

Effect of the nanoencapsulation of three essential oils on productive parameters and meat quality in Perú breed Guinea pigs

Efecto de la nanoencapsulación de tres aceites esenciales sobre los parámetros productivos y calidad de carne en cuyes de la raza Perú

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ABSTRACT

This research aimed to evaluate of nanoencapsulated essential oils of soursop, lemon, and eucalyptus as natural alternative growth promoters on productive parameters and meat quality in Guinea pigs compared to a commercial promoter. One hundred both sex Guinea pigs were used, randomly distributed into 5 treatments using completely randomized design; T0: commercial feed + 500 g of zinc bacitracin/t of feed, T1: Balanced feed + 33.4% soursop essential oils + 33.3% lemon essential oils + 33.3% eucalyptus essential oils, T2: Balanced feed + 50% soursop essential oils + 25% lemon essential oils + 25% eucalyptus essential oils, T3: Balanced feed + 50% lemon essential oils + 25% soursop essential oils + 25% eucalyptus essential oils, and T4: Balanced feed + 50% eucalyptus essential oils + 25% soursop essential oils + 25% lemon essential oils, at a dose of 75 g·t⁻¹ of feed. The Guinea pigs were subjected to productive characteristics and meat quality. Data obtained was analysis using analysis of variance followed by Tukey's test to identify statistically significant differences. Statistically significant differences ($P<0.05$) were observed in weight gain, carcass weight, carcass yield, and meat pH. The results indicated that nano–encapsulated essential plant oils could effectively replace commercial growth promoters due to their positive impact on productive parameters. Furthermore, these natural alternatives produced meat of comparable quality to the chemical growth promoter in terms of dry matter percentage, ash content, abdominal fat weight, and water retention capacity.

Key words: Guinea pigs; nanoencapsulated; essential oils; productive parameters; meat quality

RESUMEN

El objetivo de esta investigación fue evaluar la actividad de los aceites esenciales (EO) nano–encapsulados de guanábana, limón y eucalipto como un promotor de crecimiento alternativo en los parámetros productivos y la calidad de la carne de cuyes. Se usaron 100 gazapos hembras y machos, distribuidos al azar en un diseño completamente aleatorizado en 5 tratamientos. Estos fueron: T0: alimento balanceado + 500 g de bacitracina de zinc, T1: alimento comercial + 33.4 % del aceite esencial de guanábana aceites esenciales + 33.3 % de Limón aceites esenciales + 33.3 % de Eucalipto aceites esenciales, T2: alimento balanceado + 50 % de guanábana aceites esenciales + 25 % de Limón aceites esenciales + 25 % de Eucalipto aceites esenciales, T3: alimento balanceado + 50 % de Limón aceites esenciales + 25 % de guanábana aceites esenciales + 25 % de Eucalipto aceites esenciales y T4: Alimento balanceado + 50 % de Eucalipto aceites esenciales + 25 % de guanábana aceites esenciales + 25 % de Limón aceites esenciales. Se obtuvieron diferencias significativas para el aumento de peso, el peso de la carcasa, el rendimiento de la carcasa, así como el pH de la carne ($P<0.05$). Los aceites nano–encapsulados mejoraron los parámetros productivos y el pH de la carne. El valor nutricional de la carne y el porcentaje de retención de agua no muestran diferencias estadísticamente significativas entre los tratamientos ($P>0.05$). En conclusión, los aceites esenciales de guanábana, el eucalipto y el limón mejoran los parámetros productivos y mejoran parcialmente la calidad de la carne de cuyes.

Palabras clave: Cuyes; nanoencapsulado; aceites esenciales; parámetros productivos; calidad de la carne

INTRODUCTION

According to the seventh edition of the European Pharmacopoeia, essential oils (EOs) are defined as an aromatic product, generally with a complex composition, obtained from a botanically defined plant material, either by steam distillation, dry distillation, or by an appropriate mechanical method without the application of heat. An essential oil is generally separated from the aqueous phase by a physical method that does not result in significant changes to its chemical composition [1].

However, it is important to note that EOs are volatile and highly sensitive to physical and chemical degradation. They can easily break down when exposed directly to heat, moisture, light, and/or oxygen, which has limited their biological application [1].

Some antimicrobials, such as EOs, are highly volatile. Their direct incorporation can result in the loss of key characteristics of the product. Additionally, they exhibit low water solubility and are prone to oxidation, which can reduce their antimicrobial effectiveness during dosing [2], but the use of commercial and experimental phytobiotic additives represents an alternative to the excessive use of synthetic antibiotics, which act as growth promoters. These additives are administered to animals in the form of EOs, powders, and extracts to improve feed intake, weight gain, feed conversion ratio, final body weight, and carcass characteristics [3].

