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Carcass traits and meat quality of goats fed with cactus pear (*Opuntia ficus-indica* Mill) silage subjected to an intermittent water supply

Gabriel Ferreira de Lima Cruz
Federal University of Paraíba
Edson Mauro Santos
Federal University of Paraíba
Gherman Garcia Leal Araújo
Brazilian Agricultural Research Corporation, EMBRAPA Semiarid
Paulo Sérgio Azevedo
Federal University of Paraíba
Ítalo Reneu Rosas Albuquerque
Piauí Agricultural Defense Agency, ADAPI
Natália Matos Panosso
Federal University of Paraíba
Alexandre Fernandes Perazzo
Federal University of Maranhão
Anderson de Moura Zanine (anderson.zanine@ibest.com.br)
Federal University of Maranhão
Daniele de Jesus Ferreira
Federal University of Maranhão
Anny Graycy Vasconcelos de Oliveira Lima
Federal University of Maranhão
Juliana Silva Oliveira
Federal University of Paraíba

Research Article

Keywords: fatty acid profile, meat color, nutraceutical parameters, tenderness, yield carcass

Posted Date: March 2nd, 2022

DOI: https://doi.org/10.21203/rs.3.rs-1325283/v1

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Additional Declarations: No competing interests reported.

Version of Record: A version of this preprint was published at Scientific Reports on January 16th, 2023. See the published version at https://doi.org/10.1038/s41598-022-25923-7.

Abstract

The effect of different proportions of cactus pear (*Opuntia fícus-indica* Mill) silage (CPS) and intermittent water supply (IWS) to crossbreed goats' diets on carcass traits and meat quality were evaluated. The IWS caused a reduction (P = 0.03) in the percentage of leg fat in the animals. The rib eye area, carcass weight, and physical-chemical characteristics were not affected (P > 0.05) by the CPS or IWS. The IWS reduced (P = 0.04) the elongase enzyme activity. The CPS inclusion in the diet reduced C22:0 (P = 0.01), some branched-chain fatty acid (BCFA), C20:1 (P = 0.03), *c*13-C18:1 (P= 0.01) fatty acids. Therefore, in situations of water scarcity, an intermittent water supply of up to 48 hours and diets with up to 42% cactus pear silage, can be adopted in goat feedlot, without affecting carcass traits and meat quality.

Introduction

Semi-arid and arid regions around the world are home to large numbers of flocks of small ruminants subjected to water and feed shortages, which are increasingly intensified by the effects of climate change. Livestock farming in these areas is greatly affected by long periods of drought and irregular rainfall, which lead to a low productive performance in animals due to the reduced amount of food at specific times of the year[1]. Alternatives that alleviate the difficulties of animal production in regions with low rainfall, irregular rainfall, and high evaporation, should be studied, in addition to the difficulty of accessing water sources[2].

The intermittent supply of water is an alternative to mitigate water scarcity. Some previously published studies have shown that moderate water restriction does not result in considerable changes in the productivity and carcass and meat patterns of small ruminants[3–6].

Another way to mitigate the effects of water scarcity is the availability of water through feed. The adoption of moist feeds in the diet of ruminants, among them the cactus pear containing a high-water content of 80 to 90%, minerals as an energy source, through non-fiber carbohydrates (NFC)[7].

Other authors observed the potential of diets based on cactus pear silage for animals in conditions of low water availability[6,8], to meet the water needs of small ruminants, especially in the dry season. Some authors have observed an adequate fermentation profile of cactus pear silages[9,10] and cite as advantages the possibility of increasing the frequency of harvesting cladodes, maximizing their use, and increasing total productivity per area, in addition to strategic use in greater amounts during periods of reduced availability of water and feed. Goats' production in places with limited availability of water can encourage people to remain in arid places, given the lesser competition between goats and humans for water, through foods such as cactus forage.

It is hypothesized that diets based on cactus pear silage and water supply intervals of up to 48 hours do not affect the carcass parameters and meat quality of nondescript breed goats.

