Chapter 8

The Use of Cactus as Forage for Dairy Cows in Semi-Arid Regions of Brazil

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Additional information is available at the end of the chapter

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1. Introduction

The primary characteristic of semi-arid regions is frequent drought, which can be defined as a lack, scarcity, low frequency, and limited amount of rain or a poor distribution of rain during the winter period; therefore, a succession of drought years is not a rare occurrence in semi-arid regions[1]. Populations in these areas are predominantly rural, and the primary occupations of the workforce are in the agricultural sector. The combination of adverse environmental conditions and economic activity that is largely dependent on nature results in productive systems that are extremely vulnerable to unfavorable weather conditions.

Dairy farming has emerged as one of the few options in semi-arid regions, particularly in northeastern Brazil, where forage grown in pastures is the predominant source of feed for the herds. Native vegetation is used on a smaller scale and lends a number of seasonal attributes to the production in this region. According to [2], forage production largely occurs during the rainy season. Roughage supplementation, when used, consists of local fodder, such as prickly pear cactus, a crop that is widespread in the region, with or without concentrate supplements.

The spineless cactus is an important alternative for farmers due to its high productivity potential [2] and considerable survival and propagation capacity under conditions of little rain and high temperatures [3,4]. These properties have justified the use of the spineless cactus in this region to nearly 450 g/kg of the dry matter of the total diet. The spineless cactus can be successfully introduced into a diet due to its efficient water use [5]. According to [6], the spineless cactus is composed of 101 g/kg of dry matter (DM), 77 g/kg of crude protein (CP) and 278 g/kg of neutral detergent fiber (NDF).

In this context, cactus represents an extremely important feed source: it is well-adapted to the edaphic and climatic conditions of the region, and it is frequently used in dairy cattle feed, notably during periods of prolonged drought.

2. Chemical-bromatological composition of cactus

As shown in Table 1, the chemical-bromatological composition of cactus varies according to the species, age of the cladodes, and time of year [7].

Genus	DM (%)	CP[1]	NDF[1]	ADF[1]	TCH[1]	NFC[1]	MM[1]	Authors
Opuntia (Redonda)	10,40	4,20	--	--	--	--	--	[8]
Opuntia (gigante)	9,40	5,61	--	--	--	--	--	[7]
Opuntia (Redonda)	10,93	4,21	--	--	--	--	--	[7]
Nopalea (miúda)	16,56	2,55	--	--	--	--	--	[7]
Opuntia (gigante)	12,63	4,45	26,17	20,05	87,96	61,79	6,59	[9]
Opuntia (gigante)	8,72	5,14	35,09	23,88	86,02	50,93	7,98	[10]
Opuntia (gigante)	7,62	4,53	27,69	17,93	83,32	55,63	10,21	[11]
Nopalea (miúda)	13,08	3,34	16,60	13,66	87,77	71,17	7,00	[11]
Opuntia (gigante)	10,70	5,09	25,37	21,79	78,60	53,23	14,24	[12]
Opuntia (gigante)	14,40	6,40	28,10	17,60	77,10	--	14,60	[13]
Nopalea (miúda)	12,00	6,20	26,90	16,50	73,10	--	18,60	[13]
Opuntia (IPA-20)	13,80	6,00	28,40	19,40	75,10	--	17,10	[13]

[1]% at Dry Matter, DM = Dry Matter, CP = Crude Protein, NDF = Neutral Detergent Fiber, ADF = Acid Detergent Fiber, TCH = Total Carbohydrates, NFC = non-fibrous carbohydrates, MM = Mineral Matter.

Table 1. Chemical-bromatological composition of cactus

Regardless of the genus, cactus exhibits low levels of dry matter (DM, 11.69 ± 2.56%), crude protein (CP, 4.81 ± 1.16%), neutral detergent fiber (NDF, 26.79 ± 5.07%), and acid detergent fiber (ADF, 18.85 ± 3.17%). In contrast, cactus has high levels of total carbohydrates (TCH, 81.12 ± 5.9%), non-fibrous carbohydrates (NFC, 58.55 ± 8.13%), and mineral matter (12.04 ± 4.7%). The large amount of moisture found in the spineless cactus is in agreement with other reports [14,15]. This finding is very relevant to the arid and semi-arid regions in Northeastern Brazil, which suffer from a lack of available water for most of the year [16,17,18].