Encapsulation is an efficient pharmaceutical strategy to enhance the physical stability of active compounds, reduce their volatility, and thereby ensure their biological activity [1]. The encapsulation of active compounds is a relatively recent process, but rapid and significant advances have enabled its application across various industries, particularly in the pharmaceutical, cosmetic, and food sectors [3].

Encapsulation is a process in which an active component or core is trapped or coated by a matrix wall, isolating the bioactive molecule from the surrounding environment until it is released in response to external conditions such as pressure, pH, or temperature. The wall or carrier material can be selected from a wide range of natural or synthetic polymers, depending on the desired characteristics of the final product [4].

This process increases the solubility and bioavailability of the encapsulated substances, facilitates the packaging, transportation, and commercialization of EOs, masks undesirable properties such as odor and taste, and improves microbiological stability. Additionally, it prevents degradation during processing and storage and allows the use of various innovative, rapid, and scalable techniques [5].

Nanoencapsulation, which involves packaging compounds within nanometric structures, utilizes a range of techniques, including physicochemical procedures (e.g., coacervation, emulsion evaporation, and hot-melt extrusion), chemical methods (such as interfacial polycondensation and gelation), and mechanical approaches (e.g., fluidized bed, spray drying, and supercritical fluids) [6].

The advantages of nanoencapsulation include the protection of active materials from environmental conditions like heat, light, and humidity, as well as improved handling ease, stability, antioxidant and anti-degradation properties, controlled release of active components, and enhanced bioavailability [7].

Citrus fruit oils have been evaluated as potential alternatives to chemically based antimicrobials due to their constituent compounds. In particular, the limonene chemotype has demonstrated a broad spectrum of antimicrobial activity, proving effective against *Staphylococcus aureus*, *Listeria monocytogenes*, *Salmonella enterica*, and *Saccharomyces bayanus* [8].

The fatty acids present in soursop seed oil include palmitic acid, oleic acid, stearic acid, linoleic acid, and linolenic acid, which are widely used in the food, pharmaceutical, and cosmetic industries [9]. The fatty acid composition of soursop seed oil is a chemical characteristic not only useful for verifying its purity but also from a nutritional standpoint. The intake of oleic acid reduces cholesterol levels and low-density lipoproteins. The consumption of unsaturated fatty acids, such as linoleic acid, may help in the prevention of cancer, heart disease and hypertension [10].

The agricultural industry is seeking alternatives to antibiotics due to resistance and health concerns. EOs are emerging as a natural and safe option to promote growth and maintain animal health. They have strong antimicrobial properties, effectively inhibiting pathogens like *Salmonella*, *Listeria*, and *Candida* [11].

These oils also support gut health, boost immunity, improve meat quality, and provide antioxidative benefits [12, 13]. Being natural and residue-free, they meet consumer demands for organic and sustainable production [14].

Additionally, they enhance feed efficiency and palatability, aiding sustainable farming [15]. With antibiotic bans in regions like the EU, research continues to explore their full potential, making EOs a promising alternative for sustainable animal production [14, 16].

EOs found at the intracellular level in eucalyptus leaves include: eucalyptol (or cineole), α -pinene, aromadendrene, D-limonene, viridiflorene, and gurjunene, which produce beneficial effects on human health. The use of EOs to combat bacteria that can affect humans is an effective, economical, and environmentally friendly alternative to synthetic chemical compounds [17].

Research conducted on broiler chickens and laying hens using eucalyptus nanoencapsulates in greater proportions as an alternative growth promoter has improved production parameters and meat quality in broiler chickens, and egg production percentage and quality in laying hens [18, 19].

In broiler chickens (*Gallus gallus domesticus*), studies have been conducted to evaluate the effect of EOs on increasing weight gain, improving feed conversion, and enhancing overall productive parameters. These studies showed that a commercial blend of clove (*Syzygium aromaticum*) and oregano (*Origanum vulgare*) stimulates the birds' appetite, thereby improving feed conversion efficiency [20].

In an experiment involving the supplementation of microencapsulated EOs in broiler chickens, an increase in the height of intestinal villi and a reduction in crypt crypts of Lieberkühndepth were observed. The treatment with blue sage essential oil exhibited the greatest villus height and width, likely due to the presence of this compound. This indicates a larger absorptive surface area, resulting from increased mitotic activity of epithelial cells, which promotes epithelial renewal and thus enhances nutrient absorption [21].