In view of the above, the objective was to evaluate the effect of intermittent water supply and the replacement of Tifton hay with cactus pear silage on carcass traits, meat quality, fatty acid profile and nutraceutical parameters of crossbred goats finished in feedlot.

Results

Morphometric measurements and carcass traits. There was no significant difference (P > 0.05) for the variables evaluated in morphometric measurements and carcass traits (Table 3) by animals submitted to the inclusion of cactus pear silage and/or the intermittent water supply.

Commercial cuts, **tissue composition and leg muscularity index.** There were no effects of diets, water supply or interaction between cactus pear silage and intermittent water supply (P > 0.05) to weights of the left cold carcass and the commercial cuts of goat meat (shoulder, neck, rib, leg, and loin) in kg or yield percentage (Table 4).

When evaluating the tissue composition and the leg muscularity index (Table 5), we observed that the inclusion of cactus pear silage and/or the intermittent water supply did not present a significant difference between the treatments (P > 0.05), except for the leg fat percentage (P = 0.03), which was higher for the treatment without intermittent water supply. The intermittent water supply with 24 and 48 hours showed no significant difference.

Physical-chemical characteristics of meat and chemical composition Diets with cactus pear silage and intermittent water supply did not result in significative difference (P > 0.05) for most variables of physical-chemical characteristics or chemical composition of meat (Table 6).

There was a significant difference for the interaction between Cactus pear inclusion and the intermittent water supply for the characteristics of cooking losses (P = 0.012) and shear force (P = 0.018), in which animals that received a diet without cactus silage and without intermittent supply of water showed higher averages.

The ash content (P < 0.01) which showed a significant difference with the inclusion of cactus pear silage and resulted in a greater proportion in the treatment with 42% inclusion. Treatments with 0 and 21% did not differ.

Lipid Profile and Nutraceutical Parameters of meat. Intermittent water supply, cactus pear silage, and interaction between water supply and cactus pear silage did not influence (P > 0.05) most saturated fatty acids present in the *Longissimus lumborum* muscle of the animals under study, except the docosanoic acid (C22:0, P = 0.009), tricosanoic acid (C23:0, P = 0.012), branched-chain fatty acid total (BCFA, P = 0.026), anteiso-tridecanoic acid (C13:0 anteiso P = 0.026) and anteiso-pentadecanoic acid (C15:0 anteiso, P = 0.001) (Table 7).

Among the monounsaturated fatty acids (Table 8), only the C20:1 and the c13C-18:1 showed a significant difference with the inclusion of cactus pear silage, showing greater averages for the treatment with 0% cactus pear silage inclusion.

Cactus pear inclusion or the intermittent water supply did not provide significant differences (P > 0.05) for polyunsaturated fatty acids (Table 9) or fatty acid ratio or nutraceutical parameters on goats' meat (Table 10), except to the elongase that showed greater activity (P = 0.045) in the meat of the animals that were submitted to 24 hours of intermittent water supply.

Discussion

Morphometric measurements are subjective and used to assess the carcass development and quantitatively measure the muscular distribution in the carcass with estimates of its conformation. In the present study there were not significative differences observed for these parameters or for CCI, inferring that the use of cactus pear silage as well as intermittent water supply combined or alone did not alter animal growth and/or carcass conformation, maintaining the muscle pattern achieved by the control diet (usual) and demonstrating body and carcass uniformity. Since use animals in this study were homogeneous and had similar age and body performance, as indicated by the carcass morphometric measurements and by the difference between the empty carcass and hot carcass weights, which results in the sum of head + limb with an average of 8.2 ± 0.13 kg between treatments, giving an idea that the animals were similar in chronological age, since the allometric growth of the body occurs from the extremities to the interior of the body.

