Chapter 5

Potential Use of Nonconventional Silages in Ruminant Feeding for Tropical and Subtropical Areas

Jaime Salinas Chavira

Additional information is available at the end of the chapter

http://dx.doi.org/10.5772/64382

Abstract

The conventional silage uses crops such as corn, sorghum or other forages for this specific objective. The nonconventional silages use by-products, co-products and other materials obtained during the harvest or during the processing in the industry of sugarcane, juice extraction of citrus, pineapple, cassava, pumpkin and others. These products are available in high amounts during a short period of time. These by-products can be ensiled to maintain their nutritive value during longer period in the year and then used as feed for animals. These by-products have adequate characteristics for ensiling, i.e., moisture content and fermentable carbohydrates. Forages reduce their crude protein (CP) concentration in a period of the year (dry season or in winter), which may limit animal production. Most by-products used for silage have low CP concentration; some additives may help increase the nutritive value of these silages. These by-products (sugarcane, juice extraction of citrus, pineapple, cassava, pumpkin and others) can be mixed and ensiled with other by-products as poultry excreta or forage rich in protein to obtain silage with greater CP concentration. The research shows the feasibility of obtaining good quality silages from sugarcane tops, by-products of citrus, cassava and pumpkin; the particularities of each are discussed in detail in this chapter.

Keywords: potential use, nonconventional, by-products, silage, tropics

1. Introduction

The preparation of conventional silage considers crops for this specific purpose; these crops include corn, sorghum or other forages. Nonconventional silages use by-products, co-products and other materials different from conventional crops; they include by-products of sugarcane, juice extraction of citrus, pineapple, cassava, pumpkin and others. These products are available in high amounts during a short period of time, the harvest season. Their preservation is required so they can be maintained for longer periods of time and used then as feed for animals. Silage represents an appropriate technique for this purpose. Also these materials may have adequate characteristics for ensiling, i.e., adequate moisture content and high fermentable carbohydrates. These byproducts may have low crude protein (CP) and mineral concentration and some additives may help increase the nutritive value of these silages.

The improvement in nutritional quality of silages with nonconventional products may contribute to better animal feeding and production in tropical and subtropical areas. In addition, the use of alternative silages for animal feeding also may contribute by reducing environmental pollution. If by-products are not used in a short time (during the harvest season) they will be wasted in fields and in other cases they are burned. The objective of this chapter is to review the potential use of nonconventional silages (sugarcane tops [SCT], citrus byproducts, pumpkin and cassava) for ruminant feeding in tropical and subtropical areas.

2. Ensiling process

Silage is the preservation of feeds by anaerobic fermentation, usually by epiphytic bacteria that convert soluble carbohydrates mainly to lactic acid, and minor amounts of other volatile fatty acids. This reduces pH, which inactivates or inhibits microbial growth and results in the preservation of ensiled material. The ensiling process has four stages. In phase 1, aerobic microorganisms are active during the aerobic phase and occur under aerobic conditions during the few hours after ensiling. The ensiled material and facultative microorganisms (yeasts and enterobacteria) continue respiration, reducing the oxygen present. The enzymes of the ensiled material are active and pH is close to 6. In phase 2, anaerobic fermentation starts and continues for several days depending on substrate availability and ensiling conditions. Lactic bacteria become the main strain, and lactic acid reduces pH to 3.8–5.0. In phase 3, the process is stable, because changes can occur even in anaerobic conditions; most microorganisms reduce their numbers. During this phase, while the silage maintains anaerobic conditions, the process is practically unchanged. Phase 4 starts with the opening of the silage, or air exposure. The spoilage of silage in this phase is due to two processes: one is the degradation of acids that preserve the silage and the second is the spoilage by some microorganisms [1].

To produce good quality silage the following principles of fermentation during the phases of ensiling should be considered. For phase 1, adequate particle size of ensiled material with efficient filling (adequate packing density) will reduce aerobic respiration that allows faster growth of anaerobic microorganisms that produce lactic acid. Phases 2 and 3 can be enhanced and/or stabilized using some additives to silage during its preparation. For fast time of pH reduction and decrease dry matter (DM) losses, additives containing water soluble carbohydrates are used. To improve the fermentation process, some microbial inoculants, organic acids and enzymes can also be used. It is pointed out [2] that additives in silage stimulate lactic acid bacteria growth, responsible of silage stability, decreasing nutrient loss during fermentation and resulting in silage of higher nutrient concentration. Additives that contribute to silage stability are acetic, propionic and caproic acids; also ammonia and some inoculants may contribute to silage stability [2]. To reduce the spoilage of ensiled material in phase 4, it is recommended that the silage be used as fast as possible once the silo is opened [1].

