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RESEARCH ARTICLE

THE USE OF TEA AND ITS BY-PRODUCTS IN RUMINANTS FEEDING, A COMPREHENSIVE REVIEW

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ABSTRACT

The aim of this review was to go into lengthy research on the importance of tea waste in the diet of ruminants. We noticed that the waste of the tea is rich in 20-35% crude protein which is an advantage because it can replace foods known as a source of protein. In addition, because of the increase in world tea production from year to year, the same goes for wastes relating to the processing of tea, so the use of tea waste in the diet of ruminants bring an economic and environmental added value. However, the use of tea waste in ruminants is hampered by its high tannin content. The latter, once consumed in abundance, blocks the digestion of proteins, so that a simple method of extracting them would facilitate the stain in its incorporation in the TMR.

INTRODUCTION

Tea is one of the world's most popular beverages with more than 3 million t of tea leaves produced in 2001 (Kondo *et al.,* 2006) .Green tea is consumed primarily in China, Japan, and a few countries in North Africa and the Middle East (Harold N. Graham, 1992) . Nitrogenous compounds in the leaf are partially extracted by hot water and consumed as tea, but most of the compounds still remain in the residue of tea leaf (Kondo *et al.,* 2004b). As concern increases about environmental issues and material recycling, the utilization of tea by-product as feedstuff would be useful for both economic and environmental reasons (Kondo *et al.,* 2014) . It has been reported that green tea polyphenols have strong anti-oxidative properties (Nishida *et al.,* 2006) ; this is demonstrated by a reduction in thiobarbituric acid reactive substances (TBARS) values and by maintaining the oxidative stability of broiler meat (Yang *et al.,* 2003a) and egg yolk (Uuganbayar *et al.,* 2005) . The green tea leaves, their by-products, and tea polyphenols can be offered as an ingredient or as a supplement to broiler feed for reducing mortality in diseased birds (Cao *et al.,* 2005) and to hens for improving laying performance (Uuganbayar *et al.,* 2006) , and for reducing the cholesterol content of eggs. Yang et al (Yang *et al.,* 2003b) also reported that cholesterol levels were decreased and fatty acids of plasma and meat were improved when the animals were fed different levels of green tea by-products. In poultry diets, green tea and its derivatives like green tea extract, green tea leaves, green tea by-products, green tea polyphenols and green tea flowers are supplemented for improving performance (Khan, 2014) . Green tea waste (GTW) is obtained through the production of green tea in beverage factories and is disposed of as compost or incinerated by an industrial waste disposal contractor, which causes both an economical and environmental problem. In the commercial industry the green tea waste and by-products that remain after processing still contain large amounts of protein (20-80 % CP), carbohydrates and phenolic compounds (Cai Y *et al.,* 2001) . Several previous studies had suggested that green tea waste could be used as potential source of natural anti-oxidants or functional nutrients in animal feed; broiler and laying hens (Yang *et al.,* 2003a) , goats (C. Xu *et al.,* 2003b) , sheep (C. Xu *et al.,* 2003) , cattle (Nishida *et al.,* 2006) , lactating cow (Makoto Kondo, Miho Hidaka, *et al.,* 2007) and broiler chicks (Yang *et al.,* 2003a) . Kondo et al (Kondo *et al.,* 2006) reported that in Japan for example, consumption of tea drinks such as green tea has been increasing remarkably in recent years. Beverage companies manufacturing various ready-made tea drinks produce about 100,000 t of tea waste annually, most of which is burned, dumped into landfills or used as compost. The first two of these waste management practices seem to have a seriously negative impact on the environment, while the increasing volume of compost derived from these food industrial wastes is beyond the land capacity of Japan to accommodate. Tea leaves contain a variety of amino acids, proteins, tannins, polyphenols such as catechin, epicatechin gallate, epigallocatechin gallate, and vitamins, tea waste may have potential as protein supplement in animal feed (Kondo *et al.,* 2004b) .

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Tea waste, a by-product from beverage companies producing a ready-made tea drink, contains substantial concentrations of crude protein (CP, 25 ~ 30% of the DM), which may have value as a dietary supplement for goats. Tea waste also contains 6.1 ~ 9.6% total extractable tannins and 0.8 ~ 2.4% condensed tannins in the DM (Kondo *et al.,* 2007) . The aim of this article was to review the recent studies on the beneficial effect of tea and its by-products and its potential interest in ruminants feeding.

