SUPPLEMENTAL ESSENTIAL OILS IN GROWING RABBIT DIETS

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SUMMARY

This study aimed to evaluate the individual and combined effects of commercially available natural essential oils, including garlic oil (*Allium sativum L.*), basil oil (*Ocimumbasilicum*), thyme oil (*Thymus vulgaris*), and their mixtures, on the growth performance, digestibility coefficients, blood lipid profiles, and economic efficiency in growing rabbits. One hundred and twenty male New Zealand White (NZW) rabbits, six weeks old and with an average initial body weight of 636.5±7.21g, were evenly distributed into eight groups (15 rabbits per group). Each group was further divided into three replicates. The first group (T1), which served as the control, received a basal diet (16.74% CP and 2504 Kcal/Kg DM) without additives. The second group (T2) was given a basal diet with 1 mg of propylene glycol/kg of diet. The third (T3), fourth (T4), and fifth (T5) groups received the basal diet supplemented with garlic oil (GO), basil oil (BO), and thyme oil (TO) respectively, each at a concentration of 400 mg/kg diet. The sixth group (T6) received a basal diet supplemented with a mix of GO and BO, each at 200 mg/kg diet. The seventh group (T7) received a basal diet with a combination of GO and TO, each at 200 mg/kg diet, and the eighth group (T8) was supplemented with GO at 200 mg/kg diet, and both BO and TO at 100 mg/kg diet. The GO, BO, and TO were applied by spraying 400 ml/kg diet v/w on the daily pelleted feed intake to prevent the loss of volatile components and ensure the effectiveness of the essential oils in the rabbit diets. The experiment lasted for 8 weeks. Results indicated that rabbits fed with essential oils and their combinations significantly outperformed the control group in terms of body weight gain and daily weight gain (P<0.05). The T4 group showed a notable increase in feed consumption compared to the control. All experimental groups, except T2, significantly improved feed conversion ratio compared to the control group (P<0.05). The supplementation of essential oils and their combinations did not influence the digestibility of DM, OM, and NFE against the control group. However, the digestibility coefficients for CP, CF, and EE, along with the nutritive values, were significantly enhanced in the T3, T4, and T6 groups compared to the control. Additionally, all experimental groups except for T2 demonstrated a significant reduction in triglycerides, total cholesterol, low-density lipoprotein cholesterol, and very low-density lipoprotein cholesterol levels (p<0.01), while high-density lipoprotein cholesterol (HDL-c) levels significantly increased compared to the control group. The treatment groups also showed higher economic efficiency and relative economic efficiency than the control group. Overall, this study's findings suggest that the dietary inclusion of essential oils and their combinations leads to increased body weight, improved feed conversion ratios, and better economic returns compared to the control group.

