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SYNERGISTIC EFFECT OF SUPPLEMENTING DIETS WITH NATURAL ADDITIVES ON PRODUCTIVE AND PHYSIOLOGICAL PERFORMANCE ON GROWING RABBITS UNDER HOT CLIMATE

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ABSTRACT

A total seventy californian male rabbits aged 5 weeks, with initial weight ranged from 595 to 610 g. Rabbits were randomly allocated to seven treatments were used for the study; each treatment comprised ten rabbits, while the experiment lasted for 7 weeks. The first group was received un-supplemented diet and served as a control (CON). While, the 2nd, 3rd and 4th treatments were received diets supplemented with 1g Streptococcus macedonicus (SM), 5 g fenugreek (F) and 1.5 g cinnamon (C)/kg diet, respectively. The 5th, 6th and 7th groups were mix between (F and SM), (C and SM) and F, C and SM), respectively. Growth performance, carcass characteristic, digestibility coefficient of nutrient, some blood analysis and economic evaluation were studied.

***Results showed that** significant improvement was observed in the final body weight (FBW), body weight gain (BWG) and feed conversion ratio (FCR) of rabbits throughout the whole experimental period between each treatment and the control. Interestingly, groups FSM, CSM, and FCSM, which consumed fenugreek or cinnamon with probiotic achieved the heaviest FBW, BWG and recorded best FCR at 12 weeks of age. A significant increased on the relative weights of carcass yield; kidney and liver were observed in all experimental groups in compare with control. Digestibility of DM, OM, CP, CF, EE, and NFE were improved with all additives in compare with control. All hematological parameters in control group were significantly (P≤0.05) decreased through the Egyptian summer season; however, a general significant (P≤0.05) increases in RBCs, WBCs, Hb, PCV%, WBCs and IgG due to the different feed additives in comparison with control group was observed.*

There was a significant (P≤0.05) reduction in plasma total lipid (TL), tri-glycerides (TG), total cholesterol (TC), LDL, VLDL, and MDA, while *augmented HDL and TAC in all treatment groups as compared to their control. Significant increases were noticed in TP, Alb, and Glo and declines in some metabolic enzymes, such as AST and ALT, while levels of urea and creatinine were found to be insignificant in rabbits fed diets supplemented with fenugreek seeds, cinnamon and probiotic (Streptococcus macedonicus), which reflect safety of the liver and kidney. All groups supplemented with SM, F, C and their combinations were significantly (P≤0.05) improved in net profit, net revenue, economic efficiency and relative economic efficiency in compared with control. While, groups received combination treatments (FSM, CSM and FCSM) were recorded the highest net profit, net revenue, economic efficiency and relative economic efficiency in compared with all other groups. These differences in relative economic efficiency (REE) showed that diet contained medicinal plants were more economical than the control diet and could be used economical as growth promoters.*

Conclusively, *from these results, it could be recommended that Streptococcus macedonicus, fenugreek and cinnamon and their combinations supplementation in heat stressed californian growing rabbit's diets showed the most beneficial effect under hot climate.*

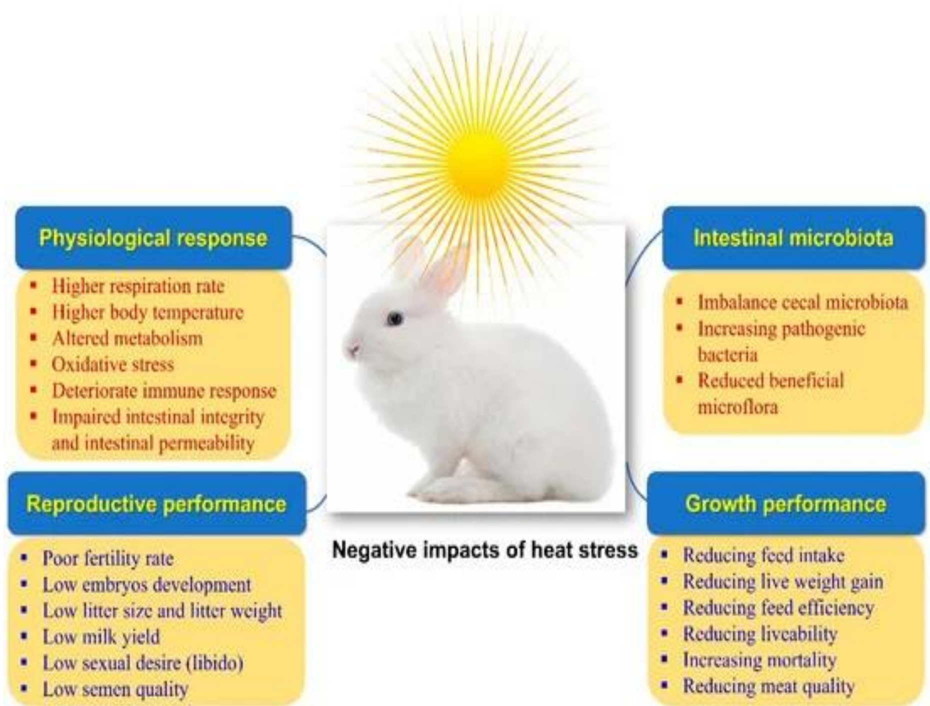
Keywords: *Biochemical blood, cinnamon, digestibility, economic, fenugreek, growth, Rabbits, Streptococcus macedonicus.*

INTRODUCTION

The rabbit industry is confronted with an assortment of major stresses as a result of the amplification of environmental change and the global warming phenomenon, especially in hot and semi-hot regions throughout the World. The World is experiencing extremely high temperatures, which have recently climbed to levels that were previously unheard. The rabbit industries are most severely impacted by heat stress**,** HS (**Liang *et al.,* 2022** and **El-Sawy 2023)**.

Compared to other farm animals, rabbits have a thicker fur coat and fewer sweat glands, resulting in heat scattering being more complex, causing them to be particularly susceptible to heat exhaustion **Oladimeji *et al.,* (2022)**.

Impacts of heat stress on rabbits' physiological response, productive and growth performance, and intestinal microbiota (Cited by **Tarek *et al.,* (2023**) as following Figure.



