Alternative animal feeds from agroforestry plants

Abdelfattah Z. M. Salem, Carlos R. Kunst & Shibu Jose

Agroforestry Systems
An International Journal incorporating
Agroforestry Forum

ISSN 0167-4366
Volume 94
Number 4

Agroforest Syst (2020) 94:1133-1138
DOI 10.1007/s10457-020-00525-2

Springer

Agroforest Syst (2020) 94:1133–1138
https://doi.org/10.1007/s10457-020-00525-2

Alternative animal feeds from agroforestry plants

Abdelfattah Z. M. Salem · Carlos R. Kunst · Shibu Jose

Received: 16 July 2020 / Accepted: 16 July 2020 / Published online: 22 July 2020

Abstract This special issue idea originated when a few researchers from around the world came together with the goal of compiling the most up-to-date information on the use of alternative animal feed resources derived from agroforestry plants, including woody perennials. It is a common animal feeding practice in many parts of the world, particularly in the tropics; however, no comprehensive source of this information exists as attempted in this special issue. In addition to exploring alternative resources such as foliage of woody plants and other plant products and by-products for animal feed, papers included in this issue also addressed their impacts on ruminant and non-ruminant performance, health and welfare, and ruminal fermentation metabolism and mitigation of methane emission. We received 78 manuscripts from more than 21 countries and 45 papers were accepted following appropriate peer reviews. Overall, alternative feed resources, including woody plant foliage, improved animal performance, particularly during dry season. Several bioactive compounds were identified in agroforestry plants and they had positive impacts as antimicrobials against some the pathogenic bacteria and for controlling gastrointestinal parasites in livestock, which improved the health, welfare and production. Most alternative feeds added at low proportions with regular feed improved digestibility and decreased methane production.

Keywords Agroforestry plants · Animal feeds · Animal welfare · Rumen fermentation · Methane

A. Z. M. Salem (✉)
Facultad de Medicina Veterinaria y Zootecnia, Universidad Autónoma del Estado de México, Toluca, Estado de México, Mexico
e-mail: salem@uaemex.mx; asalem70@yahoo.com

C. R. Kunst
INTA EEA Sgo del Estero, Manejo del Campo Natural/Range Management, Jujuy 850 G4200CQR, Santiago del Estero, Argentina
e-mail: kunst.carlos@inta.gob.ar; crgkun@gmail.com

S. Jose
College of Agriculture, Food and Natural Resources, University of Missouri, 2-44 Agriculture Bldg., Columbia, MO 65211, USA
e-mail: joses@missouri.edu

Introduction

Agroforestry is being used as an alternative land use practice for economic, environmental and social reasons the world over (Dollinger and Jose 2018; Rankoth et al. 2019; Jose 2019). Many agroforestry species and their products or by-products are used as alternative feeds for livestock, primarily based on traditional ecological knowledge. Such alternative animal feeds are often used to decrease the dependence on traditional feed resources and thereby feeding costs.

Some of these by-products are rich in crude protein and other nutrients such as minerals and vitamins (Simbaya et al. 2020). Feeding these products or by-products may contribute to enhanced nitrogen metabolism, decreased methane emissions, reduced nutritional stress caused by bloat or acidosis (thus contributing to animal welfare), and improved animal health and productivity (Ruiz-Nieto et al. 2020; El-Adawy et al. 2020a). However, alternative feed from woody plants may be high in ligno-cellulose in the plant cell wall, which is considered low digestibility feed for animals, especially for the non-herbivorous animals (El-Adawy et al. 2020a; Yang et al. 2020). The inclusion of such feed in animal diets is limited by higher secondary metabolite concentrations (such as phenolics, saponins, tannins etc.) as well. Therefore, limits of inclusion of such products and by-products in animal feed may need to be set along with the application of some pre-treatments or additives to prevent the negative impact of such secondary metabolites (Singh et al. 2020; Ashmawy et al. 2020).

In the last decade there has been an increasing interest in the use of plant-based alternative feed sources and their bioactive compounds as rumen modifiers, with some reported experimental work primarily focused on the changes in rumen fermentation and animal performance (Yusuf et al. 2020). Some of these by-products and compounds can affect methane production, stimulation of microbial metabolism, favor feed degradation and yield of ruminal microbial biomass (Jafari et al. 2020). However, effectiveness and impacts of alternative feed sources and their secondary metabolites vary depending upon the source and type and level of active substance responsible for the effect (De Jesús-Martínez et al. 2020).