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

INTRODUCTION

Rabbit meat is recognized for its health benefits, including its low-fat content, high proportion of unsaturated fatty acids (60%), and richness in essential minerals such as potassium, phosphorus, and magnesium. It is also a valuable source of high-quality proteins and amino acids, low in cholesterol and sodium (Cullere and Dalle, 2018). The economic success of rabbit farming significantly relies on the health and growth of weaned rabbits and managing high mortality rates during their fattening period. The use of antibiotics in the diets of growing rabbits has been a common practice to mitigate digestive issues, which are a leading cause of morbidity and mortality in this industry (Selim *et al*., 2021). Furthermore, feed costs constitute the largest expense in animal production, accounting for over 70% of total costs. Enhancing feed efficiency and growth rates are crucial strategies for reducing the costs associated with rabbit production (Abedel-Azeem *et al*., 2012). Feed additives play a vital role in improving feed utilization efficiency, animal performance, and immune response. The shift towards utilizing natural additives in lieu of antibiotics in animal diets is a growing trend. Herbal feed additives, including a variety of herbs, spices, and essential oils, are being explored as alternatives (Ceylan *et al*., 2003). These herbal additives offer several benefits, such as preventing digestive disturbances, enhancing feed conversion ratios, improving carcass quality, reducing the age at which animals reach market size, and lowering rearing costs (Krieg *et al*., 2009). The prohibition of antibiotic growth promoters (AGPs) in Europe, coupled with increased consumer demand for healthier and safer animal products, has motivated researchers and feed companies to find new feeding strategies that replace AGPs and synthetic antioxidants (Zotte *et al*., 2016). Essential oils and extracts from aromatic plants are considered promising growth promoters. These oils typically contain a complex mixture of compounds, including phenolics, polyphenols, terpenoids, and others, which vary in concentration. These components are known for their antimicrobial, digestive, antioxidative, and nutrient absorption-enhancing properties (Ziarlarimi *et al*., 2011). Garlic, when added to broiler diets as a supplement, has shown to improve immune function, affect blood leukocyte levels positively, and enhances growth by increasing body gain, feed intake, and feed efficiency (Onibi *et al*., 2009). Garlic extract also plays a significant role as an antibacterial agent against multi-drug resistant bacteria (Salih *et al*., 2016). Basil oil (*Ocimumbasilicum*) contains diverse chemical compounds, such as chavicol methyl ether or estragole, linalool, and eugenol, with variations influenced by chemotypes, and geographical and climatic conditions (Silva *et al*., 2003; Rao *et al*., 2011). The Ocimum genus, encompassing over 150 species, is known for its antimicrobial, antifungal, and antioxidative properties, making it a viable alternative to synthetic chemicals (Poonkodi, 2016). Thyme oil (*Thymus vulgaris*), with its major components thymol and carvacrol, has been evaluated for its antibacterial and antiviral activities (Najafi and Torki, 2010). This research focuses on assessing the individual effects of natural essential oils such as garlic oil (*Allium sativum L*.), basil oil (*Ocimumbasilicum*), and thyme oil (*Thymus vulgaris*), and their combinations on the 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 and twenty male New Zealand White (NZW) rabbits, each six weeks old and with an average body weight of 636.5±7.21 g, were randomly allocated into eight groups (15 rabbits per group). These groups were further divided into three replicates, with five rabbits each, equipped with automatic drinkers and feeders. The rabbits were all provided with a basal pelleted diet, designed according to the National Research Council (NRC) 1977 standards to meet the nutritional needs of rabbits. The first group (T1) received this basal diet (16.74% CP and 2504 Kcal/Kg DM) without any additives, serving as the control. The second group (T2) consumed the basal diet with an addition of propylene glycol (solvent for oils) at 1 mg/kg. Groups three (T3), four (T4), and five (T5) were given the basal diet supplemented with garlic oil (GO), basil oil (BO), and thyme oil (TO) respectively, each at 400 mg/kg diet. The sixth group (T6) received a mix of GO and BO at 200 mg of each per kg diet, the seventh group (T7) was supplemented with GO and TO at the same ratio, and the eighth group (T8) had a blend of GO at 200 mg/kg diet, with BO and TO at 100 mg of each per kg diet. The essential oils were sprayed onto the daily feed at a rate of 400 ml/kg diet to prevent the loss of volatile components and ensure the efficacy of the oils for the rabbits. The study spanned 8 weeks, from the 6th to the 14th week of the rabbits' age. The composition and nutritional content of the diets were detailed in Table (1). All rabbits were maintained under consistent management and sanitary conditions, housed individually in galvanized wire cages (30 x 35 x 40 cm^3), with stainless steel nipple drinkers and feeders for monitoring each rabbit's feed intake. Feed and water were provided *ad libitum*. Diet samples were analyzed for crude protein (CP), crude fiber (CF), ether extract (EE), and ash following the A.O.A.C. (2005) guidelines, while organic matter and nitrogen-free extract (NFE) were calculated. Feed consumption, body weight, body weight gain, and feed conversion ratio were monitored 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 A.O.A.C. (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 14 wks of age, three rabbits from each group were selected at random, fasted for 12 hours before being slaughtered; blood samples were then collected, placed in plain centrifuge tubes, and centrifuged at 3000 rpm for 15 minutes to obtain clear serum, which was stored at -20°C for later biochemical analyses. Serum levels of triglycerides, total cholesterol, high-density lipoprotein (HDL), and low-density lipoprotein (LDL) cholesterol were determined using commercial kits from Biodiagnostic Company. Serum very low-density lipoprotein (VLDL) cholesterol levels were calculated by dividing the serum triglyceride concentration by five, according to 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 thei^{th} treatment. e_{ij} = experimental random error.

