.28	64.22	67.01

T1: Control; T2: Control+1 mg/kg diet of propylene glycol; T3: Control + 400 mg/kg diet of garlic oil; T4: Control + 400 mg/kg diet of basil oil. ; T5: Control + 400 mg/kg diet of thyme oil; T6: Control + 200 mg/kg diet of garlic oil. +200 mg/kg diet of basil oil; T7: Control + 200 mg/kg diet of garlic oil. +200 mg/kg diet of thyme oil. T8:200 mg/kg diet of garlic oil +100 mg/kg diet of basil oil+100 mg/kg diet of thyme oil. (1) Net revenue = A – B (2) Economic efficiency = (A-B/B).

*(3) Relative Economic Efficiency = Economic efficiency of treatments other than the control/ Economic efficiency of the control group (4) Growth performance index (P1) = Live body weight (kg) /feed conversion *100, North (1981.*

CONCLUSION

Generally, it can be noticed that, dietary supplementation of garlic oil, basil oil and thyme oil, improved productive performance, digestion coefficient, biochemical blood parameters and the economic efficiency, with the best results were obtained by supplementing 400 mg/kg diet of garlic oil in diet of growing rabbits.

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إضافة الزيوت الأساسية في علائق الأرانب النامية

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تهدف هذه الدراسة إلى مقارنة التأثيرات الفردية للزيوت الأساسية الطبيعية المتاحة تجارياً مثل زيت الثوم أو زيت الريحان أو زيت الزعتر أو مخاليطهم على أداء النمو ومعاملات الهضم وبعض مقاييس الدم والكفاءة الإقتصادية للأرانب النامية، وكذلك الأنشطة المضادة للأكسدة. تم تقسيم مئة وعشرون ذكرًا ناميًا من الأرانب النيوزيلندية البيضاء بعمر ستة أسابيع، بمتوسط وزن حي 637 جم بشكل عشوائي إلى ثمان مجموعات (خمسة عشر أرنبًا لكل مجموعة)، كل مجموعة في ثلاث مكررات.

تغذت المجموعة الأولى على العليقة القاعدية بدون أي إضافات (مجموعه الكنترول). بينما غذيت المجموعة الثانية على العليقة القاعدية مضاف إليها 1 مجم / كجم عليقة البروبيلين جليكول. غذيت المجموعات من الثالثة حتى الخامسة على العليقة القاعدية مضاف إليها زيت الثوم ' زيت الريحان ' زيت الزعتر كل بمعدل 400 مجم / كجم عليقة على التوالي والمجموعة السادسة و السابعة على العليقة القاعدية مضاف إليها200 مجم من زيت الثوم مع 200 مجم من كلا من زيت الريحان و زيت الزعتر على التوالي بينما غذيت المجموعة الثامنة على العليقة القاعدية مضاف إليها 200 مجم من زيت الثوم مع 100 مجم من كلاً من زيت الريحان و زيت الزعتر/كجم عليقة. استمرت التجربة لمدة ثمانية أسابيع. أظهرت النتائج زيادة معنوية في وزن الجسم النهائي للأرانب من المجموعة الثالثة إلى المجموعة الثامنة بالمقارنة بمجموعة الكنترول وسجلت المجموعة الثالثة أعلى وزن (2388جم) مقارنة بالمجموعات التجريبية الأخرى. في حين بلغت النسبة المئوية للزيادة في وزن الجسم مقارنةً بالكنترول 23 و 22و22 % لكل من المجموعة الثالثة و الرابعة و السادسة على التوالي وبلغت 19% للمجموعة الخامسة تليهم 16و 13% لكل من المجموعة الثامنة و السابعة على التوالي. سجلت المجموعة الرابعة أعلى قيمة للغذاء المأكول خلال فترة التجربة5621 جم وبلغت 5608 جم للمجموعة الثامنة و5574 جم للمجموعة السادسة بينما سجلت كلاً من المجموعتين الخامسة والسابعة 5567 جم وسجلت المجموعة الثالثة 5509 جم خلال فترة التجربة بدون فروق معنوية مع مجموعة الكنترول. سجلت المجموعة الثالثة أفضل قيمة لمعامل التحويل الغذائى3.15 % تليها 3.23 و3.24 % للمجموعتين السادسة والرابعة مقارنة بالكنترول والمجموعات التجريبية الأخرى، في حين لم تظهر أي فروق معنوية بين المجموعة الثانية والكنترول. أدت إضافة كل من زيت الثوم والريحان والزعتر ومخاليطهم إلى رفع قيمة معامل هضم كل من البروتين الخام والألياف والمستخلص الخالي من الأزوت والمركبات الكلية المهضومة والبروتين الخام المهضوم و الطاقة المهضومة بالمقارنة بالكنترول. بينما أدت إلى إنخفاض ملحوظ في تركيز كل الدهون الثلاثية الكلية والكوليسترول الكلي والكوليسترولLDL في الدم. حققت المجموعة الثالثة أقل قيمة للتكلفة الغذائية وأعلى كفاءة اقتصادية ومؤشر نمو الاداء تليها المجموعات التجريبية الأخرى مقارنة بمجموعة الكنترول.

نستخلص من ذلك أن إستخدام الإضافات الغذائية من زيت الثوم وزيت الريحان وزيت الزعتر منفردة أو في صورة خليط كمحفزات للنمو خاصة العليقة التي تحتوي على 400 ملجم من زيت الثوم كان لهم تأثير جيد في تحسين الأداء الإنتاجي للأرانب وتحقيق أعلى قيمة للكفاءة الاقتصادية. هذا بالإضافة إلى أن هذه الإضافات الطبيعية لها فعل التأثير الوقائي لما تحتويه من مركبات طبيعية مضادة للأكسدة في رفع كفاءة أداء الأرانب.