Research Article

Effect of Addition of Gambir (*Uncaria gambir*) Leaf Extract to the Diets on Some Productive Traits and Meat Quality of Goats

Antonius[1,3], Anuraga Jayanegara[2*], Komang Gede Wiryawan[2], Simon Petrus Ginting[3], Anjas Asmara Samsudin[4], Elizabeth Wina[5]

[1]Graduate School, IPB University, Gedung Sekolah Pascasarjana Lt. 1 Kampus IPB Dramaga Bogor 16680, Indonesia; [2]Department of Nutrition and Feed Technology, Faculty of Animal Science, IPB University, Jl. Agatis Kampus IPB Dramaga Bogor 16680, Indonesia; [3]Research Center for Animal Husbandry, National Research and Innovation Agency, Jl. Raya Jakarta Bogor Cibinong16915, Indonesia; [4]Department of Animal Science, Faculty of Agriculture, University of Putra Malaysia, 43400 UPM Serdang Selangor Darul Ehsan, Malaysia; [5]Indonesian Research Institute for Animal Production, Jl Veteran III Banjarwaru Ciawi Bogor 16720, Indonesia.

Abstract | Oxidation stress causes a decrease in goats' performance and meat quality. The objective of this experiment was to evaluate the impact of supplementing gambir (*Uncaria gambir*) leaf extract as a natural antioxidant source on goat performance and meat quality. A total of 18 Boerka goats (body weight of 21±2 kg) were divided randomly into three dietary treatments (six replicates each), specifically: T0 (basal diet without gambir supplementation), T1 (basal diet + 2 g/kg DM gambir extract), and T2 (basal diet + 4 g/kg DM gambir extract). Results revealed that addition of gambir extract did not alter the consumption of dry matter, organic matter, crude protein, crude fiber and crude fat. The T1 and T2 treatments resulted higher ($P<0.05$) average daily gain of 52.87% and 48.05% than that of control, respectively. The mutton tenderness level of T1 increased from tough scale in the control treatment to quite tender. In conclusion, gambir leaf extract addition did not negatively affect palatability and nutrient intake, increased average daily gain for Boerka goats, increased tenderness, and maintained physical quality and nutritional value of mutton.

Keywords | Average daily gain, Gambir, Meat quality, Tenderness

Received | April 21, 2022; **Accepted** | August 01, 2022; **Published** | November 20, 2022
***Correspondence** | Anuraga Jayanegara, Department of Nutrition and Feed Technology, Faculty of Animal Science, IPB University, Jl. Agatis Kampus IPB Dramaga Bogor 16680, Indonesia; **Email:** anuraga.jayanegara@gmail.com
Citation | Antonius, Jayanegara A, Wiryawan KG, Ginting SP, Samsudin AA, Wina E (2022). Effect of addition of gambir (*uncaria gambir*) leaf extract to the diets on some productive traits and meat quality of goats. J. Anim. Health Prod. 10(4): 515-521.
DOI | http://dx.doi.org/10.17582/journal.jahp/2022/10.4.515.521
ISSN | 2308-2801

INTRODUCTION

Growth performance and meat quality are among the main drives in ruminant livestock industry. Performance is usually influenced by nutritional quality, palatability, consumption rate and feed digestibility. Meat quality includes flavor, tenderness, color, shelf-life and healthiness for the consumer (North et al., 2019). Besides feed, meat quality is also influenced by the metabolic system in the body of livestock. For instance, lipid oxidation causes a decrease in the shelf life and meat quality, loss of weight and nutritional value, changes in color, flavor and texture (Lorenzo and Gómez, 2012; García-Lomillo et al., 2017; Ding et al., 2015).

One of the efforts to increase the growth performance and meat quality is through the supplementation of growth promoters or synthetic antioxidants. Nitrite, butylated hydroxytoluene (BHT), butylated hydroxyanisole (BHA), tert-butyl hydroquinone (TBHQ) and propyl gallate (PG) are several synthetic antioxidants used in the livestock industry (Aminzare et al., 2019). However, these additives have been reported to have negative impacts on the health of consumers and carcinogenic potential (North et al., 2019; Landers et al., 2012; Zhong et al., 2009). In line with these evidences, it is necessary to find alternative safe and healthy feed additives that concomitantly can increase growth performance and meat quality of ruminants. Therefore, the interest regarding natural antioxidants as dietary addives has been increasing in recent years (de Florio et al., 2017; Ehsani et al., 2012).