The crude protein in the spineless cactus varies depending on the species, the fertilization of the soil and the cultivation practices. The literature reports a low crude protein content for

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the spineless cactus. Due to this low protein content and the high content of non-fibrous carbohydrates, the spineless cactus is an excellent replacement for a portion of poor fodder. The cultivars most used are: **Palma gigante** (*Opuntia ficus-índica* – Mill), **Palma miúda** (*Nopalea cochenillifera* Salm-Dyck) and **Palma redonda** (*Opuntia ficus-índica* – Mill), where are illustrated in Figures 1, 2 and 3 respectively.

Figure 1. Palma Miúda – *Nopalea cochenillifera* Salm Dyck

Figure 2. Palma Gigante – *Opuntia ficus-índica* Mill

Figure 3. Palma Redonda – *Opuntia ficus-índica* - Mill

The high levels of calcium, potassium, and magnesium in cactus (Table 2) may reduce the absorption of these minerals, as well as limit microbial growth and the digestibility of different nutrients [19]. As with the majority of tropical forages, the amounts of phosphorous in cactus are considered low and insufficient for the needs of animals [20].

The calcium/phosphorus ratio ranged from 3.4: 1 to 22.5:1. [21] reported a calcium/phosphorus ratio that ranged from 8:1 to 11:3 and mean calcium and phosphorus contents ranging from 20 to 95 g/kg DM and 2.4 to 8.4 g/kg DM, respectively, depending on the age of the spineless cactus and the type of soil. However, in these studies, the phosphorus level was found to be 27 g/kg DM (Table 1); the lower value may possibly be due to the characteristics of the semi-arid soil in which the cactus was grown, where phosphorus levels are very low.

Genus	Minerals (% of DM)				Authors
	Ca	K	Mg	P	
Opuntia (gigante)	2.0	2.37	0.85	0.12	[22]
Opuntia (gigante)	2.35	2.58	-	0.16	[7]
Opuntia (gigante)	2.0	-	-	0.18	[23]
Opuntia (gigante)	2.87	-	-	0.36	[12]
Opuntia (gigante)	2.78	2.11	-	0.13	[24]
Opuntia (gigante)	4.1	-	1.3	0.5	[13]
Nopalea (miúda)	5.7	-	1.7	0.6	[13]
Nopalea (miúda)	2.25	1.5	-	0.1	[24]

Table 2. Mineral content of cactus

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3. Energy content and digestibility of cactus

Measuring nutrient digestibility is the primary method for assessing the energy value of feeds. Using these values, the concentrations of digestible, metabolizable, and net energy can be estimated. There are also equations for estimating the energy value of feeds, such as those proposed by the [25], which estimate the total digestible nutrients (TDN) for maintenance by means of laboratory chemical analysis.

Table 3 lists the TDN content of cactus and other commonly used roughages in dairy cattle feed. The TDN content in cactus is higher than in any of the other roughages listed.

Feed	TDN[1] (% of DM)	$TDN_{NRC(2001)}$ (% of DM)	Authors
Cactus	64.33	65.91	[26]
Cactus	-	63.73	[12]
Cactus	-	61.13	[27]
Tifton hay	59.94	53.11	[26]
Sorghum silage	-	52.07	[12]
Corn silage	59.56	-	[28]
Elephant grass	49.59	-	[28]
Cane (1% urea)	60.57	-	[28]
Coastcross grass hay	50.24	-	[28]

[1]Estimated from a digestibility assessment

Table 3. Total digestible nutrient (TDN) content of various roughages

Digestion is defined as the process of converting macromolecules from food into simpler compounds that can be absorbed through the gastrointestinal tract [29]. A number of factors influence this process, such as the composition of the diet, any associative effects, the feed preparation and processing, the fodder maturity and the temperature of the surrounding environment, in addition to factors that are dependent upon the animals and their nutritional status, especially the energy density of the feed [30]. An excessive reduction in the fiber levels in the diet of ruminants can have a negative effect on the total digestibility of the feed. Fiber is fundamental to the maintenance of optimal conditions in the rumen because it alters the proportions of volatile fatty acids (VFAs), stimulates mastication and maintains the pH at adequate levels for microbial activity [31].