3. Nutritive value of silages

3.1. Nutritive value of sugarcane tops silage

In tropical areas, high amounts of vegetal biomass are produced due to the dynamic ecosystem, which is favored by the climatic conditions, i.e., humidity and temperature that propitiate accelerated growth of plants. An example of these plants is sugarcane (*Saccharum officinarum*); it can be fed to animals as an entire plant [3]. During the harvest of sugarcane for sugar extraction in the field an abundant biomass of sugarcane tops is wasted or burned; they constitute about 15% dry matter of total plant [4] and have greater protein content than the stalks [5], representing an alternative forage for ruminants in subtropical areas, where the climatic conditions complicate forage preservation; for this, sugarcane tops silage represents an alternative. The replacement of stalks by fresh tops of sugarcane in feedlot cattle diets has increased dry matter intake and body weight gain, **Table 1** [6]. The supplementation with urea of slow ruminal degradation to fresh sugarcane tops improved weight gain in lambs, **Table 2** [7]. Ruminal fermentation of fresh sugarcane tops is improved when supplemented with nitrogen and nonstructural carbohydrates [8], also similar results are observed in **Table 3** [9].

	Top:stalk fresh basis					
	0:100	**20:80**	**40:60**	**60:40**	**80:20**	**100:00**
ADG, kg/d	0.605	0.614	0.699	0.760	0.788	0.839
DMI, kg/d	4.52	4.66	6.49	6.40	6.76	7.50
Feed/gain	7.47	7.59	9.28	8.35	8.57	8.94

ADG = average daily gain; DMI = dry matter intake; feed conversion = feed intake/weight gain.
Adapted with permission from Ferreiro and Preston [6].

Table 1. Summary of growth performance of feedlot cattle fed with different proportions of tops:stalks of sugarcane.

	SCT	**SCT plus slow degrading urea**	**SCT plus slow degrading urea plus corn plant**
ADG, g/d	70	135	218
DMI, g/d	474	797	917

SCT = sugarcane tops; ADG = average daily gain; DMI = dry matter intake.
Adapted with permission from Galina et al. [7].

Table 2. Summary of growth performance of feedlot lambs fed with sugarcane tops supplemented with slow degrading urea and corn plant.

	Ruminal parameters			
	Washing loss (A)	**Degradability of water insoluble fractions (B)**	**Potential degradability (A + B)**	**Fractional degradation rate (C)**
Trial 1				
0 g/kg TG	0.17	0.36b	0.54b	0.0490
300 g/kg TG	0.17	0.39a	0.57a	0.0496
Trial 2				
0 g/kg PM	0.17	0.38b	0.56b	0.0437
300 g/kg PM	0.17	0.40a	0.58a	0.0472
Trial 3				
0 g/kg Urea	0.17	0.38b	0.56b	0.0448b
24 g/kg Urea	0.17	0.42a	0.60a	0.0568a
Trial 4				
0 g/kg HNESO	0.17	0.37b	0.55b	0.0441b
1500 g/kg HNES15	0.17	0.45a	0.63a	0.0578a

TG = Taiwan grass (*Pennisetum purpureum*); PM = poultry manure; HNES = high nitrogen and energy supplement; the latter had (g/kg) ammonium sulfate 18, animal lard 40, cement kiln dust 16, corn 112, cottonseed meal 164, fish meal 42, limestone 32, mineral salts 10, molasses 182, orthophosphate 30, poultry manure 116, rice polishing 160, NaCl 40 and urea 38; within columns, different literals (a or b), denote statistical difference (P<0.05).
Adapted with permission from Ortiz-Rubio et al. [9].

Table 3. Parameters of ruminal kinetics of sugarcane tops supplemented with different feeds, data obtained from in situ incubations in steers.

Ensiling sugarcane tops is a logical alternative; however, this process may have complications. It is reported that ensiling reduced dry matter digestibility and feed intake in lambs [10], probably because of excessive production of ethanol during the process [11].

Values of 4.7% and 10.1% crude protein, 87% and 78% neutral detergent fiber (NDF), respectively, were reported for fresh and ensiled sugarcane tops [12]; however, this increase in protein could be a dilution effect and not by the fermentative process of ensiling. Acceptable color and odor, indicating no putrefaction was also reported; pH was from 4.0 to 4.04. In vitro gas production was higher for fresh than ensiled sugarcane tops at 24 h; however, the organic matter digestibility estimated from in vitro gas production was higher for ensiled sugarcane tops [12].