Catechins are flavonoid compounds with some hydroxyl groups and are able to enhance the skeletal muscle property and antioxidant activity (Agrawal et al., 2020; Li et al., 2019). Catechins increase mitochondrial biogenesis and angiogenesis (Nogueira et al., 2011; Huttemann et al., 2013), inhibit the activity of myostatin (Gutierrez-Salmean et al., 2014) and promote muscle regeneration (Kim et al., 2017). Catechins have antioxidant capacity by authoritative to free radicals and expanding the activity of antioxidant endogenous enzymes such as superoxide dismutase, glutathione peroxidase, and catalase (Higdon and Frei, 2003; Abd El-Aziz et al., 2012). Supplementation of green tea catechins at 2, 3 or 4 g/kg feed had been detailed to progress the average daily gain (ADG) of goats (Tan et al., 2011), increase natural antioxidant and meat quality (kept under aseptic condition at 4°C), namely enhance color stability and decreased thiobarbituric acid reactive substance and drip loss of meat (Zhong et al., 2009).

Catechins can be extracted from various plant sources such as grape, cherry, pear, apple, and green tea (Agrawal et al., 2020). Each catechin source has a more dominant type of catechin with its own unique character. Generally, there are eight natural substances of catechin, namely catechin, epicatechin, catechin gallate, epicatechin gallate, gallocatechin, gallocatechin gallate, epigallocatechin, and epigallocatechin gallate (Ananingsih et al., 2013; Dalluge and Nelson, 2000).

A catechin source that widely available in Indonesia is the gambir plant. Phytochemical content detected in gambir leaves were mostly catechin (50%), pyrocatechol (20-30%), gambirin (1-3%), red kateku 3-5 (3-5%), quercetin (2-4%), wax (1-2%), and alkaloids (2-5%) (Nurdin and Fitrimiwati, 2018). Ibrahim et al. (2016) also reported that the main content of gambir was catechin. Catechin content of gambir was about 50.87-55.40% (Anggraini et al., 2019). Extraction using a UV-VIS spectrophotometer showed that *Uncaria gambir* contains catechins up to 85.3% (Musdja et al., 2018). However, there is a lack of study attempted to utilize extract of gambir leaf as a feed additive for ruminants.

This experiment therefore aimed to explore the impact of dietary gambir leaf extract supplementation on goat performance and meat quality.

MATERIALS AND METHODS

Ethical approval

The Institutional Animal Care and Use Committee, Indonesian Agency for Agricultural Research and Development (IAARD) has approved all the procedures used in this study with the approval number: Balitbangtan/Lolitkambing/Rm/02/2019.

Sample preparation

Gambir leaves were obtained from farmers' plantations in Halaban, Payakumbuh, West Sumatera, Indonesia, and extracted by traditional method. The leaves of gambir were harvested and steamed immediately using an aluminum container for 1.5 hours and then pressed. Gambir extract solution was macerated for 12 h, filtered, pressed and dried under the sun in a greenhouse for 3-4 days. The gambir extract was then ground into fine powder (80 mesh) and used as a feed additive.

Experimental animals and dietary treatments

A total of 18 Boerka male goats crossbred (Boer x Indonesian local) with average initial body weight of 21 ± 2 kg (average age of 10 months) were arbitrarily conveyed into three dietary treatments (six replicates each), specifically: T0 (basal diet without gambir supplementation), T1 (basal diet + 2 g/kg DM gambir extract), and T2 (basal diet + 4 g/kg DM gambir extract). Each goat was fed with approximately 4% body weight (on DM basis), consisted of Dwarf elephant grass (*Pennisetum purpureum cv moot)* (60%) and concentrate (40%). The ingredients and chemical composition of basal diet and catechin content of leaf gambir extract are shown in Table 1. Fresh water was freely supplied. Feeding trial was carried out for three months with an adaptation period of two weeks.