The Food and Agriculture Organization (FAO) and the World Health Organization (WHO) have recently advised against using antibiotics as growth promoters and advised against using them carelessly (**FAO, 2004** and **WHO, 2004**).The combination of essential nutrient and non-nutrient chemicals known as feed additives aims to increase the effectiveness of feed utilization, while decreasing the high cost of food. Antimicrobial agents are frequently present in rabbit diets to promote growth and control disease. Because the use of antibiotics as feed additives is restricted, pay nutrition experts and feed manufacturers to research and create other options, such as organic acids, probiotics or prebiotics, and feed enzymes (**Windisch *et al.*, 2008**).

Due to the possibility of potential drug multi-resistance in human pathogenic bacteria as well as cross-resistance, the European Union banned feed antibiotic growth promoters. The nutrition of rabbits is increasingly utilizing feeds without chemical additions. Herbs and plant extracts are therefore expected to have a variety of effects, for example, they may affect the immune system, pancreatic secretions, intestinal microbiota, and endogenous enzyme function. Several plant products and the components that make them together have wide-ranging antibacterial, antioxidant, and sedative capacities. Additionally, researchers have recently found that the attractive and stimulating effects of plant and herb extracts on animal immunological and digestive systems may improve farm animals' performance and general health (**Tucker, 2002**).

Fenugreek (*Trigonellafoenum graecum*) is grown in many countries. Its seeds have mainly therapeutic potentials such as hypoglycemic, anti-helminthes, anti-inflammatory, and anti-microbial properties (**Bash *et al.*, 2003**). It contains several agents, such as lecithin and chlorine that help decrease cholesterol and fatty substances. It also contains neurin, biotin, and trimethylamine, which tend to increase appetite through their action on the nervous system (**Micheal** and **Kumawat, 2003**). Fenugreek seeds have been extensively used to prepare extracts for medicinal use (**Smith, 2003**), anti-inflammatory and anti-microbial properties (**Bash *et al.*, 2003**).

Cinnamon is produced from the inner bark of the annual, aromatic Cinnamomum verum plant, which belongs to the *Lauraceae* family. Animal production uses a number of herb extracts as dietary supplements, including cinnamon plant oils and their bioactive components. Flavonoids and phenolic acid are two of the rich polyphenols found in cinnamon (*Cinnamomum zeylanicum*) **(Joohee *et al.*, 2023),** such as cinnamaldehyde and eugenol. These bioactive can be used for a variety of objectives, such as antibacterial action against many pathogens and promoting the growth of beneficial bacteria in an animal's stomach, such as lactic acid bacteria and bifidobacteria (**Adarsh *et al.*, 2020**). Additionally, cinnamon has strong hypercholesterolemia, anticandidal, antioxidant, analgesic, and antiulcer properties (**El-Hack *et al.*, 2020)**, and dietary aromatic herbs and extracts have been noticed to improve the health and performance of both healthy and diseased farm animals.

Probiotics may have an influence on rabbit weight gain and their ability to utilize the nutrients in their feed and successfully convert them into body mass. The feed conversion ratio (FCR) may be significantly impacted by probiotic metabolisms. It could lead to increased feed usage (**Mancini and Gisella, 2021**).

Therefore, the aim of the present study was to evaluate the beneficial effect of fenugreek seeds, cinnamon, and probiotic (*Streptococcus macedonicus*) alone or in combinations on productive and physiological performance traits of growing californian male rabbits under hot climate in Egypt.

MATERIALS AND METHODS

The experiment was carried out at a private rabbitry farm in Egypt's Qaluobia Province, during summer season. Animal care and maintenance were carried out in accordance with the recommendations of the Egyptian Research

Ethics Committee. Seventy Californian male rabbits aged 5 weeks, whose average weight ranged from 595 to 610 g, acclimatized for a week and were later randomly assigned to seven 7 treatments; each treatment comprised ten 10 rabbits while, the experiment lasted for 7 weeks.

All rabbits were reared in hutches, and the hutches were properly cleaned. The rabbits were provided with clean water *ad libitum*; while feed was served twice daily at 8:00 am and 16 pm good hygiene was also maintained during the study.

Environmental conditions

Ambient air temperature and relative humidity were recorded at 12 pm, then temperature humidity index (THI) was calculated according to **Marai *et al.*, (2001)** as the following formula:

Where: db°C is dry bulb temperature in Celsius and RH is the relative humidity as a percentage". "The values obtained are then classified as absence of heat stress (<27.8), moderate heat stress (27.8-28.8), severe heat stress (28.9-29.9) and very severe heat stress (≥30.0) as the following formula:

$$\mathbf{THI = T - [(0.31 - 0.31 \times RH) \times (T - 14.4)],}$$

Where: RH = Relative humidity and T= Temperature (Celsius).

Table 1. The average of ambient temperatures (AT), relative humidity (RH), and temperature-humidity index (THI) values, of rabbitry (indoor), during summer season

Months	**AT, °C**	**RH**	**THI**
June	28.28±0.42	52.10±2.36	26.21±0.37
July	29.82±0.43	64.88±3.21	28.14±0.38
August	31.35±0.46	77.65±3.98	30.16±0.41
Averages			

AT= Air temperature; RH= Relative humidity %; THI= Temperature humidity

The averages minimum and maximum ambient temperatures during summer season ranged between 28.28 and 31.35 °C, relative humidity from 52.10 to 77.65 % and temperature-humidity index (THI) from 26.21 to 30.16, under Qaluobia Province, Egypt as shown in Table 1.

Probiotic:

Streptococcus macedonicus (SM), viable bacteria 3.4×10^{10} Colony Forming Unit/gram (CFU/g).

Source and processing of test ingredient:

Dried fenugreek seeds and cinnamon powder were purchased from a market in Cairo, Egypt. All the test ingredients were stored in sacs until they were needed.

Experimental diet and management:

Table 2 presents the ingredient composition of the growing rabbit diets according to **De Blas and Mateos, (1998**), the basal experimental ration was formulated and pelleted to cover the nutrient requirements of rabbits, feed was allowed to a standard pelleted diet all times.

Experimental design:

The experimental groups were fed basal diet and supplemented with different additives and allocated as follows:

T1: basal diet with no feed additives served as control (CON), **T2**: basal diet supplemented with 1 g *streptococcus macedonicus* (SM)/kg diet (SM), **T3**: basal diet supplemented with 5 g/kg diet fenugreek seed powder (F), **T4**: basal diet supplemented with 1.5 g/kg diet cinnamon powder (C), **T5**: basal diet supplemented with 5 g/kg diet fenugreek seed powdered plus 1 g SM /kg diet (FSM), **T6**: basal diet supplemented with 1.5 g/kg diet cinnamon powder plus 1 g SM/kg diet (CSM), **T7**: basal diet supplemented with a mixture of 5 g/kg diet fenugreek seed powdered and 1.5 g/kg diet cinnamon powder plus 1 g SM/kg diet (FCSM).