The intermittent water supply, cactus pear silage and interaction between these factors did not result in differences in slaughter weight, BCS, EBW, HCW, CCW, WELC, BCY and LEA. On the other hand, there was a significant increase in HCY and CCY of animals on diets containing cactus pear silage (21 and 42% in DM) as a substitute for Tifton hay. Goats are animals naturally adapted to arid conditions, they have adaptations on their skin, with less dense fur, which allows better air movement by increasing heat dissipation by convection and reducing the surface temperature; reduced density of sweat glands in relation to other ruminant species, which provides less water loss by sweating; physiological adaptation to the control of osmolarity through water intake and urinary excretion, in which, through changes in plasma osmolarity that are signaled to the osmoreceptors in the hypothalamus, mediate the arginine-vasopressin antidiuretic hormone that acts on the kidneys causing more water reabsorption and consequently reduce the excretion of water via urine, so that goats and sheep can be subjected to water restriction for up to 48[3,6,11–14].

Measurements and evaluations carried out on the carcass, such as the carcass compactness index and LEA, are parameters that quantitatively measure the muscle distribution in the carcass, an edible part of greater financial return, which indicates the conformation of these animals[4], while the BCS and the measure C, which are highly correlated, measure the distribution of fat on the carcass, giving an idea of the carcass finish, in which the higher these variables, the greater the proportion of fat that allows less water loss due to carcass cooling[15]. These variables in the present study were also not influenced by the levels of cactus pear silage and water restrictions, presenting an overall mean of 0.17 kg/cm, 7.68 cm, 2.42 points and 0.7 mm respectively, and consequently did not influence the losses due to cooling, which presented an average 1.48% losses.

There were no effects of diets, water supply or interaction between cactus pear silage and intermittent water supply on weights of the left cold carcass and the commercial cuts of goat meat (shoulder, neck, rib, leg, and loin) in kg or yield percentage. The main cuts of the goat carcass are the neck, leg, shoulder, loin and rib, their economic values differ, and their proportion becomes an important index to evaluate the carcass quality[16]. The cuts of greatest importance and commercial values are the leg and the loin, called noble cuts because they present greater yield and muscle tenderness, being interesting that they present a good proportion in the carcass, for providing greater edible tissue content, mainly muscle.

Carcasses with similar weight tend to have equivalent proportions of cuts, as they exhibit isogonic growth[17]. As the CCW and the conformation of the animals were similar, with similar morphometric measurements, they had a direct relationship in the absence of an effect on commercial cuts.

The commercial value of the carcass, whether through carcass yield and/or the proportions of the cuts, is also linked to tissue composition, thus the dissection of the leg represents an estimate of measuring the tissue composition of the carcass, in which is sought a greater proportion of muscle, intermediate proportion of fat and less bone in carcasses[17–19]. In this way, diets with cactus pear silage and the different levels of intermittent water supply resulted in the constancy in the amount of muscle, fat, and bone in legs of goats. The similarity in muscle proportion is related to the lack of effects on slaughter weight and CCW, as the weight of muscles is highly correlated to carcass weight[17]. The average muscle yield was above 60% in all treatments, confirming that the animals showed good efficiency to the diets and adapted well to the water supply levels.

As for the weight and proportion of bone tissue, it is believed that because this is a tissue with early development in relation to muscle and fat[4], diets in the final stages of growth (average of eight months) would hardly change their participation in the tissue composition, where the relationship of this tissue with the others is usually only increased when there are changes in the proportion of muscle and/or fat.

Water restriction, as long as it is moderate and acute, mainly affects the loss of body water and not tissues, which does not cause deleterious effects on animal productivity and growth.

The muscle: fat ratio indicates the state of leg fattening, while the muscle: bone ratio estimates the carcass muscularity, both being attributes of quality[6]. The similarity previously reported in the weight of fat, bone and muscle corroborates that these relationships also do not have differences. The same occurs for the LMI, due to the weight of the five muscles used to determine the index and the length of the femur to have been similar between the animals.

Nevertheless, when considering fat as a percentage of participation in leg weight, it is possible to observe that the intermittency in water supply in both intervals (24 and 48 hours) reduced the proportion of fat in the leg. Although water supply levels do not sometimes affect the daily intake of dry matter, during days of water deprivation fat mobilization for energy availability may occur, possibly offsetting water stress and influencing not only feed intake, these days of deprivation, but also affecting energy metabolism, which results in the mobilization of energy reserves[3].