Analytical procedure

Feeding amount and residual feed were weighed every day to calculate feed intake levels. All goats were weighed every two weeks to adjust the amount of feeding. Average daily gain (ADG) was calculated based on initial body weight, final body weight and days of the feeding period. At the end of feeding period, the goats were humanely slaughtered in line with the approved procedures by The Institutional Animal Care and Use Committee, Indonesian Agency for Agricultural Research and Development (IAARD). The skin, feet, head, gastrointestinal tract and viscera organs were removed from the carcass and were weighed. Approximately 0.2 kg of *Gluteus medius* (GM) muscles were sampled for meat quality analysis. The pH

Table 1: Ingredients and chemical composition of basal experimental diet, and catechin content of gambir leaf extract

Ingredient (% DM)		Chemical compositions	
Dwarf elephant grass	60	Organic matter (% DM)	88.18
Palm kernel cake	8	Crude protein (% DM)	14.94
Cornstarch	8	Crude fiber (% DM)	22.13
Rice Bran	12	Ether extract (% DM)	4.91
Soybean Meal	2		
Coconut Meal	6	Gambir leaf extract	
Fish flour	1.2	Catechin (%)	62.46
Molasses	2		
Salt	0.4		
Minerals	0.4		

value of meat was measured using a pH meter. Meat and fat color were tested using a meat color card (Aus-Meat, Australia). Color score was starts from 1 (pale red) to a score of 7 (dark red). Tenderness test was conducted according to the Hopkins method (Hopkins et al., 2010). The meat sample was boiled for 35 min using a water bath at 71°C. The meat sample was formed with a cylinder corer tool and measured the value of its breaking power using the Warner-Blatzer shear tool. Cooking loss (CL) was measured by calculating the ratio of the weight loss of the meat sample after cooking for 1 h in water bath at 80°C with the initial weight (Babikerm et al., 1990). The chemical composition of meat quality was determined by using the method of AOAC (2019).

Statistical analysis

Data for feed intake, average daily gain, carcass and non-carcass proportions, meat quality and meat nutrient contents of Boerka goats were analysed by analysis of variance, using the General Linear Model (GLM), Univariate Model procedure of SPSS 25.0 (SPSS Inc., Chicago, IL, USA). If significant, further analysis was done using Duncan's test.

RESULTS AND DISCUSSION

Feed intake and average daily gain

Gambir leaf extract supplementation had a non-significant effect on the feed intake of dry matter, organic matter, crude protein, crude fiber and ether extract (Table 2). It indicated that nutritional content of ration was relatively same for each treatment. The amount of feeding was proportional to each animal. These data also illustrated that addition of gambir leaf extract up to 4 g/kg DM did not have a negative effect on level of ration palatability. With the same intake, gambir leaf extract addition at 2 and 4 g/kg feed increased ($P<0.05$) the ADG by 52.9% and 48.1% as compared to the control treatment, respectively. The increase of ADG occured apparently due to activity of phytochemical in gambir leaf extract. Phytochemical types in gambir leaf extract were mostly catechins (40-60%) and tannins (16-25%) (Yeni et al., 2014). These compounds contributed to increase ADG through several mechanisms. Tannins were able to bind proteins and protect them from rumen microbial activity (Bunglavan and Dutta, 2013; Min et al., 2005). Therefore, the protein would be available in intestine as a by-pass protein which was ready to be absorbed and used for growth (Waghorn, 2008). Tannins also played a role in increasing feed energy efficiency by reducing formation of methane in the rumen. Tannins inhibited growth of methanogenic archaea (Carulla et al., 2005) and devaunated protozoa which were growth medium for methanogenic archaea in the rumen (Goel et al., 2008). Feed energy could be optimized for growth because energy requirement to form methane was reduced.

Like tannin, catechin contributed to increase ADG with similar mechanisms relatively. Catechin was a polyphenol that have many hydroxyl groups (Agrawal et al., 2020), so it was able to bind proteins (Yang et al., 2009), prevent the formation of methane by binding hydrogen (Becker et al., 2014), inhibit the growth of methanogenic archea (Oskoueian et al., 2013), and reduce the population of protozoa (Sinz et al., 2018). The catechin content of gambir leaf extract used in this study was quite large, namely 62.46%. Thus, catechins were believed to contributed significantly to the increase in ADG.

