R. Bras. Zootec., 51:e20200203, 2022
https://doi.org/10.37496/rbz5120200203

Non-ruminants
Full-length research article

Revista Brasileira de Zootecnia

Brazilian Journal of Animal Science
e-ISSN 1806-9290
www.rbz.org.br

Effects of *Zingiber officinale* as a feed additive on productive parameters, carcass quality, and meat quality in growing rabbits

Juan Ocampo-López[1], Luisa Monserrat García-Vázquez[1], Maricela Ayala-Martínez[1], Sergio Soto-Simental[1], Armando Zepeda-Bastida[1]*

[1] Universidad Autónoma del Estado de Hidalgo, Instituto de Ciencias Agropecuarias, Tulancingo, Hidalgo, México.

***Corresponding author:**
azepeda@uaeh.edu.mx

Received: September 11, 2020
Accepted: August 8, 2021

How to cite: Ocampo-López, J.; García-Vázquez, L. M.; Ayala-Martínez, M.; Soto-Simental, S. and Zepeda-Bastida, A. 2022. Effects of *Zingiber officinale* as a feed additive on productive parameters, carcass quality, and meat quality in growing rabbits. Revista Brasileira de Zootecnia 51:e20200203.
https://doi.org/10.37496/rbz5120200203

ABSTRACT - The objective of this study was to evaluate the effects of ginger as an additive in the diet of fattening rabbits. Sixty weaned rabbits (35 days old) were randomly assigned to four groups (n = 15). Animals were fed *ad libitum* with a control diet or one of three experimental diets supplemented with 0.5, 1, and 2 g of ginger per 100 g of feed during 28 d. Weight gain in the final week of the experiment was significantly greater in rabbits fed ginger at 0.5 g/100 g of feed than in those fed ginger at 1 and 2 g/100 g of feed or the control diet. No significant differences in morphometric measurements were observed among the treatments, but higher values of live weight, carcass length, and carcass circumference were observed in rabbits treated with ginger than in those fed the control diet. Regarding carcass quality parameters involving the kidneys and empty gastrointestinal tract, we found that rabbits treated with ginger at 0.5 g/100 g of feed showed significant differences from those treated with ginger at 1 and 2 g/100 g of feed or the control diet. pH, water holding capacity, L*, and a* did not significantly differ among the treatments, although greater water holding capacity was observed in rabbits treated with ginger than in control rabbits. Parameter b* was significantly higher in rabbits fed ginger at 2 g/100 g of feed than in those fed at 0.5 and 1 g/100 g of feed and in the control. The results found suggest that ginger can be used as an additive in diets of fattening rabbits.

Keywords: ginger, medicinal plant, rabbit feed

1. Introduction

One of the main challenges in animal production is identifying diets that improve production parameters and carcass and meat quality. Much research aimed at improving carcass and meat quality has focused on the use of plants that contain bioactive compounds. In cuniculture, a very important health problem exists after animals are weaned, they show digestive disturbances that can cause infections; these disturbances are perhaps caused by dietary changes and the stress of weaning (Dalle Zotte et al., 2016). Various medicinal plants have been investigated as potential dietary sources of bioactive compounds with antioxidant or antimicrobial activity or as nutritional additives or supplements (Zeng et al., 2015; Dalle Zotte et al., 2016). These plants include ginger (Bhandari et al., 1988; Ibrahim et al., 2011; Mancini et al., 2018; Abdel-Gabbar et al., 2019), epazote (García-Vázquez et al., 2020), *Tithonia tubaeformis* (Zepeda-Bastida et al., 2019), bilberry pomace (Dabbou et al., 2017), oregano, rosemary (which contains vitamin E; Cardinali et al., 2015), onion, bilberry, and strawberry and their extracts (Kone et al., 2016).