When the physicochemical composition of the meat was evaluated, it was observed that the diets and water supply levels probably did not affect the reserves of muscle glycogen during the pre-slaughter management as can be seen through $pH_{initial}$ and pH_{final}. The $pH_{initial}$ right after slaughter should be close to neutrality, as well as in the live animal, indicating that the animal did not suffer from stress during the pre-slaughter period. The pH_{final}, on the other hand, is expected to show a considerable variation, between 5.55 and 6.2 for goat meat; due be inversely proportional to the concentration of muscle glycogen at the time of slaughter, that is, a more intense expenditure of glycogen stores results in less lactic acid production and higher pH_{final}[20,21]. In this research, the pH_{final} had average 5.74, pH higher than the isoelectric point of muscle proteins (5.2–5.3), this result being favorable, since it is above the neutral charge and presenting an excessive negative charge that provides the repulsion of filaments, that allows water molecules to bind and improve the organoleptic characteristics of the meat through succulence and texture of meat[22] evaluated by cooking loss, moisture, and shear force, principally. The cooking loss, moisture and shear were within the recommended (20 to 35% CL, moisture above 70% and SF up to 44.13 N for goat meat) to classify the meat as soft and tender[23]. Statistically, interactions were found between the supply of silage and intermittent water supply, in which goats on a diet without cactus pear silage and without intermittent water supply showed higher values of cooking losses and shear force.

Higher concentrations of collagen content and/or greater activities of calpastatin (which inhibit the action of calpains) can lead to reductions in meat tenderness[20,24]. However, it is believed that the differences for CL and SF were mainly caused by a slight shortening of muscle fibers, occurring during the cooling period of carcasses.

Because goat carcasses are generally small and with a thin layer of subcutaneous fat, there is rapid heat dissipation at the beginning of the post-mortem period, leading to cold shortening and subsequent muscle hardening[15,25].

pH_{final} of the meat has a high correlation with color parameters (L*, a*; b* and *Chroma*), as the pH_{final} can affect the reaction of myoglobin to oxymyoglobin, but all the parameters related to color corroborate the literature. The b* index or yellow pigmentation index in meat, on the other hand, may be related to the concentration of fat and/or the presence of carotenoids in the diet which can be affected by forage preservation processes, such as silage- and hay, which significantly reduces by up to 80% carotenoids levels[26]. It is believed that the carotenoid concentrations in the diet of this study were similar between treatments and consequently in values of b* of meat. Values of a* and *Chroma* directly depend on the content and state of the heme pigments in the muscle, due to the chemical state of iron (Fe), playing an important role in meat color[20]. These parameters showed no significant difference between treatments (P > 0.05), however, higher values of a* and *Chroma* in meat are desired, as a result of the increase in oxymyoglobin and decrease in metmyoglobin that provides the meat's "bloom". According to Dawson *et al.*[27] and Velasco *et al.*[28], the minimum critical value for meat luminosity (L*) is 34, lower values of L are related to elevating pH_{final}, which results in the high concentration of metmyoglobin making the meat darker, which causes rejection by consumers for associating dark meat as old meat.

The meat's presentation and more precisely its color is an important factor that can influence a consumer's purchase decision, as it gives us the idea of freshness and meat' quality, the L* and a* color parameters are the most representative for these characteristics[29]. Although in our research it did not have a significant effect for the color parameters, we can indicate that the meat obtained in this research would be well accepted by consumers, because[30] suggests that consumers will consider meat color acceptable when the L* value is equal to or exceeds 34, and a* value below 19 or equal to or exceeds 9.5 according to Khliji *et al.*[29]. In the present study, all values for L* remained above this aforementioned threshold and the values of a* remained within these values which suggests that meats for all diets and water supply levels had an acceptable color for consumers.

When evaluating the chemical composition of meat, no significant difference was observed between treatments, except the ash content, that remained above the average values found in the literature, which is 0.99 to 1.10%[31]. It is believed that because cactus pear is a rich source of Ca, Mg, K and with increasing level of cactus pear silage in the diet[32], these minerals were consumed in larger amounts, which can have resulted in a higher proportion of minerals in the meat of animals that received 42% cactus pear silage.