Apart from the mechanisms, catechins had a positive role in metabolism and muscle cell formation which was believed to contribute on increasing of animal growth. Catechins maintain balance of protein synthesis and degradation, increase absorption and metabolism of glucose and lipid, stimulate cell growth and formation of skeletal muscle mass (Li et al., 2019). Catechins stimulated differentiation of muscle cells by increasing production of heavy chain myosin and expanding the expression of myogenic regulatory factors and myocyte enhancer factor (Gutierrez-Salmean et al., 2014; Lee et al., 2017). Catechin also

Table 2: Feed intake and average daily gain of Boerka goats supplemented with gambir leaf extract

Items	T0	T1	T2	Sig.
Dry matter intake (g/d)	609±80.7	627±55.1	626±67.1	ns
Organic matter intake (g/d)	495±118	556±48.9	516±76.9	ns
Crude protein intake (g/d)	89.1±11.7	91.4±8.0	87.2±12.5	ns
Crude fiber intake (g/d)	123±16.4	124±10.9	121±14.7	ns
Ether extract intake (g/d)	33.5±4.9	35.1±3.1	34.7±4.5	ns
Average daily gain (g/d)	64.0±14.1[b]	97.8±15.5[a]	94.7±14.5[a]	*

Different superscripts within the same row are statistically different at P<0.05. T0 = Basal diet; T1 = Basal diet + 2 g/kg DM gambir leaf extract; T2 = Basal diet + 4 g/kg DM gambir leaf extract; * = significant (P<0.05); ns = not significant.

Table 3: Carcass and non-carcass proportions of Boerka goats supplemented with gambir leaf extract

Parameter (% body weight)	T0	T1	T2	Sig.
Carcass	48.6±1.48	47.9±0.95	47.1±0.50	ns
Digestive tract	18.8±0.67[b]	20.9±0.33[b]	24.9±2.11[a]	**
Rumen-reticulum	1.35±0.13[b]	1.41±0.17[b]	1.76±0.19[a]	*
Small intestine and colon	6.40±0.26	5.85±1.26	7.02±0.34	ns
Heart	0.60±0.02[a]	0.42±0.04[b]	0.46±0.09[ab]	*
Liver	1.72±0.09	1.54±0.10	1.58±0.05	ns
Kidneys	0.34±0.09	0.26±0.05	0.25±0.03	ns
Lung	0.88±0.09	0.77±0.04	0.77±0.06	ns
Skin	10.4±0.46	9.5±0.46	9.4±0.81	ns
Head	9.37±1.81	8.28±0.57	8.02±0.04	ns

Different superscripts within the same row are statistically different at P<0.05. T0 = Basal diet; T1 = Basal diet + 2 g/kg DM gambir leaf extract; T2 = Basal diet + 4 g/kg DM gambir leaf extract; **= highly significant (P<0.01); * = significant (P<0.05); ns = not significant.

Table 4: Meat quality of Boerka goats supplemented with gambir leaf extract.

Parameter	T0	T1	T2	Sig.
pH	5.78±0.04	5.88±0.18	5.90±0.12	ns
Tenderness (kg/cm^2)	7.13±1.98	5.17±0.72	6.87±1.0	ns
Cooking loss (%)	48.0±2.87	40.8±8.79	46.9±5.15	ns
Meat colour	2.0±0.0	2.0±0.0	2.0±0.0	ns
Fat colour	2.0±0.0	2.0±0.0	2.0±0.0	ns

T0 = Basal diet; T1 = Basal diet + 2 g/kg DM gambir leaf extract; T2 = Basal diet + 4 g/kg DM gambir leaf extract; ns = not significant.

Table 5: Meat nutrient contents of Boerka goats supplemented with gambir leaf extract

Parameter	T0	T1	T2	Sig.
Dry matter (%)	23.7±0.7[a]	23.2±0.21[ab]	22.6±0.71[b]	**
Organic matter (% DM)	98.9±0.06	98.9±0.03	98.8±0.08	ns
Crude protein (% DM)	18.8±1.10	19.3±0.72	18.2±1.23	ns
Ether extract (% DM)	0.79±0.14[ab]	0.45±0.06[b]	0.87±0.04[a]	*

Different superscripts within the same row are statistically different at P<0.05. T0 = Basal diet; T1 = Basal diet + 2 g/kg DM gambir leaf extract; T2 = Basal diet + 4 g/kg DM gambir leaf extract; **= highly significant (P<0.01); * = significant (P<0.05); ns = not significant.

indirectly increases skeletal muscle improvement by hindering myostatin activity (Gutierrez-Salmean et al., 2014; McDonald et al., 2015). Myostatin binds the ActRIIA / B receptor on the cell membrane and regulates muscle growth negatively (Rebbapragada et al., 2003). Epicatechin has the ability to upregulate follistatin expression, binds myostatin C-terminals and restrains interactions between myostatin and its downstream receptors, accordingly repressing the physiological function of myostatin (Gutierrez-Salmean et al., 2014).