Rabbit meat is considered a functional feed (Dalle Zotte and Szendrő, 2011) that is susceptible to lipid oxidation due to its chemical characteristics (Nakyinsige et al., 2014). Therefore, the use of nutritional additives is necessary to help counter this problem. One option is ginger, which is used as a medicinal

plant and human feed. Many bioactive compounds have been identified in ginger, such as phenols and terpenes. Ginger exhibits various biological activities, including antioxidant, anti-inflammatory, antimicrobial, and anticancer activities and prevention and control of neurodegenerative and cardiovascular diseases, obesity, diabetes mellitus, nausea induced by chemotherapy and respiratory disorders, and other conditions (Mao et al., 2019).

There is little evidence of the potential use of ginger in feeding growing rabbits; however, it can be used for this purpose, due to all abovementioned properties, and for the benefits as a feed additive it could have in production parameters and meat and carcass quality. The objective of the present work was to evaluate the effects of ginger as an additive in rabbit feed on productive parameters and carcass and meat quality in fattening rabbits; to be used as an additive, three different concentrations (0.5, 1, and 2 g) were used.

2. Material and Methods

2.1. Animals and treatments

The study was conducted in Tulancingo, Hidalgo, Mexico (20°06' N and 98°38' W). The research on animals was conducted according to the institutional committee on animal use (protocol no. CICUA/002/18).

Sixty weaned rabbits (35 days of age) were randomly assigned to three treatments (n = 15 by treatment and n = 5 by repetition). The rabbits (three) were housed for 28 days in single cages of 40 × 60 × 45 cm equipped with manual feeders and automatic drinkers. The average temperature inside the rabbit house was 20 °C. The rabbits were of the New Zealand, California, and English Pot breeds and had an average weight of 691.58±157.73 g. The feed was pelletised using a model SKJ120 pellet machine (Shandong, China) and provided *ad libitum* as isoproteic (16% of crude protein) and isoenergetic (2.5 Mcal kg^{-1} of digestible energy) diets. This study was performed using four treatments: control without ginger, and 0.5, 1, and 2 g of ginger per 100 g of feed (Table 1).

Table 1 - Ingredients and chemical composition of experimental diets

Item	Treatment (g of ginger per 100 g of feed)			
	Control	0.5	1	2
Ingredient (wet matter, %)				
Straw	16.10	16.11	15.92	15.64
Corn	18.13	17.64	17.64	18.25
Canola meal	7.70	7.71	7.71	6.84
Soybean meal	14.97	14.88	14.88	15.98
Sorghum	18.96	18.97	18.98	18.68
Molasses	2.48	2.48	2.48	2.48
Soybean husk	7.80	7.81	8.10	6.84
Bran wheat	10.89	10.90	10.31	10.31
Vitamin and mineral premix	2.96	2.96	2.96	2.96
Ginger	0.0	0.55	1.01	2.01
Calculated composition				
Crude protein (%)	16	16	16	16
Crude fiber (%)	13	13	13	13
Neutral detergent fiber (%)	28.3	28.3	28.3	28.3
Acid detergent fiber (%)	16.5	16.5	16.5	16.5
Digestible energy (Mcal kg^{-1})	2.5	2.5	2.5	2.5
Ca (%)	0.8	0.8	0.8	0.8
P (%)	0.5	0.5	0.5	0.5
Lysine (%)	0.8	0.8	0.8	0.8
Methionine (%)	0.2	0.2	0.2	0.2

Control: without ginger.

2.2. Growth performance

To determine growth performance during the experiment, live weight was determined each week. Feed intake was measured daily. Data were used to calculate daily weight gain (DWG, $g.d^{-1}$), total weight gain (TWG, g), and feed conversion ratio (FCR); FCR was determined in relation to the weight gained at the end of the experiment and the total feed intake.

2.3. Carcass quality

After the 28 days of fattening, the rabbits were slaughtered in the laboratory. There was no fasting before rabbit slaughter. Animals were weighed, stunned, and processed according to national legislation (NOM-033-SAG/ZOO-2014). Hot carcasses, liver, kidney, complete and empty digestive system, complete and empty bladder, heart, lungs, spleen, and skin were weighed, and the carcasses were stored under refrigeration at 4 °C for 24 h. *Post-mortem* animal weights were determined after slaughter. The length of each animal from the first to last caudal vertebra was measured using a measuring tape, and hip diameter was measured. Caudal extremities were cut between the distal tibial epiphysis and the tarsus (Blasco et al., 1993; Ouhayoun and Dalle Zotte, 1996).

