


# Application of some trees/shrubs in ruminant feeding: a review

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**Abstract** Ruminants play an important role in supplying human nutritional requirements. Given the increasing number of livestock and the limited resources to supply feedstuffs in order to feed ruminants, scientists are seeking ways to add to the ruminants' diets parts of trees and shrubs and to replace concentrates competitive with human food. A consequent positive result could be reduction of the costs for meat and milk yield. On the other hand, these feeds could contain some anti-nutritional factors such as tannins that can limit their use. In this paper, the use of components of some trees and shrubs as part of ruminant (cattle, sheep and goat) diets as well as their positive and negative effects on domestic animal productivity are reviewed.

**Keywords** Cattle · Sheep · Goats · Productivity · Tree · Shrub

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## Introduction

In the next 20 years, there will be an increase in the world population of 18% with variations of + 54% in Africa and – 2% in Europe. Moreover, while the global rural population will decrease by 1% (– 20% in Europe), the urban one will increase by 34% (FAO 2014).

Hence, the challenge in the next years is to increase the agricultural production and, from this point of view, ruminant rearing can play a key role also because the increase in global economic growth could be 2–3% per year (Šapkinaitė 2013) and the greater the wealth and the more milk and meat consumption increases (Smith et al. 2013). In addition, ruminants are not competitive with humans for feed and are widespread throughout the world, even in developing countries where population growth will be more pronounced (Corazzin et al. 2015; FAO 2014). As reported by Corazzin et al. (2015), the increase in products of animal origin occurs, in these countries, more for the number of ruminants not for the efficiency of production. Taking into account that Ibarrola Rivas and Nonhebel (2016) reported that the availability of arable land per person is constantly decreasing and will reach a value of less than 2000 m<sup>2</sup> in 2050, it becomes interesting to use alternative feed sources such as those derived from parts of trees or shrubs, which can be offered in the stall or grazed by the animals. The main limits in the use of these feeds resides is phenolic compounds, e.g. tannin that reduces

bioavailability of dietary protein, and other secondary metabolites, e.g. saponins or alkaloids that negatively affect ruminal metabolism (Salem et al. 2011). The intake of shrubs during grazing is complex and depends on the selectivity and feed preferences of the different animal species. Indeed, goats are considered browsers and graze more highly on shrubs than sheep who are intermediate feeders and have not preference between shrubs and grass. Conversely, cattle, which are considered grazers, prefer grasses (Uzun et al. 2016). Lamy et al. (2011) reported that on Mediterranean brush land, over the 30% of the goats' diet is composed by browsed material, and they explained that goats can tolerate tannins much better than sheep and cattle, probably because of the production with the saliva of tanning-binding protein. Moreover, goats can browse in erect position (Sen et al. 2004) reaching parts of shrubs inaccessible to sheep. Based on Lamy et al. (2011) the plant selection depends also by pasture composition (Romanzin et al. 2018) and by the levels of tannins in plants. Šarić et al. (2014) stated the intake of shrubs is higher for pastures with greater species diversity; Jozo et al. (2018) explained that sheep prefer to consume different species of shrubs with different levels of saponins and tannins in comparison with species that contain only tannins, since tannins can chelate saponins in gut reducing their toxicity. Another aspect to take into account is that the nutritive value of the diets can influence the feeding behaviour of the animals and it is particularly evident in goats. Indeed, goats in a nutritive restricted condition increase considerably their aptitude to browse shrubs (Lamy et al. 2011).

In developed countries, trees or shrubs usage for the animals' diet should be viewed in a different perspective. Indeed, in developed countries the increasing of population will be lower and the consumption of products of ruminant origin is much higher than those of developing countries; e.g. the per capita beef and sheep meat consumption, expressed as carcass weight equivalent, is 4.7 kg and 6.0 kg in Asia and Africa respectively; conversely, it reaches 24.8 kg and 12.7 kg in North America and in Europe respectively (OECD-FAO 2017). In addition, considering that the consumers are more and more aware of the health issues related to the excessive consumption of products of ruminant origin, the attention of farmers is shifting from the quantity to the quality of the production. From this point of view, extracts from

trees were recently used and proposed for improving the quality of beef and milk and the health of ruminants (Jerónimo et al. 2016), while the grazing on shrubs is considered a tool to contribute to provide the ecosystem services (MEA 2005). In the last decades, there has been a considerable abandonment of agricultural land in disadvantaged areas with values that reach 67% in Carnia (Italy) and over 30% in some parts of Austria (Battaglini et al. 2014). This process together with the degradation of pastures has favoured the increased of forestland. The correct management of grazing ruminants, and goats in particular, is a tool able to contribute to recover the lands invaded by shrub (Álvarez Martínez et al. 2016), and therefore to improve plant biodiversity, the amenity values of the landscape and the fire prevention, and all of these are considered ecosystem services.