Carcass and meat quality

The carcass proportions of Boerka goats were comparable among the dietary treatments (Table 3). The percentage of carcass was relatively in the normal range, where according to Ensminger et al. (2002), goat carcass range is 37-55% of body weight. These data illustrate that gambir leaf extract supplementation up to 4 g/kg feed did not have a negative effect on carcass. Several non-carcass components also did not appear to be significantly different between treatments, namely small intestine and colon, liver, kidneys, lung, skin and head. The supplementation of gambir leaf extract has an effect ($P<0.05$) on reducing heart weight and increasing the weight of the rumen, reticulum and digestive tract.

The pH value of the meat was relatively same in each treatment and was in the normal range, 5.78 to 5.9 (Table 4). Supplementation of gambir leaf extract as much as 2 and 4 g/kg feed did not have a negative impact on the meat physical quality, namely cooking loss, meat color and fat color. The pH value of meat was influenced by feed intake, stress during slaughter, species, individual livestock and muscle type (Soeparno, 2011). All of these components were relatively same in each treatment; therefore the pH value was not significantly different. Feed additive of gambir leaf extract has no effect on feed intake and pH value.

The pH value of the meat will affect cooking loss, where the increase in the pH of the meat will reduce cooking loss of goat meat (Lawrie, 2003). The same pH value causes cooking loss value in this study to be not different relatively. The cooking loss value was in the normal range and lower than the results of Tao et al. (2021) study, where the cooking loss value of goat meat was ranged at 44,58 - 51.38%. The pH value also affects meat color and meat fat color. The color of meat and fat in this study did not differ in each treatment with a score of 2. The assessment of meat quality using a color card showed that the Boerka goat meat in this study was classified as bright red, where this color is usually favored by consumers.

The tenderness rate of meat ranges from 5.17 to 7.13 kg/cm^2. Pearson et al. (1989) explained that the value of meat tenderness into four categories, namely tender (scale 0-3), quite tender (scale 3- 6), tough (scale 6-11), and not suitable consumption (above 11). Based on this scale, the supplementation of gambir leaf extract was able to increase the tenderness of meat from a tough scale in the control treatment to be quite tender by giving gambir leaf extract 2 g/kg feed.

The nutritional quality of meat in this study was considered quite high as presented in Table 5. The dry matter content ranged from 22.63 to 23.66 % of fresh meat with organic material content of 98.83 to 98.87 %, protein content of around 18.24 to 19.33%, and ether extract about 0.45 to 0.87 % mutton in dry matter. The supplementation of gambir leaf extract 2 g/kg DM was proven to reduce ether extract content from 0.79 to 0.45%, 43.04% compared to the control. The decrease in the amount of fat content is believed will increase the shelf life of meat, because the oxidation of fat which causes the low storage capacity will be reduced. The most variables that impact lipid oxidation in meat are fat substance and fatty acid composition (Domínguez at al., 2019). Lipid oxidation causes a decrease in meat quality, including rancid odor, discoloration, loss of nutrients, decreased shelf life, and accumulation of harmful compounds (Falowo et al., 2014).

CONCLUSION

Gambir leaf extract additions did not have any negative effects on nutrient intake and ration palatability of Boerka goats. It increased average daily gain of the goats, increased tenderness and maintained physical quality and nutritional value of the mutton.

ACKNOWLEDGMENT

The authors are thankful to Indonesian Agency for Agricultural Research and Development for providing budget and facilities for this study.

CONFLICT OF INTEREST

All authors declare that there is no conflict of interest regarding the publication of this article.

AUTHORS CONTRIBUTIONS

A designed and performed the experiment, analyzed the data, prepared the tables, wrote and revised the manuscript. AJ, KGW, SPG, AAS, and EE supervised data analysis, table presentation and discussion of the manuscript. The authors have read and approved the final manuscript.