The overall objectives of this special issue were to evaluate the use of plant-based alternative feeds and plant by-products as animal feeds and their impacts on animal performance and ruminal fermentation activity. As such, accepted papers were divided into two broad categories, the first group dealing with the effects of plant-based alternative feeds and by-products on animal performance and health, and the second group discussing their effect on ruminal metabolism and methane production.

Plant-based alternative feeds and animal performance and health

Most papers of the special issue deal with the effects of feeding plant foliage and by-products on animal performance in ruminant and non-ruminant animals. The topic was thoroughly reviewed, presenting the most relevant information along with the original research findings. We will highlight a few of the papers here.

A number of plant species and plant parts were used and evaluated as animal feed and most of them reported improvement in animal performance and health for species such as Mesquite (*Prosopis* spp.)-(Ruiz-Nieto et al. 2020), green tea (*Camellia sinensis*) (Seidavi et al. 2020), Mulberry (*Morus alba*), Leucaena (*Leucaena leucocephala*) and Moringa (*Moringa oleifera*) (Simbaya et al. 2020), *Guazuma ulmifolia* (Cediel-Devia et al. 2020), *Kochia indica* (El-Adawy et al. 2020b), Black Cumin, Pawpaw and Mustard Seeds (Adegbeye et al. 2020), *Termitomyces robustus* and *Lentinus squarrosulus* (Amadike Ugbogu et al. 2020).

Serrapica et al. (2020), in Italy, studied the substitution rate of soybean protein by feeding peas (*Pisum sativum*) as an alternative source of protein. They substituted soy protein with extruded pea protein at approximately 30% rate and found that milk yield, milk fat and protein percentages, and clotting properties did not differ between lactating buffaloes with and without the pea protein. Moreover, in vivo digestibility did not differ between the two dietary groups supporting that the partial substitution of soybean protein with pea protein would be feasible. Yang et al. (2020) evaluated sorghum hull, a by-product of sorghum, as a feed alternative for goats in China. These authors reported that sorghum hull was beneficial to growth performance, nutrients digestibility and plasma metabolites, and hence could be used as a feed alternative for goats. In Mexico, Manuel-Pablo et al. (2020) found that the use of dietary condensed tannins of cascalote fruit (*Caesalpinia coriaria*), did not influence the productive parameters, ruminal fermentation and the carcass characteristics, thereby making them an alternative feed for goats.

Simbaya et al. (2020) demonstrated the value of tree fodder as dry season protein supplements for grazing animals on traditional smallholder farms of Zambia. They found that the leaves of Mulberry,

Leucaena and Moringa were good protein supplements for grazing animals based on chemical composition, in vitro and *in sacco* nutrient digestibility and a rabbit feeding trial. They showed that rabbits fed on the tree fodder individually or all three species combined had significantly higher body weight gain than Lucerne hay alone. In Egypt, El-Adawy et al. (2020a) evaluated the dietary inclusion effect of dried *Kochia indica,* a halophytic herb, foliage on growth performance and nutrient digestibility of growing rabbits. Availability of green fodder is limited only to 5 months during summer due to the semi-arid environment in Egypt while Kochia is available year-round. These authors replaced Egyptian clover (*Trifolium alexandrinum*) with dried Kochia at different rates and found that Kochia up to 25% of the diet improved growth performance, nutrients evaluation, digestibility and productivity without any obvious negative effects.

The regrowth age of foliage is a factor that affects the nutritive value of tree fodder. In Cuba, Verdecia et al. (2020) evaluated the age of *Leucaena leucocephala* regrowth at 60, 120 or 180 days on chemical composition and secondary metabolites and digestibility. For in vitro dry matter digestibility and in situ dry matter digestibility, rumen fluid from four cannulated Merino sheep and rumen of the same four sheep were used, respectively. The cell wall components (Neutral detergent fiber (NDF), Acid detergent fiber (ADF), and lignin) and fiber to nitrogen ratios (NDF/N and ADF/N) increased while crude protein, cell content, in vitro dry matter digestibility and in situ dry matter digestibility decreased as the regrowth date was delayed. Overall, digestibility of Leucaena forage was negatively affected by age of regrowth. Reducing the age of regrowth would provide a better-quality forage with higher protein content and greater digestibility.

