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Energy supplements for leucaena
Suplementación energética para leucaena

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Abstract

Leucaena can be fed as the sole diet to fattening cattle without nutritional problems and it will promote high liveweight gains. The high crude protein concentration in leucaena suggests that energy supplements, which are readily fermented in the rumen, could be used to capture the excess rumen degradable protein and provide more microbial protein and metabolizable energy to the animal, further increasing liveweight gain or milk production. This approach has been tested in grazing cattle and also in cut-and-carry systems in Australia and Indonesia. In both systems, production (liveweight gain or milk production) increased with the addition of supplements containing large amounts of fermentable metabolizable energy. The substitution of the basal diet (leucaena or leucaena mixed with grass or crop residues) by the supplement also means that more animals can be carried in the system for a set amount or area of leucaena. The same principles would apply to any tree legume-based system. Energy supplements can come in many forms, viz. fermentable starch (cereal grains and cassava), sugars (molasses), pectins (soybean hulls and pulps) and fibre (rice bran, cassava bagasse), but they have not been compared for their efficacy nor for their economic benefit, if any, in these systems.

Keywords: Cut-and-carry systems, forage utilization, legume-energy combinations, liveweight gains, substitution effects.

Resumen

La leucaena se puede usar como dieta única para ganado de engorde sin que se presenten problemas nutricionales, resultando en altos aumentos de peso vivo. La alta concentración de proteína cruda en la leucaena sugiere que suplementos energéticos fácilmente fermentados en el rumen podrían ser usados para capturar el exceso de proteína degradable en el rumen y proporcionar más proteína microbiana y energía metabolizable al animal, aumentando aún más la ganancia de peso vivo o la producción de leche. Esta estrategia ha sido probada en sistemas de pastoreo y de corte y acarreo en Australia e Indonesia. En ambos sistemas, la producción (ganancia de peso vivo o producción de leche) aumentó con la adición de suplementos que contenían grandes cantidades de energía metabolizable fermentable. La sustitución de la dieta base (leucaena o leucaena mezclada con pasto o con residuos de cultivos) por el suplemento también significa que se pueden mantener más animales en el sistema por una cantidad o área determinada de leucaena. Los mismos principios se aplicarían a cualquier sistema basado en árboles leguminosos. Los suplementos energéticos pueden ser de muchas formas, tales como almidón fermentable (granos de cereales y yuca), azúcares (melaza), pectinas (cáscaras y pulpa de soya) y fibra (salvado de arroz, bagazo de yuca), pero aún no se han comparado por su eficacia ni por su eventual beneficio económico en estos sistemas.

Palabras clave: Combinación leguminosas-energía, efecto de substitución, ganancia de peso vivo, sistemas de corte y acarreo, utilización de forraje.

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Introduction

Leucaena has a high crude protein (CP) concentration and high dry matter digestibility (DMD) and is used as a protein supplement or legume forage within grazing systems. As well as providing a source of CP, especially during the dry season or when straw residues from cropping systems are fed, it is also a source of extra energy. It can also be used as a sole forage in grazing or cut-and-carry systems, especially in Asia and Latin America, and produces good liveweight gains (LWG). Panjaitan et al. (2014) and Dahlanuddin et al. (2014) have shown that Bali cattle fed solely on leucaena in a cut-and-carry system gained 0.47–0.61 kg/d, which is close to the genetic potential for growth of this cattle species (Figure 1). Under this feeding regime, the CP consumed is in excess of the CP requirements of all classes of ruminants.

