Calliandracalythorsus leaves as tanniferous fodder for ruminant animals

Muhammad Rusdy

Department of Forage Science and Grassland Management, Faculty of Animal Science, Hasanuddin University, Indonesia

Abstract- *Calliandracalothyrsus* is amultipurpose tree legume which haslong been used by farmers as forage for their animals in the tropics and subtropics. Calliandra is well known as the high proteins and tannins plant, however much of the protein is wastedbecause its tannins bind protein fibreand reducing its digestibility. Tannins at high concentrations affectvoluntary intake, nutritive value of the plant and rate of growth of animals consuming them . This review discussed the relationship betweentannin, digestibility and growth of animals. Animal production from supplementation of Calliandratolow qualitybasal diets in comparison with supplementation with low tannin forage legumes are presented and discussed.

Index Terms- animal production, Calliandra, digestibility, proteins, tannins

I. INTRODUCTION

Inadequate year-round proper nutrition, especially during the dry season is the most important factor contributing to the low animal production in tropical developing countries, including Indonesia. During the dry season, most farmers use low quality standing hay and crop residues as feeds for their animals. These feeds are characterized by high levels of fiber, low levels of energy, proteins, minerals and vitamins which lead to low levels intake and digestibility (Sarwatt*et al*., 2002).On average, during the wet season, grasses contain about 8 to 10% crude protein, however during the dry season,they dropto below the minimum 7% level required for maintenance, while crop residues like rice straw and standing hay only contain crude protein of 3 – 5% (Jackson, 1978). Consequently, many problems such as poor growth, weight loss, low reproductive performances, and sickness due to the lack of nutritional quality of feed arise during the dry season. One way of improving the utilization of standing hay and crop residues is by supplementation with forage tree legumes (Norton, 1998).

Calliandra is a small leguminous tree or large shrub in the familyof Leguminosae (Fabaceae) and subfamily Mimosoideae. It is native to humid tropics and sub-humid tropical areas of Central America and Mexico.It was introduced to Java, Indonesia in 1036 and have spread from there over Indonesian archipelago and other parts of southeast Asia (Palmer *et al*., 1994).Initially it was introduced to Indonesia to provide shade in coffee plantation, but the tree has now proved more useful for other purposes such as fuelwood, land reclamation and fodder.

As fodder, dry matter yield of Calliandrais quite high, it can attain 18.2 ton DM/ha, slightlyless thanGliricidia(19.2 ton DM/ha) and Leucaena(21.8 ton DM/ha) (Catchpoole and Blair, 1990). One superiority of Calliandra over Leucaena is high adaptability to acid soils which found in most eroded soils where Leucaenacan not thrive. Leucaena also suffers from psyllid attack whereas adult psyllids are unable to feed or oviposit on calliandra (Vandesschricke*et al*., 1992.

Like most legumes, Calliandracontains high levels of crude protein which is far higher than found in the grasses and crop residues. This makes Calliandra may be suitable used as sole feed or as feedsupplement to provide protein for animals fed low quality feeds. However, despite its protein content is high,its digestibility is low, because its high levels of tannin tend to bind protein and fiber.Tannin also can reduce feed intake, lower nutrient digestibility and protein availability.There is fragmented information on the nutritional quality and the suitability of Calliandra as ruminant feed available. In this review, the summary of present knowledge on nutritional composition of Calliandraand the its effects on animal growth are presented and discussed.

II. ACCEPTANCE BY ANIMALS

Freshly harvestedCalliandra leaves are generally highly palatable to ruminants where animals have prior experience with the forage. Works in Indonesia and Australia indicate that Calliandra is better used when fresh than dried or wilted. When Calliandra leaves fed in fresh to sheep, voluntary intake was 59 g dry matter/kg $W^{0.75}$, whereas for dried materials, it was 37 g dry matter/kg $W^{0.75}$. (Palmer and Schlink, 1992). However, the reduced palatability of Calliandraas affected by wilting or drying of leaves only occurred at high levels of supplementation. At normal supplementation (20 – 40%), they had no effect on intake (Anon., 2016).

