**Eastern Journal of Agricultural and Biological Sciences (EJABS)**
**ISSN: 2753-3247**
**Website: https://qabasjournals.com/index.php/ejabs**

# Phytogenics and essential oil supplementation in rabbit and monogastrate production, a panacea to improved animal production and antibiotic resistance challenge in Nigeria

Anaso, Emmanuel Ugochukwu

*Department of Animal Science, University of Abuja, Abuja, Nigeria*
**Corresponding Author:** Anaso, Emmanuel Ugochukwu; E-mail: dranasoeub@gmail.com

**ARTICLE INFO**

**Received**: March 15, 2023
**Accepted**: April 25, 2023
**Volume**: 3
**Issue**: 2

**KEYWORDS**

Essential oils, phytogenic, antibiotic resistance, lipid peroxidation, rabbits, monogastric, livestock.

**ABSTRACT**

Antibiotic resistance, lipid peroxidation and poor animal performance have been a challenge endemic in the tropics, most especially in Nigeria. Lack of adherence to antibiotic withdrawal periods by farmers and animal producers and high temperature occasioned in the tropics have caused a major problem in the health and agricultural sectors respectively. Antibiotics resistivity in the long run leads to cancer in final consumers. Lipid peroxidation on the other hand caused by high temperature leading to oxidative stress conditions have been found to be a precursor to meat deterioration or spoilage.
This review examines the supplementation or administration of essential oils, its effects on several growth, health and general body parameters. The research adopts qualitative approach to analysis which relied on secondary sources like journals, textbooks, newspapers and online publications. It is concluded that the supplementation and administration of essential oils and several phytogenic could proffer a solution to the problem of antibiotic resistivity and lipid peroxidation, which directly enhances consumer health and boosts animal production. The review recommends that government at all levels work together with universities, agricultural research institutes, ministries of agriculture and veterinary pharmaceutical companies to designate and encourage extraction of essential oils in these perilous times.

## 1. Introduction

There is a steady rise in the demand for animal protein due to the rapid growth of human population and increased incomes along with changing preferences (FAO, 2009). In Nigeria, the acute scarcity of meat due to farmer-herder crises, global pandemic and poor economic policies has compelled livestock farmers to improve feed resources utilisation, health status and meat production from their animals (Anaso *et al*., 2021). This shortage can be bridged by the farming of highly prolific monogastrates with short production cycles like rabbits.

Rabbits possess high fertility and rapid growth rates, thereby characterizing them an excellent source of meat and protein of animal origin (Dalle and Zotte, 2002). Rabbit meat is characterized as high quality due to adequate animal protein and polyunsaturated fatty acids, and low calories (El-gogary *et al*., 2018). Tropical climate characterized due to its high temperature (heat) is a major climatic factor invariably affecting rabbit farming/production. Rabbits enormously depend on respiratory evaporation for the regulation of their body temperature and this confers only a limited power of adaption to hot climates (Mailafia *et al*., 2010). Lipid peroxidation is a major problem in rabbit's production caused by oxidative stress leading to end product (meat) deterioration (El-gogary *et al*., 2018). Furthermore, lipid oxidation adversely impacts the meat quality as it causes the formation of some toxic compounds and malondialdehyde (MDA). The latter has been reported to negatively influence human's health (Koné *et al*., 2016; Cardinali *et al*., 2015).

Recently, feed additives other than antibiotics and ionophores have been used to enhance feed utilisation, and productive and reproductive performance of rabbits (Dhama *et al*., 2015; Tufarelli *et al*., 2017; Ismail *et al*., 2019). Feed additives have been utilised in diets of ruminants (Kholif *et al*., 2017, 2020; Morsy *et al*., 2018) and recently in the diets of monogastric such as horses (Elghandour *et al*., 2014, Elghandour *et al*., 2016) and rabbits (Cervantes-Valencia *et al*., 2015; Abo Hafsa *et al*., 2016; Gado *et al*., 2016) to improve feed efficiency and animal health. Feed additives, such as essential oils (EOs), spices and herbs, have been successfully utilised in animal feed to decrease

total mesophilic aerobes, *Pseudomonas spp*. and *Entero bacteriaceae* (Soultos *et al*., 2009; Koné *et al*., 2016; Tufarelli *et al*., 2017).