The excess CP may be viewed as wasteful or energetically costly as the ruminant catabolizes and excretes the excess N in the form of urea, largely in the urine. However, having a diet with excess CP is not in itself a physiological problem for the animal, as ruminants have evolved to cope with diets containing a wide range of various nutrients including CP and/or N. Nutritional principles define the excess or deficit of N in the rumen for the microbes, or amino acids at the tissue level for cell metabolism. These feeding standards demonstrate that leucaena provides excess rumen degradable protein (RDP) and hence excess N for rumen microbes given the fermentable metabolizable energy (ME) of leucaena and also provides an excess of absorbed amino acids. While animals can cope with this situation quite readily, nutritionists often assess things on a 'requirement' basis and define excess and deficit scenarios as 'problems', which need to be fixed by balancing the diet. Rather than being a 'problem', this scenario presents an opportunity to make more efficient use of the high-protein forage in the leucaena.

Figure 1. Bali bulls in a traditional fattening system with 100% leucaena in West Sumbawa District, Indonesia.

The opportunity

An excess of RDP in the rumen provides the opportunity to increase microbial crude protein (MCP) production by increasing the supply of fermentable ME to microflora within the rumen. The excess of absorbed amino acids within the small intestine (metabolizable protein, MP) presents an opportunity to increase animal performance by providing additional ME. How might this be exploited?

Supplementing a sole leucaena diet with a highly fermentable ME source with low CP concentration is one possible option. This approach would increase MCP production and also increase ME supply through absorbed volatile fatty acids from the rumen and possibly absorbed glucose from the small intestine depending on the energy substrates that are used. Possible energy sources are starches, sugars and pectins, i.e. the common carbohydrates which are rapidly fermented in the rumen, as well as other fermentable fiber sources. Starch is provided by the common cereal grains such as wheat, barley, sorghum and corn, which have moderate CP concentrations (10–14%), plus other less commonly used feedstuffs such as cassava. Devendra (1977) quotes composition of cassava tubers of about 35% starch, about 90% nitrogen free extract, 11.9–14.6 MJ ME/kg DM and 2–4% CP, while Heuzé et al. (2016) suggest a much higher starch concentration of 69–89% DM and an ME value of 11.5–12.9 MJ/kg DM (mean of 12.2) for ruminants. Pectin is found in by-products such as soybean hulls and pulps such as citrus pulp, pineapple pulp and tomato pulp, all by-products from other industries. The main sugar sources are molasses (high in ME and low in CP) and root crops such as fodder beet. From a nutritional perspective, a supplement high in ME and low in CP, e.g. cassava or molasses, is optimal, but other common cereals such as wheat, barley, sorghum or corn or the various pulps can also be used. Similarly, a case can be made for other by-products which have reasonable fermentable ME values such as rice bran, cereal bran and pollard. Availability and price will determine the energy source chosen.

The principle in such an approach is to target the excess RDP and provide a fermentable substrate containing starch, pectin, sugars or digestible fiber. This will enable capture of the excess RDP within the rumen and an increase in MCP production, in addition to an increase in ME supply. The extra MP may not be required but the response curve of LWG to extra MP is curvilinear (Black and Griffiths 1975) and, although the extra MP is used with low efficiency for growth, there will still be a LWG response. Poppi (1990) showed in New Zealand that LWG of lambs still increased in response to extra MP despite CP values in excess of 25%. This comes about by the animal using the surplus amino acids as a source of energy as well as a source of amino acids. If MP is limiting, there will be a huge response but the calculations for leucaena alone show that the primary limiting nutrient is ME.

The practical response

If the above approach is followed, viz. providing extra fermentable ME because RDP is in excess of requirements of the rumen microflora with a sole leucaena diet, a response in LWG is expected. This is not the only benefit expected since, as the level of an energy supplement is increased, there is a substitution effect on intake of the basal diet (McLennan et al. 2017). This means that, when the energy supplement is fed, the amount of leucaena consumed declines. The practical significance is that a limited amount of leucaena can be used to feed more animals when a mixed diet of leucaena plus an energy supplement is fed than if a sole leucaena diet is fed. This has important implications for cut-and-carry systems and for grazing systems based on leucaena, where dry matter yield of leucaena is the limiting component in the system. In practical terms, a cut-and-carry farmer or one with a grazing system can support more animals on a limited area of leucaena by feeding an energy supplement. Such an approach has been used by Petty et al. (1998) and Petty and Poppi (2012) in grazing systems in Australia, and by Panjaitan and Dahlanuddin (unpublished data) in cut-and-carry systems in Indonesia and Timor Leste. In places such as Australia where land is less limiting, it may be simpler and more economic to plant a larger area of leucaena.