Chemical composition

The chemical composition and other properties of green tea are complex. Abdo et al (Abdo *et al.,* 2010) found that air-dried green tea leaves contained 7.80% moisture, 92.20% dry matter, 82.40% organic matter, 18.15% crude protein, 8.72% ether extract, 19.32% crude fiber, 9.80% ash, 36.21% nitrogen free extract and 3002 kcal/kg calculated metabolisable energy (ME). Green tea has over 200 bioactive compounds and contains over 300 different substances (Khan, 2014) . The chemical composition of tea is multifaceted, consisting of polyphenols (catechins and flavanoids), alkaloids (caffeine, threobromine, theophylline), volatile oils, polysaccharides, amino acids, lipids, vitamin C, minerals and other uncharacterised compounds (Abdo *et al.,* 2010; Khan, 2014) . Green tea contains many amino acids, but L-theanine, specific to the tea plant, is the most abundant, accounting for 50.00% of the total amino acids. This form of theanine acts as an antioxidant, protecting cells from free radical damage, and also helping to induce relaxation and prevent anxiety by increasing serotonin and dopamine levels in nerve cells. Amino acid degradation is involved in the biogenesis of the tea aroma (Abdo *et al.,* 2010) ; Khan (Khan, 2014) reported that green tea leaves contained amino acids as 1.35% aspartic, 0.64% therionine, 0.67% serine, 1.98% glutamic, 0.68% proline, 0.76% glycine, 0.78% alanine, 0.78% valine, 0.55% isoleucine, 1.17% leucine, 0.57% tyrosine, 0.78% phenylalanine, 0.32% histidine, 0.85% lysine, 0.74% argnine, 0.37% methionine and 0.14% cystine.

More than 600 different molecules of volatile fractions of tea have been isolated. These include terpenoids and degradation products of amino acids, carotenoids and linoleic acid (Khan, 2014) . About tea waste, Kondo et al (M. Kondo *et al.,* 2007) reported that black tea by-product silage contain 13.2% of Dry matter (% DM), 95.3% of Organic matter (% DM), 29.0% of Crude protein (% DM), 7.8% of Acid detergent insoluble nitrogen (% T-N), 41,2% of Neutral detergent fiber (% DM), 4,3% of Total extractable phenolics (% DM), 3,6% of Total extractable tannins (% DM) and 0.5% of Condensed tannins (% DM). Kondo *et al.* (Makoto Kondo, Kazumi Kita, *et al.,* 2007) also reported that green tea by-product silage (GTBS) and dried green tea by-product (DGTB) contain more ingredients as below: DM (%) 19.4% in opposite of 95.3% for dried green tea by-product,the quantity of ash is the same in the two categories: 3.0%. About CP, they reported that GTBS contain 32.6% and 31.9% respectively, NDF: 27.7% and 34.8% respectively, CT: 1.04% and 1.68%. Tea leaves contain much nitrogen compounds, amino acids, tannins, polyphenols such as catechin, epicatechin gallate, epigallocatechin gallate, and vitamins (Kondo *et al.,* 2004b) , suggesting that tea-leaf waste may have potential as an animal feed. A method should be developed to efficiently utilize tea waste as a feed resource with no negative environmental impact.

Green tea waste (GTW) may be considered as a valuable protein source consisting of 22-35% of crude protein (CP) (Kondo *et al.,* 2004b) . Whole-crop oat silage supplemented with GTW increased the CP content of the silage, and improved the nitrogen balance and ruminal NH3-N concentration in goats fed the silage. GTW could thus be a useful protein source for animals on a feeding system employing low quality forage in protein-deficient areas. On the other hand, growing cows and lactating cows require high CP in their ration for an intensive livestock production system (Kondo *et al.,* 2004b) .

Comparison of tea ingredients with other commonly used foods

In comparison with alfalfa hay and soybean meal, Licitra *et al.* (Licitra *et al.,* 1996) and Kondo *et al.* (Makoto Kondo, Miho Hidaka, *et al.,* 2007) reported that GTW contained more CP (34.8% DM) than alfalfa hay (17.6% DM) but less than soybean meal (46.6% DM). Both NDICP and ADICP protein fractions in GTW were higher than in alfalfa hay and soybean meal, defined that the fraction of NDICP degrades slowly, and that of ADICP is low biological availability. Higher NDICP and ADICP contents could be caused by heat treatment in the dry processing of tea leaves and/or the extraction of tea from the leaves with hot water. Licitra *et al.* (Licitra *et al.,* 1996) ; Kondo et al (Makoto Kondo, Kazumi Kita, *et al.,* 2007) mentioned that tannins would possibly increase the insoluble protein associated with the plant cell wall. Incorporating GTW in TMR as a substitute for alfalfa hay or soybean meal, therefore, would supposedly lower CP degradability. The EE contents were also higher in GTW than in any other feedstuff, possibly because diethyl ether extracted not only lipids but also pigments and some tannins (Makoto Kondo, Kazumi Kita *et al.,* 2007) . Fiber fractions of NDF and ADF in GTW were higher than in soybean meal but lower than in alfalfa hay. GTW contained 11.4, 9.2 and 1.7% of TEPH, TET and CT, respectively. In terms of feedstuff characteristics, GTW is similar to tropical legume leaves with their high nitrogen and tannin contents (Rubanza *et al.,* 2005) ; (Makoto Kondo, Miho Hidaka, *et al.,* 2007) . Tea waste of low DM content possibly deteriorates easily after tea drink extraction at a beverage company. Ensiled GTW showed low pH (3.97) and high lactic acid (2.0% DM), indicating that GTW was wellpreserved by ensiling. When GTW was substituted for soybean meal and alfalfa hay at a level of 25.0% of DM, it corresponded to replacement of 5.0% of the DM and 10.0% of the CP overall. TEPH, TET and CT contents of TMR were higher in GTW treatment than control (M. Kondo *et al.,* 2007).