The purpose of present paper is review the effect of some trees/shrubs and their relative extracts on animal productivity and on the quantity and quality of products of ruminant origin.

### **Tannin extracts from tree (acacia, chestnut and quebracho)**

Acacia (*Acacia meansii*) is a leguminous tree widespread mainly in countries of the Southern Hemisphere such as South Africa, Brazil, New Zealand and Australia. The tannin extract is obtained from the bark. Chestnut (*Castanea*) is present in temperate area and includes tree and shrubs species of the Fagaceae family; the tannin extract is obtained both from bark and wood. Quebracho (*Schinopsis* spp.) is a tree mainly widespread in South America and the tannin extract is obtained from heart wood (Kardel et al. 2013). Tannins are secondary metabolites that are produced by plants for their defense, and therefore presented for many trees/shrubs (Huang et al. 2017). Their average level is 2–5% in fruit and leaves, but it can vary a lot if the plant is subjected to both biotic and abiotic stresses (Jerónimo et al. 2016).

As reported by Aguerre et al. (2016), the roles of tannins in the animals' performances, ruminal microorganisms' metabolism etc. are complex and very variable. The ruminal degradability of tannins is influenced by their solubility and by their percentage of inclusion in the diets (Buccioni et al. 2017). Tannins can be distinguished in condensates that are

oligomers/polymers of flavan-3ol subunits, hydrolysable, that usually composed by a polyol core group esterified with gallic or ellagic acid (Naumann et al. 2017).

The condensed tannins form stable compounds in rumen with dietary proteins thanks to the normal pH values present, 6–7. In abomasums, because of the lower pH, around 3, these compounds dissociate. In the intestine, which is characterized by alkaline pH, the dietary proteins are made available for intestinal absorption, while the tannins are eliminated in the faeces not being absorbed in the intestine unless there are lesions or damage to the epithelium (Aguerre et al. 2016; Jerónimo et al. 2016). As reviewed by Jerónimo et al. (2016), if the tannins pass into the blood they can lead to damage to the internal organs. The greater level of proteins and essential amino acids that by-pass the rumen and that are available to intestinal absorption can explain the greater animal performances and the greater milk protein content that can be associated with moderate intake of tannins with diet (Patra and Saxena 2011). Conversely, hydrolysable tannins may be degraded in rumen producing secondary metabolites. Condensed tannins, mainly compose the tannin extract of acacia and quebracho, 820 g kg<sup>-1</sup> and 904 g kg<sup>-1</sup> respectively. Conversely, chestnut extract is composed by 755 g kg<sup>-1</sup> of hydrolysable tannins and only by 57 g kg<sup>-1</sup> of condensed tannins (Hassanat and Benchaar 2013). Both condensed and hydrolysable tannins can influence ruminal microorganisms' metabolism, animal performance and health, but in different ways. Tannins can influence ruminal metabolism of microorganism; indeed, Buccioni et al. (2015a), considering dairy sheeps fed diet supplemented with chestnut/quebracho tannins, explained that chestnut favoured the ruminal volatile fatty acids in comparison to quebracho that seemed to have a higher depressive effect on carbohydrate and protein degradation in rumen.

In general, Buccioni et al. (2015a) reported that the diets of ewes and cows with tannins level lower than 4–5% on DM basis improve the retention of nitrogen, protecting the protein from ruminal degradation. Conversely, García et al. (2017) review indicated that tannin levels higher than 6–12% reduce DM intake, and hence the animal performances, because of the astringency sensation produced by the high levels of tannin intake. Naumann et al. (2017) reported that quebracho extract used from 1 to 6% DM level in