There is contradictory report on acceptance of Calliandara in comparison with other legume trees. Phiri*et al*. (1992) reported that acceptance of fresh Calliandra was lower than Leucaena but it was superior to *Sesbaniasesban* and *Gliricidiasepium*, however, Fadiyimu*et al*. (2014) reported that in Nigeria, preference index of Gliricidia was the highest, followed by Leucaena and Calliandra. They suggested that the highest preference index of Gliricidiawas caused by the fact that Gliricidia was the most familiar to goats at the time of study. It is generally accepted that Gliricidia is high quality forage, but of low palatability when first introduced to animals (Norton, 1998).

III. CRUDE PROTEIN CONTENT

The protein content of Calliandra within the range of 20 – 30% as reported by Patterson *et al*. (1996).This protein content is

comparable with other forage tree legumes such as *Leucaenaleucocephala* (25.9%) (Shelton and Brewbaker, 1998) and *Gliricidiasepium*(20 – 30%) (Simons and Stewart, 1998).

Crude protein content of Calliandra varied with provenances (Premaratne and Perera, 1999), plant parts, cutting interval and season (Salawu*et al*., 1997). Leaves and young shootsof Calliandracontain higher tannin than the older shoot. Increasing of cutting interval from 6 to 12 weeks reduced crude protein content from 22.4 to 21.6% (Tuwei*et al*., 2003).

Feeds containing protein less than 7% are considered as deficient in protein as they can not provide the minimum ammonia levels (70 mg N/L) required for optimum activity of rumen microbes (Norton, 1998). All reported protein contents of Calliandraare far above than this value, so it can be judged that proteins of Calliandra are adequate for high producing ruminants. However, high tannins may form complexeswith proteinwhich decrease their degradability in the rumen, thereby decreasing rumen ammonia concentrations and increasing the amount of protein bypassing the rumen.

IV. TANNIN CONTENT

Condensed tannin contents of Calliandra varied from 6.00 to 16.0%, with averagedof 9.5% (Table 1), which higher compared to Leucaena (3.51%) and Gliricidia (3.79%)(Aye and Adegun, 2013). Tannin content is influenced by provenance, maturity, season and method of sample preparation. The amount of tannin in Calliandra is affected by drying method used, with freeze drying being the preferred method of sample preparation.Oven drying decreased condensed tannin contentfrom 11.7 to 8.2% (Ahn*et al*., 1997). It is theorized that during oven drying, tannins bind with other cell polymers like protein or cell wall carbohydrates (Reed, 1986).

Table 1. Condensed tannin content of *Calliandracalothyrsus* leaves

Condensed tannin (%)	Reference
8.20	Ahn*et al*. (1997)
6.00	McSweeney*et al*.(1999)
11.3	Mahyuddin*et al*.(1998).
11.2 – 16.0	Premaratne*et al*. (1999)
8.08	Abqoriyah*et al*.(2014)
7.43	Setyawati*et al*.(2016)

Tannins can be beneficial or detrimental to ruminants, depending on how much it is consumed. Low concentrations of plant tannins is believed to leave the protein is unprotected as to be completely degraded in the rumen, while presence of moderate levels of tannin in diets prevented protein degradation in the rumen and make protein available to enzymatic digestion in the lower gut (Pererа*et al*. 1996).Barry *et al*. (1983) demonstrated that in*Lotus pedunculatus*, the ideal concentration of condensed tannin were between 2 – 4% of diet dry matter, at which level they bind with dietary protein during mastication and appear to protect the protein from microbial attack in the rumen. This leads to higher nitrogen retention, higher growth rates and milk yield (D'Mello, 1992). At high concentrations (>5% DM), however, condensed tannin formscomplex particularly with protein and act as anti-nutritional that reducing voluntary intake and digestibility (Barahona*et al*., 2003). All reported tannin contents of Calliandrain Table 1are higher than 5%, soit can be inferred that Calliandra can be categorized as high tanniferous plant.

V. DIGESTIBILITY

IVDMD and IVOMD value of Calliandra as reported by some authors are presented in Table 3. IVDMD value ranged from 25.3 to 38.9 and IVOMD values ranged from 26.1 to 48.4%. These values are lower compared to other leguminous tree such asLeucaena(IVDMD 65.2 and IVOMD 67.7%) (Datt*et al*., 2008), Gliricidia(IVDMD 54.52%) (Barrios, 2016) and *Sesbaniasesban* (IVDMD 60.5 – 76.1) (Dzowela*et al*., 1995).