Feed consumption (FC) were recorded daily then used to work out weekly feed consumption. Feed consumption was calculated by feed offered–feed refused. Weekly weight gain was calculated by subtracting initial weight from final weight of each week and weekly FCR was calculated by dividing weekly feed consumed by weekly weight gain.

Economic evaluation was estimated according to Egyptian marketing prices according to **El-Speiy *et al.*, (2015)**.

At the end of the feeding trial (12^{th} week of age), three rabbits from each group were selected for slaughter. Just prior to slaughter and again after complete bleeding, the rabbits were individually weighed, and their fur and legs were plucked and then eviscerated. Records on individual weights of eviscerated carcass and giblets (including heart, liver and kidney) were done. Carcass yield was calculated as eviscerated carcass plus giblets. All carcass traits were expressed as % of live body weight at slaughter.

Table2. Composition and chemical analysis of the basal experimental diet

Ingredients	Basal diet, kg
Barley	15.00
Yellow corn	6.22
Wheatbran	23.33
Alfalfa hay	30.12
Soybean meal44%	22.33
Premix*	0.30
Sodiumchloride	0.50
Di-calcium-phosphate	1.20
Limestone	1.00
Total	**100**
Chemical analysis of diets	**Calculated values**
Crude protein , %	17.28
DE kcal/kg diet	2680
Ether extract, %	2.69
Crude fiber, %	13.26

* **The premix provided the following** (per kg of diet): Vitamin A= 6000 IU; Vitamin D_3= 900 IU;Vitamin E= 40 mg; Vitamin K_3= 2 mg; Vitamin B_1= 2 mg; Vitamin B_2= 4 mg; Vitamin B_6= 2mg; Pantothenic acid=10 mg; Vitamin B_{12}=0.01mg;Niacin=50 mg; Folic acid=3mg;Biotin=0.05mg;Choline=250mg;Fe=50mg;Mn=85mg;Cu=5mg;Co=0.1mg;Se=1mg;I= 0.2mgandZn=50mg.

At the end of the feeding trial (12^{th} week of age), three rabbits from each group were selected for slaughter. Just prior to slaughter and again after complete bleeding, the rabbits were individually weighed, and their fur and legs were plucked and then eviscerated. Records on individual weights of eviscerated carcass and giblets (including heart, liver and kidney) were done. Carcass yield was calculated as eviscerated carcass plus giblets. All carcass traits were expressed as % of live body weight at slaughter.

In the end of the experimental period, blood samples (5 ml/rabbit) were taken from the marginal ear vein of 5 males per group before feeding. Each sample collects into two heparinized tubes. First tube was used to test hematological parameters, while the second was centrifuged at 3000 rpm for 10 minutes at 4°C to obtained blood plasma and kept in refrigerator at -20. Hemoglobin concentration (Hb, mg/dl), and red blood cells count (RBCs, 10^6/ml), white blood cells count (WBCs, 10^3/ml), packed cell volume (PCV%) were measured using blood hematology analyzer (HB 7021). Immunoglobulin in blood plasma (IgG) were determined using commercial ELISA kits (Kamiya Biomedical Company, USA) using commercially available kits methods using spectrophotometers, (GNW-Model: SM-721) according to **Ippoushi *et al.*, (2005).**

Biochemical analyses of plasma total cholesterol (TC),triglycerides (TG) and high-density lipoprotein (HDL) were assessed according to **Fasati and Principe,** (**1982),** however, low-density lipoprotein (LDL) were calculated using the formula:

LDL-c, (mg/dl) =Total cholesterol–{HDL-c+ (TG/5)},

Which explained by Friedewald *et al.,* (1972). While, total antioxidant capacity (TAC) and malondialdehyde (MDA) and different types of total plasma protein (TP), and albumin (Alb) were measured by the methods described by Doumas *et al.,* (1981); globulin (Glo) was calculated. Aspartate aminotransferase (AST), and alanine aminotransferase (ALT) were determined according to **Reitman and Frankel, (1957**) and urea, creatinine were determined according to **Canaud *et al.,*** (**2014**).All biochemical parameters were analyzed by commercially available kit methods. GNW-Model: SM-721 Spectrophotometers, Absorbance Microplate Reader and other laboratory equipment aids were used for biochemical analysis.

Statistically analysis

Data were statistically analyzed by one-way analysis to study the effect of treatment at each time using **SAS (2002).** The statistical model used was as follows:

$$Y_{ij} = \mu + T_i + e_{ij}$$

Where, Y_{ij}= The dependent variable, μ= The overall mean; T_i= The effect of treatments and e_{ij}= the random error.

The significant differences among treatment groups were tested using Multiple Range Test according to **Duncan (1955).**

RESULTS AND DISCUSSION

***Growth performance*:**

Table 3 summarized the effect of utilized different treatments of fenugreek (F), cinnamon (C), *Streptococcus macedonicus* (SM) individually or their combinations on the FBW, BWG, FC and FCR of heat stressed Californian growing male rabbits during the whole experimental period (5–12 weeks of age). Significant improvement was observed in the FBW, BWG and FCRof rabbits throughout the whole experimental period between each treatment and the control. Interestingly, groups FSM, CSM, and FCSM, which consumed fenugreek or cinnamon with probioticsachieved the heaviest FBW, BWG and recorded best FCR at 12 weeks of age.

Table 3. Synergistic effect of natural a dative on productive performance of Californian growing male rabbits

Treatment	IBW, g	FBW, g	BWG, g	FC, g	FCR
CON	592.6	1821.4[c]	1228.8[c]	4070.7	2.84
SM	595.5	2015.7[bc]	1420.2[b]	4196.2	2.77
F	593.4	2010.0[bc]	1416.6[b]	4263.0	2.84
C	590.1	2062.8 [ab]	1472.7[b]	4381.7	2.91
FSM	599.3	2255.0 [a]	1655.7[a]	4319.0	2.66
CSM	605.8	2291.4[a]	1685.6[a]	4370.7	2.69
FCSM	610.2	2295.7[a]	1685.5[a]	4380.7	2.70
MSE	10.1	87.9	99.4	148.9	0.08
Sig.	NS	*	*	NS	NS

[a-b-c]: Values in the same column with different superscripts differ significantly (P≤0.05). CON= control, SM=*Streptococcus macedonicus*, F= fenugreek, C= cinnamon, FSM= fenugreek + SM, CSM= cinnamon + SM and FCSM= fenugreek + cinnamon +SM, IBW= initial body weight, FBW= final body weight, BWG= body weight gain, FC= total feed consumption, FCR= feed conversion ratio.