Cactus is a highly digestible roughage, with the round, giant, and small cultivars exhibiting *in vitro* DM digestibility coefficients of 74.4%, 75.0%, and 77.4%, respectively. The main difference between cactus and other forages is the degradability of the nutrients in the rumen [32]. The rumen degradability for several forages is listed in Table 4. These data indicate that

among the forages studied, cactus has the largest water-soluble fraction, the highest rate of degradation for the fraction that is water-insoluble yet potentially degradable, and the greatest potential and effective degradabilities. [33] similarly observed higher *in vivo* and *in vitro* digestibility values for cactus compared to grass hay and alfalfa hay.

Table 4 lists the rumen degradability parameters of the DM, CP, and NDF observed for three varieties of cactus.

Item	Variety		
	Giant	Small	IPA-20
Dry matter (DM)			
a (g/kg of DM)	45	41	81
b (g/kg of DM)	908	872	882
kd (%/h)	7.5	8.1	7.3
ED[1] (g/kg of DM)	590	585	603
Crude protein (CP)			
a (g/kg of CP)	121	109	128
b (g/kg of CP)	884	891	872
kd (%/h)	6.0	5.9	6.2
ED[1] (g/kg of CP)	604	592	602
Neutral detergent fiber (NDF)			
a (g/kg of NDF)	56	49	50
b (g/kg of NDF)	668	703	698
Kd (%/h)	5.4	4.8	5.4
ED[1] (g/kg of NDF)	398	392	396

Adapted from [1]. [1] Considering a rate of passage of 5%/hour. a = water-soluble fraction; b = water-insoluble yet potentially degradable fraction; kd = rate of degradation of the b fraction

Table 4. Rumen degradation parameters (a, b, and kd) and effective degradability (ED) for three varieties of cactus

The data indicate that the different cactus components, particularly the DM, are highly degradable. Furthermore, the effective DM degradability values for the evaluated varieties of cactus are greater than those for other forages. This difference may be due to the high content of non-structural carbohydrates (NSC) found in cactus. High rumen degradability is associated with maximal rumen fermentation capacity and increases in the following: microbial protein synthesis, volatile fatty acid production, and nutrient absorption by the animal.

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4. The use of cactus in the diet of dairy cattle

The regulation of the dry matter intake (DMI) is complex and is influenced by physical limitations and physiological and psychogenic factors. The physical factors include distention (a sensation of being full), the NDF concentration and the diet composition, which affect the digestion rate, the time elapsed for the reduction of particle size and the passage of the digested food. The physiological factors include the control of hunger and satiation by the hypothalamic region of the brain and psychogenic factors, which include herd behavior, feed palatability, environmental factors and stress [34]. Moreover, the [25] indicates a presumed negative correlation between the moisture and the DMI.

Cactus exhibits high palatability [35], and large quantities may be voluntarily consumed. Although cactus may be an excellent source of NFC (an important source of energy for ruminants), the low DM, NDF, and CP contents of cactus are insufficient for adequate animal performance.

Due to the low DM content of cactus, diets formulated with large proportions of cactus roughage typically have a high degree of moisture, which may be favorable in regions where water is scarce during certain seasons. [36] found that crossbred cows that produced approximately 15 kg of milk per day and received diets with 50% cactus drank almost no water. Similarly, [37] observed a complete lack of water consumption by dairy heifers fed diets with 64% cactus.