Digestibility and degradability of tea and its by-products

Many researchers have assessed the nutritive value of fresh tea grounds and tea grounds silage from different aspects (Wang and Xu, 2013) . The nutritive value of GTG is thought to be equivalent to that of BG. For GTG silage, digestibilities of CP and EE are 74.6% and 50.7% on DM basis, respectively. Besides, the estimated total digestible nutrients (TDN), digestible CP and digestible energy are 71.1%, 23.9% and 13.4 MJ/kg on DM basis, respectively (Xu *et al.,* 2003) ; (Wang and Xu, 2013) . For BTG silage, however, digestibilities of CP and organic cell wall are 26.8% and 30.2%, and the TDN, digestible CP, digestible energy are 65.1%, 4.8% and 13.0 MJ/kg on DM basis, respectively. It is suggested that the nutritive value of BTG silage is about 80% of that of barley

(C. Xu *et al.,* 2003) . Xu *et al.* (C. Xu *et al.,* 2008) reported that BTG silage treated with NaOH exhibited the highest degradability of DM and CP than that of the control and BTG, then it followed by the LAB + AUS treatment. However, formic acid treatment had no effect on the DM and CP disappearance of silage. Many researchers have indicated that well-fermented GTG silage contributes to preserve more tea catechins and antioxidative activity (Nishino *et al.,* 2007; C. Xu *et al.,* 2003) . Nishino *et al.* (Nishino *et al.,* 2007) investigated the changes due to ensiling in tea catechins and antioxidative activity of wet GTG. Results indicatedthat ensiling significantly lowered antioxidative activity and decreased the contents of partial tea catechins in GTG silage, whereas, reductions of tea catechins were ameliorated and no marked changes were found in total phenols and antioxidative activity during ensiling when ensiled as a mixture with dried beet pulp. Inhibited degradation of tea catechins were also found in wet GTG silage treated with LAB and cell wall degrading enzymes (Xu *et al.,* 2003b) . Besides, it has been indicated that CT could reduce rumen forage protein degradation due to reversible binding to these proteins (Min *et al.,* 2003; Nishino *et al.,* 2007) , suppress the breakdown of protein by rumen microorganisms (Salawu *et al.,* 1999) and decrease ruminal gas production (Wang and Xu, 2013) . It is consistent with the study of Nishino *et al.* (Nishino *et al.,* 2007) that addition of dried beet pulp increased gas production of GTG silage, which in other words suppressed gas production with the increase of GTG.

However, the reduction of tea catechins during ensiling would not elicit an improvement in digestibility of GTG silage. It is consistent with the finding of Salawu *et al.* (Salawu *et al.,* 1999; Wang and Xu, 2013) that tannin protected proteolysis of proteins during silage fermentation but was digestible in the lower gut, and it also agreed with finding of Kondo *et al.* (Kondo *et al.,* 2004b) that proteins in GTG seem to be stable during ensiling, but digestible post-ruminally. Evidence also indicates that CT at levels of 20–45 g/kg DM can reduce rumen forage protein degradation and protect amino acids to increase the absorption in the small intestine of ruminants, while deteriorating intake and digestibility at >55 g/kg DM (Kondo *et al.,* 2004b; Min *et al.,* 2003). It may illustrate the following no detrimental effect on gas production with the increase of GTG, which probably due to the less amount of tannins than that is critical to suppress the activity of rumen bacteria. (Kondo *et al.,* 2004b) found that the addition of GTG to forage silage could increase gas production, whereas addition of oolong and black tea grounds suppressed gas production. It is agreed with Kondo *et al.* (Kondo *et al.,* 2006) that the addition of GTG to byproducts-mixture increased gas production. Furthermore, many researches focused on the nutritive value of silage with GTG added in different ratio. Kondo et al (Kondo *et al.,* 2004b) studied the feeding value of oat silage with GTG added at a ratio of 0, 5% and 20% on fresh matter. No significant differences were found in DM intake and digestibility, except for the increased CP digestibility with the increment of GTG. In addition, N retention and ruminal NH3-N were increased, while total volatile fatty acids (VFA) were reduced by addition of GTG. The high CP content, N digestibility and N retention indicated the potential of GTG as a protein supplement, and the addition of GTG could be up to 20% on fresh matter in oat silage. Nutritive value of tea grounds TMR silage.

Previous studies have shown that GTG can be used as protein supplements due to the high nutrition and low cost (Cai Y *et al.,* 2001; Wang and Xu, 2013; C. Xu *et al.,* 2003) . On the other hand, tannins exhibit contrasting effects on feed intake and digestibility when GTG applied in different ratio (Min *et al.,* 2003) . All these suggest that uncertain results may appear on the utilization of tea grounds. Thus, further researches are required to have a better understanding of the utilization of tea grounds.