According to Isabel and Santos [20], essential oils in animal feed improve the zootechnical parameters of broiler chickens. However, the duration of use, as well as the concentration and composition of these substances, are critical factors that lead to varying effects.

In laying hens (*Gallus gallus domesticus*), the addition of oregano extract was evaluated in terms of productive response and egg quality. Hens supplemented with the commercial product based on oregano extract at a rate of 250 g·t⁻¹ of feed showed a similar productive response to hens that consumed feed with 50 ppm of zinc Bacitracin as a growth-promoting antibiotic. The commercial oregano extract product also resulted in a reduction in the percentage of broken eggs [22].

Coliform bacteria such as *Escherichia coli* are responsible for many cases of diarrhea and general diseases in newly weaned piglets (*Sus scrofa domestica*). To avoid the use of antibiotics, EOs such as oregano and sage (*Salvia officinalis*) have been employed. This approach has been well accepted by producers because of its ease of application, therapeutic benefits, and economic advantages [23].

In pigs, EOs show effects similar to those observed in poultry, since both are non-ruminant animals and share many similarities in their digestive tracts. Oregano and sage EOs act as antioxidants, while St. John's Wort (*Hypericum perforatum*), garlic (*Allium sativum*), peppermint (*Mentha piperita*), rosemary, thyme (*Thymus vulgaris*), and juniper (*Juniperus communis*) enhance the productive performance of fattening pigs. These also support the digestibility of nutrients in the feed and improve nitrogen balance [24].

In the diet of weaned piglets, probiotics and essential oils used as phytochemical additives, have been shown to enhance the production of digestive secretions and nutrient absorption. They also reduce the influence of intestinal pathogens through strong antimicrobial action, exert antioxidant properties, and strengthen the animal's immune status, all of which help explain the improved performance observed in pigs. However, the mechanisms of action of essential oils are not fully understood, and limited information is available on the interactions between essential oils and feed ingredients or other feed additives, especially probiotics, prebiotics, and organic acids [25].

In growing and finishing pigs, EOs from a blend of thyme, rosemary (*Rosmarinus officinalis*), and oregano extract coated with starch (AROMEX®-ME, Delacon Co., Ltd., Steyregg, Austria) were tested. When 2 to 3% EOs were included in the dry matter-based diet, a positive effect on nutrient digestibility was observed. Additionally, greater animal growth was noted, although ammonia production also increased [26].

There are no or little published studies on the effect of nanoencapsulation of soursop, lemon, and eucalyptus essential oils on the productive parameters and meat quality in Guinea pigs (*Cavia porcellus*), which is the focus of this research.

MATERIALS AND METHODS

The research was conducted at the Guinea pig genetic improvement program (PMGC) facilities at the National University of Huancavelica and at the Animal Nutrition and Feeding Laboratory of the National University of Trujillo. The Guinea pigs were managed

according to the ethical guidelines for research, considered in University Council Resolution No.0361-2018/UNT [27].

Essential oil extraction

The soursop (*Annona muricata*) essential oil was obtained through the extrusion method. After collecting the soursop seeds, they were washed and dried in an oven (Pol-ekoaparatura, model SLN 15, Poland) at 70°C for 48 hours. Then, they were processed in an oil press extractor machine (Mill Power, India) at 100–105°C. The essential oils of lemon (*Citrus limon*) and eucalyptus (*Eucalypto globulus*) were extracted from the leaves using steam distillation with an essential oil extractor (Figmay, Argentina).

Nanoencapsulation preparation

Nanoencapsulated oils were prepared using the Nano Spray Dryer from Techno Search Process & Systems (Model: SPD-P-111-21/22-19, India). The ingredients required for the emulsions were Maltodextrin 15%, whey protein 5%, essential oil 15%, and distilled water 65%.

Feeding of Guinea pigs

The feed was pelletized and administered once a day throughout the growth and finishing phase. The feed was provided in individual feeders. The residual feed was weighed and recorded daily to calculate the daily consumption by difference. Water was provided ad libitum. The composition and nutritional value of the diet with nanoencapsulated oil is shown in TABLE I.