An adequate level of fiber is necessary in the diet of ruminants, particularly dairy cattle. Fiber is required for normal functioning of the rumen and associated activities, such as the following: rumination, ruminal motility, homogenization of the rumen content, salivary secretion (which helps stabilize the rumen pH in addition to providing more phosphorous for microbial fermentation), and maintenance of the correct content of milk fat [38]. The [25] has recommended that diets for lactating cows contain at least 25% NDF in the total DM and that 19% of the DM components be from roughage with high effectiveness. The NFC contents are between 36% and 44%, which reflects the NDF content in the diet and the proportion of NDF from roughage. Higher NFC values or lower NDF values may cause changes in the rumen fermentation pattern and a corresponding decrease in nutrient digestibility and milk fat content.

As indicated above, cactus has low NDF and high NFC contents, and these values should be taken into consideration when cactus is used in ruminant feed. Indiscriminate use of cactus as roughage has been found to cause several problems, including diarrhea, decreased milk fat content, reduced DM consumption, and weight loss, especially in lactating cows [8,39]. [6] previously emphasized the need to combine cactus with other roughages because cactus alone may increase the rate of passage through the digestive system and cause diarrhea.

In light of these observations, the combination of cactus with other roughages in dairy cattle diets was assessed (Table 5). Diarrhea, weight loss, changes in DM consumption, and reduced milk fat content were not observed. With regard to the feed composition, it should be noted that in all of the studies, the NDF and NFC contents were within the limit recom-

mended by the [25] for maintaining normal rumen conditions. The authors provided evidence for the viability of low-cost feeds containing cactus and other roughages and demonstrated that milk production levels were similar to those obtained with more expensive feeds.

Roughage	MP	Cactus %	Roughage %	Concentrate %	NDF %	NFC %	Reference
SS	13.9	38.0	37.80	23.2	40.45	35.00	[23]
SB	13.6	55.4	17.80	25.3	36.00	39.00	
SS	29.5	29.00	28.00	43.00	34.00	41.50	[40]
TGH	17.6	49.81	25.35	22.31	34.60	42.39	[41]
EGH	17.6	46.66	27.98	22.33	33.91	42.26	
SB	16.2	50.05	24.07	22.34	36.38	41.47	
SS	25.7	24.00	33.00	43.00	31.90	43.42	[22]
SS	10.71	58.81	34.63	3.29	40.39	36.33	[42]
SuS	11.8	62.65	33.30	0.7	35.48	37.50	
GH	9.85	60.46	35.79	0.64	40.63	37.16	

Milk production (MP); sorghum silage (SS); sugarcane bagasse (SB); Tifton grass hay (TGH); elephant grass hay (EGH); sunflower silage (SuS); Guandu hay (GH)

Table 5. Combination of cactus with other roughages

When other roughages are combined with cactus, the balance between fibrous and non-fibrous carbohydrates in the diet should be considered alongside financial restrictions. The amount of cactus incorporated into diets rich in NDF and poor in NFC can be much greater than in diets with a greater level of concentrated feeds. All of these considerations can be summarized as a single objective: the elimination of such problems as diarrhea, low DM consumption, and weight loss, which are most often the result of an inefficient combination of feeds in cactus-based diets.

4.1. Cactus as a substitute for feed concentrate

The increasing cost of corn kernels reflects the following factors: its high value as a food product for human consumption, the need to use it in monogastric animal diets, and the demand for it in regions where it is not produced. The high NFC content of cactus has sparked interest in it as a substitute for energy concentrates and also in combination with non-protein nitrogen (NPN) sources, notably urea.

[43] substituted up to 75% of ground corn with cactus meal in a digestibility trial for cows and found no changes in the energy contents of the diets. It should be noted that consumption was restricted to 2.5% of the live weight of the animals. However, when cactus meal replaced 100% of the ground corn in the diets of growing sheep fed *ad libitum* [44], linear

reductions in the weight gain of the animals and in the TDN content of the diets were observed, although DM consumption was unaffected.