The recent ban on antibiotic growth promoters by several countries and the jeopardy of antibiotic resistant bacteria have compelled the search for alternatives of improving animal productivity and minimizing adverse effects on human consumers. Due to this ban, extensive research has been conducted to explore the use of phytogenics as alternate feed additives in animal nutrition. Phytogenic substances such as essential oils are generally regarded as safe and are frequently used in the food and feed industries. The impact of EOs, as a phytogenic feed substance, on the intestinal health, antioxidant status and antimicrobial activity in livestock is considered vital for the biological activities (Ahmed and Abdallah, 2020).

Essential oils or volatile oils are mainly aromatic oily liquids extracted by distillation from plant parts, such as flowers, buds, seeds, leaves, twigs, bark, wood, fruits and roots (Miguel, 2010). They are steam-volatile or rather organic-solvent extracts which have so far been used traditionally for many centuries in various parts of the world. They are basically known to have pleasant flavour and aroma, as well as preservative properties. EOs usually contain a rich amount of different compounds, such as terpenes, alcohols, acetones, phenols, acids, aldehydes and esters (Negi, 2012). These substances can exert defensive roles against bacterial, fungal or insect attacks. Studies on EOs have reported several positive effects on feed utilisation, animal health and live performance of rabbits (Celia *et al*., 2016).

## 2. Literature Review

*The following are the factors of essential oil supplementation to be considered*;

I. Voluntary feed intake, digestibility and body weight gain
II. Apparent digestibility and nutrient utilization
III. Blood profile and oxidative stress indices
IV. Effects of essential oil and factors affecting semen characteristics
V. Effect of essential oil on body thermoregulatory parameters
VI. Effect of essential oil on carcass characteristics and meat quality
VII. Effect of essential oil on microbial profile

### *I. Voluntary feed intake, digestibility and body weight gain*

El-Nomeary *et al*. (2020) recommended the use of several essential oils such as cinnamon, garlic and juniper essential oils as supplemented in the basal diet as feed additives at 0.5ml /kg in rabbit diets without adverse effect on the rabbit general performance and showed positive effects in digestion and growth. The experiment was conducted using about 72 male New-Zealand White rabbits after weaning. Juniper EO significantly decreased the crude protein digestibility by about 5.5% and the fibre digestibility by about 3.3% as compared to the control. Garlic EO significantly increased the body weight by about 12.4% and the average body weight gain by about 12.4%, compared to the control group. Adding cinnamon and juniper EOs to diets led to a significant reduction in the daily dry matter intake as compared to the control group.

Similarly, Ahmed *et al*. (2019) reported dry matter digestibility and digestible energy significantly increased with rabbit fed dietary supplementation of phytogenics and EO such as betaine (BET) and thyme oil (THY). The control group was fed a basal diet without supplementation (T1), whereas the other groups were fed the same basal diet supplemented with 1500 mg BET (T2), 750 mg BET (T3), 1000 mg THY (T4), 500 mg THY (T5), 1500 mg BET and 1000 mg THY (T6), 1500 mg BET and 500 mg THY (T7), 750 mg BET and 1000 mg THY (T8), 750 mg BET and 500 mg THY (T9). The results similarly proved that feed dry matter digestibility and digestible energy were significantly improved with rabbit fed T2, T3, T4, T6, and T9 diets. In contrast to El-Nomeary *et al*. (2020), Ahmed *et al*. (2019) reported a significant reduction in total volatile fatty acids and ammonia nitrogen concentration of cecum content was recorded with rabbits fed T4, T5, T7, T8 and T9 diets compared with (T1) those fed the control diet in an eight week experiment using a total number of 72 growing New Zealand white (NZW) male rabbits divided into 9 experimental groups. It was concluded that Dietary supplementation with 1500 mg betaine or 1000 mg thyme oil/kg diet or mixture of theme with the same levels are recommended to improve the feed utilization and growth performance parameters and health status of NZW rabbits.