2.4. Carcass jointing

Carcasses were divided after 24 h of refrigerated storage following Blasco et al. (1993), with some modifications: the head was cut at atlas level, the forequarter was obtained by cutting between the sixth and seventh ribs, the thoracic cage was determined by cutting at the last rib, loin was obtained by cutting between the sixth and seventh lumbar vertebrae, and the hind leg was obtained by cutting the abdominal wall transversally to the vertebral column. All these parts were weighed separately (Blasco et al., 1993; Ouhayoun and Dalle Zotte, 1996).

2.5. Meat quality

After 24 h of refrigeration, the cold carcass was weighed, and primary cuts were made to separate the head and the cranial, middle, and caudal parts (*longissimus dorsi*). Skeletal muscle, legs, and kidneys were dissected to separate and weigh the bone, fat, and meat. Meat quality parameters were measured in *longissimus dorsi*. pH was measured with a HANNA potentiometer equipped with a blade electrode for penetrating the meat. Colour was measured as indicated by the American Meat Science Association (AMSA, 2012) with a MicroOptix i-LAB VRV-300 handheld visible analysing colorimeter, which had been calibrated according to the manufacturer's instructions, with five measurements performed at five different points. A CIELab scale was used to measure parameters L*, a*, b*, c*, H, and C. Water holding capacity (WHC) was determined using the method of Honikel (1987), which involved placing 0.3 g of meat between two pieces of filter paper positioned between two plates of Plexiglass weighing 1 kg for 10 min; the paper and sample were then weighed to calculate WHC based on the weight difference.

2.6. Statistical analysis

All data were analysed according to a one-way experimental design. For all of the growth performance parameters—except total average daily weight gain, total weight gain, and feed conversion rate—, an analysis of variance accounting for repeated measures over time was used:

$$Y_{ijk} = \mu + t_i + \beta_i + (t*\beta)_j + \varepsilon_{ijk},$$

in which Y_{ijk} = dependent variable, μ = variable mean, t_i = day of the week of measurement, β_i = fixed effect of *i*-th rabbit of the group, $(t*\beta)_j$ = variable of the group of rabbits evaluated through day of the week, and ε_{ijk} = experimental error associated with observation Y_{ijk}.

For all other parameters, analysis of variance was carried out with feeding treatment as a fixed factor following the general linear model procedure of SAS software (Statistical Analysis System, 2004). The statistical model was as follows:

$$Y_{ij} = \mu + \beta_i + \varepsilon_{ij},$$

in which Y_{ij} = dependent variable; μ = variable mean; β_i = fixed effect of *i*-th rabbit of the group; and ε_{ij} = experimental error associated with observation Y_{ij}. When significant differences were found ($P<0.05$), Tukey's test was used for post hoc comparisons.

3. Results

3.1. Growth performance

The DWG and FCR during the fattening period of rabbits were analysed (Table 2). From week 1 to week 3, there were no differences in DWG; however, at week 4, DWG was significantly higher ($P<0.05$) in rabbits treated with ginger at 0.5 g/100 g of feed than in those in either in the control treatment or in the other two treatments (1 and 2 g/100 g of feed). Furthermore, rabbits fed ginger at 0.5 g/100 g of feed showed the highest FCR among the groups, which suggests that these animals were taking better advantage of the feed.

Table 2 - Growth performance of rabbits fed diets supplemented with ginger during the fattening period

Parameter	Treatment (g of ginger per 100 g of feed)			
	Control	0.5	1	2
DWG1 ($g.d^{-1}$)	50.41±14.27	48.18±5.38	50.42±6.44	51.33±12.52
DWG2 ($g.d^{-1}$)	42.02±10.59	42.59±4.34	42.71±6.70	42.99±5.29
DWG3 ($g.d^{-1}$)	38.57±8.24	36.63±8.03	36.28±4.96	40.42±6.02
DWG4 ($g.d^{-1}$)	38.04±7.36ab	43.69±10.44a	30.57±12.03b	33.33±16.01ab
ADWG ($g.d^{-1}$)	43.67±6.71	39.49±2.32	40.69±5.12	43.01±6.80
Total weight gain (g)	1222.91±187.96	1105.90±65.03	1139.33±143.56	1204.33±190.58
FCR	2.30±0.29	2.44±0.21	2.42±0.36	2.27±0.35

Control: without ginger.
DWG - daily weight gain; ADWG - average daily weight gain over the fattening period; FCR - feed conversion ratio.
ab - Different letters within rows indicate significant differences between treatments according to Tukey's test ($P<0.05$).