The total substitution of corn with fresh cactus and the partial substitution of soybean meal with fresh cactus and urea were studied in the diets of lactating cows (Table 6). An interesting finding of these studies was the minimal effect on milk production when corn was substituted with cactus in contrast to the changes in milk production that were observed when soybean meal was substituted with cactus. In general, reductions were observed in milk production when urea was included in the diets of lactating cows, regardless of the concentrate used with urea.

The most important observation was that the complete or partial substitution of concentrates with cactus lowered feed costs due to the reduced use of concentrates. Because there may be ways to compensate for the changes in milk production, this particular application of cactus is economically advantageous.

MPCF	Cactus %	Roughage %	*Corn %*	*Soybean %*	Urea %	NDF %	NFC %	CC kg	Reference
19.36	31.94	30.44	*14.27*	*21.95*	0.00	36.57	36.98	8.00	[12]
17.87	37.77	31.20	*13.92*	*14.04*	1.58	37.72	34.28	6.00	
15.90	36.00	37.00	*15.12*	*8.37*	1.89	39.64	36.68	3.70	[45]
14.83	50.00	37.00	*0.00*	*9.03*	1.69	39.80	33.28	1.30	
19.85	0.00	67.42	*16.39*	*14.19*	0.00	57.51	15.06	7.10	[46]
19.31	51.00	27.85	*0.00*	*19.15*	0.00	43.13	30.02	3.50	
13.66	45.00	30.00	*9.30*	*14.00*	0.20	40.00	34.70	4.40	[47]
11.12	60.00	30.00	*0.00*	*6.88*	1.63	41.50	34.40	1.30	

Milk production corrected for 4% fat (MPCF); concentrate consumption (CC)

Table 6. Cactus as a substitute for feed concentrate in the diets of lactating cows

4.2. Storage, preparation methods, and administration of the diet

In the majority of farms that use cactus as a feed resource for dairy cattle, the cactus is manually harvested and transported by horses, horse-drawn carts, or tractors. This typically occurs on a daily basis, which results in increased production costs. [48], studying the effects of different storage periods (0, 8, and 16 days) for giant cactus on dairy cattle performance, did not observe any effects on the composition of the cactus, DM consumption, and milk production by lactating cows in response to different storage periods. Similarly, there were no apparent losses in the DM and CP of cactus stored for up to 16 days [49]. These findings indicate that greater quantities of cactus can be harvested at a single time, regardless of whether it will be used immediately, to minimize costs associated with harvest and transportation.

The most common approach to administering cactus to dairy cattle is mincing it in the trough without mixing it with any other roughage. The concentrate, when used, should be offered at the time of milking. When the feeds are supplied separately in this manner, it is not always possible to obtain an accurate estimate of the real intake of these feeds, especially when more than one type of roughage is consumed. This difficulty in measuring is due to a preference for certain feeds, making it difficult to calculate the average individual consumption and to characterize the diet ingested by the animal. It is important to stress that roughage rich in NFC, such as cactus, may cause a number of rumen disorders when provided separately and in large amounts. As a result, the use of the complete ration or TMR (total mixed ration) has become a common practice for regulating the composition of the diet [29]. These approaches also contribute to the supply of the diet, which should provide an adequate balance of nutrients. As a result, the use of the complete ration or TMR (Figure 4) has become a common practice for regulating the composition of the diet.

Figure 4. Total mixed ration containing spineless cactus

[50] previously reported that diets consisting of cactus, sorghum silage, and concentrate should be provided in the form of a complete mixture (Table 8).

The authors observed that the proportion of ingredients in the diet actually consumed was different than that of the diet offered, especially when the ingredients were provided separately. In such cases, animals consumed smaller amounts of sorghum silage, which led to a reduced amount of effective fiber along with a decrease in rumination and chewing.