Al-Sagheer *et al*. (2017) concluded from experiment investigating the effects of supplemental dietary extra virgin olive oil (EVOO), gallic acid (GA), or lemongrass essential oil (LGEO) on growth performance and nutrient digestibility that inclusion in growing rabbit's diet could be used effectively to alleviate negative impacts of heat stress load on performance, nutrient and digestibility.

Ahmed *et al*. (2018) reported that thyme EO inclusions of up to 100 mg/kg ration with 1.50 g/kg olive oil as a supplement in the ration of young / growing rabbits can be used as an effective feed additive to improve performance under hot environmental and stressful conditions.

### *II. Apparent digestibility and nutrient utilization*

The mode of action (MOA) of the bioactive compounds in EOs has not yet been properly fully explained. However, various mechanisms have been suggested for the MOA of EOs on nutrients digestion. Several authors have indicated that the use of EOs stimulates and enhance production of digestive enzyme (such as trypsin and amylase) activity (Jang *et al*., 2004), others a production and induction of a higher secretion of bile acids (Platel and Srinivasan, 2004). Ding *et al*., (2017) reported that the addition of the various / different experimental quantities of EOs to the laying hen's diet did not affect dry matter (DM) digestion. Radwan Nadia *et al*. (2008) detected that the addition of 0.5% to 1.0% of EOs from thyme, oregano, rosemary, or curcuma to laying hen's diet did not affect the digestibility of organic matter (OM). Yu *et al*. (2018) stated that adding different doses of anise oil (200, 400, and 600 mg/kg) increased the digestibility of OM in laying hens. Although it has been determined in some studies that the addition of EOs increased digestibility of crude protein (CP) in laying hens (Ding *et al*., 2017 and Yu *et al*., 2018).whereas in another research no effect was found (Radwan *et al*., 2008). However, Arslan *et al*. (2022) reported that the addition of EOs at 100 or 200 mg/kg increased the dry matter, organic matter, and crude protein digestion as compared to control.

### *III. Blood profile and oxidative stress indices*

Elghalid *et al*. (2020) reported that administration of lower (LA) and higher doses (HA) of a newly developed mixture of herbal plants and spices enriched with special extracts and essential oils decreased blood cholesterol, triglycerides and low-density lipoproteins; however, the LA treatment increased high-density lipoproteins and total antioxidant capacity but decreased malondialdehyde relative to the control treatment. The experiment was conducted using precisely ninety weaned unsexed V-Line rabbits, weighing 668.7±8.2g and aged 30±1days and were randomly distributed to three groups of 30 rabbits each and fed a basal diet without additives (Control rabbits) or supplemented with 0.5mL (LA) or 1mL (HA) of the additives mixture per litre of drinking water.

Similarly, El-Gogary *et al*. (2018) explained the efficacy of rosemary essential oil (REO), as feed additive, on growth and blood constituents of growing NZW rabbits. Precisely thirty six NZW were distributed into four groups: 1 control and 3 treated groups. The control was fed the basal diet, while feeds of other treatments were fortified with 0.25, 0.50 and 0.75 g/kg REO for groups 2, 3 and 4, respectively. It was therefore concluded that REO at 0.5 g/kg of diet has a beneficial impact on immunity and antioxidant status of rabbits.

Bassiony *et al*. (2015) similarly reported a significant improvement as compared to the control in some blood hematology WBC, RBC, Hb and Lymphocytes when a total number of seventy NZW male rabbits at about 5 weeks of age with similar / equal body weight were randomly allocated into seven treatment groups (10 rabbits in each group). The group one was fed the basal diet without supplementation as control. The group two, group three and group four were fed the basal diet supplemented with 50,100 and 200 mg cinnamaldehyde/Kg diet, respectively. The group five, group 6 and group seven were fed the basal diet supplemented with 50,100 and 200 mg thyme/kg diet respectively.