Table 2.In Vitro Dry Matter Digestibility (IVDMD) and In Vivo Dry Matter Digestibility (IVOMD)of Calliandra

IVDMD (%)	IVOMD (%)	Reference
19.5 – 40,2	26.6	Dwozela*et al*. (1995)
25.3	26.6	Perera*et al.* (1996)
	27.3 – 36.1	Premaratne and Parera (1999)
38.9 and 36.5		Tuwei et al.2003)
	48.4	Santoso*et al*.(2013)
35.88		Barrios, (2016)

IVDMD and IVOMD value are influenced by method of drying, ADF and tannin content. In Calliandra, the highest IVDMD value was obtained by freeze drying method, followed by sun-dried and oven-dried method (Dzowela*et al*. (1995). As ADF content of Calliandra was fairly low (around 25%) (Premaratne and Perera, 1999), it is strongly suggested that the low IVDMD and IVOMD valueof Calliandraarecaused by its high tannin content.The low digestibility of Calliandra indicates that this plant is not suitable used as sole diet, and it should be used as supplement. When dried Calliandra was fed*ad libitum* as a sole diet, DDM intake decreased to 21.6 g/kg$^{0.75}$ per day (similar to barley straw plus urea-molasses (Norton and Waterfall, 2000).

The average value of IVOMD of Calliandra (Table 2) is around 30% which is lower than critical level of 65% required for feeds to be considered as having acceptable digestibility. Forage with IVOMD value of <65% can be classified as low quality feed and may results in reduced dry matter intake (Moore and Mott, 1973).

VI. ANIMAL PRODUCTION

When used as sole diet, daily gain of sheep fedCalliandra was lower (44 g) compared to Gliricidia (50 g) and Leucaena (55 g) (Widiawati*et al*., 2000). However, when used as supplement to low quality basal diets, live weight gains of animals fedCalliandra were higher than those fed low tannin plants likeSesbania (Wanbui*et al*., 2005),Lucerne and Gliricidia (Pamo*et al*. 2006; Kinuthia*et al*., 2007) as well as high tannin plant likeDesmodium(Kaitho and Kariuki, 1998), but their daily gains were lower compared to animals supplemented withTithonia and Leucaena(Table 3). This indicates that when used as supplement to low quality basal feeds, the growth of animals fedCalliandra are higher compared to many other tree legumes, irrespective their tannin contents. It is suggested that by supplementing Calliandra to low tannin basal diet, concentration of tannin in diets decreased. When concentration of tannins reached 2 - 4% (Barry *et al*., 1983), protein is prevented from microbial attack and making protein is available for enzymatic digestion in lower gut, leading to higher growth rates.The low daily gain of animals supplemented with low tannin plants in the present study might be attributed to the low tannin and by-pass protein levels of diets and much of protein is wasted in the rumen.

Table 3. Effect of supplementation of Calliandra on growth of animals fed low quality diets

Animal	Basal diet	Calliandra/other legumesinclusion	Live weight gain (g/day)	Reference
Goats	*Cenchrusciliaris* hay	Calliandra0%, Calliandra16%, 35% (fresh), and 27% (wilted)	-27.0 39.0 52.0 25.0	Ibrahim, 1994)
Dairy heifers	Old Napier grass	25% of either: Calliandra, Sesbania or Desmodium	 732 606 638	Kaitho and Kariuki, (1998)
Sheep	Napier grass Maize stover	Fresh Calliandra 32.4% Wilted Calliandra 37.3% Fresh Calliandra, 52.7% Wilted Calliandra, 51.7%	90.1 79.1 26.1 42.7	Tuwei *et al*., (2003)
Goats	Urea treated corn stover + 100 g maize germ	Tithonia 27%, Calliandra 30%, Sesbania 32%	82.6 57.1 39.3	Wanbui *et al*., (2006).
Goats	Improved forage and natural grass	6 g protein of either: Calliandra, Gliricidia or Leucaena	 13.8 4.50 20.6	Pamo*et al*., (2006)
Goats	Rhodes grass hay	Calliandra0%, Calliandra 100 and 200 g/goat /day Lucerne 100 and 200 g/goat/day	17.4 30.8 and 56.8, respectively 26.1 and 40.1, respectively.	Kinuthia *et al*., (2007)

Besides is attributed to the lowering of tannin content of diets as effect of supplementation, the high animal production from supplementation with Calliandra may be caused by adaptability of herbivore animals to high tannin plants. Narjisse*et al*. (1995) states that proline rich protein in saliva of ruminants can bind tannin which cancel their negative effect on palatability and improve digestion of tannin rich feeds.