The fatty acid lipid profile in meat has a major impact on sensory properties and nutritional quality, influencing acceptance and health for consumers[33,34]. Intermittent water supply, cactus pear silage, and interaction between water supply and cactus pear silage did not influence most fatty acids present in the *Longissimus lumborum* muscle of the animals under study, except only a few saturated fatty acids so docosanoic acid (C22:0), tricosanoic acid (C23:0), branched-chain fatty acid total (BCFA), anteiso-tridecanoic acid (C13:0 anteiso) and anteiso-pentadecanoic acid (C15:0 anteiso).

Biohydrogenation of ruminal bacteria results in a circumstantial variety of fatty acids, which will be absorbed in the intestine and later incorporated into the meat of goats. In addition to the diet and the biohydrogenation, the meat lipid profile can vary due to de novo synthesis, desaturation, duration of the feeding period and differences in pathways of various FAs by the animal organism[35].

A high concentration of saturated fatty acids present in meat is not desirable, as there is evidence that saturated fatty acids, mainly C16:0, as well as myristic (C14:0) and lauric (C12:0) increase the blood cholesterol and LDL concentration, due to interferences with hepatic LDL receptors[36], however, in studied treatments, there was no significant difference for these fatty acids. On the other hand, C18:0 has no impact on cholesterol levels, due to being poorly digested and easily desaturated to C18:1 by Δ9-desaturase[37], present in the cell endoplasmic reticulum. This fatty acid is not harmful to health and is considered the only desirable SFA. As the levels of C18:0 in diets tend to be minimal, their main origin is the biohydrogenation of PUFA and de novo syntheses in diets with a high energy pattern[38].

In addition to carrying out the biohydrogenation process, ruminal bacteria synthesize a series of FA, mainly those of odd and branched chain, that comprise mainly the lipids of the bacterial membrane[39–41], to maintain membrane fluidity[42]. Linear odd-chain fatty acids are formed when propionyl-CoA, instead of acetyl-CoA, is used as a de novo synthesis initiator[39]. On the other hand, iso and anteiso FA are synthesized by the precursors branched-chain amino acids (valine, leucine, and isoleucine) and their corresponding branched- short-chain carboxylic acids (isobutyric, isovaleric and 2-methyl butyric acids)[43].

There is an increasing interest to study odd-and branched-chain fatty acids (OBCFAs) from animal products, mainly in milk due to its higher concentration compared to meat. Researchers reported that several OBCFAs have potential health benefits in humans[44,45] as improve the gut health[46] and presents anti-cancer activity[47,48], as well as improve the sensory characteristics of the meat, providing a greater sensation of tenderness and juiciness, because BCFA content are associated with a less consistent fat in meat from lambs due to its lower melting point and its chain structure[42,49].

The FAs profile in the ruminal bacteria is largely composed by OBCFAs (C15:0; anteiso C15:0; iso C15:0; C17:0; iso C17:0; C17:1 and anteiso C17:0) in the bacteria membrane lipids[39]. Thus, the higher concentration of OBCFAs might be the result of the difference in the rumen bacterial populations induced by variation in the dietary carbohydrate, that is, a higher concentration of cellulolytic bacteria in relation to amylolytic bacteria, due to the high NDF content in the diet with 0% cactus forage silage. It is also known amylolytic bacteria produce more linear odd chain and anteiso FAs than iso FAs, whereas cellulolytic bacteria produce more iso FAs[43,49]. As the Tifton hay-based diet had the highest NDFap and starch content (highest % of ground corn), the meat of those animals had higher concentrations of anteiso C15:0 and anteiso C13:0 compared to animals fed diets with the inclusion of cactus pear silage, also influencing the total sum of branched chain fatty acids.

Although levels of intermittent water supply have generated punctual changes in tricosanoic acid (C23:0) SFA, the same was not observed for MUFA and PUFA, due to changes in the rumen environment, promoted by water restrictions, which were not sufficient to circumstantially modify biohydrogenation, resulting in similarities in concentrations of unsaturated fatty acids in goat meat.