The evidence: Grazing systems

Grazing systems do not use a leucaena-only pasture base. The early work of Quirk et al. (1990) in south Queensland showed that annual LWG could be increased from 90 kg/steer on native pasture to 205 kg/steer on native pasture with leucaena planted in rows 3 m apart. Current recommendations in Australia are to plant leucaena at 8–10 m inter-row spacings to increase the total biomass production within the system by increasing grass growth (S. Buck pers. comm.).

The principle of energy supplementation could also be applied in these grazing systems, both to utilize the high RDP from leucaena and to increase overall ME intake. Petty et al. (1998) and Petty and Poppi (2012) grazed cattle on a pangola (*Digitaria eriantha*)-leucaena pasture and supplemented them with increasing levels of maize grain or molasses up to 10 g DM/kg LW/d. In both experiments significant responses in LWG (up to 0.35 kg/hd/d) to molasses were obtained but responses to maize grain occurred only in the first study. Both studies showed a similar substitution effect whereby leucaena intake declined at high levels of maize or molasses supplementation. This substitution effect is very important as it allows more stock to be supported on a limited area or quantity of leucaena. The economics of this practice needs careful evaluation as supplementation is rarely profitable in these grazing situations in Australia. The response curves developed by Petty et al. (1998) and Petty and Poppi (2012) provide a methodology to assess various situations economically.

A similar experiment in Brazil with goats grazing a leucaena-grass system and supplemented with increasing amounts of maize grain produced almost identical results to the studies with cattle in northern Australia (Carvalho et al. 2017). They compared levels of maize grain supplement up to 13 g DM/kg LW/d, and LWG of the goats increased from 18 g/d without supplement to 67 g/d at the highest supplement level in a linear fashion, allowing stocking rate to be increased in response to the substitution effect.

The evidence: Cut-and-carry systems

There is a large number of reports whereby feeding leucaena or other tree legumes in a cut-and-carry system increased intake and LWG or milk production of ruminant animals (Poppi and Norton 1995). Legumes are used to supplement forages with low (e.g. straws) to moderate (e.g. elephant grass) CP concentration, all with relatively low DMD. In all cases there is a curvilinear response in intake and LWG with a rapid increase up to an inclusion level of approximately 10 g DM/kg LW/d and a slower increase to a plateau at higher levels.

As with grazing systems, leucaena is usually a supplement and not the sole forage. In these cases the results are similar to those from the grazing systems outlined above, i.e. increases in total intake and LWG. Flores et al. (1979) supplemented dairy cows grazing nitrogen-fertilized Rhodes grass with leucaena up to 3.5 g DM/kg LW/d and increased milk production from 9.6 to 10.3 kg/d. Where an energy supplement has been used with the leucaena the results mirror those of the grazing systems, viz. a further increase in LWG combined with a substitution effect. For example, Muinga et al. (1995) reported milk production of dairy cows fed Napier grass (5.1 kg milk/d) or Napier grass supplemented with 2 kg DM leucaena/d (5.5 kg/d) or 2 kg DM leucaena plus 1 kg DM maize bran/d (6.5 kg/d) in a cut-and-carry system. Quigley et al. (2009) conducted a series of experiments to evaluate LWG of weaner Bali cattle fed grasses, and supplemented with tree legumes and protein meals, alone and in combination with energy supplements. LWG was increased from 0.1–0.2 kg/d (grass only) to >0.5 kg/d, with the highest gains in weaners fed leucaena ad libitum with 10 g maize or 10 g rice bran/kg LW/d (0.56 and 0.61 kg/d, respectively). This was comparable with gains by weaners fed a high CP (18%) concentrate ration (0.65 kg/d). To basal diets of either corn stover or elephant grass hay fed ad libitum to Bali bulls, Marsetyo et al. (2012) fed a supplement of gliricidia (*Gliricidia sepium*) at 10 g DM/kg LW/d. Gliricidia supplementation at this level increased LWG from 0.17–0.23 to 0.28–0.31 kg/d. There are many such examples in the literature and from this conference.