A number of papers demonstrated the health benefits of feeding animals with alternative feeds. Many of the bioactive compounds in these alternative feeds have a notable impact on animal health especially by eliminating gastrointestinal parasites thereby improving the health and welfare and production performance. According to Adegbeye et al. (2020), inclusion of the seeds of black cumin (*Nigella sativa*), pawpaw (*Carica papaya*) and mustard (*Brassica nigra*) are capable of antimicrobial functions and thereby reducing pathogenic microbes in the gut of livestock. These authors reviewed the available literature and showed that dietary inclusion of 15% mustard oil was capable of reducing methane formation. Sinapine, a derivative of mustard, is cable of enhancing the growth of some microbes except *Escherichia coli* and thus a potential probiotic for animals. Pawpaw seed is very potent in their control of wide range of ecto and endo parasites. Such alternative feeds must be able to kill, reduce, or inhibit pathogenic microbial population while improving the commensal microbes in livestock.

In another review, Zeineldin et al. (2020) discussed the research efforts towards the development of plant bioactive compounds for controlling gastrointestinal parasites in livestock. The worldwide emergence of anthelmintic resistance against gastrointestinal parasites has led researchers to investigate sustainable alternative approaches. They concluded that plants bioactive compounds were certainly valuable for livestock health but highlighted the need for further in-depth and controlled in vivo studies to validate and assess the plants bioactivity. Isolating plant bioactive compounds is vital to understand the bioactive components and their mechanism of action to achieve maximum efficacy of the plants and reduced their potential toxicity. In their research Mexico, De Jesús-Martínez et al. (2020) reported that the hydroalcoholic extract from *Caesalpinia coriaria* fruit possessed in vitro ovicidal and larvicidal properties against *Haemonchus contortus*, a pathogenic nematode of ruminants.

Safaei-Cherehh et al. (2020) studied the effect of different level of fennel extract (*Foeniculum vulgare*) on growth performance, carcass quality and health status of broiler chicken, and found that the best diet was 100 ppm of fennel extract due to the remarkable growth performance, carcass quality and health status. They further reported that an increase in the level of fennel extract significantly improved Newcastle vaccination efficiency on day 35, and immunoglobulin production on day 42 to ensure better immunity against bacterial and viral infections. Chicken fed with fennel extract supplemented diet had higher resistance to infectious bronchitis virus, but lower resistance to infectious bursal disease when compared with chicken fed with control diet. Similarly, addition of different levels of sage (*Salvia officinalis*) aqueous leaf extract in drinking water improved broiler chicken

performance, blood parameters, immunity response and ileal microflora (Rasouli et al. 2020).

Archundia Velarde et al. (2020) reported that hydro-alcoholic extracts of the leaves of three different species, Avocado (*Persea americana)* Hass variety, Guava (*Psidium guajava*) Calvillo variety, and Cherry plum (*Prunus cerasifera* Ehrh) Pissardii variety, had strong antimicrobial activity against different pathogenic microorganisms and could be considered as a potential alternative to synthetic antibiotics for use in animal production. In their study of oils from seeds of *Moringa oleifera* and fruits of *Cassia fistula* and *Ceratonia silique*, Abbassy et al. (2020), they concluded that all three species had antibacterial activity against the growth of *Bacillus subtilis*, *Bacillus cereus*, *Staphylococcus aureus,* but *Pseudomonas aeruginosa* showed resistance to the oils. Authors found that the phytochemical compounds identified in the oils, especially in the agroforestry tree *M. oleifera*, could be recommended as commercial ingredient formulations for human and animal health and as feed additives for livestock.

Ruminal metabolism and methane production

An estimated 14 to 22% of global greenhouse gas emissions results from land use changes related to agricultural production, and methane from ruminants constitutes nearly 6% of all emissions (Flay et al. 2019). There is considerable interest in reducing enteric methane production using genetic approaches or management strategies. A number of authors discussed the use of alternative feeds from agroforestry plants as a management strategy to reduce enteric methane production.

A number of plant extracts and bioactive compounds, as stated in the review paper by Dhanasekaran et al. (2020) from India, have great potential to reduce and mitigate greenhouse gases, especially methane emission in ruminants. Bouazza et al. (2020) evaluated the impact of several Algerian steppe browse species such as *Albizia julibrissin* (pods), *Acacia nilotica* (pods), *Punica granatum* (leaves and pericarp), *Vicia faba* (leaves), *Artemisia herba-alba* (aerial part), *Attriplex halimus* (leaves) and *Calligonum azel* (bark) on rumen fermentation and methane mitigation. According to these authors, all the browse species, with the exception of *C. azel* bark, can be used as alternative feeds for ruminant nutrition. The most promising in terms of reduced methane emissions was *A. halimus* foliage because the decreased methane production was not associated with any reduction in fermentation or digestibility.