The animals subjected to 24h IWS presented the highest concentration of C23:0 in relation to other treatments, which is interesting because involved in the synthesis of ceramide and reduces the risk of diabetes in human[50,51].

The cactus pear has high NFC content (mainly pectin), that provides changes in rumen bacterial populations because have 59.5% high and medium rumen degradation carbohydrates[52]. Thus, there is probably a higher rate of biohydrogenation, reducing the percentages of cis-13 C18:1 in goat meat in animals' cactus pear silages-based diets. Furthermore, diets with high proportions of CPS, such as 42% CPS diet, can decrease ruminal pH and affects the final stages of biohydrogenation, resulting in escape of intermediate fatty acids isomers, that are absorbed in the small intestine[53], which can explain the similarity of C20:1 in 42% CPS diet from the Tifton hay-based diet, with differences between goat meat from 21% CPS diet and Tifton hay-based diet.

Oleic acid (*c*9-C18:1) was the MUFA with the highest participation in the lipid profile of goat meat, which is interesting because it has a hypocholesterolemic effect, being a DFA for not reducing the serum HDL levels and thus prevent cardiovascular disease by reducing LDL levels[54]. The high concentrations of *c*9-C18:1 in ruminant meat come from the food intake, the effect of biohydrogenation, and mainly of the high activity of Δ9-desaturase, necessary for animal biosynthesis through desaturation of C18:0 to *c*9-C18:1[41]. This fatty acid in the lipid profile of red meat varies between 30 and 43%[55], confirming that the meats in the present study had a good concentration of this fatty acid.

Much of unsaturated fatty acids, which have 18 carbons or 16 carbons, are largely converted to C18:0 and C16:0 through biohydrogenation, and when this process is not 100% completed, in addition to the AGPI that pass through this process intact, some products intermediates are formed, reach the duodenum and are absorbed by the animal, in which significant amounts of cis and trans-monounsaturated, such as vaccenic fatty acid (*t*11-C18:1), reach the duodenum and are absorbed, later composing the muscle tissue[34].

The literature indicates that the precursor of conjugated linoleic acid (CLA) in the meat of animals is trans vaccenic acid (*t*11-C18:1), so the enzyme Δ9-desaturase, besides acting in the conversion of stearic into oleic fatty acid, also converts the trans-vaccenic acid to its corresponding CLA isomer, *c*9*t*11-C18:2[56]. This pathway is more expressive in the mammary gland, and as the concentration of vaccenic acid (*t*11-C18:1) was not different, the concentration of CLA was not affected by the supply of silage and intermittent water supply, in the same way, that there are also no differences in the activity of Δ9-desaturase. Nevertheless, it is worth noting that in the human adipose tissue there is also the presence of Δ9-desaturase, and therefore, increased intake of vaccenic fatty acid could have the same beneficial effects associated with the intake of CLA, where the dietary vaccenic fatty acid shows 19 to 30% conversion rate[57].

Tifton hay is a natural source of n-3 fatty acids, mainly C18:3 n-3 with up to 20% participation in the lipid profile[4], allowing a certain part of these PUFAs to be absorbed and increased in the tissue muscle, with 10 to 30% PUFAs in the diet generally escaping from biohydrogenation.

Linoleic fatty acid (*c*9*c*12 C18:2) and α-linolenic acid (C18:3 n-3) are essential fatty acids for humans, that serve as precursors of the n-3 and n-6 pathways, distinct families, but synthesized by some of the same enzymes (Δ4-desaturase, Δ5-desaturase, and Δ6-desaturase)[37]. Arachidonic fatty acid (C20:4 n-6) comes from elongation and desaturation of linoleic acid, where its concentrations even close to that of its precursor may indicate that there was a high activity of Δ6-desaturase (desaturation to γ-linolenic), elongase (elongation of γ-linolenic to dihomo-gamma-linolenic) and Δ5-desaturase. This fatty acid was influenced by the diets, presenting lower concentrations in the meat of animals fed the 42% cactus pear silage when compared to the Tifton hay diet (0% cactus pear silage).