Supplementing with leucaena will markedly increase animal performance where the basal diet is low in CP (<7% CP) as it will stimulate the microflora and increase DM intake, but can also increase performance where the basal diet is higher in CP (>7% CP), although responses would be smaller. The latter effect is moderated by the comparative DMD of both feed sources. The major effect of leucaena in these systems is to increase overall ME intake but the accompanying increase in MP intake is also important. Providing an energy supplement with the grass-leucaena mix will usually further increase LWG. As with grasses, quality of leucaena can vary markedly depending on the proportion of leaf consumed. Some cut-and-carry systems feed the whole plant in an intact form and animals select mostly leaf and leave a large amount of stem residue, so the CP % and DMD of the leucaena consumed is high. Other systems put the leaf and stem through a chopper to minimize waste and the overall CP % and DMD of the chopped mixture is reduced by the large amount of stem so animals have difficulty selecting a high quality diet. Hand-plucked leucaena leaf can have CP of 30% and DMD of 61.7% (Petty et al. 1998), while Karachi (1998) showed leaf averaged 25% CP and 58% DMD and stem averaged 13% CP and 36% DMD. The large difference in these parameters between leaf and stem highlights the difference in quality of feed selected by animals fed whole branches and those fed chopped material.

There are fewer reports where leucaena (or other tree legumes) was the sole diet of fattening animals and where an energy supplement has been fed with leucaena. Budisantoso (cited by Quigley et al. 2009) demonstrated an increase in LWG of Bali bulls from 0.42 kg/d (leucaena alone) to 0.61 kg/d (leucaena plus maize) or 0.56 kg/d (leucaena plus rice bran), both supplements constituting about 34% of the final ration. Partial substitution occurred as intake of leucaena with the supplemented rations was 15–23% lower than when leucaena was fed alone. Dahlanuddin et al. (2014) compared leucaena, sesbania (*Sesbania sesban*) and gliricidia when fed as the sole diet and found leucaena and sesbania resulted in much higher LWG than gliricidia. With all tree legumes, animals responded to an energy supplement usually in the form of rice bran or maize grain. These findings support the theoretical arguments outlined in the early section of this paper. Dahlanuddin et al. (2014) showed LWGs of 0.34 kg/d in Bali bulls fed sesbania alone and 0.43 kg/d with sesbania plus rice bran, while Panjiatan et al. (2018) demonstrated LWGs of 0.33 kg/d in Bali bulls fed native grass alone and 0.53 kg/d when the native grass was supplemented with sesbania plus maize grain. Bali bulls fed leucaena plus maize grain achieved 0.66 kg/d (Dahlanuddin et al. 2018).

Differences in response to additional energy could depend on the form of energy supplement (e.g. starch vs. sugars vs. pectin vs. highly digestible fiber) but such comparisons are limited, e.g. Budisantoso (cited by Quigley et al. 2009). More recently a series of unpublished experiments (Kusmartono and F. Cowley pers. comm.; Dahlanuddin and Panjaitan unpublished data) have shown that cassava and cassava bagasse ('onggok') may be used as effective energy sources but high levels of inclusion (>50% cassava or bagasse in the ration) can depress intake and LWG. This phenomenon does not appear to be related to starch alone, as similar studies, where grain was fed with grass-based diets, showed no depression in LWG but a substitution effect of the grain on hay intake (McLennan et al. 2017).