3.2. Carcass quality

The effect of ginger administered via feed on the quality of rabbit carcasses has been little studied. The morphometric variables (Table 3) did not show significant differences between the control and experimental treatments; however, compared with control rabbits, those treated with ginger (at all three concentrations) had higher values of all morphometric measures evaluated. Similar patterns were observed with respect to the carcass quality parameters (Table 4). Kidneys and empty gastrointestinal tract showed significantly higher values ($P<0.05$) in treatment with ginger at 0.5 g/100 g of feed than in the control group and the other two groups (1 and 2 g/100 g of feed), suggesting that the use of ginger is a good option during the fattening of rabbits.

3.3. Meat quality

Regarding meat quality, significant differences ($P<0.05$) were observed in the colour parameters (Table 5). Parameter L* was similar between control and treatment with ginger at 1 g/100 g of feed, but significantly different between each of these groups and both 0.5 and 2 g/100 g of feed. Parameter a* was similar between control and treatment with ginger at 2 g/100 g of feed but significantly different

between each of these groups and both treatments with ginger at 0.5 and 1 g/100 g of feed. Parameter b* significantly differed between treatment with ginger at 2 g/100 g of feed and each of control, 0.5, and 1 g/100 g of feed. pH was similar among the control and treatment groups. Water holding capacity did not significantly differ among groups, although the use of ginger resulted in higher values. Regarding leg parameters (empty body weight, meat, bone, and fat), no significant differences were observed between control and any of the ginger-treatment groups, although the use of ginger was associated with higher values of empty body weight, meat, and fat, which suggests that the use of ginger might increase the amount of meat obtained.

Table 3 - Morphometric measurements of rabbits fed ginger

Parameter	Treatment (g of ginger per 100 g of feed)			
	Control	0.5	1	2
Animal length (cm)	29.96±2.88	29.71±1.97	30.05±1.63	28.93±1.85
Live hip circumference (cm)	24.50±2.40	24.71±1.25	24.18±1.72	24.96±1.91
Live lumbar circumference (cm)	20.46±2.41	19.96±1.07	18.86±1.28	20.57±1.92
Carcass length (cm)	29.92±1.69	30.13±1.06	30.23±0.87	30.14±0.92
Carcass hip circumference (cm)	22.65±2.49	23.67±1.62	23.27±0.64	23.18±1.10
Carcass lumbar circumference (cm)	15.23±1.90	15.48±1.17	15.55±1.03	15.00±1.09
Skin (g)	259.31±65.62	256.58±36.02	265.09±29.81	276.07±53.94
Feet (g)	42.38±5.89	43.25±5.67	43.00±4.75	43.50±5.01

Control: without ginger.