In Ethiopia, researchers found that the highest methane production per gram of dry matter was noted for *M. stenopetala* and the lowest for *A. nilotica* though opposite situation was observed when methane production was expressed as a ratio to total gas produced. Overall, most of the studied browse plants were desirable candidates as a supplement to low-quality forages for mitigation of enteric methane emission while supplying optimum level of nitrogen (Tirfessa et al. 2020). Deuri et al. (2020) reported that tree leaves of *Mangifera indica, A. nilotica, Psidium guajava, Cassia fistula, Eucalyptus globulus and Phoenix dactylifera* at 1% had great potential to improve digestibility and or decrease methane production.

In Mexico, Albores-Moreno et al. (2020) observed that forage grass *Pennisetum purpureum* supplemented with 30% of foliage from *Tabernaemontana amygdalifolia*, *Piscidia piscipula* and *Leucaena leucocephala* had no negative effect on organic matter digestibility, synthesis of microbial biomass and the volatile fatty acid concentration. Additionally, the supplementation with *L. leucocephala* reduced methane production in the rumen by 12.78%. Singh et al. (2020) evaluated plant bioactive compounds individually and in association for modulation of rumen fermentation in buffalo (*Bubalus bubalis*) with the aim to develop phytogenic feed additive for enteric methane mitigation from ruminants. They reported that extracts from *Sapindus mukorossi* fruits (aqueous and ethanolic) as a source of saponins, *Ficus bengalensis* leaves *(aqueous and acetonic) as a source of tannins* and *E. globulus* as a source of essential oils and their blends had the potential to act as anti-methanogenic agents. They added that a positive associative effect in reducing enteric methanogenesis suggested their potential use as phytogenic feed additive in ruminants.

Conclusions

As noted by Jose (2011), choice of species plays a major role in defining the ecological, environmental

and economic sustainability of agroforestry systems. Deliberate selection of woody perennials is evident from the age-old homegardens to the modern-day intensive perennial polycultures to optimize the economic and environmental benefits of the respective agroforestry systems (Lovell et al. 2018). This special issue has brought together 45 manuscripts from around the world to showcase the value of alternative animal feeds from agroforestry plant species. Most of the tested species or their products or by-products were beneficial in terms of increasing animal performance and health. Several of these alternative feeds also increased fermentation efficiency in ruminants and decreased methane production. Considering the significant contribution of enteric methane production to total agriculture-related greenhouse gas emissions, such management strategies offer promise as a climate-change mitigation strategy.

Acknowledgements The guest editors of the special issue would like to thank the authors for their contributions. We are also grateful for the time and commitment given by all the reviewers to evaluate the manuscripts.

References

Abbassy MMS, Salem MZM, Rashad NM, Afify SM, Salem AZM (2020) Nutritive and biocidal properties of agroforestry trees of *Moringa oleifera* Lam., *Cassia fistula* L., and *Ceratonia siliqua* L. as non-conventional edible vegetable oils. Agrofor Syst. https://doi.org/10.1007/s10457-018-0325-4

Adegbeye MJ, Elghandour MMMY, Faniyi TO, Rivero Perez N, Barbabosa-Pilego A, Zaragoza-Bastida A, Salem AZM (2020) Antimicrobial and antihelminthic impacts of black cumin, pawpaw and mustard seeds in livestock production and health. Agrofor Syst. https://doi.org/10.1007/s10457-018-0337-0

Albores-Moreno S, Alayón-Gamboa JA, Miranda-Romero LA, Alarcón-Zúñiga B, Jiménez-Ferrer G, Ku-Vera JC, Piñeiro-Vázquez AT (2020) Effect of supplementation with tree foliage on in vitro digestibility and fermentation, synthesis of microbial biomass and methane production of cattle diets. Agrofor Syst. https://doi.org/10.1007/s10457-019-00416-1

Amadike Ugbogu E, Emmanuel O, Salem AZM, Elghandour MMMY (2020) Nutritional composition of *Termitomyces robustus* (Agaricomycetes) and *Lentinus squarrosulus* (Mont.) singer in South East Nigeria. Agrofor Syst. https://doi.org/10.1007/s10457-018-0323-6