Leucaena and most tree legumes have a CP concentration of 20–25% with leaf plus small amounts of stem, and up to 30% CP in leaf alone, a DM digestibility of approximately 60% and a degradability of 66% (Bamualim et al. 1980; 1984a; 1984b). The RDP:DOM ratio is 188–236 g RDP/kg DOM compared with a rumen microbial requirement of 130 g RDP/kg DOM (PISC 2007). A supplement or total mixed ration of 50% leucaena and 50% energy supplement would supply approximately 177 g RDP/kg DOM for a cereal grain energy source and 138 g RDP/kg DOM for a cassava tuber energy source, both of which are close to the requirements of rumen microbes for N and should maximize MCP production. We were unable to find a comparison of these energy sources in such a situation. As both energy sources are readily available at very competitive prices (depending on country and region), there is an urgent need to evaluate them under these feeding systems. While the role here is primarily to provide fermentable ME for the high RDP from leucaena, when used at very high levels (or at total mixed ration formulation), this proportional mix provides both RDP and high ME to the animal. With the substitution effect it would enable a limited amount of leucaena to be used to feed more animals. These formulations have application in fattening diets in Asia and could have a role in enhancing the use of leucaena in northern Australia. The use of cassava with leucaena would be a system similar to that already studied by Petty et al. (1998) and Petty and Poppi (2012) with maize or molasses. Cassava and its by-products could also be used with leucaena or any other protein source (e.g. algae, forage legumes or protein meals) to devise supplements or total mixed rations for use in backgrounding live export cattle or finishing cattle out of season. In all these circumstances biological and economic responses need to be evaluated, as economic analysis may show that feeding leucaena alone is the most economic. A whole-of-enterprise analysis is required rather than an individual animal response as greater throughput (more animals) may be of more interest to smallholders wishing to increase cattle numbers and overall profit.

The case for cassava-leucaena systems

The mix of cassava or its by-products with leucaena has many advantages from a systems perspective as outlined above and meets the nutrient requirements of both rumen microflora and the ruminant animal (e.g. fattening bulls). The current inter-row system used in Australia, Asia and Latin America combines leucaena and grass, which is often low in ME. Maize or cassava could be substituted for grass in the inter-row of a leucaena system, especially those systems in Asia (Figure 2), and the grain, stover, cassava tubers and cassava leaves could be utilized. Cassava tubers are very high in ME (see above) and low in CP. This would substantially increase the total DM yield from the system and mixing the whole cassava tubers with leucaena in a total mixed ration would provide a high quality product. Feeding a 50:50 mixture of cassava tuber and leucaena ad libitum or at 16 g/kg LW/d to Bali bulls resulted in LWGs of 0.57 and 0.42 kg/d (Dahlanuddin unpublished data; Panjaitan unpublished data). When 40–50% cassava was fed with a range of protein sources (gliricidia, copra meal or palm kernel cake), LWGs of 0.39 kg/d in Bali bulls (Marsetyo unpublished data), 0.75 kg/d in Madura bulls (Kusmartono and F. Cowley pers. comm.) and 1.39 kg/d in Limousin/Ongole crossbred bulls (Retnaningrum and Kusmartono pers. comm.) were achieved. Commercial feedlot rations fed to Ongole bulls using cassava and protein meals achieved 0.8 kg/d (Antari et al. 2012) and, in a village supplement experiment, 0.82 kg/d (Ratnawati et al. 2015). These values are very high and approaching or equivalent to the highest recorded LWGs for most of these cattle breeds. One might expect that using leucaena as the protein source would produce similar results.

Figure 2. Leucaena cv. Tarramba inter-row maize in West Sumbawa District, Indonesia.