Antimicrobial effect of tea and its by-product

Tea catechins have many health benefits such as anti-inflammatory, antiarthritic, anticarcinogenic, anti-cancerous, antimutagenic, antibacterial, antiviral, antifungal, anticoccidial, antiprotozoal, antiparasitic, anti-infective, hypocholesterolemic, resistantto capillary blood congestion and hypolipidemic effects (Saeed *et al.,* 2017) . Health benefits of tea, and in vitro antioxidant and antimicrobial activity of tea extracts have been mainly attributed to the phenolic content of tea (Pilar Almajano *et al.,* 2008) . Khan (Khan, 2014) reported in his review that the polyphenolic compounds of green tea have been shown to improve body weight gain and feed efficiency in pigs (Hossain Md. Elias *et al.,* 2012) , cattle (Sarker *et al.,* 2010) and broilers (Biswas Hai *et al.,* 2001) . Ensiled or oven-dried green tea by-products have also been evaluated in goats for their nutritive potential as protein feedstuffs (Makoto Kondo, Miho Hidaka, *et al.,* 2007) . These compounds also maintain microflora balance and exhibit antimicrobial effects against pathogenic bacteria (Guray Erener *et al.,* 2011; Hara-Kudo *et al.,* 2005) . It has been reported that green tea polyphenols have strong anti-oxidative properties (Nishida *et al.,* 2006) ; this is demonstrated by a reduction in thiobarbituric acid reactive substances (TBARS) values and by maintaining the oxidative stability of broiler meat (Yang *et al.,* 2003a) and egg yolk (Uuganbayar *et al.,* 2005) . The green tea leaves, their by-products, and tea polyphenols can be offered as an ingredient or as a supplement to broiler feed for reducing mortality in diseased birds (Cao *et al.,* 2005) and to hens for improving laying performance (Uuganbayar *et al.,* 2006), and for reducing the cholesterol content of eggs. (Yang *et al.,* 2003a) also reported that cholesterol levels were decreased and fatty acids of plasma and meat were improved when the animals were fed different levels of green tea by-products. In poultry diets, green tea and its derivatives like green tea extract, green tea leaves, green tea by-products, green tea polyphenols and green tea flowers are supplemented for improving performance.

Tea and its by-products as growth promoter

Plant-derived natural products assist in the prevention and treatment of various diseases. Green tea and its major constituent polyphenols (also known as green tea catechins, GTCs) are well known for their contributions to human health, including their antitumor, antioxidative, and antimicrobial activities (Xu *et al.,* 2017) . Tan et al (mendel Friedman *et al.,* 2006) reported that the high tea catechins dosage in the diets could improve the growth rate of growing goats. The reason for the increasing ADG may be attributed to TC supplementation, as a growth promoter, presumably acting on the intestinal and ruminal microorganism leading to higher nutrient digestion. Tea polyphenols, especially the catechins, are effective antimicrobial and antioxidant agents (Tan *et al.,* 2011) . Therefore, dietary TC inclusion could enhance the animal growth performance through regulating the physiological function of rumen microorganisms (MENDEL FRIEDMAN *et al.,* 2006). Consumers have given more attention to meat quality during recent years because of the high incidence of disease related to diet, especially related to fatty acid composition of meat and Tan et al's results showed that tea catechins supplementation could increase the CP content in SM (MENDEL FRIEDMAN *et al.,* 2006). Recently, green tea supplementation has been reported to possess properties that may improve the quality of male and female gametes largely due to the ability of catechin polyphenols to quench ROS (Reactive oxygen species). Epigallocatechin-3-gallate (EGCG) is considered the most promising bioactive compound in green tea due to its strong antioxidant activity. The unique property of green tea catechins may potentially improve reproductive health and pose an important research area (Roychoudhury *et al.,* 2017) .The effects of tea and green tea catechins on biomarkers of oxidative stress, especially oxidative DNA damage, appear very promising in animal models, but data on biomarkers of in vivo oxidative stress in humans are limited (Higdon and Frei, 2003).

been assessed mainly in tropical leguminous leaves and fruit pods (Wambui *et al.,* 2012) and agro-industrial by-products (Kondo *et al.,* 2014). Previous reports showed that tannins at levels of 1.5-5.0% decreased protein degradation in rumen (Salawu *et al.,* 1999). Yang *et al.* (Yang *et al.,* 2003a) reported that plasma total cholesterol decreased clearly in a chicken fed diet with GTW at rates of 1.0-2.0%. Therefore, it is suggested that GTW has the potential to decrease plasma total cholesterol in ruminants, but the effect would be more moderate than for mono-gastric animals. Condensed tannin is historically known as an antinutritional factor for causing astringency in the animal and thereby reducing feed intake. However, at low concentrations, condensed tannin can increase dietary rumen undegradable protein fraction (RUP) (Mezzomo *et al.,* 2011). This increase occurs due to the capacity of tannin to bind protein through hydrogen bonds forming a tannin–protein complex which is stable in the rumen (pH, 5.0–7.0) and resistant to microbial degradation (Mezzomo *et al.,* 2011). Tea leaf waste has a low dry matter so it easily deteriorates after being released as a by-product of tea drink companies. It is necessary to develop ways to preserve tea leaf waste as a feed resource (Kondo *et al.,* 2004a)

Table 1. Antimicrobial activity of green tea polyphenols (Gramza et al., 2005) .