animals' diet was able to linearly decrease the protein degradation in rumen, and that acacia extract used at the level of 10–17 g kg<sup>-1</sup> DM level in steers' diet was able to increase the ruminal by-pass of amino acids of 30%. However, quebracho tannins, having a more compact structure, seem to be less effective in influencing ruminal microorganisms than acacia tannins (Toral et al. 2013). Aguerre et al. (2016) review indicated that quebracho tree extract reduced DM intake and nutrient digestibility if added at a level higher than 3–4%, but not at a level of 0.5–1% of the dietary DM intake of cattle. The above cited authors found that a level of quebracho or chestnut extract of 0.45% DM of diet was suitable to reduce environmental impact in terms of nitrogen excretion with a very limited effect on animals' production. In general, tannins can decrease the fat content in milk, modify its composition in fatty acids, influencing both ruminal bio-hydrogenation and mammary gland fat synthesis (Iussig et al. 2015; Abo Donia et al. 2017). Toral et al. (2013) explained that tannins reduce the last process of bio-hydrogenation in the dietary fatty acids in rumen, with the consequent increase of the intermediate products such as CLA and vaccenic acid. Despite Luciano et al. (2011) argued the fate of tannins in organs is still unclear, from the point of view of the mammary gland synthesis; Abo Donia et al. (2017) revealed tannins increase the efficiency of delta-9 desaturase, with the result of increasing the oleic acid in milk. Considering milk production, Buccioni et al. (2015b) showed inclusion of chestnut/quebracho tannins extract, with a concentration of 750 and 456 g of equivalent tannic acid kg DM<sup>-1</sup>, to sheep diets could increase the milk production to 18%, and increase the fatty acids of dietary origin in milk confirming the reduction of the rumen bio-hydrogenation. Conversely, Nudda et al. (2014) reviewing different studies that used quebracho and chestnut extract from 10 to 40 g d<sup>-1</sup> in sheep, reported that tannins are not able to markedly improve fatty acid composition and milk yield. Grainger et al. (2009) revealed milk production was reduced if the animal' diet was supplemented with 163–326 g of tannins from acacia. These data confirm that the effect of tannins is complex and depends on the animal species, diets characteristics, and their inclusion level in diets. Moreover, Min and Hart (2003) and Huang et al. (2017) revealed tannins can reduce the incidence of frothy bloat, and if their concentration in the diet of

ruminants is higher than 20–40 g kg<sup>-1</sup> they can be useful for reducing intestinal parasites. In this case, as reviewed by Jerónimo et al. (2016), the beneficial role of tannins is obtained inhibiting the eggs production and the development and larvae vitality, and strengthening the immune system by improving the nutritional balance of animals. Moreover, it was possible to improve the health of cows by enhancement the antioxidant enzyme activities both in liver and plasma supplementing the diet of transition cows with 10 g of chestnut tannins kg DM<sup>-1</sup> (Liu et al. 2013). Rivera Méndes et al. (2017) showed that tannin addition from quebracho at the level of 0.6% DM in diets of steers tended to increase the average daily gain of animals probably because of the higher metabolisable protein available. Min et al. (2015) explained that chestnut and acacia tannins could improve the average daily gain of grazing steers by reducing the parasites infections. Krueger et al. (2010), considering chestnut and acacia tannin extract at levels of 800 g kg<sup>-1</sup> DM hydrolysable tannins and of 700 g kg<sup>-1</sup> DM condensed tannins respectively, did not find any effect on growth performance of steers with the exception of hot carcass weight, which was lower in animals that received acacia extract. Luciano et al. (2011) considering meat quality, observed that quebracho tannin extract added to lambs diet at 9% DM level was able to enhance the meat's colour stability, but the mechanism of which tannins improve the antioxidant power of muscle is unknown (Huang et al. 2017). The possibility of using tannins in the diet of animals to reduce the emissions of methane; in fact the enteric emissions contribute more than 40% to the global warming potential in cattle farms (Salvador et al. 2016, 2017) is an increasing interest. As reviewed by Jerónimo et al. (2016) tannins can reduced methane production in rumen reducing both fibre digestion and the activity and populations of methanogens bacteria. Hassanat and Benchaar (2013) showed, in an in vitro study, that 50 g kg<sup>-1</sup> of dietary tannins both from chestnut and acacia were able to decrease the ruminal methane production reducing the environmental impact of the farm. Similarly, Liu et al. (2011) showed that, up to 30 g of chestnut tannins kg<sup>-1</sup> of diet, the methane emission was reduced without influencing animals' growth performances.