These results are in agreement with the findings by **Seleem *et al.*, (2008)** who found DWG and FCR of growing Californian rabbits fed diets supplemented with 0.3% fenugreek seeds improved significantly (P≤0.05), while **DFI** was insignificantly higher than those received the un-supplemented diet. **Zeweil *et al.*, (2015)** found an increase in LBW of fed diet rabbits supplemented with fenugreek. Same results were obtained by **Abdelatif *et al.*, (2012**) and **El-Kholy *et al.*, (2012),** who obtained that improvement in **BWG**, **FC** and **FCR** were improved when fed diet supplemented with fenugreek compared with the control group. Summarily results obtained by **Adejola *et al.*, (2019)** who mentioned that fenugreek seed powder supplemented to diet improved the growth performance of the weaned rabbits.

Abdel-Azeem *et al.*, (2022) noticed that treatment growing rabbits with cinnamon powder significantly increased LBW, BWG and best FC. Also, **Attia *et al.*, (2019)** noticed that herbs may increase FC by increasing appetite. A potential cause for the increased feed intake in comparison to the control group might involve the stimulating effect of cinnamon due to was superior to as a rabbit growth stimulant on the gastrointestinal tract, which increases starvation and thus increases feed intake.At the same line, **Shihabudeen *et al.*, (2011)** mentioned that cinnamon has major component antibacterial, antioxidant, and hypo-cholesterolaemic activities as essential oil from *Cinnamomum zeylanicum*is rich in trans-cinnam aldehyde with antimicrobial effects against animal pathogens. Also, **Mastura *et al.*, (1999)** resulting in decreasing the growth and colonization of several pathogenic and non-pathogenic species of bacteria in chickens' guts, leading to employment of gut microbial ecosystems that cause better feed utilization, reflected by an improved FCR. Another result recorded by **Zeweil *et al.*, (2016)** revealed that supplementation of cinnamon powder to growing rabbit's diets improved the performance traits.

Regarding to probiotics, **El-Sawy *et al.*, (2023)** found that asignificant increase in FBW and BWG of rabbits treated by Grow star®, FIDAL® and EM1® probiotics in drinking water, while feed intake was a significantly increased withEM1as compared to other groups. However, FCR mathematically decreased in rabbits receivedFIDAL, while performance index mathematically improved in both FIDAL and EM1 Groups compared with control one. Also, **El-Sawy, Basma *et al.*, (2021)** found that *S. cerevisia eboulardii* improved LBW and BWG when supplemented 200 or 400 g/ton diet for growing rabbits. However, **El-Sawy, Basma, (2022)** reported that feed intake was improved significantly (P≤0.01) for all experimental groups fed diet supplemented with *Saccharomyces ceriveisiae bolardii* compared to control one. They suggested that addition of *Saccharomyces ceriveisiae bolardii* (SCB) in growing rabbits feed might enhance the growth of lactic acid fermenting bacteria in the gut and improved the food digestibility and utilization of ammonia. **Rayes *et al.*, (2009)**who recorded that the improvement in BWG of rabbits utilizing probiotic in diets may be attributed to a rise in feed intake because fenugreek contains several bioactive compounds such as antibacterial, antifungal, anti-inflammatory, carminative, and antioxidant activities.Emphasizing the role of probiotics, **Ahmed *et al.*, (2021)** recorded that treatment rabbits by fenugreek seeds and probiotics combination showed heaviest growth performance and improvement nutrient digestibility. Harmony with obtained, **Amal *et al.*, (2013)** and **Mamoun *et al.*, (2014**)revealed that achieved best of FCR could be related to the improvement of rabbit gut morphological changes of gastrointestinal tract tissues that can be induced by deferent change in gut-fluid microbial content including their metabolites. Conversely, **El-Kloub (2006)** who showed that fenugreek seeds led to insignificant effect on FC compared to the control. Finally, **Doaa and Moshira (2015)** recorded that dietary rabbit supplementation of prebiotic and probiotic and their mixture improves BWG and FCR.

Carcass characteristics:

Results given in Table 4 showed that the dietary supplementations of fenugreek, cinnamon, and probioticand their combinations had a significant (P≤0.05) effect on the relative weights of carcass yield, kidney and liver carcass weight and total edible parts were in harmony with the FBW.

Table 4. Synergistic effect of natural a dative on carcass characteristics of California growing male rabbits

Tr	Carcass %	Giblets			Total giblets %	Total edible part %
		kidneys %	Heart %	Liver %		
CON	54.23	0.54[b]	0.34[b]	1.99[c]	2.87 [c]	57.07[b]
SM	59.21	0.75[a]	0.32[b]	2.78[b]	3.85[b]	63.06[a]
F	58.76	0.77 [a]	0.29[c]	2.98[ab]	4.04[ab]	62.80[a]
C	59.41	0.82 [a]	0.31[bc]	3.12[a]	4.25[ab]	63.55[a]
FSM	57.59	0.75 [a]	0.33[ab]	3.01[ab]	4.09[ab]	61.68[ab]
CSM	58.88	0.77 [a]	0.35[a]	3.22[a]	4.34 [a]	63.22[a]
FCSM	58.21	0.78 [a]	0.30[bc]	3.11[a]	4.19[ab]	62.40[ab]
MSE	1.22	0.007	0.04	0.041	0.34	1.56
Sig.	NS	*	*	*	*	*

[a-b-c]: Values in the same column with different superscripts differ significantly (P≤0.05). CON= control, SM= *Streptococcus macedonicus*, F= fenugreek, C= cinnamon, FSM= fenugreek + SM, CSM= cinnamon + SM and FCSM= fenugreek + cinnamon + SM.

Seleem *et al.*, (2008) found that feeding diet supplemented with 0.3% fenugreek significantly (P≤0.05) improved dressing percentage, carcass, and internal organs percentages of each of spleen; kidneys; liver; heart and lungs of growing Californian rabbits. **Ahmed *et al.*, (2021)** reported that dietary treatment with fenugreek and probiotics greatly affected the percentages of carcass yield and some organs compared to control. **Alloui *et al.*, (2012**) noticed that an increase in the dressing percentage of rabbit feed utilized a diet supplemented with fenugreek seed powder.