Archundia Velarde ED, Pinzón Martínez DL, Salem AZM, Mendoza García PG, Mariezcurrena Berasain MD (2020) Antioxidant and antimicrobial capacity of three agroindustrial residues as animal feeds. Agrofor Syst. https://doi.org/10.1007/s10457-018-00343-7

Ashmawy NA, Al Farraj DA, Salem MZM, Elshikh MS, Al-Kufaidy R, Alshammari MK, Salem AZM (2020) Potential impacts of *Pinus halepensis* Miller trees as a source of phytochemical compounds: antibacterial activity of the cones essential oil and n-butanol extract. Agrofor Syst. https://doi.org/10.1007/s10457-018-0324-5

Bouazza L, Boufennara S, Bensaada M, Zeraib A, Rahal K, Saro C, Ranilla MJ, López S (2020) In vitro screening of Algerian steppe browse plants for digestibility, rumen fermentation profile and methane mitigation. Agrofor Syst. https://doi.org/10.1007/s10457-019-00408-1

Cediel-Devia D, Sandoval-Lozano E, Castañeda-Serrano R (2020) Effects of different regrowth ages and cutting heights on biomass production, bromatological composition and in vitro digestibility of *Guazuma ulmifolia* foliage. Agrofor Syst. https://doi.org/10.1007/s10457-019-00354-y

De Jesús-Martínez X, Olmedo-Juárez A, Rojas Hernández S, Zamilpa A, Mendoza de Gives P, Lopez-Arellano ME, Villa-Mancera A, Camacho-Díaz LM, Cipriano Salazar M, Olivares-Pérez J (2020) Evaluation of the hydroalcoholic extract elaborated with *Caesalpinia coriaria* Jacq Willd tree fruits in the control of *Haemonchus contortus* Rudolphi. Agrofor Syst. https://doi.org/10.1007/s10457-019-00398-0

Deuri P, Sood N, Wadhwa M, Bakshi MPS, Salem AZM (2020) Screening of tree leaves for bioactive components and their impact on in vitro fermentability and methane production from total mixed ration. Agrofor Syst. https://doi.org/10.1007/s10457-019-00374-8

Dhanasekaran DK, Dias-Silva TP, Abdalla Filho AL, Sakita GZ, Abdalla AL, Louvandini H, Elghandour MMMY (2020) Plants extract and bioactive compounds on rumen methanogenesis. Agrofor Syst. https://doi.org/10.1007/s10457-019-00411-6

Dollinger J, Jose S (2018) Agroforestry for soil health. Agrofor Syst 92:213–219

El-Adawy MM, Aboelez ZR, Rashad AM, Elghandour MMMY, Adegbeye MJ, Ashtoy MR, Cipriano-Salazar M, Rojas Hernández S, Salem AZM (2020a) Effects of dietary inclusion of dried Kochia indica Wight tree foliages on growth performance and nutrient digestibility of growing rabbits. Agrofor Syst. https://doi.org/10.1007/s10457-019-00352-0

El-Adawy MM, Salem AZM, Khodeir MH, Khusro A, Elghandour MMMY, Rojas Hernández S, Al-Shamandy OAA (2020b) Influence of four tropical medicinal and aromatic plants on growth performance, digestibility, and blood constituents of rabbits. Agrofor Syst. https://doi.org/10.1007/s10457-018-0322-7

Flay HE, Kuhn-Sherlock B, Macdonald KA, Camara M, Lopez-Villalobos N, Donaghy DJ, Roche JR (2019) Selecting cattle for low residual feed intake did not affect daily methane production but increased methane yield. J Diary Sci 102:271–2708

Jafari S, Yong Meng G, Ali Rajion M, Ebrahimi M (2020) The use of plant by-products as non-conventional feedstuff for livestock feeding with reference to rumen methanogenesis. Agrofor Syst. https://doi.org/10.1007/s10457-019-00426-z

Jose S (2011) Managing native and non-native plants in agroforestry systems. Agrofor Syst 83:101–105

Jose S (2019) Environmental impacts and benefits of agroforestry. Oxford encyclopedia of agriculture and environment. Oxford University Press, USA. https://doi.org/10.1093/acrefore/9780199389414.013.195

Lovell ST, Dupraz C, Gold M, Jose S, Revord R, Stanek E, Wolz K (2018) Temperate agroforestry research: considering multifunctional woody polycultures and the design of long-term field trials. Agrofor Syst 92:1397–1415