Similarly, Abdelnour *et al*. (2018), concluded that dietary red pepper oil (RPO) or black pepper oil (BPO) supplementation significantly increased growth in rabbits and improved the immunity parameters, improved anti-oxidant activity in a research conducted using 140 male New Zealand white growing weaned rabbits. Rabbits were randomly divided into seven groups (7 groups × 5 rabbits × 4 rooms). The study continued for eight weeks and ended at 13 weeks of age. The dietary treatments used were as follows: C: control; RPO 0.5: basal diet and 0.5 g RPO/kg diet; RPO1.0: basal diet and 1.0 g RPO/kg diet; RPO1.5: basal diet and 1.5 g RPO/kg diet; BPO0.5: basal diet and 0.5 g BPO/kg diet; BPO1.0: basal diet and 1.0 g BPO/kg diet; and BPO1.5: basal diet and 1.5 g BPO/kg diet.

### *IV. Effects of essential oil and factors affecting semen characteristics*

El-Ratel *et al*. (2021) reported that the supplementation of extra virgin olive oil (EVOO), betaine (BET), or ginger (GIN) improved the sexual desire (libido), progressive motility, vitality, intact acrosome and membrane integrity, sperm cell concentration, sperm outputs and fertility in rabbit bucks distributed randomly into four experimental treatments of precisely ten rabbits each. The first treatment was fed the commercial pellet diet (CPD) without supplementation and was designated as the control group. The other three treatments were fed same basal CPD supplemented with EVOO (300 mg), BET (1,000 mg), and GIN (200 mg) per kg diet for 3 consecutive months during the summer (warm) season.

Similar to previous finding, Ahmed and Abdallah (2020) revealed / showed that thyme essential oil (TEO) increased the sperm livability, sperm motility and ejaculate volume compared to positive control (PC) and negative control (NC) groups at the end of treatments. Abnormal sperm was significantly reduced with increasing TEO, compared to PC and NC groups in an experiment using a total of about one hundred and fifty 70-day-old male Californian rabbits assigned to five dietary treatments including a basal diet as a negative control, a basal diet was supplemented with an antibiotic as positive control and the basal diet was supplemented with 60, 120 or 180 mg/kg of TEO. The experiment period lasted for about 60 days.

### *V. Effect of essential oil on body thermoregulatory parameters of rabbits*

Daader *et al*. (2018) reported that extra virgin olive oil, betaine, lemongrass essential oil, gallic acid, vitamin C and vitamin E supplementations had positive and ameliorating effects on the rearing / growing of rabbits under a severe heat load in terms of lowered body temperatures. In this experiment, Rabbits were fed diets with no supplementation (designated as the control group) or supplemented with 15 g of extra virgin olive oil, 400 mg of lemongrass EO, 500 mg of garlic acid, 1000 mg of betaine, 500 mg of vitamin C, or 200 mg of vitamin E per kg of the basal diet.

### *VI. Effect of essential oil on carcass characteristics and meat quality*

Benlemlih *et al*. (2014) whose study was to compare the effect of dietary fennel and thyme essential oil supplementation with the effect of antibiotic on zootechnical parameters and caecal microflora of rabbits. Precisely 40 weaned rabbits of about 35 days old, white New Zealand, were divided (allocated) into two groups and submitted to two dietary treatments: EOFT (diet with essential oil of *Feoniculum vulgaris* and *Thymus capitatus*) and OTC (diet with oxytetracycline in drinking water). The mean carcass yield of OTC group was higher than EOFT group after about twenty five days of the experiment.

Contrary to the result of Benlemlih *et al*. (2014), Denli *et al*. (2004) reported that the supplementation of the diet of quail with thyme essential oil did not affect carcass yield and carcass weight.