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Changes in the amount of milk fat indicated that the production of saliva was probably also decreased, which would have subsequent effects on rumen conditions [51]. The NDF and NFC contents in the diet were 30.3% and 39.22%, respectively. These values are notably close to the limits recommended by the [25] for maintaining rumen health and milk fat. Thus, any changes in the proportion of feed components could significantly alter these values and the nutritional balance of the feed supplied to the animals. According to [52], the balance of structural and non-structural carbohydrates is important for animal health and function along with nutrient utilization, which is one of the intended goals of providing the diet as a complete mixture. A better utilization of energy for milk production was also observed when using a complete mixture feeding strategy, rather than supplying the ingredients separately [53]. A better utilization of energy for milk production was also observed when using a complete mixture feeding strategy, rather than supplying the ingredients separately (Figure 5)

Figure 5. Dairy cows eating total mixed ration.

In addition to the supply strategy, another aspect that warrants attention is the way in which the cactus is processed (Figure 6, 7, 8 and 9). Generally, the cactus is minced with a knife or with specific forage equipment. The difference between the two types of processing

is that mincing with a knife does not lead to mucilage exposure, while the use of forage equipment does. When cactus was combined with sugarcane bagasse and soybean meal and fed to lactating cows, higher consumption rates were observed when the cactus was passed through a forage machine compared to processing with a knife (16.3 versus 15.2 kg/day, respectively) [54]. This result probably reflects the exposure of the mucilage, which adheres to the other feed components. As a result, feed selectivity is reduced, and consumption of the complete feed, including unpalatable components such as sugarcane bagasse, is facilitated. Animals that received cactus minced with a knife had a greater opportunity to select particular feed components, which resulted in an imbalance of structural and non-structural carbohydrates in the diet. In turn, this imbalance led to a reduction in milk fat compared to animals fed cactus processed using a forage machine (36 versus 39 g/kg, respectively).

Figure 6. Forage machine

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Figure 7. The laborer doing the process

Figure 8. Spineless cactus processed in machine

Figure 9. Spineless cactus minced with a knife

4.3. Cactus in the diet of heifers

The establishment of an efficient rearing system, mainly of females, is a challenge for the majority of milk producers. Although heifers should receive appropriate feed and management to reach an ideal weight for breeding and to start productive life earlier, there are important economic considerations. It is therefore necessary to strike a balance between calving at an early age and economic factors. The feeding plan adopted for the heifers should allow for the weight at puberty and first mating to be reached as soon and economically as possible. In semi-arid regions, achieving this goal requires supplementation of the diets with roughage and concentrate feeds.

The literature on the use of cactus in the diets of growing dairy cattle is limited; a portion of the available data is listed in Table 7.

Breed	Cactus %	Bagasse %	Urea %	Supplement (kg/day)	WG (kg/day)	Reference
Holstein	69.80	27.60	2.60	Wheat meal (1)	0.71	[55]
Holstein	69.80	27.60	2.60	Soybean meal (1)	1.20	
Crossbred*	64.00	30.00	4.00	Wheat meal (1)	0.60	[37]
Crossbred*	64.00	30.00	4.00	Soybean meal (1)	0.72	
Crossbred*	64.00	30.00	4.00	Cotton meal (1)	0.84	
Crossbred*	64.01	30.01	4.01	Cottonseed (1)	0.75	
Crossbred*	64.02	30.02	4.02	No supplement	0.43	

*5/8 Holstein/Gir

Table 7. Cactus in the diets of growing heifers

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5. Spineless cactus in organic farming and food production

Brazil has the second largest area of organic farming in the world, being second only to Australia. The country holds the largest consumer market for organic foods in South America since the data is based on survey means that was conducting between January and February this year by the Coordination of Agroecology of the Ministry of Agriculture, Livestock and Supply – MAPA.

Organic agriculture presents as a cost-effective and relevant alternative to small farmers which it can also be an important way to people from countryside and downtown have health food easily. The aim is to produce healthy vegetables, grains and meat, providing ecological balance at the ground without harming the environment. As a social view that combination can increase the life quality of countryside's families, the value of the local cultural and it can supply the livelihood to farmers too.

The spineless cactus has being great potential in organic animal production system where it has traditionally been grown with the use of organic manure, especially because manure is considerably to increases the green matter per hectare, figure 10. As an example, considering a production of 175 tons of green matter (GM) per hectare per year, and a cow consuming 60 kg per day of spineless cactus, that production might be enough to feed 12 cows per hectare for about 240 days.