### Barberry (*Berberis vulgaris* L.)

Barberry (*Berberis vulgaris* L.) is a large group of evergreen spruce shrubs whose roots, leaves, peel and fruits have been used in ancient medicine. As reviewed by Ghavipanje et al. (2016), barberry has a good crude protein content, 13.9% DM, and contains some secondary metabolites such as tannins, 2.9% of which the great part, 2.8% are hydrolysable, and alkaloids, 0.42 mg g<sup>-1</sup>. Barberry is used in traditional medicine as an anti-fever and heart rate regulator. Today, by recognising the chemical composition of this plant such as berberine, it has been widely used in the pharmaceutical industry (Baryeh 2002). So far, 500 barberry species have been identified (Ahrendt 1961). Barberry has bioactive compounds with therapeutic effects that widely used in pharmaceutical and food industries.

Shahverdi et al. (2007) revealed the ethanolic extract of pit of barberry increases the antimicrobial properties of ceftizoxime and cephalexin on *Escherichia coli* and *Staphylococcus aureus* bacteria. Fatehi et al. (2005) reported that fruit of barberry without pit has beneficial effects on the cardiovascular and nervous systems. The researchers also suggested that barberry fruit can be used to treat the high blood pressure and nervous problems such as seizures and epilepsy. Aliakbarlu and Mohammadi (2015) examined the effects of *Berberis vulgaris* L. and *Rhus coriaria* L. extracts on chemical changes of lamb's meat and microbial growth in winter nutrition. Based on their findings, barberry extract effectively reduces the fat oxidation and the formation of Met hemoglobin in sheep meat.

### Jujube (*Zizyphus jujuba* Mill.)

*Zizyphus jujube* Millis a drought-tolerant tree that is native to tropical regions (Zargari 1993). This plant is found in most parts of Iran, especially in the Khorasan, Golestan provinces etc. (Mirheydar 1994). The jujube branch is the most important agricultural sub-product used mainly in rural areas and non-industrial farms in hot and dry areas of South Khorasan province (Nath et al. 1969). Jujube has a crude protein level of 151 g kg<sup>-1</sup> DM and 56 g kg<sup>-1</sup> DM in leaves and stem respectively, and a level of tannins of 27.5 g kg<sup>-1</sup> DM and 100 g kg<sup>-1</sup> DM in leaves and stem respectively (Kongmanila and Ledin 2009; Cheema et al. 2011).

The use of medicinal herbs in traditional medicine is one of the safe treatments for diabetes. Jujube fruit has antioxidant and anti-inflammatory activity and is beneficial in the prevention of diabetes-induced inflammation and diabetes treatment (Asgari and Goli 2016).

Kongmanila et al. (2007) showed the dietary use of jujube leaves as much as 10% resulted to increasing DM, crude protein and maintaining N in the diet of goats, while the use of jujube leaves led to increased weight gain in these animals. Morton (1987) reported that the fresh leaves of the jujube tree contain saponin, which, by drying the leaves, eliminates this anti-nutritional agent. As previously reported, the jujube leaf has tannin that reduces protein digestibility. In general, there is little research on the nutritional value and the use of jujube leaves in livestock feeding, but according to researches, different levels of jujube leaves can be substituted for alfalfa for increase the milk and meat yield and modification of milk compositions. It has positive effects on blood metabolites and lactation performance, and some fermentation characteristics in crack goats. Most researchers have attributed the reduction in feed intake in the diets included jujube to its tannin. Generally, shrubs and tropical shrubs, including jujube, contain anti-nutritional agents such as tannin and oxalate, which can be reduce its flavourity consumption (Morton 1987). Nourian-Server and Moeini (2016) investigated the effect of jujube fruit powder on fermentation parameters, protozoal population and methane production by in situ method. The results showed that jujube has the ability to increase and improve fermentation capacity by up to 6%, reduce methane gas to 17.4% and decrease the ammonia nitrogen is up to 43.8% deceased acetate/propionate ratio up to coefficient of 0.2 and a total protozoal population.