Compound tested	Species	Effects	References
Green tea catechins	Helicobacter pylori	Weak inhibition of Helicobacter pylori growth.	(Shin et al., 2005)
EGCG	Legionella pneumophila	EGCG enhanced the in vitro resistance of alveolar macrophages to Legionella pneumophila infection by selective immunomodulatory effects on cytokine formation.	(Yamamoto et al., 2004)
EGC	Staphylococcus aureus	EGC showed a weak activity against Staphylococcus aureus; substitution of the gallate group of ECG with 3-O-acyl chains of varying lengths led to enhanced antistaphylococcal activity.	(Stapleton et al., 2004)
EGCG	S. aureus, S. epidermidis, S. hominis, S. haemolyticus	Minimum Inhibitory Concentrations (MICs) : 50–100 µg/mL.	(Yoda et al., 2004)
Lung Chen tea, ECG,EC	Helicobacter pylori	The MIC_{90} for Lung Chen was 0. 25–0.5% (w/w) and these of ECG and EC were 50–100 and 800–1600 µg/mL, respectively.	(Yee & Koo, 2000)
Aqueous extracts of tea	30 bacterial species	Tea extracts were bactericidal to staphylococci and Yersinia enterocolitica at well below "cup of tea" concentration. In black tea extracts, theaflavin and its gallates are the antibacterially active components.	(Yam et al., 1997)
Green and black tea	Mycoplasma	At a concentration of 0.2%, green tea and black tea showed microbicidal activities against M. pneumoniae and M. orale but not against M. salivarium.	(Chosa et al., 1992)
Green tea, black tea, and EGCG	Bordetella pertussis	Green tea, black tea, and EGCG might act as prophylactic agents against Bordetella pertussis infection.	(Horiuchi et al., 1992)
Green tea extract,EGCG, and theaflavin digallate (TF3)	Methicillin resistant Staphylococcus aureus (MRSA)	20% tea extract, EGCG (63 µg) and TF3 (125 µg) added to one mL of culture medium each inhibited the growth of all strains of MRSA and food with poisoning S. aureus tested.	(Toda et al., 1991)
Green tea catechins and theaflavins	21 phytopathogenic bacterial species	Tea catechins as well theaflavins showed a marked inhibitory effect against phytopathogenic bacteria.	(Fukai et al., 2014)
Green tea catechins	Staphylococcus aureus, Vibrio cholerae	EGC, ECG, EGCG inhibited the growth of Staphylococcus aureus and Vibrio cholerae.	(Toda et al., 1990)

Constraints in the use of tea waste in animal nutrition

Tea waste is known to be one of the by-products which contain high rate of tannin, these are known to decrease the digestibility of proteins (Kondo *et al.,* 2014). The tannins are a group of plant secondary compounds which have been known and used by man for centuries; their name comes from the French tan meaning the bark of the holm oak and other trees used in tanning (Frutos *et al.,* 2004). Licitra *et al.* (Licitra *et al.,* 1996) mentioned that tannins would possibly increase the insoluble protein associated with the plant cell wall. The suppressive activity of tannins on rumen degradability has

Conclusion

The objective of this review was to gather a lot of scientific information on the valorization of the tea wastes that it is the wastes of the green tea or the black tea. This valuation concerns their use in the goat's diet and research studies show that tea waste, instead of being a source of environmental pollution, can also be incorporated into the feeding of domestic animals. Many of these studies show that the tea waste can be used as a protein supplement because of their richness in crude protein to replace some preferred sources such as soy or wheat.

The tea also contains polyphenols, which are strong antioxidants that even play a phytogenic and antimicrobial role. In addition, the use of tea waste brings a gain because the usual sources of protein are often expensive and even imported. The sellers of cattle feed have an added value and the breeders and industrialists find the feedstuff a little cheaper. And it would be both economically and environmentally beneficial to use such local by-products instead of commercial feedstuff. The use of tea waste in animal feedstuff contributes to increase productivity and reduce production costs. However, tea is one of the plants with a significant amount of tannin. The latter, according to the research, blocks the digestibility of proteins which must attract particular attention to circumvent this problem. A method of extraction of these must be developed for a good use of tea waste in goat feeding.

REFERENCES

Abdo, Z. M. A., Hassan, R. A., El-Salam, A. A., and Helmy, S. A. 2010. Effect of adding green tea and its aqueous extract as natural antioxidants to laying hen diet on productive, reproductive performance and egg quality during storage and its content of cholesterol. *Egyptian Poultry Science Journal, 30* (4), 1121-1149.

Biswas Hai, Md Abdul Wakita, and Masaaki. 2001. Comparison of Two Dietary Factors, Green Tea Powder Feeding and Feed Restriction, Influencing Laying Performance and Egg Quality in Hens. *Bulletin of the Faculty of Bioresources, Mie University*.

Cai, Y., Masuda, N., Fujita, Y., Kawamoto, H. and S, A. 2001. Development of a new method for preparation and conservation of tea grounds silage. *Anim Sci J., 72*, 536–541.