Similarly, Bassiony *et al*. (2015) researched and evaluated the effect of using different levels of cinnamaldehyde and thymol as essential oil bioactive compounds on growth performance, carcass traits, some blood and caecum characteristics and economic efficiency of growing rabbits reported that the relative weight of the carcass, digestive tract, abdominal fat and caecum weight and length were not significantly affected by dietary treatments.

Rhouma *et al*. (2018) who conducted a study to evaluate the effect of different levels of thymol on zootechnical performances, caecal microflora and the quality of rabbit carcass during the summer season, similarly reported that the incorporation of thymol in the diet did not affect significantly carcass yields during the summer period.

### *VII. Effect of essential oil on microbial profile*

Elghalid *et al*. (2020), reported that both higher and lower dose mixture of herbal plants and spices enriched with special extracts and essential oil increased beneficial *Lactobacillus spp*. bacteria and decreased the concentrations of coliform bacteria and *E.coli* compared with the control treatment and concluded that additives mixture enhanced feed conversion and daily gain and positively altered caecal bacteria profile, with better resultant effects of the lower dose of the phytogenic additives mixture compared with the high dose.

Similarly, Rhouma *et al*. (2018) showed that the addition of thymol has a significant effect on the number of *E. coli* and *Lactobacilli*. Indeed, the number of *Lactobacilli* in the rabbits receiving the two doses of thymol was higher than the control group. In addition, this supplementation reduced the number of E. coli in treatment one. For this experiment, 90 rabbits (35 days old) were divided into three homogeneous groups: T: control with no thymol and the other two groups with thymol (T1 and T2) which received 200 and 300 g/T of the thymol, respectively. Each of the 3 diets was fed to replicates of 6 rabbits each from day 35 to 77.

Contrarily, Benlemlih *et al*. (2014) reported no difference on caecal count of *E.coli* and *C.perfringens* in both EOFT (diet with essential oil of *Feoniculum vulgaris* and *Thymus capitatus*) and OTC (diet with oxytetracycline in drinking water). In this experiment, 40 weaned rabbits (35 days old), white New Zealand, were divided into two groups and submitted to two dietary treatments: EOFT and OTC.

## 3. Conclusion

The problem of antibiotic resistance and lipid peroxidation leading to meat spoilage can be abated by harnessing the supplementation / administration of essential oils and phytogenics in Nigeria. Essential oils and phytogenics supplementation can be used as a supplement to antibiotics and guarantee better output and curb the menace associated with poor adherence to withdrawal periods. Empirical evidences of supplementation and administration of essential oils and phytogenics in the diets of livestock have been proven to improve their productivity without compromising their health abound.

**Recommendations**

Government at all levels should provide facilities for universities via the faculty of agriculture, agricultural research institutes and ministries of agriculture for further research and collaborations with veterinary pharmaceutical companies on the extraction procedures which is cheap and simple, thereby boosting production levels. Governments at all levels should also prioritise legislations outlawing unlawful use of antibiotics where essential oils and phytogenic feed substances can be utilised in animal's diet to maximize productivity.

**Conflicts of Interest**

The author declares no conflict of interest in the design, collection, writing of the manuscript and decision to publish this review.

**References**

Abdelnour, S., Alagawany, M., Abd El-Hack, M.E., Sheiha, A.M., Saadeldin, I.M. and Swelum, A.A. (2018). Growth, Carcass Traits, Blood Hematology, Serum Metabolites, Immunity, and Oxidative Indices of Growing Rabbits Fed Diets Supplemented with Red or Black Pepper Oils. *Animals* 8: 168.

Abo Hafsa, S.H., Salem, A.Z.M., Hassan, A.A., Kholif, A.E., Elghandour, M.M.Y., Barbabosa, A. and Lopez, S. (2016). Digestion, growth performance and caecal fermentation in growing rabbits fed diets containing foliage of browse trees. *World Rabbit Science* 24: 283–293.