In contrast, **Zeweil *et al.*, *(*2015)** presented that diets containing fenugreek seeds had no significant effect on carcass weight percentage and organs relative weights as compared with the control group. **Adejola *et al.*, (2019)** concluded that the fenugreek seed powder had no effect on carcass characteristics.

Regarding cinnamon, results are in agreement with **Matusevicius *et al.*, (2011)** who used cinnamon in fattening NZW rabbits. Also**, Jeroch *et al.*, (2009)** showed that total hot carcass weight and the weight of carcass parts were increased in harmony with supplementation of cinnamon additive due to the increase in FBW. The same authors found that Cinnamon powder, at its highest levels, significantly increased carcass weight, dressing percentage, and relative spleen, kidney, liver, and heart weights. Also, **Mohammed *et al.*, (2022**) mentioned that supplementing the diet with cinnamon increased LBW, carcass weight, and heart percentage.

On the other hand, **Toghyani *et al.*, (2011)** showed that dietary supplementation with cinnamon powder as growth promoter agents did not significantly affect the internal organ weights and carcass characteristics of broiler chickens.

Regarding to probiotics, **El-Sawy *et al.* (2023)** found that in growing rabbit's carcass traits and different parts of carcass did not affected by probiotics.

Digestibility coefficients:

Digestibility coefficients of DM, OM, CP, CF, EE, and NFE were summarized in Table 5. There was a significant difference (P≤0.05) across each experimental parameter when the bioactive component was included with or without SM. The treatment groups, whether having SM or not showed a progressive increase in FC compared to the control group. This is consistent with the finding of **Diaz *et al.*, (1993)** who observed that feeding sheep with supplements of Sapindus saponaria saponin, often known as fenugreek, inhibits rumen protozoa and increases the population of bacteria and fungi, thereby improving the digestibility of DM. An increased caecal fermentation pattern may be related to the significant increase in DM digestibility caused by the addition of fenugreek saponin.

Table 5. Synergistic effect of bioactive components and probiotic *(Streptococcus macedonicus*) on digestibility coefficients of growing male rabbits

	Parameters					
Tr	**DM**	**OM**	**CP**	**CF**	**EE**	**NFE**
CON	66.07[b]	89.10[b]	62.17[b]	42.84[b]	46.19[c]	55.60[c]
SM	77.12[a]	93.32[a]	85.22[a]	55.65[a]	79.78[b]	85.15[a]
F	74.78[a]	91.10[ab]	83.59[a]	51.81[a]	93.70[a]	78.72[b]
C	74.27[a]	92.90[a]	82.54[a]	53.15[a]	72.48[b]	79.80[b]
FSM	74.68[a]	93.22[a]	84.21[a]	52.43[a]	86.43[ab]	81.31[ab]
CSM	75.73[a]	92.54[a]	81.20[a]	52.21[a]	75.91[b]	77.98[b]
FCSM	75.96[a]	93.41[a]	83.31[a]	55.21[a]	85.70[ab]	80.21[ab]
MSE	1.98	2.88	1 .43	1.99	1.54	2.98
Sig.	*	*	*	*	*	*

[a-b-c]: Values in the same column with different superscripts differ significantly (P≤0.05). CON= control, SM= *Streptococcus macedonicus*, F= fenugreek, C= cinnamon, FSM= fenugreek + SM, CSM= cinnamon + SM and FCSM= fenugreek + cinnamon + SM. DM= dry matter, OM= organic matter, CP= crude protein, CF= crude fiber, EE= ether extracts, NFE= nitrogen free extract.

On the other hand**, Zeweil *et al.*, (2016)** agreed with our results, who documented that cinnamon supplementation significantly (P≤0.05) improved the digestibility of DM, OM, CP, CF, EE, and NFE and also improved the nutritive values of nutrients such as TDN and DCP in comparison with control. **Kamel (2001)** indicated that various kinds of plant extracts, including herbs and spices, have antibacterial properties as well as a capacity to promote digestion and starvation. Different compounds with fundamental bioactivities for animal physiology and metabolism can be found in plant extracts.

We are unable to determine the precise mechanisms through which these products affect growth performance and gut bacteria. Considering our incomplete comprehension of the underlying mechanisms, the plant extract has obvious antibacterial properties (**Dorman and Deans, 2000**).

Hematological parameters:

Results in Table 6 showed that all hematological parameters in control group were significantly ($P \leq 0.05$) decreased through the Egyptian summer season; however, a general significant ($P \leq 0.05$) increases in **RBCs**, **WBCs**, **Hb**, **PCV% WBCs** and **IgG** due to the different feed additives in comparison with control group was observed.

Our results documented that the control group had fewer values during heat stress compared to all treatments. These results are in agreement with those observed by **Ludders (2004),** who recorded that breathing (thermal panting) is a method by which the body discharges heat; it involves increasing the rate of respiration while lowering tidal volume. Also, **Comito *et al.*, (2007)** confirm that heat and thermal panting may reduce the production of hemoglobin. **Hassan *et al.*, (2016)** and **Abdelnasir *et al.*, (2013)** reported that the administration of fenugreek to rabbits results in enhanced erythrogram (RBCs, Hb, PCV% and blood indices) and immunological profiles (WBCs count, differential leukocytes count, phagocytic activity, and phagocytic index). Results of our study recommended improvement and rise in hematological parameters, as agreed with **Abdel-Azeem *et al.*, (2022)** and **Zeweil *et al.*, (2016**) who recorded significantly increased RBCs, WBCs and PCV% with cinnamon in rabbits. Interestingly, **Moataz *et al.*, (2017)** revealed that supplemented fed rabbit with probiotic and prebiotic recorded significant higher hemoglobin, RBCs, platelets and improved cell-mediated immunity compared to control group.

Similarly, **Doaa and Moshira (2015)** recorded that dietary rabbit supplementation of prebiotic and probiotic and their mixture improves cell-mediated immune response phagocytic activity, phagocytic index, and total leukocytes count, when compared with control group. In addition**, Sjofjan *et al.*, (2021)** noted that the mechanism by which probiotic additives to diet led to an elevation of the level of total protein and albumin (Table 7) is a good indicator of the level of immune-globulins and improved immune systems in rabbits.