Table 4 - Carcass quality parameters of rabbits fed ginger

Parameter	Treatment (g of ginger per 100 g of feed)			
	Control	0.5	1	2
Empty body weight (EBW; g)	1576.22±243.84	1420.11±311.75	1644.00±135.36	1599.10±144.90
Viscera (g.kg^{-1} EBW)	293.10±47.86	324.17±69.55	267.69±40.27	302.28±38.30
Full gastrointestinal tract (g.kg^{-1} EBW)	216.88±36.28	246.86±60.72	200.11±33.38	222.82±41.07
Full bladder (g.kg^{-1} EBW)	5.72±3.57	6.88±5.17	5.51±3.45	9.64±8.70
Heart (g.kg^{-1} EBW)	3.42±0.86	3.52±0.95	3.63±1.21	3.77±0.92
Lungs (g.kg^{-1} EBW)	9.28±3.56	9.51±3.01	7.34±2.05	8.20±1.92
Spleen (g.kg^{-1} EBW)	0.75±0.41	0.74±0.18	0.61±0.05	0.60±0.11
Liver (g.kg^{-1} EBW)	49.05±15.22	43.61±10.06	40.95±7.97	45.44±11.75
Kidneys (g.kg^{-1} EBW)	7.21±1.81ab	8.22±1.32a	6.58±0.79b	6.78±0.72ab
Empty gastrointestinal tract (g.kg^{-1} EBW)	102.05±19.44ab	117.18±25.98a	88.78±14.24b	99.80±14.73ab
Empty bladder (g.kg^{-1} EBW)	2.47±0.82	2.83±1.15	2.36±0.67	2.52±0.44
Hot carcass weight (g)	912.92±208.56	951.50±153.00	949.09±70.72	962.86±136.11
Carcass yield	45.06±12.63	47.02±3.02	46.70±1.98	45.16±11.81
Cold carcass weight (g.kg^{-1} EBW)	615.77±180.59	675.72±150.14	541.11±78.60	573.02±90.06
Kidney fat (g.kg^{-1} EBW)	11.48±7.91	13.36±5.62	10.84±5.17	8.89±3.71
Scapular fat (g.kg^{-1} EBW)	3.76±2.31	3.59±1.87	2.97±1.34	3.24±1.82
Head (g.kg^{-1} EBW)	58.65±13.54	66.08±17.67	52.79±5.51	56.38±8.43
Fore part carcass (g.kg^{-1} EBW)	147.69±42.99	163.88±33.34	126.71±18.76	134.14±22.32
Intermediate part carcass (g.kg^{-1} EBW)	63.93±21.07	67.85±19.94	55.99±10.99	60.60±13.60
Hind part carcass (g.kg^{-1} EBW)	121.53±40.61	125.37±27.86	103.57±14.90	107.00±17.16
Legs (g.kg^{-1} EBW)	209.65±60.32	235.23±52.72	187.99±26.51	199.99±31.58
Meat (g.kg^{-1} legs)	730.82±43.02	746.40±37.32	739.79±20.77	732.94±26.47
Bone (g.kg^{-1} legs)	241.71±42.24	229.07±33.26	230.94±18.91	238.53±23.28
Fat (g.kg^{-1} legs)	5.94±4.55	8.72±4.44	7.35±3.92	8.15±6.43

Control: without ginger.
a-b - Different letters within rows indicate significant differences between treatments according to Tukey's test (P<0.05).

Table 5 - Meat quality parameters of rabbits fed ginger

Parameter	Treatment (g of ginger per 100 g of feed)			
	Control	0.5	1	2
L*	57.87a	56.93ab	55.84a	57.13ab
a*	1.67a	0.49b	0.44b	1.14a
b*	7.46b	7.23b	7.95ab	8.56a
pH	5.55	5.60	5.52	5.65
WHC (%)	19.48	21.98	22.84	23.48

Control: without ginger.
WHC - water holding capacity.
ab - Different letters within rows indicate significant differences between treatments according to Tukey's test (P<0.05).

4. Discussion

4.1. Growth performance

The use of dietary ginger in rabbits has been little studied. Ibrahim et al. (2011), using 0.75% ginger in rabbit feed, obtained FCR results similar to those of the present study; however, Mancini et al. (2018), using 4 and 8 g of ginger in the diet, found no intergroup differences in productive parameters. Other plants have been used as feed additives to promote growth performance in rabbits (Dalle Zotte et al., 2016). Ayala-Martínez et al. (2020) showed that dietary rue at week 4 increased rabbit weight gain and FCR. Hernández-Martínez et al. (2017) found no differences in productive behaviour between rabbits fed *Trametes maxima* and rabbits fed a control diet. Cullere et al. (2016) used *Silybum marianum* as a supplement in rabbit diets and found no effect on productive parameters when it was included in the diet at 5 or 10 $g.kg^{-1}$. Kovitvadhi et al. (2016), using *Lythrum salicaria* as a feed supplement for growing rabbits, found no effect on growth performance. Ginger has been reported to have antioxidant, antibacterial, and anticancer activities (Mao et al., 2019); here, we found improvements in growth performance with ginger supplementation, perhaps due to a healthier digestive system.