Cao, B. H., Karasawa, Y., and Guo, Y. M. 2005. Effects of Green Tea Polyphenols and Fructo-oligosaccharides in Semi-purified Diets on Broilers' Performance and Caecal Microflora and Their Metabolites. *Asian-Aust. J. Anim. Sci., 18* (1), 85-89. doi: 10.5713/ajas.2005.85

Chosa, H., Toda, M., Okubo, S., Hara, Y. and Shimamura, T. 1992. [Antimicrobial and microbicidal activities of tea and catechins against Mycoplasma]. *Kansenshogaku Zasshi, 66* (5), 606-611.

Frutos, P., Hervás, G., Giráldez, F. J. and Mantecón, A. R. 2004. Review. Tannins and ruminant nutrition. *Spanish Journal of Agricultural Research, 2* (2), 12. doi: 10.5424/sjar/2004022-73

Fukai, K., Ishigami, T. and Hara, Y. 2014. Antibacterial Activity of Tea Polyphenols against Phytopathogenic Bacteria. *Agricultural and Biological Chemistry, 55* (7), 1895-1897. doi: 10.1080/00021369.1991.10870886

Gramza, A., Korczak, J., and Amarowicz, R. (2005). TEA polyphenols – their antioxidant properties and biological activity-a review. *Polish journal of food and nutrition sciences, 14/55* (3), 219–235.

Guray Erener, Ocak, N., Altop, A., Cankaya, S., Aksoy, H. and Ozturk, E. 2011. Growth Performance, Meat Quality and Caecal Coliform Bacteria Count of Broiler Chicks Fed Diet with Green Tea Extract. *Asian-Aust. J. Anim. Sci., 24* (8), 1128 - 1135. doi: 10.5713/ajas.2011.10434

Hara-Kudo, Y., Yamasaki, A., Sasaki, M., Okubo, T., Minai, Y., Haga, M.,... Sugita-Konishi, Y. 2005. Antibacterial action on pathogenic bacterial spore by green tea catechins. *Journal of the Science of Food and Agriculture, 85*, 2354-2361. doi: 10.1002/jsfa.2259

Harold N. and sGraham, P. D. 1992. Green tea composition, consumption, and polyphenol chemistry. *Preventive Medicine, 21*, 334-350.

Higdon, J. V., and Frei, B. 2003. Tea Catechins and Polyphenols: Health Effects, Metabolism, and Antioxidant Functions. *Critical Reviews in Food Science and Nutrition, 43* (1), 89-143. doi: 10.1080/10408690390826464.

Horiuchi, Y., Toda, M., Okubo, S., Hara, Y. and Shimamura, T. 1992. [Protective activity of tea and catechins against Bordetella pertussis]. *Kansenshogaku Zasshi, 66* (5), 599-605. doi: 10.11150/kansenshogakuzasshi1970.66.599

Hossain Md. Elias, Seok Young Ko and Yang, C. J. 2012. Dietary supplementation of green tea by-products on growth performance, meat quality, blood parameters and immunity in finishing pigs. *Journal of Medicinal Plants Research, 6* (12), 2458-2467. doi: 10.5897/jmpr11.1643.

Khan, S. 2014. The use of green tea (Camellia sinensis) as a phytogenic substance in poultry diets. *Onderstepoort Journal of Veterinary Research, 81* (1). doi: 10.4102/ojvr.v81i2.706.

Kondo, M., Hidaka, M., Kita, K. and Yokota, H.-o. 2007. Feeding value of supplemented diet with black tea by□product silage: Effect of polyethylene glycol addition to the diet on digestibility of protein fractions in goats (Vol. 53) : *Japanese Society of Grassland Science*.,

Kondo, M., Hidaka, M., Kita, K. and Yokota, H. 2007. Ensiled green tea and black tea waste as protein supplement for goats. In H. Ben Salem, L. Biondi, P. Morand-Fehr and A. Priolo (Eds.), *Advanced nutrition and feeding strategies to improve sheep and goat* (Vol. 74, pp. 165-169) : Zaragoza : CIHEAM.

Kondo, M., Hirano, Y., Ikai, N., Kita, K., Jayanegara, A. and Yokota, H.-o. 2014. Assessment of Anti-nutritive Activity of Tannins in Tea By-products Based on In vitro Rumen Fermentation. *Asian-Australasian Journal Animal Science, 27* (11), 1571-1576. doi: 10.5713/ajas.2014.14204.

Kondo, M., Kita, K. and Yokota, H.-o. 2004a. Effects of tea leaf waste of green tea, oolong tea, and black tea addition on sudangrass silage quality and in vitro gas production. *Journal of the Science of Food and Agriculture, 84* (7), 721-727. doi: 10.1002/jsfa.1718.

Kondo, M., Kita, K. and Yokota, H.-o. 2004b. Feeding value to goats of whole-crop oat ensiled with green tea waste. *Animal Feed Science and Technology, 113* (1), 71-81. doi: https://doi.org/10.1016/j.anifeedsci.2003.10.018.

Kondo, M., Kita, K. and Yokota, H.-o. 2006. Evaluation of Fermentation Characteristics and Nutritive Value of Green Tea Waste Ensiled with Byproducts Mixture for Ruminants. *Asian-Aust. J. Anim. Sci., 19* (4), 533-540. doi: 10.5713/ajas.2006.533.