REFERENCES

Abd El-Aziz TA, Mohamed RH, Pasha HF, Abdel-Aziz HR (2012). Catechin protects against oxidative stress and inflammatory-mediated cardiotoxicity in adriamycin-treated rats. Clin. Exper. Med. 12 (4): 233-240. https://doi.org/10.1007/s10238-011-0165-2

Agrawal M, Khan DSK, Siddique S, Ajazuddina, Sarafe S, Sarafe SH, Alexandera A (2020). Extraction of catechins from green tea using supercritical carbon dioxide. Green Sustain. Proc. Chem. Environ. Engineer. Sci. 3: 41-46. https://doi.org/10.1016/B978-0-12-817388-6.00003-9

Aminzare M, Hashemi M, Ansarian E, Bimkar M, Azar H H, Mehrasbi M R, Daneshamooz S, Raeisi M, Jannat B, Afshari A (2019). Using Natural Antioxidants in Meat and Meat Products as Preservatives: A Review. *Adv. Anim. Vet. Sci.* **7** (5): 417-426. https://doi.org/10.17582/journal.aavs/2019/7.5.417.426

Ananingsih VK, Sharma A, Zhou W (2013). Green tea catechins during food processing and storage: A review on stability and detection. Food Res. Int. 50(2): 469-479. https://doi.org/10.1016/j.foodres.2011.03.004

Anggraini T, Neswati, Asben A (2019). Gambir Quality from West Sumatra Indonesia Processed With Traditional Extraction. IOP Conf. Series: Earth Environ. Sci., 347: 012066. https://10.1088/1755-1315/347/1/012066

AOAC (2019). Official Method of Analysis, 21st Edition. Association of Official Analytical Chemists, Virginia, USA.

Babikerm SA, Elkhiderml A, Shafie SA (1990). Chemical composition and quality attributes of goat meat and lamb. Meat Sci. 28: 273-277. https://doi.org/10.1016/0309-1740(90)90041-4

Becker PM, Wikselaar PG, Franssen MCR, de Vos RCH, Hall RD, Beekwilder J (2014). Evidence for a hydrogen-sink mechanism of (+)catechin-mediated emission reduction of the ruminant greenhouse gas methane. Metabolomics. 10 (2): 179-189.

Bunglavan SJ, Dutta N (2013). Use of tannins as organic protectants of proteins in digestion of ruminants. J. Livest. Sci. 4: 67-77.

Carrula JE, Kreuzer M, Machmiller A, Hess HD (2005). Supplementation of Acacia mearnsii tannins decreases methanogenesis and urinary nitrogen in forage-fed sheep. Aust. J. Agric. Res. 56:961-970. https://doi.org/10.1071/AR05022

Dalluge JJ, Nelson BC (2000). Determination of tea catechins. J. Chromatography A. 881(1-2): 411-424. http://dx.doi.org/10.1016/S0021-9673(00)00062-5

Ding Y, Wang SY, Yang DJ, Chang MH, Chen YC (2015). Alleviative effects oflitchi (Litchi chinensis Sonn.) flower on lipid peroxidation and protein degradation in emulsified pork meatballs. J. Food Drug Anal. 23: 501-508. https://doi.org/10.1016/j.jfda.2015.02.004

de Florio Almeida J, dos Reis AS, Heldt LFS, Pereira D, Bianchin M, de Moura, Plata Oviedo MV, Haminiuk CWI, Ribeiro IS, da Luz CFP (2017). Lyophilized bee pollen extract: A natural antioxidant source to prevent lipid oxidation in refrigerated sausages. LWT-Food Sci. Technol. 76: 299-305. http://dx.doi.org/10.19026/ajfst.13.5070

Domínguez R, Pateiro M , Gagaoua M, Barba FJ, Zhang W, Lorenzo JM (2019). A Comprehensive Review on Lipid Oxidation in Meat and Meat Products. Antioxidants. 8(10): 429. https://doi.org/10.3390/antiox8100429

Ehsani A, Mahmoudi R (2012). Phytochemical properties and hygienic effects of Allium ascalonicum and Pimpinellaanisum essential oils in Iranian white brined cheese. J. Essent. Oil Bear Pl. 15 (6): 1013-1020. https://doi.org/10.1080/0972060X.2012.10662606

Ensminger ME, Oldfield JE, Heinemann WW (2002). Feeds and nutrition, 2nd ed. Illionist. The Ensminger Publishing Company, California, USA.