4.2. Carcass quality

Ibrahim et al. (2011), using 0.75% ginger in rabbit feed, and Mancini et al. (2018), using 4 g and 8 g of ginger in the diet, reported no effects of ginger treatment on carcass quality. Although several other plants have been used in rabbit feed in previous studies, in general, no effects on carcass quality have been found. Zepeda-Bastida et al. (2019) found that *Tithonia tubaeformis* in rabbit feed increased kidney size relative to that of controls; similarly, we found that dietary ginger increased kidney size. Ayala-Martínez et al. (2020) showed that the use of rue in rabbit feed did not alter carcass quality; similarly, Cullere et al. (2016) found no effect of dietary *Silybum marianum* on rabbit carcass quality. Molina et al. (2018) replaced conventional ingredients with *Amaranthus dubius* at levels of up to 32% and did not observe a negative impact on carcass quality, suggesting that this plant could serve as a substitute for conventional ingredients in rabbit diets. Kovitvadhi et al. (2016) supplemented the diet of growing rabbits with *Lythrum salicaria* and found no effects on carcass quality traits; they suggested that this plant could be used to feed rabbits during the fattening period.

4.3. Meat quality

pH is associated with meat colour; low pH tends to result in low L* values, as observed in this study. Mancini et al. (2018), using 4 and 8 g of ginger in rabbit feed, reported pH values higher than those in the present study; however, they reported a* values similar to ours. Zepeda-Bastida et al. (2019), using *Tithonia tubaeformis*, and Ayala-Martínez et al. (2020), using rue, obtained L* and a* values significantly different between plant-treated and control rabbits, similar to the results of the present

study. Molina et al. (2018) found a lower pH (4.49) in rabbits fed *Amaranthus dubius* than in control rabbits. Kovitvadhi et al. (2016) reported L* values near 54 and a pH of 5.6 in rabbits fed *Lythrum salicaria*. The colour and pH of rabbit meat can be affected by age, breed, muscle type, sex, diet, and *ante-mortem* and *post-mortem* conditions, among other factors (Hulot and Ouhayoun, 1999; Dalle Zotte, 2002).

5. Conclusions

The inclusion of ginger as an additive in the diet for fattening rabbits can be considered a feeding strategy to improve the production parameters of rabbits, because it results in weight gain; likewise, the use of ginger improves carcass quality parameters (kidney, full gastrointestinal tract, and parameter b*).

Conflict of Interest

The authors declare no conflict of interest.

Author Contributions

Conceptualization: J. Ocampo-López, L.M. García-Vázquez, M. Ayala-Martínez, S. Soto-Simental and A. Zepeda-Bastida. Data curation: M. Ayala-Martínez, S. Soto-Simental and A. Zepeda-Bastida. Formal analysis: J. Ocampo-López, S. Soto-Simental and A. Zepeda-Bastida. Funding acquisition: A. Zepeda-Bastida. Investigation: L.M. García-Vázquez, M. Ayala-Martínez and A. Zepeda-Bastida. Methodology: J. Ocampo-López and S. Soto-Simental. Project administration: A. Zepeda-Bastida. Resources: J. Ocampo-López, L.M. García-Vázquez, M. Ayala-Martínez, S. Soto-Simental and A. Zepeda-Bastida. Supervision: M. Ayala-Martínez and S. Soto-Simental. Validation: L.M. García-Vázquez, M. Ayala-Martínez and A. Zepeda-Bastida. Visualization: M. Ayala-Martínez and S. Soto-Simental. Writing-original draft: J. Ocampo-López, L.M. García-Vázquez, M. Ayala-Martínez, S. Soto-Simental and A. Zepeda-Bastida. Writing-review & editing: A. Zepeda-Bastida.

Acknowledgments

The authors would like to thank the PRODEP program (Project number DSA/103.5/16/10281; SEP-PFCE 2018) for providing financial support to this work.