#### Oak (*Quercus* L.)

The oak (*Quercus* L.) belongs to the family of beech or oak (Akram et al. 2012). Oak leaves contain a moderate level of crude protein, 85 g kg<sup>-1</sup> DM, and high level of tannins 82 g kg<sup>-1</sup> DM of which 67 g kg<sup>-1</sup> DM are hydrolysable. Nowadays, due to the development and growth of resistant strains, some antibiotics have lost their effect. Furthermore, antibiotics can lead to severe allergic reactions and weaken the immune system, so the use of medicinal herbs for

treatment infectious diseases became widespread (Berahou et al. 2007). This antibacterial activity is somewhat due to tannins (Motevaselian and Farahi 1979). Ebrahimi et al. (2012) revealed the capacity of herbs extracts on the bacteria is dependent to herb concentration. Meanwhile, fruit has antibacterial effect greater effect than the leaves, bark of trunk, and peel of the fruit. In addition, the antibacterial effect of the leaf, bark of trunk and peel of fruits are similar to each other and in most cases less than antibiotics. On the other hand, the obtained results suggest that oak has antibacterial properties. This antibacterial activity is likely due to extract's tannins. Tannin has astringent, antiseptic, and antimicrobial effects. Harsini et al. (2013) studied efficiency of oak pit on absorbability and digestibility in Arab sheep. The results showed that the digestibility of dietary DM increased linearly with increasing of oak levels, ruminal pH, and ammonia nitrogen concentration was significantly reduced by increasing of dietary oak levels, so the oak pit can be used as a source of carbohydrates and energy in sheep's diet.

#### Thistle (*Alhagi pseudalhagi*)

Thistle (*Alhagi pseudalhagi*) is a plant with thin, branching and spiny stems at an average height of 50 cm, a plant of the family of butterflies (Fabaceae), subfamily of the Fabioideae. Another name is ternary grass. The fruit of this family is unsophisticated and with a regular appearance. The bushes are semi-shrub and semi-wooden, with a height of 50–150 cm. Its shoots are green with sharp yellow thorns. The plant is resistant to cold, has deep roots and requires little water. This plant is distributed in different regions of North Africa, Saudi Arabia, Syria, Iraq, Iran, Turkmenistan, Central Asia and other countries (Ghasemi Dehkordi 2002). Traditional sweat has different properties from its boiled and has cold characteristics and used for the removal of bile, kidney stone and bladder stone, as well as urinary and antipyretic effects, and fever and chills. It has been reported and there is no specific effect on its use (Zargari 1995). The only scientific study that was done on the scabies was the protective effect of its aqueous extracts in preventing of stomach ulcers caused by stress and alcohol in rats (Gharibn and Mard 2007). It has been reported that the thistle used as a mouthwash cleaner for treating of food and mouth disease. Feeding this herb is not

effective, but it can be sprayed with a sponge with the sweat of the plant and then wash the wounds of gum and mouth with it, because it prevent the growth of wounds and reduce the pain. This plant prevents wound inflammation and starvation of livestock, which increases mortality due to a decrease in the immune system, and improves them. Actually, this plant has a soothing, anti-inflammatory, analgesic and repair agent that eliminates the effects of this disease within 24–48 h (Fazelinasab and Fouladvand 2014).

Bashtaini et al. (2005) reported that thistle has good nutritional value and digestibility, thistle included valuable nutrients and chemical compounds for ruminant feeding, in particular for ewe and ram in semi-arid and arid regions, as a substitute for wheat straw and dry alfalfa. Thistle can supply the requirements for maintenance, pregnancy and lactation in sheep and goats. However, Wagay et al. (2018) reported that this plant can contain alkaloids, 8.4% DM, and saponins, 3.7% DM. Silage is one of the ways for keeping forages, which prevents food shortages during dry seasons (Farhomand 2001). The use of additives during silage forage improves its fermentation and sweetness of the silage.

Hence, the effect of thistle silage and date wastes on DM intake, digestibility of nutrients and blood parameters in sheep were studied. They showed that date waste improve thistle quality during silage. Moreover, they showed that the use of thistle silage supplemented with date wastes had no negative effect on blood parameters in sheep, but DM intake increases with increasing the amount of dietary thistle silage supplemented with date wastes up to 21% (Mamman 2015). Another group of researchers investigated the effects of thistle silage supplemented with date wastes on microbial protein synthesis, digestibility, fermentation, protozoal populations in ewe and ram. They showed that the apparent digestibility of crude protein in studied diets decreased by the addition of thistle silage, while nitrogen intake, digested nitrogen and retained nitrogen was the highest in sheep fed 21% thistle silage. Therefore, with increasing of thistle silage level, the excreted allantoin and the synthesis of microbial protein increased linearly. The highest total protozoan population and *Entodinium* species were found in rumen fluid of animals fed 21% thistle silage. Therefore, in view of improving the nitrogen balance and increasing of the microbial protein by feeding 21% of the thistle silage supplemented with date

wastes, it can be used without negative effect on the ruminant's productivity (Kermanshahi et al. 2014).