Falowo AB, Fayemi PO, Muchenje V (2014). Natural antioxidants against lipid–protein oxidative deterioration in meat and meat products: A review. Food Res. Int. 64: 171-181. https://doi.org/10.1016/j.foodres.2014.06.022

García-Lomillo J, Gonzalez-SanJose ML, Delpino-García V, Ortega-Heras M, Muñiz Rodríguez P (2017). Antioxidant effect of seasonings derived from wine pomace on lipid oxidation in refrigerated and frozen beef patties. LWT-Food Sci. Technol. 77: 85-91. https://doi.org/10.1016/j.lwt.2016.11.038

Goel G, Makkar HPS, Becker K (2008). Effects of Sesbania sesban and Carduus pycnocephalus leaves and Fenugreek (Trigonella foenum-graecum L.) seeds and their extracts on partitioning of nutrients from roughage- and concentratebased feeds to methane. Anim. Feed Sci. Technol. 147: 72-89. https://doi.org/10.1016/j.anifeedsci.2007.09.010

Gutierrez-Salmean G, Ciaraldi TP, Nogueira V, Barboza J, Taub PR, Hogan V, Henry RR, Meaney E, Villarreal F, Ceballos G, Ramirez-Sanchez I (2014). Effects of (-)-epicatechin on molecular modulators of skeletal muscle growth and differentiation. J. Nutrit. Biochem. 25 (1): 91-94. https://doi.org/10.1016/j.jnutbio.2013.09.007

Higdon JV, Frei B (2003). Tea catechins and polyphenols: health effects, metabolism, and antioxidant functions: Critical Reviews. Food Sci. Nutrit. 43 (1): 89-143. https://doi.org/10.1080/10408690390826464

Hopkins DL, Toohey ES, Warner RD, Kerr MJ, van de Ven R (2010). Measuring the shear force of lamb meat cooked from frozen samples: a comparison of 2 laboratories. Anim. Prod. Sci. 50: 382-385. https://doi.org/10.1071/AN09162

Huttemann M, Lee I, Perkins GA, Britton S, Koch LG, Malek MH (2013). (-)-Epicatechin is associated with increased angiogenic and mitochondrial signalling in the hindlimb of rats selectively bred for innate low running capacity. Clin. Sci. 124 (11): 663-674. https://doi.org/10.1042/CS20120469

Ibrahim N, Yusoff NZM, Ahmad R (2016). Quantification of Catechin in Leaves and Stems of Malaysian Uncaria Gambir (Hunter) Roxb. By Hplc-Dad. Malaysian J. Analyt. Sci. 20 (3): 567-572. http://dx.doi.org/10.17576/mjas-2016-2003-15

Kim AR, Kim KM, Byun MR, Hwang JH, Park JI, Oh HT, Kim HK, Jeong MG, Hwang ES, Hong JH (2017). Catechins activate muscle stem cells by Myf5 induction and stimulate muscle regeneration. Biochem. Biophys. Res. Commun. 489 (2): 142-148. https://doi.org/10.1016/j.bbrc.2017.05.114

Landers TF, Cohen B, Wittum TE, Larson EL (2012). A review of antibiotic use in food animals: perspective, policy, and potential. Public Health Rep. 127: 4-21. https://doi.org/10.1177/003335491212700103

Lawrie RA (2003). Meat Science. Fifth Edition. University of Indonesia-Press, Jakarta, Indonesia.

Lee SJ, Leem YE, Go GY, Choi Y, Song YJ, Kim I, Kim DY, Kim YK, Seo DW, Kang JS, Bae GU (2017). Epicatechin elicits MyoD-dependent myoblast differentiation and myogenic conversion of fibroblasts. PLoS One. 12 (4): e0175271. https://doi.org/10.1371/journal.pone.0175271

Li P, Liu A, Xiong W, Lin H, Xiao W, Huang J, Zhang S, Liu Z (2019). Catechins enhance skeletal muscle performance. Food Sci. Nutrit. 60 (3): 515-528. https://doi.org/10.1080/10408398.2018.1549534

Lorenzo JM, Gómez M (2012). Shelf life of fresh foal meat under MAP, overwrap and vacuum packaging conditions. Meat Sci. 92 (4): 610-618. https://doi.org/10.1016/j.meatsci.2012.06.008

McDonald C, Henricson E, Oskarsson B, Aguilar C, Nicorici A, Joyce N, Reddy D, Wagner A, deBie E, Goude E, Abresch R, Villareal F, Perkins G, Hathout Y, Dugar S, Schreiner G (2015). Epicatechin enhances mitochondrial biogenesis, increases dystrophin and utrophin, increases follistatin while decreasing myostatin, and improves skeletal muscle exercise response in adults with Becker muscular dystrophy (BMD). Neuromuscular Disorders. 25:S314-S315. https://doi.org/10.1016/j.nmd.2015.06.456