Ahmed E. Abd El-Azeem*, Adham A. Al-Sagheer, A.H. Daader and S.M. Bassiony. (2019). Effect of dietary supplementation with betaine, thyme oil and their mixtures on productive performance of growing rabbits. *Zagazig Journal of Agricultural Research* 46(3).

Ahmed, A.A.A. and Abdallah, E.M. (2020). Effects of dietary phytogenic supplementation on performance, semen quality and serum biochemical of rabbits. *Research square* https://doi.org/10.21203/rs.3.rs-28978/v1

Al-Sagheer, A.A., Daader A.H., Gabr, H.A. and Abd El-Moniem, E.A. (2017). Palliative effects of extra virgin olive oil, gallic acid, and lemongrass oil dietary supplementation on growth performance, digestibility, carcass traits, and antioxidant status of heat-stressed growing New Zealand White rabbits. *Environmental Science and Pollution Research* 24: 6807–6818.

Anaso, E.U., Olafadehan, O.A. and Oluwafemi, R.A. (2021). Biodegradation of agro industrial by products as a panacea to feed scarcity in Nigeria amidst farmer insecurity and global pandemic. *Proceedings of the 46th Annual Nigerian Society for Animal Production Conference, Dutsin-Ma,* Nigeria, pp. 616 - 620.

Arslan, C., Pirinc, A., Eker, N., Sur, E., Undag, I. and Kusat, T. (2022). Dietary encapsulated essential oil mixture influence on apparent nutrient digestibility, serum metabolic profile, lymphocyte histochemistry and intestinal morphology of laying hens. *Animal Bioscience* 35(5):740-751.

Bassiony, S.S.M., Elhindawy, M.M., Attia, A.E. and Ismail, I.E. (2015). Effect of some bioactive components of essential oils on growing rabbits performance. *Zagazig Journal of Agricultural Research* 42(5).

Benlemlih, M., Aarab, A., Bakkali, M., Arakrak, A. and Laglaoui, A. (2014). Effect of dietary fennel and thyme essential oil supplementation on zootechnical parameters and caecal microflora of growing rabbit. *Revue Microbiologie Industrielle, Sanitaire, et Environnementale* 8(1):16-25.

Cardinali, R., Cullere, M., Dal Bosco, A., Mugnai, C., Ruggeri, S., Mattioli, S. and DalleZotte, A. (2015). Oregano, rosemary and vitamin E dietary supplementation in growing rabbits: Effect on growth performance, carcass traits, bone development and meat chemical composition. *Livestock Science* 175: 83-89.

Celia, C., Cullere, M., Gerencsér, Z.S., Matics, Z.S., Giaccone,V., Kovács, M., Bónai, A., Szendro, Z.S., Dalle Zotte, A., Matics, Z.S., Celia,C., Dalle Zotte, A., Szendrő, Z., KOvács, M., Cullere, M., Giaccone, V., Dalle Zotte, A. (2016). Dietary supplementation of Digestarom® herbal formulation: effect on apparent digestibility, faecal and caecal microbial counts and live performance of growing rabbits. *World Rabbit Science* 24: 95–105.

Cervantes-Valencia, M.E., Alcala-Canto, Y., Salem, A.Z.M., Kholif, A.E., Ducoing-Watty, A.M., Bernad-Bernad, M.J., Gutiérrez-Olvera, C. (2015). Influence of curcumin (*Curcumalonga*) as a natural anticoccidial alternative in adult rabbits. *Italian Journal of Animal Sci*ence 14: 299–303.

Daader, A.H., Al-Sagheer, A.A., Gabr, H.A. and Abd El-Moniem, E.A. (2018). Alleviation of heat-stress-related physiological perturbations in growing rabbits using natural antioxidants. *Spanish Journal of Agricultural Research* 16(3):163-13184.