TABLE I
Composition and nutritional value of the diet with nano encapsulated oils for Guinea pigs

Ingredients	%
Bran	37.29
Molasses	1.00
Yellow corn	34.80
Soya cake – 48% cp	19.10
Alfalfa meal	5.44
DL-methionine	0.19
Calcium carbonate	1.50
Salt	0.05
Coccidiostat	0.05
Mycotoxin binder	0.05
Nanoencapsulates	0.08
Nutritional value:	
Crude protein	18.00
Digestible energy (kcal·kg ⁻¹)	2969.50
Lysine	0.87
Methionine	0.46
Methionine + cysteine	0.74
Calcium	0.80
Total phosphorus	0.41
Dry matter	88.71

Management of Guinea pigs

100 weaner Guinea pigs were randomly allotted in completely randomized design (CRD) into five treatments (T0, T1, T2, T3, T4), with 20 Guinea pigs per treatment, each Guinea pig constituting an experimental unit and housed in a metabolic cage.

The TABLE II shows the description of treatments. The control treatment (T0) used zinc bacitracin as a growth promoter at a dose of 500 g·t⁻¹ of feed, while the treatments with nanoencapsulates (T1, T2, T3, and T4) were dosed with 75 g·t⁻¹ of feed, this dose was determined in the research work by, Mendoza–Ordoñez *et al.* [18].

TABLE II Description of treatments	
Treatment	Description
T0	Balanced feed + Zinc bacitracin growth promoter
T1	Balanced feed + 33.4% Soursop Essential Oil + 33.3% Lemon Essential Oil + 33.3% Eucalyptus Essential Oil
T2	Balanced feed + 50% Soursop Essential Oil + 25% Lemon Essential Oil + 25% Eucalyptus Essential Oil
T3	Balanced feed + 50% Lemon Essential Oil + 25% Soursop Essential Oil + 25% Eucalyptus Essential Oil
T4	Balanced feed + 50% Eucalyptus Essential Oil + 25% Soursop Essential Oil + 25% Lemon Essential Oil

Productive performance and carcass characteristics

The Laboratory analyses were conducted following the guidelines provided by the Official Association of Analytical Chemists [28].

- Weight gain (g): Calculated by the difference between the final and initial weights of the Guinea pigs.
- Carcass weight (g): Weight of the Guinea pig minus its internal organs. The processing and hygiene of the meat were conducted according to the standards of the poultry health system outlined in the Peruvian Resolution No. 093-2010-AG–SENASA.
- Carcass yield (%): The ratio of carcass weight to live weight, multiplied by 100.
- Feed consumption (g): The total amount of feed supplied minus the feed rejected during the entire experimental period.
- Feed conversion (FCR): The ratio of feed intake to weight gain in Guinea pigs during the evaluation period.
- Dry matter percentage (%): Calculated by dividing the dry matter by the sample weight, multiplied by 100, using a Pol–eko drying oven, (model SMM53ECO15, Poland).
- Ash percentage: Determined from the inorganic residue of the meat sample after incinerating the dry sample at 600°C for 4 hours, using a Nabertherm muffle furnace (Germany).

- Protein percentage (%): Determined using the Kjeldahl method, with a Hannon micro Kjeldahl apparatus, model K9860, China.
- Abdominal fat weight (g): This refers to the fat that accumulates in the abdomen of the animals. The samples were weighed using a precision scale.
- Meat pH: Determined using a Hanna Instruments pH meter (model H12211, Romania).
- Water retention percentage (%): The water retention capacity of the meat was calculated by measuring the water loss via dripping under external force.

Statistical analysis

ANOVA based on a completely randomized design (CRD). In cases where statistically significant differences were found among treatment averages, at the 5 % significance level. Data processing was performed using Excel 2024, and statistical analysis was SPSS vs. 27.

RESULTS AND DISCUSSION

Productive characteristics of the Guinea pigs

The results for the productive characteristics of the Guinea pigs are shown in TABLE III. Statistically significant differences ($P<0.05$) were observed for weight gain, with the best weight gains achieved by treatments T1, T3, and T4, which were statistically superior to the control group (T0). Treatment T2 was statistically similar to both T0 and the best treatment.

For carcass weight, the best results were obtained with T1 and T3, which were statistically superior to T0 ($P<0.01$). Treatments T2 and T4 were statistically similar to both T0 and the best treatments.