Conclusions

Leucaena leaves have high CP and ME concentrations. There are no detrimental nutritional consequences of such a high CP concentration in the diet, and the only issues associated with feeding a 100% leucaena diet are mimosine and DHP toxicity. The high CP concentration creates opportunities for using leucaena in fattening systems. The traditional approach is to use it as a supplement to low-CP dry season pastures (grazing scenario) or crop residues (various stovers) with positive effects on LWG. In Australia this has evolved into year-round grazing (leucaena-grass pasture) providing a higher quality overall diet than grass alone and supporting higher stocking rates. With total mixed rations in cut-and-carry systems leucaena can be combined with an ingredient with high ME, such as cereal grains, pulps, bran or cassava, resulting in a high quality mixture which promotes improved LWGs. The advantage of feeding a leucaena-energy source mixture is that a given amount of leucaena can be used to fatten more animals and increase cash flow of the smallholder farmer.

References

(Note of the editors: All hyperlinks were verified 29 April 2019.)

Antari RA; Pamungkas D; Umiyasih U. 2012. Performance and meat quality of fattened beef cattle fed on dried cassava powder based feedlot. Proceedings of the International Conference on Livestock Production and Veterinary Technology 2012, Indonesian Center for Animal Research and Development, Bogor, Indonesia. p. 172–178.

Bamualim A; Jones RJ; Murray RM. 1980. Nutritive value of tropical browse legumes in the dry season. Proceedings of the Australian Society of Animal Production 13:229–232. livestocklibrary.com.au/handle/1234/7118

Bamualim A; Weston RH; Hogan JP; Murray RM. 1984a. The contributions of *Leucaena leucocephala* to post ruminal digestible protein for sheep fed tropical pasture hay supplemented with urea and minerals. Proceedings of the Australian Society of Animal Production 15:255–258. livestocklibrary.com.au/handle/1234/7470

Bamualim A; Stachiw S; Jones RJ; Murray RM. 1984b. The effect of fresh *Leucaena leucocephala* as a supplement on the utilisation of pasture hay by goats. Proceedings of the Australian Society of Animal Production 15:259–262. livestocklibrary.com.au/handle/1234/7469

Black JL; Griffiths DA. 1975. Effects of liveweight and energy intake on nitrogen balance and total N requirement of lambs. British Journal of Nutrition 33:399–413. doi: 10.1079/BJN19750044

Carvalho WF de; Oliveira ME de; Alves AA; Moura RL de; Moura RMAS. 2017. Energy supplementation in goats under a silvopastoral system of tropical grasses and leucaena. Revista Ciência Agronômica 48:199–207. doi: 10.5935/1806-6690.20170023

Dahlanuddin; Panjaitan T; Sofyan; Poppi DP; Quigley SP. 2018. Bali × Hissar cattle fed *Leucaena leucocephala* supplemented with maize grain grew faster than Bali cattle. Proceedings of 10th International Symposium on the Nutrition of Herbivores, Clermont-Ferrand, France, September 2–6, 2018. (in press).

Dahlanuddin; Yanuarianto O; Poppi DP; McLennan SR; Quigley SP. 2014. Liveweight gain and feed intake of weaned Bali cattle fed grass and tree legumes in West Nusa Tenggara, Indonesia. Animal Production Science 54:915–921. doi: 10.1071/an13276

Devendra C. 1977. Cassava as a feed source for ruminants. In: Nestel B; Graham M, eds. Cassava as animal feed. Proceedings of a workshop held at the University of Guelph, Ontario, Canada, 18–20 April 1977. International Development Research Centre (IDRC), Ottawa, Canada. p. 107–119. hdl.handle.net/10625/18510

Flores JF; Stobbs TH; Minson DJ. 1979. The influence of the legume *Leucaena leucocephala* and formal-casein on the production and composition of milk from grazing cows. The Journal of Agricultural Science 92:351–357. doi: 10.1017/s0021859600062870

Heuzé V; Tran G; Archimède H; Régnier C; Bastianelli D; Lebas F. 2016. Cassava peels, cassava pomace and other cassava by-products. Feedipedia, a programme by INRA, CIRAD, AFZ and FAO. feedipedia.org/node/526