RESULTS AND DISCUSSION

Rabbits Performance:

Table (2) presents the data concerning body weight, feed intake, and feed conversion ratio of growing New Zealand rabbits throughout the study period. It was observed that rabbits supplemented with essential oils and their mixtures exhibited a marked improvement in body weight and daily weight gain, significantly surpassing the control group's performance (P<0.05). Specifically, the T4 group demonstrated a notable increase in feed intake when compared to the control group, a difference that was statistically significant (P<0.05). Moreover, a significant enhancement in feed conversion efficiency was recorded across all treatment groups in comparison to the control group, with the exception of the T2 group, which did not show any significant difference from the control. These findings align with Abedo *et al*. (2015), who noted improvements in daily weight gain and feed conversion ratio in rabbits supplemented with garlic oil. The beneficial impacts of phytogenic additive supplementation could be attributed to certain compounds that boost the digestion and nutrient absorption in the diets, likely due to the bioactive components (curcuminoids and allicin) found in garlic, which enhance efficiency and growth (El-Nomeary *et al*., 2020). Sidiropoulou *et al*. (2020) highlighted the critical biological roles of essential oils from plant sources in the metabolism and physiology of humans, animals, and other organisms. Using feed additives to modify gut function and microbial environment in domestic animals has been acknowledged as a crucial strategy for enhancing growth performance and feed efficiency (Collington *et al*., 1990). Zucca *et al*. (2019) noted that garlic, rich in sulfur-containing compounds, is used in nutraceuticals to prevent certain diseases. Garlic (*Allium sativum*) serves as a medicinal plant for the prevention and treatment of various ailments (Adibmoradi *et al*., 2006). The reduction in feed intake observed with treatments supplemented with essential oils, such as garlic, may be due to the flavors and smells released by the active substances in the plants, which could suppress animal intake, making some herbs less palatable (Jugl-Chizzola *et al*., 2006). Thyme (*Thymus vulgaris*) volatile oil, thymol, and carvacrol, key components derived from thyme's essential oil have been evaluated for their antibacterial and antiviral properties as microbial growth inhibitors (Najafi and Torki, 2010). Yasser *et al*. (2014) found that thymol and carvacrol from thyme, and allicin from garlic, act as active ingredients in these plants, serving as appetizers and digestion stimulants, in addition to their antimicrobial effects against gut bacteria, thereby improving health status and growth. Abedo *et al*. (2020) discussed the potential of using herbal plants as nutritional supplements in rabbit diets to enhance productive performance, marking a novel direction in livestock research. Alatrony *et al*. (2022) concluded that incorporating thyme, moringa, and licorice leaf extracts into the diets of growing rabbits can boost growth performance. Herbal feed additives have been shown to enhance average daily gain (ADG) and feed conversion ratio (FCR), decrease mortality, and increase rabbit viability (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:

Table (3) outlines the digestibility of nutrients across various experimental diets. The inclusion of essential oils and their blends did not significantly impact the digestibility of dry matter (DM), organic matter (OM), and (NFE) when compared to the control diet. However, the digestibility coefficients for crude protein (CP), crude fiber (CF), and ether extract (EE) were significantly higher ($P<0.05$) in the T3, T4, and T6 groups relative to the control. No significant variance was observed between the T2 group and the control group. These findings are in line with El-Nomeary *et al*. (2020), who reported that essential oils (EOs) supplementation, particularly with garlic oil; enhance the digestibility of CP and CF due to the increased availability of proteins for tissue deposition. This enhancement in CP and CF digestibility mirrors observations by Shehata *et al*. (2003) and Hernandez *et al*. (2004), who attributed the improved digestibility to garlic inclusion at various levels. Furthermore, garlic extract consumption was linked to enhanced nutrient digestion, notably CP, by reducing harmful microbial populations, including *E. coli*, *Clostridium* spp., and *Enterococci*.

Numerous studies have posited that dietary essential oils augment animal performance by promoting digestive enzyme secretion, thereby improving nutrient digestion, gut passage rates, or feed intake (Muhl and Liebert, 2007). Herbal growth promoters are recognized for their appetizing, digestive, antibacterial, antiviral, anthelmintic, anti-inflammatory, and immunostimulatory properties (Platel *et al*., 2002). EOs, as complex substance mixtures, are thought to bolster enzyme activity (e.g., trypsin, amylase) and secretion (e.g., bile, saliva), partly by enhancing epithelial tissue's ability to prolong stomach retention time, thus facilitating digestion and absorption (Platel and Srinivasan, 2004). Additionally, EOs may protect and improve liver function by increasing glutathione enzymes, aiding cell repair (Shehata *et al*., 2003), or enhancing the S-transferase enzyme system, as seen with allyl sulfides in garlic (Kyo *et al*., 1998). EOs may also modulate cecum metabolism and selectively inhibit methanogenesis (Boadi *et al*., 2004). Hernandez *et al*. (2004) found that a mixture of carvacrol (from thyme oil), cinnamaldehyde, and capsaicin significantly enhances feed digestibility in broilers.

While different additives have been observed to marginally improve performance, these effects were not statistically significant. Sabrin *et al*. (2019) explored the potential biological activities of essential oils from peppermint and basil in rabbits, inspired by their historical use in traditional medicine and their positive impacts on digestive and immune systems. Khempaka *et al*. (2013) demonstrated that diets with 0.5–2.0% dried peppermint did not negatively affect DM, OM, CF digestibility, or nitrogen retention compared to the control diet. Conversely, Emami *et al*. (2012) noted a significant increase in CP digestibility with peppermint oil supplementation at 400 mg/kg in broiler diets. However, data on basil's effects on nutrient digestibility and nitrogen balance are scarce. Alatrony *et al*. (2022) observed that adding moringa, thyme, and licorice leaf extracts significantly improved the digestion coefficients for DM, OM, NFE, CP, CF, and EE. These extracts, known for their strong antioxidant properties, enhance the secretion of digestive juices, including pancreatic juice and bile, which contain enzymes crucial for digesting carbohydrates, fats, and proteins (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

Table (3) illustrates the nutritional values of the experimental diets, highlighting significant increases in total digestible nutrients (TDN), digestible crude protein (DCP), and digestible energy (DE) for diets supplemented with essential oils and their blends compared to the control and T2 groups. Specifically, the diet with 400 mg/kg of garlic oil (T3) exhibited the highest nutritional values, with TDN at 57.81%, DCP at 14.73%, and DE at 2560.9 kcal/kg DM. This was closely followed by the T6 diet, which included 200 mg/kg each of garlic and basil oils, showing TDN at 57.51%, DCP at 13.99%, and DE at 2547.6 kcal/kg DM. No significant difference was observed between the control group and the T2 group. These enhancements suggest that essential oils from garlic, basil, and thyme or their combinations can boost the digestive system by enhancing diet palatability and stimulating appetite. Shehata *et al*. (2003) observed significant improvements in DCP and TDN with garlic addition, possibly due to the role of glutathione enzymes in the liver, which protect cells from oxidative damage and support detoxification, organ function, and immunity, while also inhibiting lipid peroxidation.