For carcass yield, treatment T1 showed the best results, being statistically superior to T0 ($P<0.01$), whereas treatments T2, T3, and T4 were statistically similar to both T0 and T1. These results are in agreement with those published by Mendoza–Ordoñez *et al.* [18], who found that the use of nanoencapsulated essential oils of soursop, lemon, and eucalyptus in broiler chickens resulted in increased weight gain by 10.4 %, carcass weight by 9.6 %, carcass yield by 2.6 %, decreased feed intake by 0.6%, and improved feed conversion by 8.8 % in broiler chickens. Higher weight gain, better feed conversion, and higher carcass yield the control group. Similarly, a study in broiler chickens demonstrated that the EOs of oregano and clove stimulated the birds’ appetite, thereby improving feed conversion [20]. This also aligns with the findings of Mendoza–Ordoñez *et al.* [19], who used nanoencapsulated essential oils in the diets of laying hens, leading to improvements in egg production percentage, feed conversion, and egg quality. Similarly, in a study exploring the use of microencapsulated essential oils combined with organic acids (OAO) in piglets, a significant shift in the microbial community structure was observed in the cecum and colon. Dietary treatment with OAO increased the abundance of beneficial microbes, such as *Faecalibacterium* and *Muribaculaceae*, in the cecum and improved the apparent digestibility of nutrients. This suggests an overall improvement in gut health and a potential impact on the microbial population [29].

However, the results do not align with those of a study conducted on Guinea pigs using oregano essential oil, where no significant differences ($P>0.05$) were found in weight gain, feed consumption, and feed conversion [30]. Similarly, a study evaluating improved Guinea pig growth with oregano and an enzyme complex in the diet found no statistical differences ($P>0.05$) in the accumulated weight gain per Guinea pig and accumulated feed conversion [31].

TABLE III
Productive Characteristics of Guinea Pigs by Treatment

Parameters	T0	T1	T2	T3	T4	SEM	P value
Weight gain, g (15–70 d)	582.00 ^b	648.25 ^a	609.50 ^{ab}	649.75 ^a	662.00 ^a	7.85	0.040
Carcass weight, g (15–70 d)	698.80 ^b	773.95 ^a	742.30 ^{ab}	783.85 ^a	764.35 ^{ab}	8.39	0.009
Carcass yield, % (15–70 d)	69.86 ^b	72.21 ^a	71.11 ^{ab}	71.08 ^{ab}	71.14 ^{ab}	0.16	0.000
Feed consumption, g (15–70 d)	3330.29	3296.86	3343.43	3301.29	3291.43	28.53	0.976
Feed conversion (15–70 d)	5.77	5.19	5.73	5.13	5.01	0.11	0.100

a,b,c: Means with different superscripts within columns differ significantly ($P<0.05$). SEM: Standard error of the means. P-values associated with dietary treatment. T0: Balanced Feed + Zinc Bacitracin Growth Promoter. T1: Balanced Feed + 33.4% Soursop Essential Oil + 33.3% Lemon Essential Oil + 33.3% Eucalyptus Essential Oil. T2: Balanced Feed + 50% Soursop Essential Oil + 25% Lemon Essential Oil + 25% Eucalyptus Essential Oil. T3: Balanced Feed + 50% Lemon Essential Oil + 25% Soursop Essential Oil + 25% Eucalyptus Essential Oil. T4: Balanced Feed + 50% Eucalyptus Essential Oil + 25% Soursop Essential Oil + 25% Lemon Essential Oil

Food consumption and feed conversion characteristics of Guinea pigs

The characteristics of food consumption and feed conversion evaluated from 15 to 70 d of age in Guinea pigs (TABLE III) did not show statistically significant differences between the groups ($P>0.05$). However, a slightly higher numerical difference was observed in the treatments containing nanoencapsulated EOs for both of these characteristics. Studies on pigs supplemented with oregano oil (*Origanum vulgare* subsp. *hirtum*) and sage oil (*Salvia officinalis*), which act as antioxidants, and with St. John's Wort (*Hypericum perforatum*), garlic (*Allium sativum*), peppermint (*Mentha piperita*), rosemary (*Rosmarinus officinalis*), thyme (*Thymus vulgaris*), and juniper (*Juniperus communis*), have shown that these natural supplements increase the productive indices of fattening pigs and improve the digestibility of nutrients in the offered feed [23].

Similarly, in a study on the effects of supplementation with microencapsulated EOs from *Stachys arvensis* "Pedorra," *Eugenia punicifolia* "Unquia," and *Salvia sagittata* "Salvia Azul" on productive parameters and intestinal morphology in broiler chickens, the oils showed good potential as growth promoters. Specifically, the essential oil of *Salvia sagittata* "Salvia Azul" yielded the best results, improving the final weight, daily weight gain, feed conversion, and abdominal fat yield, while also positively influencing the development of intestinal villi height and width in broilers [21]. Studies have indicated that the incorporation of EOs into the diet of piglets can modify the microbial composition and enhance digestive function and metabolic profiles. EOs have been observed to increase beneficial bacterial populations, such as Lactobacillales,

and improve metabolic processes related to protein, amino acid, and lipid metabolism. This microbial and metabolic modulation contributes to a healthier intestinal architecture [32].