It was found that sugarcane tops (SCT) had lower CP and minerals than broiler litter (BL). These two feed ingredients can improve silage nutritional composition, fermentation characteristics, degradation of DM by microorganisms in the rumen and destruction of mycotoxin-producing fungi (MPF). Excessively high amount of BL can cause deleterious effects on the quality of the resulting silage product. It would therefore be recommended that a 30–45% inclusion rate is the most appropriate level of incorporation of BL in silages. Adequate levels of moisture are needed in silage [13]. From 30 to 45% BL enhanced lactic acid production and pH was acceptable; however, 60% of BL in silage resulted in high buffer capacity with high levels of ammonia production that caused silage pH increased.

In a study, sorghum stover was substituted with sugarcane top silage supplemented with urea [0 (T1), 5 (T2) and 10% (T3) DM] in high concentrate diets for feedlot hair lambs. It was observed a reduction of effective ruminal degradability with increased SCT contents in silage. Feedlot hair lambs observed reduced feed intake augmenting sugarcane tops silage in their ration. Nevertheless daily weight gain was not affected by diet. Feed efficiency (gain/feed intake) was not influenced by treatment. It was concluded that ensiled sugarcane tops constitute alternative forage in diets for growing-finishing feedlot lambs [14].

3.2. Nutritional value of citrus silage

Most citrus species are well adapted in tropical and subtropical areas. Citrus fruits are used as dessert, although considerable amounts are used for industrial juice extraction. Citrus production in the producing countries is increasing [15]. The augmented disposal costs in many parts of the world have stimulated attention in utilizing citrus by-product feedstuffs (BPFs) as alternate feeds for ruminants [16]. In ruminant feeding, the principal citrus by-products are fresh pulp, silage, dried, meal, molasses and citrus peel liquor. Other minor BPFs from citrus include cull or excess fruit. Citrus BPFs can be used as a high-energy feed in ruminant rations to support growth and lactation, with fewer negative effects on rumen fermentation than starch-rich feeds.

The world citrus production of the genus *Citrus* are sweet orange (*C. sinensis*: 67.8%), tangerine (*C. reticulata*: 17.9%), lemon (*C. limon*: 6.3%) and grapefruit (*C. paradisi*: 5.0%).

The remaining 3.0% of the *Citrus* genera are sour orange (*C. quarantium*), shaddock (*C. grandis*), citron (*C. medica*) and lime (*C. aurantifolia*). The largest world orange juice producing countries are Brazil, the United States, Mexico, Spain, China and Italy. Other significant orange producing countries include South Africa, Israel, Egypt, Iran, Cuba, Costa Rica, Belize, Japan and Australia [17]. It would be convenient to develop methods to preserve the fruit surplus during the production season in tropical countries that would enable this plant material to be utilized as animal feeds for longer periods of time [18].

It was showed that ensiling citrus by-products are possible; however, the high water content might affect the quality of the product [16]. This sense, citrus pulp silage produces high quality fermentation when straw and poultry litter are added [19]. In other research [20], fresh orange peel was ensiled without additive (control), or with enzyme inoculate (EI), formic acid (FA), propionic acid (PA) and acetic acid (AA). Samples of fresh and ensiled orange peel were analyzed for dry matter (DM), crude protein (CP), neutral detergent fiber (NDF), acid detergent fiber (ADF), *in vitro* dry matter and cell wall disappearance, pH, buffering capacity and ammonia N. In this study, it was concluded that the additives used did not improve nutritional value of orange peel silage. Similarly, it was observed that orange peel silage showed a high apparent digestibility, although additives did not alter nutritive value of silages [21]. In different results, three silages of orange fruit wastes (OFWs) combined with (1) urea (0.5%);

(2) leucaena (ratio 1:1 leucaena-OFW) and (3) orange fruit wastes plus a fish (*Oreochromis aureus*) of noncommercial size disintegrated (ratio 2:1). In this report, it was observed that orange fruit wastes plus leucaena silage showed high alcohol content. But the silage with fish had adequate chemical properties and could be recommended to farmers [22]. In the silage of kinnow mandarin (*Citrus nobilislour* × *Citrus deliciosa tenora*) fruit waste, it was observed that this by-product can be used to prepare good quality silage for goats [23]. In a similar report [24], the fermentative characteristics, intake, digestibility and aerobic stability of pineapple silage (PS) or citrus silage (CS) were studied. Crossbred rams were used to determine the *in vivo* digestibility. Final pH at 65 d was 3.21 and 3.32 for PS and CS; in both silages, population of Enterobacteriaceae was not detected. The DM and CP intakes and digestibility were similar among treatments. In this study, it was noted that both silages of by-products were unstable upon aerobic exposure, PS after 1 d when fermented 29 d and CS after 3 d when fermented 65 d. Results indicate that pineapple and citrus by-products could be preserved as silage and included in sheep diets at 20% substitution of grass without adverse results; however, they are susceptible to aerobic deterioration. This may represent the use of silage in feeding the animals as fast as possible when silage is open (**Table 4**).