References

Abdel-Gabbar, M.; Ahmed, R. R.; Kandeil, M. A.; Mohamed, A. E. H. and Ali, S. M. 2019. Administration of ginger and/or thyme has ameliorative effects on liver and kidney functions of V-line rabbits: Histological and biochemical studies. Journal of Animal Physiology and Animal Nutrition 103:1758-1767. https://doi.org/10.1111/jpn.13166

AMSA - American Meat Science Association. 2012. Meat color measurement guidelines. American Meat Science Association, Champaign, IL, USA. Available at: <https://meatscience.org/publications-resources/printed-publications/amsa-meat-color-measurement-guidelines>. Accessed on: June 01, 2020.

Ayala-Martínez, M.; Zepeda-Bastida, A. and Soto-Simental, S. 2020. Dietary supplementation effects with *Ruta graveolens* on performance, carcass traits and meat quality on rabbits. Revista Mexicana de Ciencias Pecuarias 11:1220-1230. https://doi.org/10.22319/rmcp.v11i4.5460

Bhandari, U.; Sharma, J. N. and Zafar, R. 1998. The protective action of ethanolic ginger (*Zingiber officinale*) extract in cholesterol fed rabbits. Journal of Ethnopharmacology 61:167-171. https://doi.org/10.1016/s0378-8741(98)00026-9

Blasco, A.; Ouhayoun, J. and Masoero, G. 1993. Harmonization of criteria and terminology in rabbit meat research. World Rabbit Science 1:3-10. https://doi.org/10.4995/wrs.1993.189

Cardinali, R.; Cullere, M.; Dal Bosco, A.; Mugnai, C.; Ruggeri, S.; Mattioli, S.; Castellini, C.; Trabalza-Marinucci, M. and Dalle Zotte, 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. https://doi.org/10.1016/j.livsci.2015.02.010

Cullere, M.; Dalle Zotte, A.; Celia, C.; Renteria-Monterrubio, A. L.; Gerencsér, Z.; Szendró, Z.; Kovács, M.; Kachlek, M. L. and Matics, Z. 2016. Effect of *Silybum marianum* herb on the productive performance, carcass traits and meat quality of growing rabbits. Livestock Science 194:31-36. https://doi.org/10.1016/j.livsci.2016.10.012

Dabbou, S.; Renna, M.; Lussiana, C.; Gai, F.; Rotolo, L.; Kovitvadhi, A.; Brugiapaglia, A.; Helal, A. N.; Schiavone, A.; Zoccarato, I. and Gasco, L. 2017. *Bilberry pomace* in growing rabbit diets: effects on quality traits of hind leg meat. Italian Journal of Animal Science 16:371-379. https://doi.org/10.1080/1828051X.2017.1292413

Dalle Zotte, A. 2002. Perception of rabbit meat quality and major factors influencing the rabbit carcass and meat quality. Livestock Production Science 75:11-32. https://doi.org/10.1016/S0301-6226(01)00308-6

Dalle Zotte, A. and Szendrő, Z. 2011. The role of rabbit meat as functional food. Meat Science 88:319-331. https://doi.org/10.1016/j.meatsci.2011.02.017

Dalle Zotte, A.; Celia, C. and Szendrő, Z. 2016. Herbs and spices inclusion as feedstuff or additive in growing rabbit diets and as additive in rabbit meat: A review. Livestock Science 189:82-90. https://doi.org/10.1016/j.livsci.2016.04.024

García-Vázquez, L. M.; Zepeda-Bastida, A.; Ayala-Martínez, M. and Soto-Simental, S. 2020. Infusion of *Chenopodium ambrosioides* consumed by rabbits: effects on carcass, meat and burger quality. Food Science and Technology 40(Suppl. 2):451-457. https://doi.org/10.1590/fst.32819

Hernández-Martínez, C. A.; Maldonado Herrera, J. A.; Méndez-Zamora, G.; Hernández-Luna, C. E. and Gutiérrez-Soto, G. 2017. Enzymatic extract of *Trametes maxima* CU1 on productive parameters and carcass yield of rabbits. Canadian Journal of Animal Science 97:683-688. https://doi.org/10.1139/cjas-2016-0150

Honikel, K. O. 1987. How to measure the water-holding capacity of meat? Recommendation of standardized methods. p.129-142. In: Evaluation and control of meat quality in pigs. Current Topics in Veterinary Medicine and Animal Science, vol. 38. Tarrant, P. V.; Eikelenboom, G. and Monin, G., eds. Springer, Dordrecht.