Meat quality of the Guinea pigs

The effects of supplementation with nanoencapsulated EOs in the diet of Guinea pigs on meat quality indicators are shown in TABLE IV. No statistically significant differences ($P>0.05$) were observed in the dry matter, ash, abdominal fat weight, protein, and water retention percentages. However, for the pH of the meat, the inclusion of nanoencapsulated oils in the Guinea pig diets lowered the meat pH, with highly significant differences observed between groups T1, T2, and T4 compared to T0 ($P<0.01$). Group T3 was statistically similar to T0 and the other groups.

Similarly, in a study evaluating the final weight and meat quality in Guinea pigs with different levels of oregano in the diet, it was suggested that feeding with alfalfa forage and balanced feed containing phytogenic additives, such as oregano at doses of 3 and 4 kg·t⁻¹ of balanced feed, resulted in similar weights compared to the control group without affecting the organoleptic indicators of the meat. This outcome is attributed to the favorable effects of the organic compounds in the supplemented oregano [33].

In contrast, the present study disagrees with Barraza-Santos *et al.* [34] research, the effect of oregano EOs on quail meat quality was evaluated. They found that the water retention capacity decreased, with statistical differences for this characteristic ($P<0.05$).

TABLE IV
Meat Quality Characteristics of Guinea Pigs

Parameters	T0	T1	T2	T3	T4	SEM	P value
% Dry Matter	32.9	30.23	29.47	36.07	31.67	1.03	0.300
% Ash	0.497	0.47	0.48	0.47	0.59	0.02	0.370
% Protein	19.5	19.85	19.97	19.85	20.05	0.14	0.070
Abdominal Fat Weight	0.747	1.62	1.49	0.98	1.77	0.24	0.070
Meat pH	6.89 ^a	6.36 ^b	6.32 ^b	6.71 ^{ab}	6.36 ^b	0.07	0.009
% Water Retention	69.89	71.28	65.63	67.16	66.38	1.54	0.790

a,b,c: Means with different superscripts within columns differ significantly ($P<0.05$). SEM: Standard error of the means. P-values associated with dietary treatment. T0: Balanced Feed + Zinc Bacitracin Growth Promoter. T1: Balanced Feed + 33.4% Soursop Essential Oil + 33.3% Lemon Essential Oil + 33.3% Eucalyptus Essential Oil. T2: Balanced Feed + 50% Soursop Essential Oil + 25% Lemon Essential Oil + 25% Eucalyptus Essential Oil. T3: Balanced Feed + 50% Lemon Essential Oil + 25% Soursop Essential Oil + 25% Eucalyptus Essential Oil. T4: Balanced Feed + 50% Eucalyptus Essential Oil + 25% Soursop Essential Oil + 25% Lemon Essential Oil

CONCLUSION

The supplementation of commercial feed with mixtures of nanoencapsulated essential oils of soursop, lemon, and eucalyptus significantly improved the productive performance of Guinea pigs compared with zinc bacitracin. In particular, treatments T1, T3, and T4 achieved the highest values of weight gain and carcass weight ($P<0.05$), without affecting feed intake or feed conversion.

In addition, a significant increase in carcass yield was observed in treatment T1 (72.21 %) compared to that in the control (69.86 %).

Similarly, no significant variations were found in the parameters of dry matter, ash, protein, abdominal fat, or water-holding capacity ($P>0.05$) indicating that the nutritional quality of the meat remained stable when using natural growth promoters. However, significant differences were observed in meat pH ($P=0.009$), where the control treatment (6.89) showed a higher value than to T1, T2, and T4, suggesting that supplementation with nanoencapsulated essential oils may help improve meat stability and preservation.

Overall, the results demonstrate that replacing the antibiotic growth promoter with mixtures of nanoencapsulated essential oils does not compromise the proximate composition of Guinea pig meat and may even enhance technological characteristics related to its postmortem quality. These findings suggest that the evaluated combinations of essential oils represent a natural and effective alternative to antibiotic growth promoters in Guinea pig feeding, contributing to improved productivity without compromising feed efficiency.

Conflict of interest

The authors declare no conflict of interest.

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