Table 6. Synergistic effect of natural a dative on blood hematology and IgG in blood plasma of growing male rabbits

Tr	Hb, (g/100 ml)	RBCs ($\times10^6$/ml)	WBCs ($\times10^3$/ml)	PCV (%)	IgG (mg/dl)
CON	9.04^{c}	4.72^{b}	3.42^{b}	31.43^{c}	209.60^{c}
SM	12.13^{a}	5.56^{a}	5.11^{a}	39.42^{b}	346.22^{b}
F	11.21^{a}	5.78^{a}	5.29^{a}	41.22^{ab}	389.31^{b}
C	11.39^{ab}	5.98^{a}	5.63^{a}	44.13^{a}	441.30^{a}
FSM	11.97^{a}	5.91^{a}	5.38^{a}	42.17^{ab}	420.12^{ab}
CSM	12.29^{a}	5.89^{a}	5.89^{a}	43.89^{ab}	429.91^{ab}
FCSM	11.45^{a}	5.81^{a}	5.34^{a}	42.23^{ab}	427.23^{ab}
MSE	0.55	0.43	0.91	1.23	18.67
Sig.	*	*	*	*	*

$^{a-b-c}$: Values in the same column with different superscripts differ significantly ($P\leq0.05$). CON= control, SM= *Streptococcus macedonicus*, F= fenugreek, C= cinnamon, FSM= fenugreek + SM, CSM= cinnamon + SM and FCSM= fenugreek + cinnamon + SM. Hb= Hemoglobin; RBCs= Red blood cells count; WBCs= White blood cells count and IgG = Immunoglobulin G.

Lipid profile and antioxidant parameters:

Table 7 shows the mean value of lipid profile parameters;there was a significant ($P\leq0.05$) reduction in plasma total lipid (TL), tri-glycerides (TG), total cholesterol (TC), LDL, VLDL, and MDA, while augmented HDL and TAC in all treatment groups as compared to their control. Our findings are consistent with those reported by **Megh and Prema (2014), Abdel-Azeem (2006),** and **Zeweil *et al.*, (2008),** who stated that after a period of eight weeks of treatment using fenugreek, there was an important reduction in the values of TC, TG, and VLDL. The majority of the phenolic chemicals found in fenugreek seeds are flavonoids. The fenugreek was shown to contain hydroxyl-isoleucine, an amino acid compound (**Sharma, 1986**). According to **Belaid *et al.*, (2012),** fenugreek's activity on adipocytes and liver cells results in decreased production of TG and TC, as well as a higher absorption of LDL by LDL receptors, which in effect reduces TC levels. In this context, **Salim (2012)** reported that fenugreek seeds significantly decreased plasma malondialdehyde (MDA) levels and significantly increased plasma glutathione (GSH) levels in rabbits. These clearly indicate that fenugreek is a natural antioxidant. Also, **Zeweil *et al.*, (2015)** and **Marine *et al.*, (2020)** mentioned that increased total antioxidant capacity and glutathione peroxidase and catalase enzymes significantly increased at the same

Table 7. Synergistic effect of natural a dative on lipid profile and antioxidant status in blood plasma of growing male rabbits

	Parameters							
Tr	**TL, mg/dl**	**TG, mg/dl**	**TC, mg/dl**	**HDL, mg/dl**	**LDL, mg/dl**	**V-LDL, mg/dl**	**TAC, µm/l**	**MDA, nmol/ml**
CON	247.00[a]	65.66[a]	95.66[a]	33.66[c]	48.89[a]	13.13[a]	1.60[b]	20.11[a]
SM	207.16[b]	59.44[b]	75.12[b]	42.11[ab]	21.12[b]	11.89[b]	2.31[a]	17.11[b]
F	211.32[b]	57.98[b]	72.98[b]	40.19[ab]	20.34[b]	11.60[b]	2.09[a]	16.67[b]
C	201.00[b]	60.00[b]	74.00[b]	39.20[b]	21.80[b]	12.00[b]	2.27[a]	16.20[b]
FSM	200.79[b]	58.99[b]	74.21[b]	40.32[ab]	22.09[b]	11.80[b]	2.38[a]	17.23[b]
CSM	214.38[b]	57.78[b]	73.31[b]	41.21[ab]	20.54[b]	11.56[b]	2.54[a]	16.98[b]
FCSM	216.27[b]	55.67[b]	75.16[b]	44.01[a]	20.01[b]	11.14[b]	2.61[a]	16.87[b]
MSE	12.33	1.22	1.87	5.70	6.54	0.87	0.43	1.05
Sig.	*	*	*	*	*	*	*	*

[a-b-c]: Values in the same column with different superscripts differ significantly (P≤0.05). CON= control, SM= *Streptococcus macedonicus*, F= fenugreek, C= cinnamon, FSM= fenugreek + SM, CSM= cinnamon + SM and FCSM= fenugreek + cinnamon + SM. TL= Total lipids, TG= Triglycerides, TC= Total cholesterol, HDL= High density lipoprotein, LDL= Low density lipoprotein, VLDL=Very low lipoprotein. TAC=Total antioxidant capacity, MDA= Malonaylaldehayed.

time diminishing MDA with fenugreek-containing diets as compared with control. Interestingly, **Zeweil *et al.*, (2016)** demonstrated that adding cinnamon to the feed led to an improvement in lipid profile, increased TAC concentrations, glutathione peroxidase activities, and reduced MDA in compare with the control group. The same results were obtained by **Hemmati *et al.*, (2018),** who reported that major bioactive components in cinnamon contribute to the antioxidant activity, enhancing the activities of catalase (CAT), superoxide dismutase (SOD), and glutathione peroxidase (GPx) in supplemented diet mice. On the other hand**, Azam *et al.*, (2018)** mentioned that cinnamon significantly increased serum TAC and diminishing MDA, as well as significantly improved serum levels of TC, LDL and HDL**.**

Regarding the probiotic effect on lipid profile and antioxidants, **Meroni and Dongiovanni (2019** and **2023)** recorded that rabbits consumed a diet supplemented with probiotics showed improved lipid profile by decreasing circulating TC, HDL, LDL, TG and increased antioxidants. In addition, **Sjofjan *et al.*, (2021)** noted that probiotic additives to diets are involved in a reduction in TG levels by lowering lipid transport to the blood. El-Sawy *et al.*, (2023) found that liver enzymes (AST and ALT) were decreased mathematically in rabbits treated with probiotics FIDAL and EM1, while, triglycerides and total cholesterol were increased significantly in same rabbits groups compared to control group.