	Days of fermentation			
	0	**7**	**29**	**65**
pH	5.4	3.7	3.5	3.3
Dry matter, %	24.2	19.7	19.0	18.7
Crude protein, %	5.7	5.9	6.4	6.5
NDF, %	16.2	23.4	24.2	23.7
Water soluble carbohydrates, %	5.6	1.8	4.2	5.4
Lactic acid, g/kg	0.02	1.17	1.2	1.7
Acetic acid, g/kg	0	0.20	0.27	0.36
Propionic acid, g/kg	0	0	0.01	0.01
Butyric acid, g/kg	ND	ND	ND	ND
Ammonia-N, g/kg	1.4	1.3	1.3	1.2

Adapted with permission from Pagán et al. [24]. NDF = neutral detergent fiber.

Table 4. Fermentation characteristics of citrus by-products silage at different periods of process.

3.3. Nutritive value of pumpkin silage

Fresh pumpkin can be fed to animals; they have seasonal availability. To preserve pumpkins and use them in different seasons of the year, silage may represent an alternative in ruminant feeding. The complete fruits are carbohydrate and protein rich. The total sugar and crude protein are 48.1% and 18.2%, respectively; however they have low dry matter concentration (16.8%). For this reason, when ensiling pumpkin, an adsorbent material should be included to have adequate water level. The silage of pumpkin with dried beet pulp has about 11% CP [25]. The nutritional quality of pumpkin silage was assessed by Halik et al. [26] who produced silages with chopped pumpkin (*Cucurbita maxima*) fruits mixed with dried beet pulp at an 80:20 ratio. Silages were prepared with or without inoculant; the inoculant contained *Lactobacillus plantarum* bacteria, endo-1,4-beta-glucanase, xylanase and glucoamylase. The inoculant was applied at 0.2% of the ensiled material. The material after ensiling (10 weeks) had lower crude fiber and ADF compared to fresh material, whereas the inoculant had no effect on silage pH (4.5 and 4.4 for no inoculant and with inoculant) but reduced ammonia, nitrogen and ethanol and increased lactic and acetic acids, indicating higher aerobic stability with improved silage quality.

Silages were made of pumpkin (*C. maxima*), sorghum straw, urea and cane molasses at levels of 73.4%, 25.6%, 1% and 0% (treatment 1); 72.13%, 21.87%, 0% and 6% (treatment 2); treatment 3 had 72.2%, 20.8%, 1% and 6%, respectively. With these three silages, three diets were formulated for lambs with similar concentrations of crude protein and metabolizable energy. With these silages, two trials were conducted. In trial 1, of growth performance, results showed similar weight gain, feed intake and feed efficiency of lambs fed the three diets. Based on these results, they concluded that silages of pumpkin with sorghum straw and additives can be used in ruminant feeding [27]. In trial 2, the apparent digestibility of complete diets for lambs containing the same silages was studied. The in vivo digestibility was of 81.27%, 70.7% and 70.31% for crude protein; 75.21%, 62.04% and 80.95% for ether extract (EE). These values were different ($P < 0.05$). The in vivo digestibility of dry matter and nitrogen-free extract was similar between the rations ($P > 0.05$). In this study, it was concluded that the digestibility was improved in ration with silage that contained only urea [28]. Although this study did not report fermentative characteristics of silages, urea might contribute for growth of bacteria that digested nitrogen.

Pumpkin can be cultivated for seed collection, with abundant residues that many times are wasted in field and have potential for ensiling and use in ruminant feeding. For this application, Hashemi and Razzaghzadeh [29] used pumpkin residue (PR; fleshy part of fruit that remains after seeds are collected). Pumpkin residue (71.4%) was mixed with wheat straw (28.6%) and ensiled with dry beet molasses (10% or 20%) and urea (0% or 5%). After 2 months, silages were evaluated for pH and dry matter. They concluded that PR may be ensiled with wheat straw as absorbent of moisture and beet molasses as fermentable additive.

In other research [30], the growth performance of male buffalo calves fed diets containing silage of pumpkin (*Cucurbita pepo*) residues was studied. Silages were prepared using pumpkin residues chopped at 2 cm; 700 kg of this was mixed with 300 kg of wheat straw and ensiled adding 100 l of a solution (10 kg urea plus 50 kg beet molasses in water). Pumpkin residual silage (PRS) replaced forage (alfalfa) at 0% (control), 20%, 40% and 60%. In this study, it is concluded that part of the alfalfa may be substituted with PRS at 60% level with no negative effects on male buffalo calves' fattening performance.