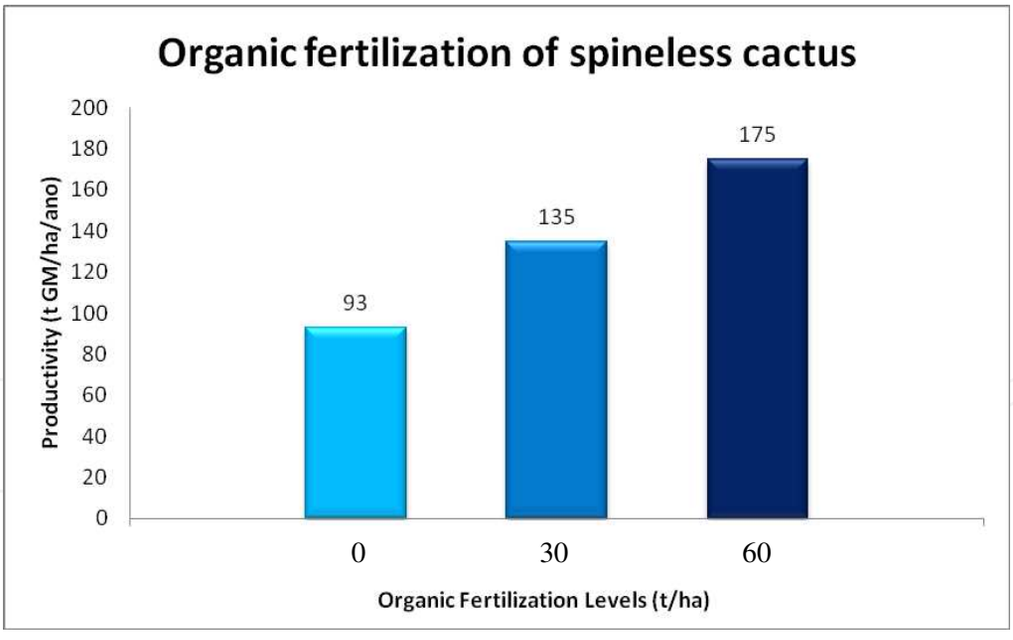

Figure 10. Effect of organic fertilization in the production of spineless cactus Source: [56]

In the semiarid region of Brazilian there is already success stories about the example cited above, as Timbaúba Farm Organic Food Ltd. - Cacimbinhas / AL. The Farm is about a thousand hectares of land operates a livestock complex integrated with nature, where it takes almost all the inputs needed to produce. The property was one of the pioneers of the country,

and it was the fourth company to receive certification seal advice given by IBD in 2002.On that farm the spineless cactus is one of the feeds produced to supply for herd.

6. Conclusion

The spineless cactus is presented as a forage crop vital to the sustainability of farming systems in semi-arid regions, primarily as an energy source. Information about your use rationally in ruminant diets has been obtained, and therefore must be effectively adopted. Aspects such as providing complete diet and association with bulky and nitrogen sources, are basic premises when the use of spineless cactus. As seen, it is possible to provide it in large quantities to ruminants, regardless of the animal category, the physiological stage and the purpose of the production system.

The combination of cactus and urea represents a viable option because it provides adequate energy and sufficient nitrogen for the microorganisms in the rumen. The high concentration of soluble carbohydrates in cactus facilitates the incorporation of nitrogen into microbial protein, which is the main source of metabolizable protein for the host animal. In this manner, the protein content of cactus, which is normally insufficient for adequate animal performance, may be increased. Furthermore, combining cactus with sugarcane bagasse, which has a high NDF content (of low nutritional value), makes it possible to improve nutrient absorption because sugarcane bagasse introduces effective fiber into the system. The increased fiber promotes rumen health and improves the absorption of nutrients from the diet. In addition to the cactus-fiber-NPN triad, providing a supplementary source of amino acids (true protein) is also an important consideration.

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