DalleZotte, A. (2002). Perception of rabbit meat quality and major factors influencing the rabbit carcass and meat quality. *Livestock Production Science* 75:11–32.

Denli M., Okan F. and Uluocak A. M. (2004): Effect of dietary supplementation of herb essential oils on the growth performance carcass and intestinal characteristics of quail (*Coturnix coturnix japonica*). *South African Journal of Animal Science* 34:174-179.

Dhama, K., Latheef, S.K., Mani, S., Samad, H.A., Karthik, K., Tiwari, R., Khan, R.U., Alagawany, M., Farag, M.R., Alam, G.M., Laudadio, V. and Tufarelli, V. (2015). Multiple beneficial applications and modes of action of herbs in poultry health and production-a review. *International Journal of Pharmacology* 11: 152–176.

Ding, X., Yu, Y., Su, Z. and Zhang, K. (2017). Effects of essential oils on performance, egg quality, nutrient digestibility and yolk fatty acid profile in laying hens. *Journal of Animal Nutrition* 3:127-31. https://doi.org/10.1016/j.aninu.2017.03.005.

El-Azeem, A.A.A., Al-Sagheer, A.A., Daader, A.H. and Bassiony, S.M. (2019). Effect of dietary supplementation with betaine, thyme oil and their mixtures on productive performance of growing rabbits. *Zagazig Journal of Agricultural Res*earch 46(3).

Elghalid, O.A., Kholif, A.E., El-Ashry, G.M., Matloup, O.H., Olafadehan, O.A., El-Raffaa, A.M and AbdEl-Hadya, A.M. (2020). Oral supplementation of the diet of growing rabbits with a newly developed mixture of herbal plants and spices enriched with special extracts and essential oils affects their productive performance and immune status. *Livestock Science* 238: 104082.

Elghandour, M.M.Y., Kholif, A.E., López, S., Mendoza, G.D., Odongo, N.E. and Salem, A.Z.M. (2016). *In vitro* gas, methane and carbondioxide productions of high fibrous diet incubated with fecal inocula from horses in response to the supplementation with different live yeast additives. *Journal of Equine Veterinary Science* 38: 64–71.

Elghandour, M.M.Y., Vázquez Chagoyán, J.C., Salem, A.Z.M., Kholif, A.E., Martínez Castañeda, J.S., Camacho, L.M. and Buendía, G. (2014). In vitro fermentative capacity of equine fecal inocula of 9 fibrous forages in the presence of different doses of *Saccharomyces cerevisiae*. *Journal of Equine Veterinary Science* 34: 619–625.

El-Gogary, M. R., Mansour, A. M. and El-Said, E. A. (2018). Blood biochemical and immunological responses to garlic oil administration in growing rabbit's diet. *Journal of Agricultural Science* 10(1): 217-224.

El-Gogary, M.R., El-Said, E.A. and Mansour, A.M. (2018). Physiological and immunological effects of rosemary essential oil in growing rabbit diets. *Journal Agricultural Science* 10: 485.

El-Nomeary, Y.A.A., Abedo, A.A. Fatma, M., Salman, Abo Sedera, S, Soad, M. Nasr Somia,. Nassar, A and Ibraheim, Sh.A.M. (2020). Effect of adding cinnamon, garlic and juniper essential oils on productive performance of New-Zealand White rabbits. *Egyptian Journal of Nutrition and Feeds* 23(3): 409-424.

El-Ratel, I.T., Attia, K.A.H., El-Raghi, A.A. and Fouda, S.F. (2021). Relief of the negative effects of heat stress on semen quality, reproductive efficiency and oxidative capacity of rabbit bucks using different natural antioxidants. *Animal bioscience* 34(5): 844-854.

FAO. (2009). Food Security and Agricultural Mitigation in Developing Countries:Options for Capturing Synergies. Rome, Italy. www.fao.org/docrep/012/i1318e/i1318e00.pdf.