Hulot, F. and Ouhayoun, J. 1999. Muscular pH and related traits in rabbits: A review. World Rabbit Science 7:15-36. https://doi.org/10.4995/wrs.1999.378

Ibrahim, S. A. M.; Omer, H. A. A.; Abedo, A. A.; Ali, F. A. F. and Abdel-Magid, S. S. 2011. Ginger root (*Zingiber officinale*) as feed additive in rabbit diets with two levels of protein. American-Eurasian Journal of Agricultural & Environmental Sciences 10:906-916.

Kone, 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. https://doi.org/10.4995/wrs.2016.3665

Kovitvadhi, A.; Gasco, L.; Ferrocino, I.; Rotolo, L.; Dabbou, S.; Malfatto, V.; Gai, F.; Peiretti, P. G.; Falzone, M.; Vignolini, C.; Cocolin, L. and Zoccarato, I. 2016. Effect of purple loosestrife (*Lythrum salicaria*) diet supplementation in rabbit nutrition on performance, digestibility, health and meat quality. Animal 10:10-18. https://doi.org/10.1017/S1751731115001822

Mancini, S.; Secci, G.; Preziuso, G.; Parisi, G. and Paci, G. 2018. Ginger (*Zingiber officinale Roscoe*) powder as dietary supplementation in rabbit: life performances, carcass characteristics and meat quality. Italian Journal of Animal Science 17:867-872. https://doi.org/10.1080/1828051X.2018.1427007

Mao, Q.-Q.; Xu, X.-Y.; Cao, S.-Y.; Gan, R.-Y.; Corke, H.; Beta, T. and Li, H.-B. 2019. Bioactive compounds and bioactivities of ginger (*Zingiber officinale Roscoe*). Foods 8:185. https://doi.org/10.3390/foods8060185

Molina, E.; González-Redondo, P.; Moreno-Rojas, R.; Montero-Quintero, K. and Sánchez-Urdaneta, A. 2018. Effect of the inclusion of *Amaranthus dubius* in diets on carcass characteristics and meat quality of fattening rabbits. Journal of Applied Animal Research 46:218-223. https://doi.org/10.1080/09712119.2017.1287078

Nakyinsige, K.; Fatimah, A. B.; Aghwan, Z. A.; Zulkifli, I.; Goh, Y. M. and Sazili, A. Q. 2014. Bleeding efficiency and meat oxidative stability and microbiological quality of New Zealand White rabbits subjected to halal slaughter without stunning and gas stun-killing. Asian-Australasian Journal of Animal Sciences 27:406-413. https://doi.org/10.5713/ajas.2013.13437

NOM-033-SAG/ZOO-2014. Norma Oficial Mexicana. Métodos para dar muerte a los animales domésticos y silvestres. Available at: <http://www.economia-noms.gob.mx/normas/noms/2010/033sagzoo2015.pdf>. Accessed on: May 15, 2020.

Ouhayoun, J. and Dalle Zotte, A. 1996. Harmonization of muscle and meat criteria in rabbit meat research. World Rabbit Science 4:211-218. https://doi.org/10.4995/wrs.1996.297

Zeng, Z.; Zhang, S.; Wang, H. and Piao, X. 2015. Essential oil and aromatic plants as feed additives in non-ruminant nutrition: a review. Journal of Animal Science and Biotechnology 6:7. https://doi.org/10.1186/s40104-015-0004-5

Zepeda-Bastida, A.; Ayala Martínez, M. and Soto Simental, S. 2019. Carcass and meat quality of rabbits fed *Tithonia tubaeformis* weed. Revista Brasileira de Zootecnia 48:e20190074. https://doi.org/10.1590/rbz4820190074