Min BR, Attwood GT, McNabb WC, Molan AL, Barry TN (2005). The effect of condensed tannins from Lotus corniculatus on the proteolytic activities and growth of rumen bacteria. Anim. Feed Sci. Technol. 121: 45-58. https://doi.org/10.1016/j.anifeedsci.2005.02.007

Musdja MY, Abdul HA, Hasan D (2018). Antioxidant Activity of Isolate of Uncaria Gambier Roxb in Male Rats. Int. J. Heal Life-Sci. 4(2): 34-46. https://doi.org/10.20319/lijhls.2018.42.3446

Nogueira L, Ramirez-Sanchez I, Perkins GA, Murphy A, Taub PR, Ceballos G, Villarreal FJ, Hogan MC, Malek MH (2011). (-)-Epicatechin enhances fatigue resistance and oxidative capacity in mouse muscle. J. Physiol. 589 (18): 4615-4631. https://doi.org/10.1113/jphysiol.2011.209924

North MK, Zotte AD, Hoffmana LC (2019). The use of dietary flavonoids in meat production: A review. Anim. Feed Sci. Technol. 257: 1-15. https://doi.org/10.1016/j.anifeedsci.2019.114291

Nurdin E, Fitrimiwati (2018). The effect of the gambir (*Uncaria gambir (hunt.) roxb*.) leaves waste and white turmeric (*Curcuma zedoaria*) for the productivity, antioxidant content and mastitis condition of the fries holland dairy cows. IOP Conference Series: Earth Environ. Sci., 119: 012041. https://doi.org/10.1088/1755-1315/119/1/012041

Oskoueian E, Abdullah N, Oskouiean A (2013). Effects of flavonoids rumen fermentation activity, methane production, and microbial population. Biomed. Res. Int. 2013: 1-8. https://doi.org/10.1155/2013/349129

Pearson AM, Young RB (1989). Muscle and Meat Biochemistry. Academic Press Inc, London, Inggris.

Rebbapragada A, Benchabane H, Wrana JL, Celeste AJ, Attisano L. (2003). Myostatin signals through a transforming growth factor beta-like signaling pathway to block adipogenesis. Molecul. Cellul. Biol. 23(20): 7230-7242. https://doi.org/10.1128/MCB.23.20.7230-7242.2003

Sinz S, Marquardt S, Soliva CR, Braun U, Liesegang A, Kreuzer M (2019). Phenolic plant extracts are additive in their effects against in vitro ruminal methane and ammonia formation. AsianAustralian J. Anim. Sci. 32: 966-97. https://doi.org/10.5713/ajas.18.0665

Soeparno (2011). Meat Science and Technology. Gadjah Mada University Press, Yogyakarta, Indonesia.

Tan CY, Zhong RZ, Tan ZL, Han XF, Tang SX, Xiao WJ, Sun ZH, Wang M (2011). Dietary inclusion of tea catechins changes fatty acid composition of muscle in goats. Lipids. 46 (3): 239-247. https://doi.org/10.1007/s11745-010-3477-1

Tao Y, Ma L, Li D, Tian YT, Liu J, Liu D (2021). Proteomics analysis to investigate the effect of oxidized protein on meat color and water holding capacity in Tan mutton under low temperature storage. LWT-Food Sci. Technol. 146: 111429. https://doi.org/10.1016/j.lwt.2021.111429

Waghorn G (2008). Beneficial and detrimental effects of dietary condensed tannins for sustainable sheep and goat production-Progress and challenges. Anim. Feed Sci. Technol. 147: 116-139. https://doi.org/10.1016/j.anifeedsci.2007.09.013

Yang CS, Wang X, Lu G, Picinich SC (2009). Cancer prevention by tea: animal studies, molecular mechanisms and human relevance. Nat. Rev. Cancer. 9 (6): 429-439. https://doi.org/10.1038/nrc2641

Yeni G, Syamsu K, Suparno O, Mardliyati E, Muchtar E (2014). Repeated extraction process of raw gambiers (Uncaria gambier Roxb.) for the catechin production as an antioxidant. IJAER. 9: 24565-24578.

Zhong RZ, Tan CY, Han XF, Tang SX, Tan ZL, Zeng B (2009). Effect of dietary tea catechins supplementation in goats on the quality of meat kept under refrigeration. Small Rumin. Res. 87: 122-125. https://doi.org/10.1016/j.smallrumres.2009.10.012