Gado, H.M., Kholif, A.E., Salem, A.Z.M., Elghandour, M.M.Y., Olafadehan, O.A., Martinez, M.A. and AlMomani, A.Q. (2016). Fertility, mortality, milk output and body thermoregulation of growing Hy-Plusrabbits fed on diets supplemented with multi-enzymes preparation. *Tropical Animal Health and Production* 48: 1375–1380.

Ismail, I.E. and Bealish, A.M.A. (2014). Effect of acetic acid addition on growth and some physiological and immunological characteristics of growing rabbits. *Egyptian Journal of Rabbit Science* 24 (1): 19 – 34.

Jang, I.S., Ko, Y.H. and Yang, H.Y. (2004). Influence of essential oil components on growth performance and the functional activity of the pancreas and small intestine in broiler chickens. Asian-Australas *Journal of Animal Science* 17:394-400. https://doi.org/ 10.5713/ajas.2004.394.

Kholif, A.E., Hassan, A.A., ElAshry, G.M., Bakr, M.H., El-Zaiat, H.M., Olafadehan, O.A., Matloup, O.H. and Sallam, S.M.A. (2020). Phytogenic feed additives mixture enhances the lactational performance, feed utilization and ruminal fermentation of Friesian cows. *Journal of Animal Biotechnology* .inpress.10.1080/10495398.2020.1746322.

Koné, A.P., Cinq-Mars, D., Desjardins, Y., Guay, F., Gosselin, A. and Saucier, L. (2016). Effects of plant extracts and essential oils as feed supplements on quality and microbial traits of rabbit meat. *World Rabbit Science* 24: 107-119.

Mailafia, S., Onakpa, M.M. and Owoleke O.E. (2010). Problems and prospects of rabbit production in Nigeria – a review 2010 *Bayero Journal of Pure and Applied Sciences* 3(2): 20 – 25.

Miguel MG (2010) Antioxidant activity of medicinal and aromatic plants. A review. *Flavour Frag Journal* 25: 291-312.

Morsy, T.A., Kholif, A.E., Matloup, O.H., Abu Elella, A., Anele, U.Y. and Caton, J.S. (2018). Mustard and cumin seeds improve feed utilisation, milk production and milk fatty acids of Damascus goats. *Journal Dairy Research* 85: 142–151.

Negi, P.S. (2012) Plant extracts for the control of bacterial growth: Efficacy, stability and safety issues for food application. *International Journal of Food Microbiology* 156: 7-17.

Platel, K. and Srinivasan, K. (2004). Digestive stimulant action of spices: a myth or reality? *Indian Journal of Medical Research* 119:167-79.

Radwan Nadia, L., Hassan, R.A., Qota, E.M. and Fayek, H.M. (2008). Effect of natural antioxidant on oxidative stability of eggs and productive and reproductive performance of laying hens. *International Journal of Poultry Science* 7:134-50. https://doi.org/10.3923/ijps. 2008.134.150

Rhouma, R.B., Abbassi Mohamed, M.S. and Boubaker, A. (2018). Effects of supplementing diets with thymol on performance growth and caecal microflora of growing rabbit. *Journal of new sciences, Agriculture and Biotechnology* 57(1): 3693-3697.

Soultos, N., Tzikas, Z., Christaki, E., Papageorgiou, K. and Steris, V. (2009). The effect of dietary oregano essential oil on microbial growth of rabbit carcasses during refrigerated storage. *Meat Science* 81: 474–478.

Tufarelli, V., Casalino, E., D'Alessandro, A.G. and Laudadio, V. (2017). Dietary phenolic compounds: biochemistry, metabolism and significance in animal and human health. *Current Drug Metabolism*.18.https://doi.org/10.2174/1389200218666170925124004.

Yu, C., Guo, Y., Yang, Z., Yang, W. and Jiang, S. (2018). Effects of star anise (*Illicium verum Hook.f.*) essential oil on nutrient and energy utilization of laying hens. *Animal Science Journal* 90:880-6. https:// doi.org/10.1111/asj.13221.