The proportion of Calliandra in the diets that yielded the highest daily gainis influenced by basal dietquality. With low quality *Cenchrusciliaris* hay as basal diet, the best proportion was 35% of fresh Calliandra (Ibrahim, 1994) (Table 3).

Supplementation offreshor wilted Calliandra at lower proportionto Napier grassbasal diet gave higher daily gain compared to supplementation offresh or wilted Calliandraat higher proportion to maize stover basal diet (Tuwei*et al.,* 2003) (Table 3). This indicates that for high quality basal feed like Napier grass, proportion of Calliandra supplemented should be lower than supplementation to low quality basal feed like maize stover.

VII. CONCLUSION

Calliandra leaves are rich in crude protein, but its high level tannins reduced its digestibility and animal growth when it is used as sole diet.However, when used as supplement to low to moderate quality basal diets, growth of animals supplemented with Calliandrais higher than supplemented with lower tannin plants such asGliricidia, Lucerne and Sesbania. Therefore the use of Calliandra as supplement provides much promise to increase animal production in tropical and subtropical region.

REFERENCES

[1] Abqoriyah, Utomo, R. Suwignyo, B. 2014. Effect of different tannin of Caliandra (Calliandracalythorsus on in vitro digestibility in different defoliation. In: 16th AAAP Animal Science Congress, 10 – 14 November 2014.

[2] Ahn, J.H., Erriot, R., Norton, B.W. 1997. Oven drying improves nutritional value of Calliandracalythorsis and Gliricidiasepium as supplements for sheep given low-quality straw. J. Sci. Food. Agric. 75 (4) : 503 – 510.

[3] Anonymous, 2016.Calliandracalythorsus.http://www.tropicalforages.info/key/Forages/Media /Html/Calliandra_calothyrsus.htm. Retrieved on October 13, 2016.

[4] Aye, P.A., Adegun, M.K., 2013.Chemical composition of some functional properties of Moringa, Leucaena, and Gliricidia leaf meal. Agric. Biol. J. North Am. 4 (1) : 71 – 77.

[5] Barrios, E. 2016.The in vitro dry matter digestibility method.Tropical Soil Biology and Fertility Institute of CIAT, Cali, Columbia. http://ciat-library.ciat.cgiar.org/articulos_ciat/tsbf/pdf/nut_mgt_paper_6.pdf

[6] Barry, T.N. 1983. The condensed tannin content of vegetative Lotus pedunculatus, its regulation by fertilizer application, and effect upon protein solubility. J. Sci. Food. Agric. 34 (10) : 1047 – 1056.

[7] Barahona, R. Lascano, C.E., Narvaez, N., Owen, N., Morris, P., Tehodorou, M.K. 2003.In vitro digestibility of mature and immature leaves of tropical forage legumes differing in condensed tannin and non-starch polysaccharide content and composition. J. Sci. Food Agric., 83 : 1256 – 1266.

[8] Catchpoole, D.W. and Blair, G. 1990. Forage Tree Legumes. I. Productivity and N economy of Leucaena, Gliricidia, Calliandra, and Sesbania and tree/Panic mixtures. Aust. J. Agric. Res. 41 : 521 – 530.

[9] Datt, C. Datta, M., Singh, N.P. 2008.Assessment of fodder quality of leaves of multipurpose trees in subtropical humid climate of India. J. Forest. Res. 19 (3) : 209 – 212.

[10] D'Mello, J.F.P. 1992. Nutritional potentialities of fodder tree and shrub as protein sources in monogastric nutrition. In: A. Speedy and P.I. Pugliese (Eds). Legume tree and other fodder tree as protein sources for livestock. F.AO., Rome: 115 - 117

[11] Dwozela, B.H.,Hove, L. and Mafongoya, P.L. 1995. Effect of drying method on chemical composition and in vitro digestibility of multi-purpose tree and shrub fodder. Trop. Grassld, 29 (263 – 269).

[12] Ebong, C. 1996. Calliandra leaf meal in goat ration: effects on protein degradability in the rumen and growth in goats. Proc.The Third Biennual Conference of the African Small Ruminant Research Network. Ed. S.H.B. Lebbie and E. Kagwini

[13] Fadiyimu, A.A., Fajemisin, A.N., Arigbede, M.O. 2014. Rumen dry matter dedgradability and preference by West African dwarf goats for selected multipurpose trees in Nigeria. Report and Opinion, 6 (9) : 8 – 13.