#### Tagasaste (*Chamaecytisus palmensis*)

Tree lucerne or tagasaste (*Chamaecytisus palmensis*) is a perennial evergreen leguminous shrub (around 5–7 m of height) originating in the Canaries and that has spread to Oceania and the African and American highlands adapting to altitudes up to 3000 m asl (Mekonnen et al. 2017). It is a highly productive shrub with yields up to 10–12 t ha<sup>-1</sup> with 20–30% of leaves (Assefa 1998). The edible sections of the plant are twigs, pods and leaves, and it is well adapted to the ruminants browsing (Oppong et al. 2009; Sulas et al. 2016). Tagasaste is good and important source of protein for cow and sheep and other ruminants. Indeed, it has a high level, and stable for a long time during the vegetative season, of crude protein ranging between 160–255 and 67–108 g kg<sup>-1</sup> DM in leaf and branch respectively (Assefa 1998; Assefa et al. 2008a; Sulas et al. 2016). It has also a good amino acids profile, indeed, Assefa et al. (2015) reported that if lysine is taken as a reference (value of 1), all the amino acids are presented with a value higher than 1, with only the exceptions of methionine, histidine and cysteine that have lower values (< 0.5). The organic matter digestibility ranges between 524 and 572 g kg<sup>-1</sup> in browse samples reaching 704 g kg<sup>-1</sup> in leaves (Melesse et al. 2017). Ventura et al. (2002) obtained a net energy content (ENI) ranging between 4.9 MJ kg<sup>-1</sup> DM in winter and 5.6 MJ kg<sup>-1</sup> DM in summer in browse samples. Considering the ruminants' nutrient requirements, tagasaste has appropriate minerals content with the exception of S, P and especially Na (Mekonnen et al. 2009; Assefa et al. 2015). Tagasaste contains anti-nutritional compounds that vary with season and harvesting management, such as: hydrolysable tannins, 134–206 g kg<sup>-1</sup> DM and 47–83 g kg<sup>-1</sup> DM in leaf and branch respectively, condensable tannins, 8 g kg<sup>-1</sup> DM in browse plants, alkaloids, 40–53 mg kg<sup>-1</sup> DM and 167–245 mg kg<sup>-1</sup> DM in leaf and branch respectively. Approximately 90% of all the alkaloids is sparteine (Tolera et al. 1997; Assefa et al. 2008b). However, Mengesha et al. (2017) reported that the amounts of tannins and alkaloids are within levels that do not seem to cause toxicity to ruminants. Furthermore, Kumara Mahipala et al. (2009) reported that only a level over 55 g kg<sup>-1</sup> DM

of condensed tannins is able to reduced digestibility of ruminants.

As reviewed by Assefa et al. (2008a), in general, the effect tagasaste on feed intake of ruminants is highly variable in relation to its inclusion in diet, and to the plant secondary metabolites contents that vary with maturity. Álvarez et al. (2007) have not shown differences in the production and in the protein and fat percentage of milk of goats substituting lucerne and straw with tagasaste and tederá. Considering meat production, Avendaño et al. (2004) showed that increasing the tagasaste up to the 90% of the dietary forage fraction, the voluntary feed intake in rams decreased, however, even at level of 60–90%, the animals were able to obtain moderate growths, around 130 g d<sup>-1</sup>, confirming the good nutritive value of this plant. Indeed, steers browsing tagasaste without supplementation were able to gain 0.23 kg of live weight per head d<sup>-1</sup> (Milton et al. 2000). Kitaw et al. (2012) supplemented 250 g of leaves and edible branches of tagasaste into diet of grazing lambs and showed similar daily weight gain than those supplemented with noug seed cake, but lower performance than those supplemented with linseed cake. In agreement with this study, Assefa et al. (2008a) ended their trial suggesting that tagasaste can substitute a concentrate based on wheat bran-noug seed cake for sheep without affecting the carcass variables. Recently, Mengesha et al. (2017), supplementing sheep fed barley straw with tagasaste up to 400 g d<sup>-1</sup> observed an increase of the average daily gain of more than three times and an improvement of the dressing percentage of 7.7 pp. Therefore, tagasaste for ruminants that graze poor pastures allows them to obtain an improvement in their production performance; however, the level of this inclusion must take into account the more or less marked presence of secondary metabolites in the plants.