Karachi M. 1998. Variation in the nutritional value of leaf and stem fractions of nineteen leucaena lines. Animal Feed Science and Technology 70:305–314. doi: 10.1016/s0377-8401(97)00117-x

Marsetyo; Damry; Quigley SP; McLennan SR; Poppi DP. 2012. Liveweight gain and feed intake of weaned Bali cattle fed a range of diets in Central Sulawesi, Indonesia. Animal Production Science 52:630–635. goo.gl/LuJg2D

McLennan SR; Bolam MJ; Kidd JF; Chandra KA; Poppi DP. 2017. Responses to various protein and energy supplements by steers fed low-quality tropical hay. 1. Comparison of response surfaces for young steers. Animal Production Science 57:473–488. doi: 10.1071/an15659

Muinga RW; Topps JH; Rooke JA; Thorpe W. 1995. The effect of supplementation with *Leucaena leucocephala* and maize bran on voluntary food intake, digestibility, live weight and milk yield of *Bos indicus* × *Bos taurus* dairy cows and rumen fermentation in steers offered *Pennisetum purpureum ad libitum* in the semi-humid tropics. Animal Science 60:13–23. doi: 10.1017/s1357729800008080

Panjaitan T; Fauzan M; Dahlanuddin; Halliday MJ; Shelton HM. 2014. Growth of Bali bulls fattened with *Leucaena leucocephala* in Sumbawa, Eastern Indonesia. Tropical Grasslands-Forrajes Tropicales 2:116–118. doi: 10.17138/tgft(2)116-118

Petty SR; Poppi DP; Triglone T. 1998. Effect of maize supplementation, seasonal temperature and humidity on the liveweight gain of steers grazing irrigated *Leucaena leucocephala/Digitaria eriantha* pastures in north-west Australia. Journal of Agricultural Science 130:95–105. doi: 10.1017/s0021859697004966

Petty SR; Poppi DP. 2012. The liveweight gain response of heifers to supplements of molasses or maize while grazing irrigated *Leucaena leucocephala/Digitaria eriantha* pastures in north-west Australia. Animal Production Science 52:619–623. doi: 10.1071/an11242

PISC (Primary Industries Standing Committee on Agriculture). 2007. Nutrient requirements of domesticated ruminants (NRDR). CSIRO Publishing, Melbourne, Australia. goo.gl/gg1v9J

Poppi DP. 1990. Manipulation of nutrient supply to animals at pasture. Opportunities and consequences. Proceedings of the 5th AAAP Animal Science Congress, May 27–June 1, 1990, Taipei, Taiwan. p. 40–79.

Poppi DP; Norton BW. 1995. Intake of tropical legumes. In: D'Mello JPF; Devendra C, eds. Tropical legumes in animal nutrition. CAB International, Wallingford, UK. p. 173–189. goo.gl/jMqAz1

Quigley SP; Poppi DP; Budisantoso E; Dahlanuddin; Marsetyo; McLennan SR; Pamungkas D; Panjaitan T; Priyanti A. 2009. Strategies to increase growth of weaned Bali calves. Final Report LPS/2004/023. Australian Centre for International Agricultural Research (ACIAR), Canberra, Australia. goo.gl/yMDCnB

Quirk MF; Paton CJ; Bushell JJ. 1990. Increasing the amount of leucaena on offer gives faster growth rates of grazing cattle in South East Queensland. Australian Journal of Experimental Agriculture 30:51–54. doi: 10.1071/ea9900051

Ratnawati D; Cowley F; Mayberry D; Pamungkas D; Poppi DP.

2015. Concentrate supplementation for crossbred bulls to increase profitability of smallholder fattening operations in East Java. Indonesian Journal of Animal and Veterinary Sciences 20:42–48. doi: [10.14334/jitv.v20i1.1115](https://doi.org/10.14334/jitv.v20i1.1115)

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