Manuel-Pablo A, Elghandour MMY, Olivares-Pérez J, Rojas-Hernández S, Cipriano-Salazar M, Cruz-Lagunas B, Camacho-Diaz LM (2020) Productive performance, rumen fermentation and carcass yield of goats supplemented with cascalote fruit (*Caesalpinia coriaria* J. Wild.). Agrofor Syst. https://doi.org/10.1007/s10457-018-0312-9

Rankoth L, Udawatta R, Jose S (2019) Agroforestry and biodiversity. Sustainability 11(10):2879. https://doi.org/10.3390/su11102879

Rasouli B, Movahhedkhah S, Seidavi A, Imranul Haq QM, Kadim I, Laudadio V, Mazzei D, Tufarelli V (2020) Effect of sage (*Salvia officinalis* L.) aqueous leaf extract on performance, blood constituents, immunity response and ileal microflora of broiler chickens. Agrofor Syst. https://doi.org/10.1007/s10457-019-00401-8

Ruiz-Nieto JE, Hernández-Ruiz J, Hernández-Marín J, Mendoza-Carrillo J, Abraham-Juárez M, Isiordia-Lachica PM, Mireles-Arriaga AI (2020) Mesquite (*Prosopis* spp.) tree as a feed resource for animal growth. Agrofor Syst. https://doi.org/10.1007/s10457-020-00481-x

Safaei-Cherehh A, Rasouli B, Adeniyi Alaba P, Seidavi A, Rojas Hernández S, Salem AZM (2020) Effect of dietary *Foeniculum vulgare* Mill. extract on growth performance, blood metabolites, immunity and ileal microflora in male broilers. Agrofor Syst. https://doi.org/10.1007/s10457-018-0326-3

Seidavi A, Belali M, Elghandour MMY, Adegbeye MJ, Salem AZM (2020) Potential impacts of dietary inclusion of green tea (*Camellia sinensis* L.) in poultry feeding: a review. Agrofor Syst. https://doi.org/10.1007/s10457-019-00444-x

Serrapica F, Masucci F, Romano R, Santini A, Manzo N, Seidavi A, Omri B, Salem AZM, Di Francia A (2020) Peas may be a candidate crop for integrating silvoarable systems and dairy buffalo farming in southern Italy. Agrofor Syst. https://doi.org/10.1007/s10457-018-0316-5

Simbaya J, Chibinga O, Salem AZM (2020) Nutritional evaluation of selected fodder trees: Mulberry (*Morus alba* Lam.), Leucaena (*Leucaena leucocephala* Lam de Wit.) and Moringa (*Moringa oleifera* Lam.) as dry season protein supplements for grazing animals. Agrofor Syst. https://doi.org/10.1007/s10457-020-00504-7

Singh RK, Dey A, Paul SS, Singh M, Dahiya SS, Punia BS (2020) Associative effects of plant secondary metabolites in modulating in vitro methanogenesis, volatile fatty acids production and fermentation of feed in buffalo (*Bubalus bubalis*). Agrofor Syst. https://doi.org/10.1007/s10457-019-00395-3

Tirfessa G, Tolera A (2020) Comparative evaluation of chemical composition, in vitro fermentation and methane production of selected tree forages. Agrofor Syst. https://doi.org/10.1007/s10457-019-00391-7

Verdecia DM, Herrera RS, Ramírez JL, Leonard I, Bodas R, Andrés S, Giráldez FJ, Valdés C, Arceo Y, Paumier M, Santana A, Álvarez Y, Mendez Y, López S (2020) Effect of age of regrowth, chemical composition and secondary metabolites on the digestibility of Leucaena leucocephala in the Cauto Valley Cuba. Agrofor Syst. https://doi.org/10.1007/s10457-018-0339-y

Yang K, Wu Q, Tian X, Han E, Sun L (2020) Evaluation of sorghum hull serving as feed alternative on growth performance, nutrients digestibility and plasma metabolites for growing goats. Agrofor Syst. https://doi.org/10.1007/s10457-018-0318-3

Yusuf AO, Egbinola OO, Ekunseitan DA, Salem AZM (2020) Chemical characterization and in vitro methane production of selected agroforestry plants as dry season feeding of ruminants livestock. Agrofor Syst. https://doi.org/10.1007/s10457-019-00480-7

Zeineldin MM, Sabek AA, Barakat RA, Elghandour MMMY, Salem AZM, de Oca Jiménez RM (2020) Potential contribution of plants bioactive in ruminant productive performance and their impact on gastrointestinal parasites elimination. Agrofor Syst. https://doi.org/10.1007/s10457-018-0295-6