### *Moringa oleifera* L.

*Moringa oleifera* as perennial tree of Moringaceae 's family originating in India and that has spread in tropical and sub-tropical areas (Falowo et al. 2018). This tree is adapted to high altitudes above 2000 m asl, and to different types of soils, and it can grows under drought and high temperatures conditions (Gandji et al. 2018). It reaches 5–10 m of height, and it is a highly productive tree with yields range from 40 to

over 110 t of biomass ha<sup>-1</sup> year<sup>-1</sup> in relation to environmental and management conditions (Kholif et al. 2015). The consumable pieces of the plant are leaf, root, bark, seed and pods (Falowo et al. 2018). The chemical composition of *Moringa oleifera* seems particularly appropriate for ruminant diets. Indeed, on DM basis, the crude protein content ranges between 107–303 g kg<sup>-1</sup>, 100–518 g kg<sup>-1</sup> and 88–128 g kg<sup>-1</sup> in leaf, seed and stem respectively. The leaf and seed contain considerable amounts of minerals, up to 10% dry matter and vitamins (Nouman et al. 2014; Falowo et al. 2018). The total essential amino acids are about 46% of the total amino acids (Falowo et al., 2018), and, as reported by Damor et al. (2017), the level of rumen by-pass protein in leaf meal is particularly high, 47%. Researchers reported that the energy content of leaves is around 12.3 MJ ME kg<sup>-1</sup> DM, and that the in vitro DM digestibility is approximately 80% (Reyes Sánchez et al. 2006). The leaves contain rather low level of phytates and tannins 21 and 12 g kg<sup>-1</sup> DM, respectively, they contain alkaloids and saponins, but in inactive forms or at levels not harmful for ruminants (Nouman et al. 2014; Worku 2016), and they contain also high levels of polyphenols as reported by Cohen-Zinder et al. (2016). However, it is reviewed chemical composition of *Moringa oleifera* is highly variable in relation to soil type, environmental conditions, and stage of maturity (Kholif et al. 2015).

In general, the high antioxidant value, the low tannin level, and the high protein quality and by-pass of *Moringa oleifera* can improve the performances of ruminants as observed by many studies. Babiker et al. (2016) observed an increasing of milk yield by 22% adding 25% DM of dried leaves of *Moringa oleifera* to the diet of ewes in substitution of alfalfa hay. Moreover, the level of 100 g kg<sup>-1</sup> DM for *Moringa oleifera* when substitute with sesame meal in diets of goats, was able to increase the milk yield and enhance the fatty acids profile of milk by increasing polyunsaturated fatty acids (Kholif et al., 2015). For same inclusion amount, Yusuf et al. (2018) argue *Moringa* did not have negative effects on growth performance and health in goats. Kholif et al. (2016) explained the better productive performances of goats can be achieved by offering *Moringa oleifera* as silage, followed by the fresh form and hay. In a study with lactating cows, Cohen-Zinder et al. (2016) revealed milk production was enhanced by 2% if cows were fed

with *Moringa oleifera* silage in substitution of wheat silage. Moreover, milk production was not influenced offering over 10 kg DM d<sup>-1</sup> of *Moringa* to dairy cows instead of elephant grass and commercial concentrate (Mendieta Araica et al. 2011a). Conversely, Mendieta Araica et al. (2011b) showed the replacing the total amount, 20% DM, of soybean meal with *Moringa* leaf meal in dairy cow's diet, the milk production was reduced by 7%. Similarly, Elghandour et al. (2017), observed that substituting soybean meal with *Moringa* leaf meal the nutritive value of the diets of steers decreased. Zhang et al. (2018) showed that milk production of cows increased by 5% supplementing the diet with 6%, but not with 9%, of *Moringa*. Concerning meat, Cohen-Zinder et al. (2017) revealed 18.2% DM of *Moringa oleifera* silage in diets' of lamb could improve the tenderness and reduce the intramuscular fat content. The above cited authors hypothesised that *Moringa oleifera* could influence the type of fibres of the muscle and/or favours the muscle protein degradation. Damor et al. (2017) showed that offering *Moringa oleifera* leaves to grazing kids at 1% of body weight level in substitution of concentrate, the average daily gain could increase by 21%. Sultana et al. (2018) reported that, *Moringa* leaves added to diets of goat up to 3.4% of live weight, the carcass lean tissue increase without affecting dietary feed intake and carcass weight. Briefly, we can conclude that *Moringa oleifera* is suitable to improve the productivity of ruminant especially if they are fed with coarse fodder in arid and semiarid regions.