Kondo, M., Kita, K. and Yokota, H.-o. 2007. Ensiled or Oven-dried Green Tea By-product as Protein Feedstuffs: Effects of Tannin on Nutritive Value in Goats. *Asian-Aust. J. Anim. Sci., 20* (6), 880-886. doi: 10.5713/ajas.2007.880.

Kondo, M., Nakano, M., Kaneko, A., Agata, H., Kita, K. and Yokota, H.-o. 2004b. Ensiled Green Tea Waste as Partial Replacement for Soybean Meal and Alfalfa Hay in Lactating Cows. *Asian-Aust. J. Anim. Sci., 17* (17), 960-966. doi: 10.5713/ajas.2004.960.

Licitra, G., Hernandez, T. M. and Van Soest, P. J. 1996. Standarization of procedures for nitrogen fractionation of ruminant feed. *Animal Feed Science and Technology, 57*, 347-358. doi: 10.1016/0377-8401 (95) 00837-3.

Mendel friedman, I., Henika, P. R., Levin, C. E., Mandrell, R. E. and Kozukue, N. 2006. Antimicrobial Activities of Tea Catechins and Theaflavins and Tea Extracts against Bacillus cereus. *Journal of Food Protection, 69* (2), 354-361.

Mezzomo, R., Paulino, P. V. R., Detmann, E., Valadares Filho, S. C., Paulino, M. F., Monnerat, J. P. I. S.,... Moura, L. S. 2011. Influence of condensed tannin on intake, digestibility, and efficiency of protein utilization in beef steers fed high concentrate diet. *Livestock Science, 141* (1), 1-11. doi: https://doi.org/10.1016/j.livsci.2011.04.004

Min, B. R., Barry, T. N., Attwood, G. T. and McNabb, W. C. 2003. The effect of condensed tannins on the nutrition and health of ruminants fed fresh temperate forages: a review. *Animal Feed Science and Technology, 106* (1), 3-19. doi: https://doi.org/10.1016/S0377-8401 (03) 00041-5

Nishida, T., Eruden, B., Hosoda, K., Matsuyama, H., Nakagawa, K., Miyazawa, T. and Shioya, S. 2006. Effects of Green Tea (Camellia sinensis) Waste Silage and Polyethylene Glycol on Ruminal Fermentation and Blood Components in Cattle. *Asian-Aust. J. Anim. Sci., 19* (12), 1728 - 1736. doi: 10.5713/ajas.2006.1728

Nishino, N., Kawai, T. and Kondo, M. 2007. Changes during ensilage in fermentation products, tea catechins, antioxidative activity and in vitro gas production of green tea waste stored with or without dried beet pulp. *Journal of the Science of Food and Agriculture, 87* (9), 1639-1644. doi: 10.1002/jsfa.2842

Pilar Almajano, M., Carbó, R., Jiménez, J. A. L. and Gordon, M. H. 2008. Antioxidant and antimicrobial activities of tea infusions. *Food Chemistry, 108* (1), 55-63. doi: https://doi.org/10.1016/j.foodchem.2007.10.040

Roychoudhury, S., Agarwal, A., Virk, G. and Cho, C. L. 2017. Potential role of green tea catechins in the management of oxidative stress-associated infertility. *Reprod Biomed Online, 34* (5), 487-498. doi: 10.1016/j.rbmo.2017.02.006

Rubanza, C. D. K., Shem, M. N., Otsyina, R., Bakengesa, S. S., Ichinohe, T. and Fujihara, T. 2005. Polyphenolics and tannins effect on in vitro digestibility of selected Acacia species leaves. *Animal Feed Science and Technology, 119* (1), 129-142. doi: https://doi.org/10.1016/j.anifeedsci. 2004.12.004

Saeed, M., Naveed, M., Arif, M., Kakar, M. U., Manzoor, R., Abd El-Hack, M. E.,... Sun, C. 2017. Green tea (Camellia sinensis) and l-theanine: Medicinal values and beneficial applications in humans—A comprehensive review. *Biomedicine* and *Pharmacotherapy, 95* (Supplement C), 1260-1275. doi: https://doi.org/10.1016/j.biopha.2017. 09.024

Salawu, M. B., Acamovic, T., Stewart, C. S., Hvelplund, T. and Weisbjerg, M. R. 1999. The use of tannins as silage additives: effects on silage composition and mobile bag disappearance of dry matter and protein. *Animal Feed Science and Technology, 82* (3), 243-259. doi: https:// doi.org/10.1016/S0377-8401 (99) 00105-4.

Sarker M.S.K., M., K. G. and J., Y. C. 2010. effect of green tea and biotite on performance, meat quality and organ development in ross broiler. *Egypt. Poult. Sci., 30* (I), 77-88.

Shin, J. E., Kim, J. M., Bae, E. A., Hyun, Y. J. and Kim, D. H. 2005. In vitro inhibitory effect of flavonoids on growth, infection and vacuolation of Helicobacter pylori. *Planta Med, 71* (3), 197-201. doi: 10.1055/s-2005-837816.