Pumpkin was ensiled (*C. maxima* D.) with dried sugar beet pulp (80:20 ratio) and studied its antioxidant potential. It was observed that ensiling increased the saturated fatty acid content and decreased the polyunsaturated content. Ensilage increased the polyphenol compounds and decreased the carotenoid and alpha-tocopherol content of the silages. Although there was a reduction of carotenoid and tocopherol compounds, the increase of polyphenol compounds suggests that the ensiling did not lower the silage antioxidant potential of pumpkins compared to fresh material [25].

3.4. Nutritive value of cassava silage

The importance of cassava (*Manihot esculenta* crantz) for livestock feeding was reported [31]. Cassava has high productivity per unit of land; it has low crude protein but a high amount of starch (about 85% DM basis). Different methods for ensiling this material have been explored. A study investigated the chemical composition and organoleptic traits of maralfalfa silage (*Pennisetum* sp.), containing 0%, 5%, 10% and 15% fresh cassava (*M. esculenta*). This research reported improved silage characteristics of maralfalfa grass with 15% of cassava, with acceptable pH; reduction of cell wall (NDF) fraction and the crude protein is maintained in the silage [32]. The fermentation characteristics of cassava silage at laboratory scale have been improved with microorganism-inoculant of genus *Lactobacillus*. This study reports reduction of ethanol and total VFA but maintained or increased lactic acid for adequate pH with inoculant treatment of silos; also it is reported that acid treatment goes to alcoholic fermentation. In addition, *Lactobacilli inoculum* generated homofermentative pattern [33]. In a similar study, *L. plantarum* and *Lactobacillus cellobiosus* increased the acidification rates of *M. esculenta* silages [34]. The results at laboratory silos are satisfactory; however, more conclusive results are required.

The chemical composition of cassava starch by-products before and after ensiling was studied; fermentation characteristics and growth of microorganisms were also determined. The results showed that ensiling reduced NDF and hemicellulose concentrations, but increased concentrations of ADF, cellulose and lignin. pH and microbial populations were reduced as the duration of silage fermentation increased. Predrying did not change the fermentative profile and microbiological population of silages at 28 and 56 d and reduced neutral detergent fiber and hemicellulose of silages. The wet waste residue silage showed a reduction in crude protein content in the course of the fermentation period. This research showed that cassava by-products have good fermentation characteristics [35]. Also, the fermentative characteristics and chemical composition of Elephant-Grass silages with cassava by-product (SM in relation to the grass fresh matter) was explored [36] . It was observed that in the level of 7.1% of SM addition, the silages had adequate dry matter content (30–35%) for a good fermentative process. In all levels of SM addition, the silages had appropriate pH values for silages (3.8–4.2). The cassava by-product up to the 20% level (on a grass fresh matter basis) at the elephant grass ensiling produced good fermentative characteristics and a better silage chemical composition. Although a minimum level of CP (7%) was not reached in any level of SM.

In another study [37], Holstein cows in diets were fed with silage of the residue from the extraction of cassava starch (SRECS), replacing 0%, 25%, 50%, 75% or 100% of the corn feed. Before ensiling the material had 128.0 g kg^{-1} of dry matter (DM), 25.3 g kg^{-1} of crude protein (CP), 25.0 g kg^{-1} of mineral matter (MM), 297.0 g kg^{-1} of neutral detergent fiber (NDF) and 6.1 g kg^{-1} of ether extract (EE) on a dry matter basis. After ensiling (40 d) the silage had

189.8 g kg^{-1} of DM, 24.4 g kg^{-1} of CP, 23.8 g kg^{-1} of MM, 324.9 g $kg^{-1}$of NDF, 271.9 g kg^{-1} of ADF and 05.4 g kg^{-1} of EE (dry matter basis). In this study, it was concluded that the silage of the residue from the extraction of cassava starch to replace the ground corn on feed negatively affects nutrient intake without changing the efficiency of milk production, milk composition or blood parameters of lactating cows.

Cassava by-product is starch-rich and promotes good fermentation characteristics; however, it is low in protein. The age was compared at harvesting time (7, 8 and 9 months) of cassava plants on whole crop silage quality. Plants were ensiled in laboratory silos. The results showed that ensiling reduced HCN content (more than 60%). Harvesting cassava plant at 8 months of age gave the best whole cassava plant silage quality (best physical characteristics and in vitro rumen digestibility). They also conclude that the low crude protein of cassava for ensiling could be improved mixing with other protein rich by-products like poultry litter [38]. In other research, silage of cassava (*M. esculenta*) by-product with poultry litter at 0%, 5%, 10%, 15% and 20% was produced. They observed that increasing levels of poultry litter influenced DM, CP, EE, ash, calcium, NDF, ADF, cellulose and hemicellulose content of the silage; however, no clear tendencies were found for lignin content. On the other hand, poultry litter addition decreased nonfibrous carbohydrate concentration and IVDMD of the silage. Although pH increased, the level was acceptable in all silages. The authors recommend 10% poultry litter to preserve nutritional and fermentative characteristics of the cassava silage [39].