Blood parameters:

Data presented in Table 8 illustrated significant increases in TP, Alb, and Glo and declines in some metabolic enzymes, such as AST and ALT, while levels of urea and creatinine were found to be insignificant in rabbits fed diets supplemented with fenugreek seed, cinnamon, and probiotic (*Streptococcus macedonicus*), which reflect safety of the liver and kidney. These results were in agreement with findings by **Abdel-Azeem (2006)**, who found that broilers fed diet-supplemented with fenugreek had decreased plasma AST and uric acid compared to the control group, but serum TP, Alb, and Glo concentrations were significantly increased by supplementation. On the other hand, **Zeweil *et al.*, (2008)** reported that serum urea-N concentration was not affected by fenugreek additive.

Table 8. Synergistic effect of natural a dative on blood parameters of growing male rabbits

	Parameters						
Tr	**TP, (g/dl)**	**Alb, (g/dl)**	**Glo, (g/dl)**	**AST, (U/l)**	**ALT, (U/l)**	**Urea, (mg/dl)**	**Creatinine, (mg/dl)**
CON	5.91^{b}	3.2^{b}	2.70^{b}	45.22^{a}	60.34^{a}	29.17	0.56
SM	6.98^{a}	3.9^{a}	3.08^{a}	39.96^{b}	54.31^{b}	28.27	0.51
F	7.20^{a}	4.1^{a}	3.10^{a}	39.66^{b}	52.75^{b}	26.44	0.55
C	7.18^{a}	3.8^{a}	3.38^{a}	40.31^{b}	53.17^{b}	32.67	0.57
FSM	7.07^{a}	3.8^{a}	3.17^{a}	40.43^{b}	50.67^{b}	31.45	0.54
CSM	7.31^{a}	3.9^{a}	3.41^{a}	38.89^{b}	51.23^{b}	30.21	0.50
FCSM	7.12^{a}	3.7^{a}	3.42^{a}	37.87^{b}	49.89^{b}	29.88	0.52
MSE	0.14	0.09	0.20	1.04	1.34	1.08	0.06
Sig.	*	*	*	*	*	NS	NS

$^{a-b-c}$: Values in the same column with different superscripts differ significantly ($P \leq 0.05$). CON= control, SM= *Streptococcus macedonicus*, F= fenugreek, C= cinnamon, FSM= fenugreek + SM, CSM= cinnamon + SM and FCSM= fenugreek + cinnamon + SM. TP= Total protein, Alb= Albumin, Glo= Globulin, AST= Aspartate aminotransferase, ALT= Alanine aminotransferase.

Otherwise, **El-Nomeary *et al.*, (2020)**, reported that cinnamon powder consumption significantly reduced the serum levels of urea and AST in rabbit blood plasma. As reported by **Abd-El-Rahman *et al.*, (2016**), fed including fenugreek seed or cinnamon, or agro-industrial by-products, significantly improved blood TP, Alb, Glo, and urea. **Mahpara *et al.*, (2016)** reported that cinnamon supplementation has no adverse impacts on the physiology and morphology of normal, healthy kidneys in rats fed a diet; so, kidney is safe. On the other hand, **Doaa and Moshira (2015)** reported that there was a significant decrease in creatinine and ALT, AST and urea-N in groups fed experimental diets containing probiotics compared with the control group. At same line, **Adli *et al.*, (2023)** reported that there was significant decrease in creatinine and ALT, AST and urea in groups fed experimental diets contains probiotic compared with control group. **El-Sawy *et al.*, (2023)**showed insignificant differences in plasma TP and its fractions (ALB and GL) but globulin was higher mathematically in rabbits treated with probiotics FIDAL and EM1 compared to control.

Economic evaluation:

Economic efficiency is defined as the net revenue per unit feed cost calculated from input output analysis as described by **El-Speiy *et al.*, (2015)**. Results presented in Table 9 show that all groups supplemented with SM, F,C and their combinations were significantly ($P \leq 0.05$) improved economic efficiency and relative economic efficiency compared with control.Results indicated that supplemented growing rabbits, including SM, F and C showed improved FBW, net profit, net revenue, economic efficiency and relative economic efficiency in compared with control. While, groups received combination treatments (FSM, CSM and FCSM) were recorded the highest FBW, net profit, net revenue, economic efficiency and relative economic efficiency in compared with all other groups. These differences in relative economic efficiency (REE) showed that diet contained medicinal plants were more economical than the control diet and could be used economical as growth promoters. These improvements could be attributed to the better findings obtained either in growth performance, feed utilization of rabbits or reducing the amount of feed required to produce BWG. Results similarly with **El-Sawy *et al.*, (2023)** who found that the rabbits which received drinking water supplemented with 0.5 ml/l of probiotic FIDAL achieved the best relative economic efficiency, followed by those received 1 ml/l of probiotic EM1 compared with control group. Morever, FIDAL and EM1 were significantly higher net profit and net revenue in compared to control **(El-Sawy *et al.*, 2023)**. **Kalma *et al.*, (2018)** found that supplementation of probiotics (*Saccharomyces cerevisiae or Lactobacillus sporogenes*) in rabbit diets improved economic returns. **El-Adawy *et al.*, (2000)** recorded the highest economic efficiency value with the addition of probiotics. **Abdel-Azeem *et al.*, (2009)** observed the best net return, percentage of economic efficiency, relative economic efficiency, and cost performance index due to rabbit probiotic consumption. **El-Katcha *et al.*, (2011)** indicated that dietary supplementation of probiotics in the diet improves economic efficiency.