Contrarily, Abedo *et al*. (2020) found that adding garlic and cinnamon together significantly reduced DCP compared to the control diet, suggesting no impact of garlic alone on DCP. El-Nomeary *et al*. (2020) reported that the inclusion of cinnamon, garlic, and juniper essential oils (EOs) did not influence TDN, whereas juniper EO alone significantly reduced DCP. Additionally, Sabrin *et al*. (2019) noted that basil oil did not adversely affect nutrient digestibility or nutritional values in growing rabbits. Alatrony *et al*. (2022) demonstrated that adding moringa, thyme, and licorice leaf extracts significantly improved both TDN and DCP in diets fed to growing rabbits.

Herbal supplements containing secondary compounds like essential oils, saponins, and tannins have become key feed additives and antioxidants, enhancing health in humans and animals. Moreover, herbal feed additives are known to boost nutrient digestion, reduce mortality, and increase the viability of rabbits (Zeweil *et al*., 2013). EOs enhances digestion, combat intestinal pathogens, promote haemostasis, and improve antioxidant and immune status (Zeng *et al*., 2015). Their combination benefits the intestinal microflora ecosystem by mitigating oxidative stress, controlling potential pathogens, and stabilizing intestinal microbes. The improvement in nutrient absorption may be partially attributed to stimulated secretions of saliva and bile, along with increased enzyme activity (Jang *et al*., 2007). The diverse phytochemicals in plant herbs can activate digestive secretions and influence feed intake, thus affecting the digestive process differently (Frankič *et al*., 2009). The positive impact of phytogenic inclusion on nutrient digestion, gut health, growth performance, and intestinal integrity has been well-documented

(Brenes and Roura, 2010). Amad *et al.* (2011) also reported enhanced nutrient digestibility in broiler chickens supplemented with herbal feed additives at various ages. Herbal plants and their extracts contribute to animal nutrition by stimulating appetite, activating the immune response, enhancing digestive enzyme secretion, and offering antiviral, antibacterial, and antioxidant benefits, thereby impacting the physiological and chemical functions of the digestive tract (Rahimi and Ardekani, 2013).

Blood serum lipid profile:

Table (4) reveals that the serum levels of 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 reduced ($p<0.05$) in rabbits fed diets supplemented with essential oils and their combinations, compared to the T2 and control groups. No significant differences were noted between the T2 group and the control group. These findings align with those of El-Nomeary *et al.* (2020), who observed that essential oils (EOs) lowered serum (ALT) levels, indicating improved lipid profiles due to the hepatoprotective effects of EOs on liver function and lipid metabolism by reducing cholesterol synthesis. El-Gogary *et al.* (2018) found no significant changes in plasma cholesterol, triglycerides, and LDL across all groups, except for an increase in HDL levels in rabbits fed a diet with 0.5 g/kg garlic oil. The observed cholesterol reduction could be attributed to decreased efficiency of synthetic enzymes, as suggested by Chowdhury *et al.* (2002). Alagawany *et al.* (2016) noted that garlic not only reduced blood lipid profiles but also boosted immunity responses, lipid peroxidation in the liver, and increased hepatic antioxidant efficacy in treated rabbits. Iyad *et al.* (2015) highlighted that basil oil contains important compounds like alpha-terpinene and terpenes, which are major components of volatile oils in aromatic plants, showing variations in structural composition based on their source. Some terpenes, such as ursolic acid derivatives, have been found to lower blood cholesterol and phospholipid concentrations. Alatrony *et al.* (2022) reported that dietary supplements like thyme, moringa, and licorice leaves extracts lowered total cholesterol in blood serum compared to controls. Juniper EO significantly reduced triglycerides by 18.4%, total cholesterol by 12.4%, and LDL-cholesterol by 4% (non-significantly) while significantly increasing HDL-cholesterol by 30.5%, indicating a potent hypolipidemic effect. Cinnamaldehyde has been reported to stimulate lipolysis through the activation of adenosine monophosphate-activated protein kinase (AMPK), involved in lipid and cholesterol homeostasis (Shen *et al.*, 2014).