[14] Ibrahim, T.M. 1994. Yield and utilization of shrub legumes in acid infertile soils of the humid tropics. PhD Thesis, James Cook University of North Queensland, Department of Biomedical and Tropical Veterinary Sciences, Australia.

[15] Jackson, M.G. 1978. Rice straw as livestock feed. In: World Animal Review. FAO of the United Nations, Rome, Italy.

[16] Kaitho, R.J. and Kariuki, J.N. 1998. Effects of Desmodium, Sesbania and Calliandra on growth of dairy heifers fed Napier grass basal diet. AJAS, 11 (6) : 680 – 684.

[17] Kinuthia, M.N., Wanyoike, M., Gachuiri, C.K., Wakhungu, J.W. 2007. Effect of supplementing weaner goats with graded levels of *Calliandracalothyrsus* and lucerne (*Medicago sativa*) on feed intake aand weight gain. Livestock Res. Rur.Dev. 19 (8).

[18] Mahyuddin, P., Liale, D.A., and Lowry, J.B. 1998. Drying treatment drastically affects feed evaluation and feed quality with certain tropical legume species. Anim. Feed Sci. Technol. 22 : 69 -78.

[19] McSweeney, C.S., Palmer, B., Bunch, R., Krause, D.O. 1999. Isolation and characterization of proteolytic ruminant bacteria from sheep and goats fed the tannin-containing shrub legume Calliandracalythorsus. Appl. Env. Microbiol. 65 (7) : 3075 – 3083.

[20] Moore, J.E. and Mott, G.O. 1973. Structural inhibitors of quality in tropical grasses. In: Matches (edition. Anti-quality Components of Forages, CSSA. Special Publication, No.4 Madison, Wisconsin, pp. 53 – 98.

[21] Narjisse, H., Elhonsali, M.A. Olsen, J.D. 1995. Effect of oak (*Quercus ilex*) tannins on digestion nitrogen balance in sheep and goats. Small Ruminant Res. 18 : 21 – 26.

[22] Nhrera, F.V., Ndlovu L.R., B.H. Dwozela, B.H. 1998. Utilization of *Leucaenadiversifolia*, *Leucaenaesculenta*, *Leucaenapallida* and *Calliandracalothyrsus* as nitrogen supplement for growing goats fed maize stover. Anim. Feed Sci. Technol. 74 (1 : 15 – 2.

[23] Norton, B.W. 1998.The nutritive value of tree legumes. In: Forage Tree Legumes in Tropical Agriculture. Ed. R.C. Gutteridge and H.M. Shelton.Tropical Grassland Society of Australia Inc.

[24] Norton, B.W. and Waterfall, M.H. 2000.The nutritive value of *Tipuanatipu* and *Calliandracalothyrsus* as supplements to low-quality straw for goats.Small Rum. Res. 38 : 175 – 182.

[25] Palmer, B. and Schlink, A.C. 1992. The effect of drying and on the intake and rate of digestion of the shrub legume *Calliandracalothyrsus*. Trop. Grassld, 26 : 89 – 93.

[26] Palmer, B., Macqueen, D.J., Gotteridge, R.C. 1994. *Calliandracalothyrsus* – a multipurpose tree legume for humid locations. In: Forage Tree Legumes in Tropical Agriculture. Ed. R.C. Gutteridge and H. Max Shelton.Tropical Grassland Society of Australia.

[27] Pamo, E.T. ,Tendonkeng, F. and Kadjito, J.T.T. 2006. Evaluation of comparative growth and reproductive growth and reproductive performance of west African dwarf goats in the western highlands of Cameroon. Small Ruminant Res. 65 (1-2 : 31 – 37.

[28] Patterson, R.T., Roothaert., R.L., Nyaata, O.Z., Akyeampong, E., Hove, L. 1996. Experience with *Calliadracalothyrsus* as feed for livestock in Africa. In: Evans, D.O. Proceeding of the International Workshop on the Genus Calliandra. 23rd – 27th January 1996. Bogor, Indonesia, pp. 183 – 194.