Another alternative to improve crude protein in the cassava by-product is the inclusion of forage rich in protein. Cassava peels (CaPe) was ensiled with mixtures of *Gliricidia sepium* and *Leucaena leucocephala*; the nutritive value was assessed in goats. All diets were supplemented with molasses (40 g/kg) before ensiling which lasted 3 months. The silage with only CaPe (control) had the lowest hydrocyanic acid content. All silages had low pH (<4.5). Authors reported that *L. leucocephala* and *G. sepium* ensiled with CaPe did not affect fermentation but improved the CP content of the resulting silage. Increasing level of *L. leucocephala* reduced weight gain of animals. Silage of CaPe (control) improved weight of animals. They conclude that ensiling CaPe with foliages of *G. sepium* and *L. leucocephala* may be recommended, especially for the season of year when forages reduce availability and nutritive value.

During the harvest of root cassava, also can be collected the aerial part, the vegetative fraction containing mainly leaf may generate about 1.8 tons per ha of dry matter. Cassava leaf is protein rich; it contains about 21% CP [40]. The silage of cassava foliage with different levels of molasses was studied. Increasing molasses level did not influence DM, pH or lactic acid of silages; however, reduced CP and increased water soluble carbohydrates. Cyanic acid (HCN) was not influenced by molasses; however, all silages reduced HCN concentration after 2 months of fermentation. These results show the possibility of ensiling leaf cassava with low levels of molasses [41]. In other study, cassava leaves were used without additives, with molasses or with caged layer waste. All silages had adequate fermentation parameters. In this study, HCN was lower in silages with additives; the HCN (mg/kg) was of 112.3, 95.8, 84.7 and 89.3 for fresh leaves, silage of leaves, silages of leaves with molasses and silage of leaves with poultry excreta, respectively [42].

4. Conclusions

Silages of sugarcane tops, citrus, cassava and pumpkin represent an alternative in animal feeding; the particular characteristics of each should be considered for better silage production. The research shows the feasibility of producing good quality silages with these materials. This technology represents an alternative to enhance animal production, converting these products or by-products in good quality protein of animal origin. Research to improve the fermentation process during ensiling of these materials and their incorporation with other available resources must continue.

Author details

Jaime Salinas Chavira

Address all correspondence to: jsalinas@uat.edu.mx

College of Veterinary Medicine and Zootechnology, Autonomous University of Tamaulipas, Cd. Victoria, Tamaulipas, México

References

[1] Stefanie JWH, Elferink O, Driehuis F, Gottschal JC, Spoelstra SF. 1999. Paper 2.0: Silage fermentation processes and their manipulation. In: Silage Making in the Tropics with Particular Emphasis on Smallholders. Edited by 'tMannetje L. Available from: http://www.fao.org/docrep/005/x8486e/x8486e00.htm#Contents [accessed: 2016-02-01].

[2] Yitbarek MB, Tamir B. Silage additives: review. Open Journal of Applied Sciences 2014; 4: 258–274. http://dx.doi.org/10.4236/ojapps.2014.45026.

[3] Landell MGA, Campana MP, Rodrigues AA. The IAC 862480 variety as a new choice of sugar cane for forage purposes: production management and use in animal feeding. Technical Bulletin IAC193, Series Technological APTA 2002; 36 p.

[4] López I, Aranda EM, Ramos JA, Mendoza GD. Nutritional evaluation of eight sugar-cane varieties with forage potential. Cuban Journal of Agricultural Science 2003; 37: 375–380.

[5] Juárez LF, Vilaboa AJ, Díaz RP. 2009. Sugar cane (*Saccharum officinarum*): an alternative for substitution of corn (*Zea mays*) in the feeding of feedlot cattle. Available from: http://www.produccionbovina.com.ar/informaciontecnica/ invernada o engorde a corral o feedlot/69-cana azucar.pdf [accessed: 2016-02-01].

[6] Ferreiro HM, Preston TR. Fattening cattle with sugar cane: the effect of different proportions of stalk and tops. Tropical Animal Production 1976; 3: 131–138.

[7] Galina MA, Guerrero M, Puga CD. Fattening Pelibuey lambs with sugar cane tops and corn complemented with or without slow intake urea supplement. Small Ruminant Research 2007; 70: 101–109.