#### *Willow (Salix spp.)*

*Willow (Salix spp.)* is deciduous tree or shrubs that is spread mainly in temperate and cold regions, and it is considered an important woody species for ruminants for Nordic areas (Hejcman et al. 2016). It is tolerant to metals and saturated soils, and it is used to control the soil erosion and for animals alimentation. Depending of the species, it provides 2.5–8 ton DM ha<sup>-1</sup> year<sup>-1</sup> of edible parts of the plant, that are leaves and stem (lower than 5 mm in diameter; Oppong et al. 2001). The leaves stem<sup>-1</sup> ratio varies from 0.4 to 0.8, in relation to species and height of the cut (Oppong et al. 2001), and influences its chemical composition that is, consequently, highly variable. On DM basis, the crude protein is about 190–199 g kg<sup>-1</sup>, 84–99 g kg<sup>-1</sup> in leaf, and stem respectively (Muklada et al. 2018). The

DM digestibility in vitro is around 40–80% (Douglas et al. 1996). However, willow contains secondary metabolites compounds such as condensed tannins, 69–303 g kg<sup>-1</sup> DM and 45–274 g kg<sup>-1</sup> DM in leaf and stem respectively, and phenols 89–94 g kg<sup>-1</sup> DM and 48–58 g kg<sup>-1</sup> DM in leaf and stem respectively (Oppong et al. 2001; Muklada et al. 2018). The most important phenolic glucoside in willow is salicin (1.2–1.4 mg g<sup>-1</sup> of fresh leaf) that has anti-inflammatory action (Muklada et al. 2018).

Muklada et al. (2018) ended suggesting that up to 600 g d<sup>-1</sup> the willow fodder is not harmful to goats. Despite a decrease in the feed intake, the above cited authors showed that feeding goats with this level of willow fodder did not affect the milk yield. Moreover, willow have a positive effect on animals' health, indeed it was able to reduce milk somatic cell count probably reducing the apoptosis process of mammary gland. Mupeyo et al. (2011) observed that willow can reduce the worm fecundity in parasitised lambs. McWilliam et al. (2005) showed that willow increases the fecundity, and the twin's frequency in particular, of ewes. These studies confirm the beneficial effect of willow on ruminants' health. Considering meat production, Moore et al. (2003) highlighted that the loss of body weight of beef cows grazing on sparse pasture under drought conditions was reduced if the animals were supplemented with 4 kg of fresh willow for at least 60–80 days. In similar conditions, Pitta et al. (2009) observed that willow intake of 0.26 kg DM d<sup>-1</sup> can reduce the proteins catabolism in ewes. In general, it seems that the willow supplementation in diets can be favourable for health rather than for considerable improvement of the performances of ruminants.

#### Conclusion

Actually, many trees and shrubs can be and are used in ruminant feeding because they are inexpensive local products. Although they frequently have good contents of nutraceuticals, proteins, and nutrients, especially in the leaves, their use is limited by the reduced palatability and the presence of anti-nutritional factors. Future studies should define the ideal level of tree and shrubs, or their parts, in ruminant diets and, on the other hand, also through genetic analysis technologies such as the next generation sequencing whose cost is increasingly diminishing, try to improve genetically

these plants in order to reduce the presence of anti-nutritional factors and increase their livestock use, especially where the quality of the plants are not found to be suitable for ruminant rearing. Regarding the tannin extracts from trees, despite the fact that their use seems promising, their mechanism of action/interaction with the rumen microbiota is not completely clear yet. Clarifying these mechanisms could lead not only to an improvement in the performance of the animals or of the quality of the products, but also to a reduction of greenhouse gas emission by ruminants with a possible favourable impact on climate change.

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