[29] Perera, A.N.F., Perera, E.R.K., and Gunasena, H.P.M. 1996. Nutritive value and degradation characteristics of Caliandracalylhorsisprovenences. In: Proc. International workshop on the genus Calliandra. Ed. D.O. Evans. Bogor, Indonesia, Jan. 23 – 27, 251 – 259.

[30] Perera, A.N.F. and Perera, E.R.K. 1966. Use of *Calliandracalothyrsus* leaf meal as substitute for coconut oil meal for ruminats.In: Proc. International workshop on the genus Calliandra. Ed. D.O. Evans. Bogor, Indonesia, Jan. 23 – 27, 251 – 259.

[31] Phiri, D.M., Coulman, B., Steppler, H.A., Kamara, C.S. and Kwesiga, F. 1992. The effect of browse supplementation on maize husk utilization by goats.Agroforestry system. 17 (2) : 153 – 158.

[32] Premaratne, S. and Perera, H.G.D. 1999. Evaluation of provenance variation in condensed tannin content of fresh leaves of Calliandracalythorsis. AJAS, 12 (6) : 891 -894.

[33] Reed, J.D. 1986. Relationships among soluble phenolics, insoluble proanthocyanidinsand fibre in East African browsw species. J. Range Mngmt, 39: 5 – 7.

[34] Salawu, M.B., Acamovic, T., Stewart, C.S., Maasdorp, B.V. 1997.Assesment of nutritive value of *Calliandracalythorsus*: Its chemical composition and the influence of tannin,,pipecolic acid and polyethylene glycol on in vitro organic matter digestibility. Anim Feed Sci. Technol. 69 (1) : 207 – 217.

[35] Santoso, B., Saragih, E.W. and Hariadi, B.T. 2013. Effect of water extract of plants containing tannin on in vitro methanogenesis and fermentation characteristics of the grass *Pennisetumpurpureophoides.* J. Trop. Anim. Agric. 38)1) : 47 – 54.

[36] Sarwatt, S.V., Kapange, S.S. and Kakengi, A.M.W. 2002. Substituting sunflower seed-cake with *Moringaoleifera* leaves as a supplemental goat feed in Tanzania. Agrof.Sys.56 : 241 – 247.

[37] Setyawati, I., Putra, I.G.N.A.D., Wiratmini, N.I., Sudatri, N.W. 2016. Liver histology of female rat (Rattusnovergicus) fed diet containing Calliandra leaf and pineapple peel during gestation. Int. J. Adv. Pharm. Biol. Chem. 5 (1) : 9 – 14.

[38] Shelton, H.M., Brewbaker, J.L. 1998.*Leucaenaleucocephala* – the most widely used forage tree legume. In: Forage Tree Legumes in Tropical Agriculture. Ed. R.C. Gutteridge and H. Max Shelton, Tropical Grassland Society of Australia, Queensland.

[39] Simons, A.J., Stewart, J.L. 1998. *Gliricidiasepium* – a multipurpose forage tree legume. In: Forage Tree Legumes in Tropical Agriculture. Ed. R.C. Gutteridge and H.M. Shelton.Tropical Grassland Society Australia.

[40] Tuwei, P.K., Kang'Ara, J.N.N., Stewatt, J.L., Poole, J. ,Ngugi, F.K., Harvey, M. 2003. Factors affecting biomass production and nutritive value of *Calliandracalothyrsus* leaf as fodder to ruminants. J. Agric. Sci. 141 (01) : 113 – 127.

[41] Vandesschricke, F., Quilici, S. Gauvin, J and Roederer, Y. 1992. The Leucaenapsyllid in Reunion: the extent of damage and prospect of biological control. Bois et Forest des Tropiques, 234 : 47 – 59.

[42] Wambui, C.C., Abdulrazak, S.A., and Noordin, Q. 2006. The effect of supplementing urea treated maize stover with Tithonia, Calliandra and Sesbania to growing goats. Livestock Res. Rur.Dev. 18 (5).

[43] Widiawati, Y., Teleni, E. and Winugroho, M. 2000. The nutritive value of Gliricidiasepium, Leucaenaleucocephala and Calliandracalothrsus for growing sheep.Asian.Aus. J. Anim. Sci. C : 163.

AUTHORS

First Author – Muhammad Rusdy, Department of Forage Science and Grassland Management , Faculty of Animal ScienceHasanuddin University, Indonesia