[8] Gendley MK, Singh P, Garg AK, Tiwari SP, Kumari K, Dutta GK. The studies on nutrient balances in crossbred cattle bulls fed chopped green sugarcane tops supplemented with some agro industrial by-products. Tropical Animal Health and Production 2009; 41: 943–949.

[9] Ortiz-Rubio MA, Ørskov ER, Milne J, Galina HMA. Effect of different sources of nitrogen on in situ degradability and feed intake of Zebu cattle fed sugarcane tops (*Saccharum officinarum*). Animal Feed Science and Technology 2007; 139: 143–158.

[10] Alcántara E, Aguilera A, Elliot R, Shimada A. Fermentation and utilization by lambs of sugarcane fresh and ensiled with and without NaOH. Animal Feed Science and Technology 1989; 23: 323–331.

[11] Bernardes TF, Silveira RN, Coan RM, Reis R, Moreira AL, Iturrino RPS. Fermentative characteristics and presence of yeast on raw or burnt ensiled sugar cane with additive. Reunião daSociedade Brasileira de Zootecnia, 39, 2002. Anais, Recife–Brazil (CD ROM).

[12] Nyakira BS, Tuitoek JK, Onjoro PA, Ambula MK. Determination of the nutritive value of sugar cane tops, mulberry leaves (*M. alba*) and calliandra (*C. calothyrsus*) as feed supplements for goats in Kenya. Journal of Animal Science Advances. 2015; 5: 1225–1233.

[13] Mthiyane DMN, Nsahlai IV, Bonsi MLK. The nutritional composition, fermentation characteristics, in sacco degradation and fungal pathogen dynamics of sugarcane tops ensiled with broiler litter with or without water. Animal Feed Science and Technology 2001; 94: 171–185.

[14] Salinas-Chavira J, Almaguer LJ, Aguilera-Aceves CE, Zinn RA, Mellado M, Ruiz-Barrera O. Effect of substitution of sorghum stover with sugarcane top silage on ruminal dry matter degradability of diets and growth performance of feedlot hair lambs. Small Ruminant Research 2013; 112: 73–77.

[15] Arribas L. Agriculture as a problem: worldwide citrus export. Agrícola Vergel, Fruticultura, Horticultura, Floricultura, Year XX, Num., 230, 2001; 56 p.

[16] Bampidis VA, Robinson PH. Citrus by-products as ruminant feeds: a review. Animal Feed Science and Technology 2006; 128: 175–217.

[17] Spreen TH. The citrus industries of the United States and Mexico after Nafta. Revista Chapingo Serie Horticultura 2000; 6: 145–152.

[18] Aguilera A, Perez-Gil F, Grande D, de la Cruz I, Juarez J. Digestibility and fermentative characteristics of mango, lemon and corn stover silages with or without addition of molasses and urea. Small Ruminant Research 1997; 26: 87–91.

[19] Migwi PK, Gallagher JR, Van Barneveld RJ. The nutritive value of citrus pulp ensiled with wheat straw and poultry litter for sheep. Australian Journal of Experimental Agriculture 2001; 41: 1143–1148.

[20] Itavo LCV, dos Santos GT, Jobim CC, Voltolini TV, Bortolassi JR, Ferreira CCB. Conservation of fresh orange peel by ensilage process using additives. Revista Brasileira de Zootecnia 2000; 29: 1474–1484.

[21] Itavo LCV, dos Santos GT, Jobim CC, Voltolini TV, Faria KP, Ferreira CCB. Composition and apparent digestibility of orange peel silage additives. Revista Brasileira de Zootecnia 2000; 29: 1485–1490.

[22] Revuelta-Llano D, Mosquera-López D, Cuba-Mora F. Ensiling potential of orange fruit wastes (Citrus sinensis). Revista Ciencias Técnicas Agropecuarias 2008; 17: 41–44.

[23] Malla BA, Rastogi A, Sharma RK, Ishfaq A, Farooq J. Kinnow madarin (*Citrus nobilis* lour × *Citrus deliciosa* tenora) fruit waste silage as potential feed for small ruminants. Veterinary World 2015; 8: 19–23.

[24] Pagán S, Rodríguez AA, Valencia EM, Randel PF. Pineapple and citrus silage as potential feed for small ruminant diets: fermentation characteristics, intake, nutrient digestibility, and aerobic stability. Revista Colombiana De Ciencias Pecuarias 2013; 27: 37–46.

[25] Lozicki A, Koziorzebska A, Halik G, Dymnicka M, Arkuszewska E, Niemiec T, Bogdan J. Effect of ensiling pumpkin (*Cucurbita maxima* D.) with dried sugar beet pulp on the content of bioactive compounds in silage and its antioxidant potential. Animal Feed Science and Technology. 2015; 206: 108–113.