Table 9. Synergistic effect of natural a dative on economic evaluation of growing male rabbits

Items	Experimental groups						
	CON	SM	F	C	FSM	CSM	FCSM
Final body weight,kg(A	1.82^{b}	2.02^{ab}	2.01^{ab}	2.06^{ab}	2.26^{a}	2.29^{a}	2.30^{a}
body weight price, L.E./kg (B)	110	110	110	110	110	110	110
Net profit, L.E./rabbit (C)**	200.2^{c}	222.2^{b}	221.1^{b}	226.6^{b}	248.6^{a}	251.9^{a}	253.0^{a}
Total feed consumed, kg (D)	4.07^{c}	4.20^{b}	4.26^{b}	4.38^{a}	4.32^{a}	4.37^{a}	4.38^{a}
Price of kg feed, L.E.(E)	17.00	17.00	17.00	17.00	17.00	17.00	17.00
Feed cost, L.E. (F)**	69.19	71.40	72.42	74.46	73.44	74.29	74.46
Weaned rabbits cost, L.E. (J)	60	60	60	60	60	60	60
Additives cost/rabbit/L.]	0	0.84	0.86	1.31	1.70	2.15	3.01
Total cost, L.E. (H)**	129.19	132.24	133.28	135.77	134.14	136.44	137.47
Net revenue L.E. (I)**	71.01^{c}	89.96^{b}	87.82^{b}	90.83^{b}	113.46^{a}	115.46^{a}	115.47^{a}
Economic efficiency (G)**	54.97^{c}	68.03^{b}	65.89^{b}	66.90^{b}	83.96^{a}	84.62^{a}	83.99^{a}
REE (K)**	100	123.76	119.87	121.70	152.74	153.94	152.79

[a-b-c]: Values in the same column with different superscripts differ significantly (P≤0.05). CON= control, SM= *Streptococcus macedonicus*, F= fenugreek, C= cinnamon, FSM= fenugreek + SM, CSM= cinnamon + SM and FCSM= fenugreek + cinnamon + SM.weaning live rabbit + electricity + vaccination …. ect,
** C= A×B, F= D×E, H= F+J, I= C-H, G= I/H×100, K= G of treatment/G of control×100.
Price of 1kg fenugreek = 40 L.E, 1Kg Probiotic = 50 L.E, 1Kg cinnamon = 200 LE, according to price in July 2023., REE(%):Relative economic efficiency

Conclusively, from these results, it could be recommended that *Streptococcus macedonicus*, fenugreek and cinnamon and their combinations supplementation in heat stressed Californian growing rabbit's diets showed the most beneficial effect under hot climate.

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التأثيرالتآزري للمكونات الحيوية والبروبيوتيك على الأداءالإنتاجي والفسيولوجي للأرانب النامية تحت ظروف المناخ الحار

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أجريت هذه التجربة لدراسة تاثير المكونات الحيوية و البروبيوتك غلى الأداء الإنتاجي والفسيولوجي للأرانب النامية. تم توزيع ٧٠ أرنب ذكر كاليفورنيا عمر ٥ أسابيع بوزن إبتدائى متوسط٥٩٥ ـ ٦١٠ جم بشكل عشوائي في سبعة مجموعات تجريبية بعدد ١٠ بكل معاملة، المجموعة الأولى غذيت علي العليقة الأساسية كمجموعة مقارنة، المجموعة الثانية والثالثة والرابعة تم إضافة البروبيوتيك (SM) وبذور الحلبة (F) ومسحوق القرفة (C) للعلائق بمقدار ١، ٥ و٥.١جرام/كجم علف بينما كانت المجموعات الخامسة والسادسة والسابعة (FSM، CSM وFCSM) خليط من الحلبة والقرفة والبروبيوتك طوال فترة التجربة والتى إستمرت ٧ أسابيع (من عمر ٥ أسابيع حتى ١٢ أسبوع).

أظهرت النتائج تحسنا معنويا في وزن الجسم النهائي (FBW)، وزيادة وزن الجسم المكتسب (BWG)، ونسبة التحويل الغذائي (FCR) للأرانب خلال الفترة التجريبية بأكملها بين كل المعاملات ومجموعة المقارنة. ومن المثيرللاهتمام أن مجموعات FSM وCSM وFCS، التي استهلكت الحلبة أوالقرفة مع البروبيوتيك حققت أثقل FBW و BWGوسجلت أفضل FCR عندعمر ١٢ أسبوعً. ولوحظ وجود تأثيرمعنوي في الأوزان النسبية للذبيحة والكلية والكبد والقلب في جميع المجموعات التجريبية مقارنة مع مجموعة

المقارنة. تحسنت قابلية هضم DM،OM ، CP،CF،EE،وNFE مع جميع الإضافات مقارنة مع الكنترول. لوحظ انخفاض جميع مؤشرات الدم في مجموعة المقارنة معنويا (P<0.05) خلال موسم الصيف المصري؛ ومع ذلك ،لوحظ وجود زيادة معنوية عامة (P<0.05) في عدد كرات الدم الحمراء ،عدد كرات الدم البيضاء ،الهيموجلوبين وPCV٪ بسبب اختلاف الإضافات الغذائية مقارنة مع مجموعة االمقارنة. من ناحية أخرى، زادت أعداد كرات الدم البيضاء ومستوى IgG نتيجة لإستخدام الإضافات المختلفة.كان هناك انخفاض معنوي (P<0.05) في الدهون الكلية في البلازما (TL)، الجليسريدات الثلاثية (TG)، الكوليسترول الكلي ((TC، LDL،VLDL،وMDA، في حين تم زيادة HDL و TACفي جميع المجموعات المعاملة مقارنة مع مجموعة الكنترول. وقد لوحظ زيادة كبيرة في TP وAlb وGlo وانخفاض في بعض الإنزيمات الأيضية ،مثل AST وALT ، في حين وجد أن مستويات اليوريا والكرياتينين غيرذات أهمية في الأرانب التي تتغذى على وجبات غذائية مكملة ببذور الحلبة والقرفة والبروبيوتيك والتي تعكس سلامة الكبد والكلى. فى جميع المجموعات المضاف إلى علائقه SM ،F ،C وخلطانها تحسنت معنوياً (P<0.05) في صافي الربح وصافي الإيرادات والكفاءة الاقتصادية والكفاءة الاقتصادية النسبية مقارنة مع مجموعة الكنترول. بينما سجلت المجموعات التي حصلت على خلطات (FSM ،CSM وFCSM) أعلى صافي ربح وصافي إيرادات و كفاءة اقتصادية وكفاءة اقتصادية نسبية مقارنة بجميع المجموعات الأخرى. أظهرت هذه الاختلافات في الكفاءة الاقتصادية النسبية (REE) أن النظام الغذائي الذي يحتوي على نباتات طبية كان أكثر اقتصاديا من النظام الغذائي التقليدى ويمكن استخدامها اقتصاديا كمحفز للنمو.

التوصية: إن إضافة بكتيريا *Streptococcus macedonicus* كـ بروبيوتيك والحلبة والقرفة وخلطاتها في علائق نمو الأرانب أظهرت التأثيرالأكثر فائدة في ظل المناخ الحار.