Stapleton, P. D., Shah, S., Hamilton-Miller, J. M., Hara, Y., Nagaoka, Y., Kumagai, A.,... Taylor, P. W. 2004. Anti-Staphylococcus aureus activity and oxacillin resistance modulating capacity of 3-O-acyl-catechins. *Int J Antimicrob Agents, 24* (4), 374-380. doi:10.1016/j. ijantimicag.2004.03.024

Tan, C. Y., Zhong, R. Z., Tan, Z. L., Han, X. F., Tang, S. X., Xiao, W. J.,... Wang, M. 2011. Dietary inclusion of tea catechins changes fatty acid composition of muscle in goats. *Lipids, 46* (3), 239-247. doi: 10.1007/s11745-010-3477-1

Toda, M., Okubo, S., Hara, Y. and Shimamura, T. 1991. [Antibacterial and bactericidal activities of tea extracts and catechins against methicillin resistant Staphylococcus aureus]. *Nihon Saikingaku Zasshi, 46* (5), 839-845.

Toda, M., Okubo, S., Ikigai, H., and Shimamura, T. (1990). [Antibacterial and anti-hemolysin activities of tea catechins and their structural relatives]. *Nihon Saikingaku Zasshi, 45* (2), 561-566.

Uuganbayar, D., Bae, I. H., Choi, K. S., Shin, I. S., Firman, J. and Yang, C. J. 2005. Effects of Green Tea Powder on Laying Performance and Egg Quality in Laying Hens. *Asian-Aust. J. Anim. Sci., 18* (12), 1769-1774. doi: 10.5713/ajas.2005.1769.

Uuganbayar, D., Shin, I. S. and Yang, C. J. 2006. Comparative Performance of Hens Fed Diets Containing Korean, Japanese and Chinese Green Tea. *Asian-Australas J Anim Sci, 19* (8), 1190-1196. doi: 10.5713/ajas.2006.1190.

Wambui, C. C., Ando, S., Abdulrazak, S. A., Osuga, I. M. and Ichinohe, T. 2012. In vitro assessment of ruminal fermentation characteristics of tropical browse mixtures supplemented with yeast. *Grassland Science, 58* (1), 53-57. doi: 10.1111/j.1744-697X.2011.00236.x.

Wang, H. and Xu, C. 2013. Utilization of tea grounds as feedstuff for ruminant. *Journal of Animal Science and Biotechnology, 4* (1), 54. doi: 10.1186/2049-1891-4-54

Xu, C., Cai, Y., Fujita, Y., Kawamoto, H., Sato, T. and Masuda, N. 2003. Silage Preparation of Barley Tea Grounds and their Nutritive Value (Vol. 74, pp. 343-348).

Xu, C., Cai, Y., Fujita, Y., Kawamoto, H., Sato, T. and Masuda, N. 2003b. Chemical Composition and Nutritive Value of Tea Grounds Silage Treated with Lactic Acid Bacteria and Acremonium Cellulase. *Nihon Chikusan Gakkaiho, 74* (3), 355-361. doi: 10.2508/chikusan.74.355.

Xu, C., Cai, Y., Zhang, J., Fukasawa, M. and Moriya, N. 2008. Ensiling and subsequent ruminal degradation characteristics of barley tea grounds treated with contrasting additives. *Animal Feed Science and Technology, 141* (3), 368-374. doi: https://doi.org/10.1016/ j.anifeedsci.2007.05.032.

Xu, J., Xu, Z. and Zheng, W. 2017. A Review of the Antiviral Role of Green Tea Catechins. *Molecules, 22* (8). doi: 10.3390/molecules22081337.

Yam, T. S., Shah, S. and Hamilton-Miller, J. M. 1997. Microbiological activity of whole and fractionated crude extracts of tea (Camellia sinensis), and of tea components. *FEMS Microbiol Lett, 152* (1), 169-174.

Yamamoto, Y., Matsunaga, K. and Friedman, H. 2004. Protective effects of green tea catechins on alveolar macrophages against bacterial infections. *Biofactors, 21* (1-4), 119-121.

Yang, C. J., Yang, I. Y., Oh, D.-H., Bae, I.-H., Cho, S.-G., Kong, I.-K.,... Choi, K. S. 2003a. Effect of Green Tea By-product on Performance and Body Composition in Broiler Chicks. *Asian-Aust. J. Anim. Sci., 16* (6), 867-872. doi:

10.5713/ajas.2003.867.

Yang, C. J., Yang, I. Y., Oh, D.-H., Bae, I.-H., Cho, S.-G., Kong, I.-K.,... Choi, K. S. 2003b. Effect of Green Tea By-product on Performance and Body Composition in Broiler Chicks. *Asian-Aust. J. Anim. Sci., 16* (6), 867-872. doi: 10.5713/ajas.2003.867

Yee, Y.-K. and Koo, M. W.-L. 2000. Anti-Helicobacter pylori activity of Chinese tea: in vitro study. *Alimentary Pharmacology* and *Therapeutics, 14* (5), 635-638. doi: 10.1046/j.1365-2036.2000.00747.x.

Yoda, Y., Hu, Z. Q., Zhao, W. H. and Shimamura, T. 2004. Different susceptibilities of Staphylococcus and Gram-negative rods to epigallocatechin gallate. *J Infect Chemother, 10* (1), 55-58. doi: 10.1007/s10156-003-0284-0.

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