[26] Halik GD, Lozicki A, Koziorzębska A, Dymnicka M, Arkuszewska E. Effect of ensiling pumpkin Cucurbita maxima with the addition of inoculant or without it on chemical composition and quality of silages. Annals of Warsaw University of Life Sciences – SGGW, Animal Science. 2014; 53: 103–110.

[27] Medina LJB, Salinas-Chavira J, Martinez DR, Lerma-Doria CE. 1993. Silage of ripe pumpkins (*Cucurbita maxima*) with sorghum ratoons, urea and molasses in complete rations for sheep. Available from: http://agris.fao.org/agris-search/search.do?recordID=MX19950101212 [accessed: 2016-02-01].

[28] Medina LJB, Salinas-Chavira J, Lerma DEC, Martinez Delgadillo R, Yado-Puente R. 1995. In vivo digestibility of squash silage (*Cucurbita maxima*) with sorghum hay, urea and sugar cane molasses in integral diets for ovine. VIII Congreso nacional de produccion ovina. Memorias. Chapingo, Mexico, pp. 77–81.

[29] Hashemi A, Razzaghzadeh S. Investigation on the possibility of ensiling cucurbit (*Cucurbita pepo*) residues and determination of best silage formula. Journal of Animal and Veterinary Advances 2007; 6: 1450–1452.

[30] Razzaghzadeh S, Amini-jabalkandi J, Hashemi A. Effects of different levels of Pumpkin (*Cucurbita pepo*) residue silage replacement with forage part of ration on male buffalo calves fattening performance. Italian Journal of Animal Science 2007; 6 (Suppl. 2): 575–577.

[31] Anjos FR, Tivana L, Da-Cruz-Francisco J, Kagande SM. Cassava (Manihot esculenta crantz): an affordable energy source in dairy rations. Online Journal of Animal and Feed Research 2014; 4: 10–14.

[32] Maza AL, Vergara GO, Paternina DE. Chemical and organoleptic evaluation of maralfalfa silage (*Pennisetum* sp.) plus fresh cassava (*Manihot esculenta*) . Revista MVZ Córdoba. 2011; 16: 2528–2537.

[33] Saucedo GC, Gonzalez PB, Revah SM, Viniegra GG, Raimbault M. Effect of lactobacilli inoculation on cassava (manihot-esculenta) silage—fermentation pattern and kinetic-analysis. Journal of the Science of Food and Agriculture 1990; 50: 467–477.

[34] Meraz M, Shirai K, Larralde P, Revah S. Studies on the bacterial acidification process of cassava (Manihot-Esculenta). Journal of the Science of Food and Agriculture 1992; 60: 457–463.

[35] Goncalves JAG, Zambom MA, Fernandes T, Mesquita EE, Schimidt E, Javorski CR, Castagnara DD. Chemical composition and profile of the fermentation of cassava starch by-products silage. Bioscience Journal 2014; 30: 502–511.

[36] Maciel RP, Neiva JNM, Oliveira RC, de Araujo VL, Lobo RNB. Fermentative patterns and chemical composition of Elephant-Grass silages with cassava by-product. Revista Ciência Agronômica 2008; 39: 142–147.

[37] Zambom MA, Fernandes T, Schmidt EL, Goncalves JA, Pozza MS, Javorski CR, de Souza LC, Tinini RC. Silage of residue from the extraction of cassava starch in diets from lactating Holstein cows. Semina: Ciências Agrárias, Londrina 2015; 36: 1701–1712.

[38] Despal D, Lestad A, Permana IC, Hidayah P. 2012. Effect of age at harvest on whole Cassava (*Manihot esculenta*) silage qualities. Proceedings of the 15AAAP Animal Science Congress. Thailand, pp. 594–599.

[39] Arce J, Rojas A, Poore M. Effect of poultry litter addition on the nutritional and fermentative characteristics of cassava (*Manihot esculenta*) by-product silage. Agronomía Costarricense 2015; 39: 131–140.

[40] Gomez G, Valdivieso M. Cassava for animal feeding: effect of variety and plant age on production of leaves and roots. Animal Feed Science and Technology 1984; 11: 49–55.

[41] Man NV, Wiktorsson H. Effect of molasses on nutritional quality of Cassava and Gliricidia tops silage. Asian-Australian Journal of Animal Science 2002; 15: 1294–1299.

[42] Oni AO; Sowande OS, Oni OO, Aderinboye RY, Dele PA, Ojo VO A, Arigbede OM, Onwuka CFI. Effect of additives on fermentation of cassava leaf silage and ruminal fluid of West African Dwarf goats. Archivos de Zootecnia 2014; 63: 449–459.