Economic efficiency:

Data in Table (5) indicate higher economic efficiency and relative economic efficiency for the experimental groups compared to the control. The T3 group (supplemented with 400 mg/kg diet of garlic oil) recorded the highest values of economic efficiency (0.677) and relative economic efficiency (121%), followed by T6 (200 mg/kg diet of garlic oil plus 200 mg/kg diet of basil oil), T4 (supplemented with 400 mg/kg diet of basil oil), and T5 (supplemented with 400 mg/kg diet of thyme oil), with economic efficiency values of 0.637, 0.631, and 0.612, and relative economic efficiency values of 113%, 112%, and 109%, respectively. The study demonstrates that dietary supplementation with essential oils such as garlic oil, basil oil, or thyme oil at 400 mg/kg diet, and the combination of 200 mg/kg diet of garlic oil plus 200 mg/kg diet of basil oil, offered the best economic returns over the control group, primarily due to higher body weight and improved feed conversion ratio. Performance index (PI) results showed that the experimental groups fed diets with essential oils or their combinations achieved better values, especially T3 with the highest PI value (75.81), followed by T6, T4, T5, and T8 and T7 with values of 73.28, 72.99, 70.55, 67.01, and 64.22 respectively, compared to the control group. Abdelnour *et al.* (2022) explored the modulatory role of thyme essential oil (TEO) in enhancing blood metabolites, antioxidant status, immune response, ovarian activity, reproductive traits, and fecundity in rabbit does under environmental stress. Herbal growth promoters are recognized for their roles as appetizers, digestive aids, antibacterial, antiviral, anthelmintic, anti-inflammatory agents, and immunostimulants (Platel *et al.*, 2002). Plant-derived additives, including aromatic plant extracts, offer several benefits over antibiotics, such as being residue-free and potentially more efficient in feed utilization, leading to improved growth and economic efficiency (Franz *et al.*, 2010).

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.

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 oilin 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 مخاليط هم 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 أيإضافات (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 التوال ي بينما غذيت المجموعة الثامنة على العليقة القاعدي 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 ف ي وزن الجسم النهائي للأرانب من المجموعة الثالثة إلى المجموعة الثامنة بالمقارنة بمجموعة الكنترول وسجلت المجموعة الثا لثة أعلى وزن (2388جم) مقارنة بالمجموعات التجريبية الأخرى. في حين بلغت النسبة المئوية للزيادة في وزن الجسم مقارنةً بالكنترول 23و22و22 %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 و5574جم للمجموعة السادسة بينما سجلت كلاً من المجموعتين الخامسة والسابعة 5567جم وسجلت المجموعة الثالثة 5509 جم خلال فترة التجربة بدون فروق معنوية مع مجموعة الكنترول. سجلت المجموعة الثالثة أفضل قيمة لمعامل التحويل الغذائى 3.15 % 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 والزعترومخاليطهم 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 تركيزكل الدهون الثلاثية الكلية والكوليسترول الكلي والكوليسترول LDL في الدم. حققت المجموعة الثالثة أقل قيمة للتكلفة الغذائية و أعلى 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 التيتحتوي على 400 ملجم من زيت الثوم كان له م تأثير جيد فـي تحسين الأداء الإنتاج ي للأرانب وتحقيق أعلى قيمة للكفاءة الاقتصادية. هذا بالإضافة إلى أن هذه الإضافات الطبيعية لها فعل التأثير الوقائي لما تحتوي ه من مركبات طبيعية مضادة للأكسدة في رفع كفاءة أداء الأرانب.