A higher concentration of long-chain PUFA n-3, docosahexaenoic (C22:6 n-3), was observed in the muscle of animals fed on Tifton hay, this was probably due to the high concentration of C18:3 n-3, precursor of C22:6 n-3, that the hay presents in relation to the palm silage.

Diets with cactus pear silage, intermittent water supply, as well as the interaction between water supply and the diets with cactus pear silage showed not differences for ∑SFA, ∑MUFA, ∑PUFA as well as for the ratios PUFA/ SFA; PUFA/ MUFA; MUFA/ AGS; n-6/ n-3; ∑n-3; ∑n-3.

The ratios and proportions of fatty acids are used to determine nutritional and nutraceutical values of the product or diet, and mainly, to indicate the cholesterolemic potential[4]. It is interesting that the n-6/n-3 ratio is low due to the pro-inflammatory properties of n-6; it is recommended to decrease its intake to assist in disease prevention[58], while n-3 fatty acids are anti-inflammatory, antithrombotic, antiarrhythmic and reduce blood lipids, with vasodilating properties, being interesting that they present a higher proportion[36]. n-6 fatty acids tend to have a higher percentage in meat, and this directly influences the formation of n-3 isomers, since linoleic acid, when in excess, can reduce the synthesis of linolenic acid metabolites[59]. The percentage of FA in one family can interfere with the metabolism of the other, reducing its incorporation into tissue lipids and altering its general biological effects[60]. Therefore, it is not recommended that the n-6/n-3 ratio be kept above 5 or 6[61], demonstrating that the averages of the current research remained acceptable.

In relation to AI and TI, Ulbricht & Southgate[62] proposed that sheep meat should have values of up to 1.0 and 1.58, respectively, and the lower the values for these indices in the lipid fraction, the greater the prevention of early stages from cardiovascular diseases[63]. In the present study, the general averages observed were 0.29 for the AI, and 0.81 for the TI, although there was no significant difference, all treatments are within the recommended range, despite having been used the comparative standard to sheep, due to the absence of the proposed standard for goat meat.

The h:H ratio did not differ for diets and water supply levels, but had an average of 1.90, below the reference value for meat products, which is 2.0. Values above 2.0 are recommended and favorable[64], as it indicates a higher proportion of hypocholesterolemic fatty acids, that are beneficial to human health.

The Δ9-desaturase enzyme that acts on both the mammary gland and adipose tissue, responsible for the transformation of SFA into UFA, as well as in the endogenous conversion of CLA[56] did not differ between treatments, on the other hand, the elongase showed less activity. Probably there was a greater "de novo" synthesis which resulted in a greater accumulation of palmitic fatty acid, and a reduction in the activity of the elongase enzyme.

The crossbred goats demonstrated to present efficient mechanisms for adapting to water restrictions, especially when receiving feed with higher water content, such as cactus pear silage, being able to replace Tifton hay with 42% cactus pear silage in the diet for goats in confinement without negatively affecting the carcass traits and meat quality. Because although these animals have shown some differences in the indices of tenderness and juiciness of your meats, however, all presented values of juiciness and tenderness compatible with meat extremely appreciated by the consumer market. And even goat meat showing some fatty acids with different concentrations induced by the supply of silage and water intermittence, the final lipid profile was appropriate to the health of consumers, observed by the absence of differences in the total concentrations of PUFA and in the main nutraceutical parameters (DFA, n-6/n-3; h: H; AI and TI).

These results are relevant, indicating that goat feedlots in regions with low water availability may adopt strategies of lesser demand for drinking water and diets with considerable concentrations of cactus pear silage in the diet, reducing production costs without considerably affecting the product to be marketed, and therefore, provide higher profitability of the system.

Methods

The study was conducted from December 2014 to February 2015 in the Animal Nutrition sector of the Brazilian Agricultural Research Corporation – Semi-arid EMBRAPA, located in the municipality of Petrolina, state of Pernambuco, Brazil, at 9˚23'35" S and 40˚30'27" W. Animal care and use standards were approved and based on the National Council for the Control of Animal Experimentation (Protocol 04/2016 - IMS/CAT – UFBA). The Semi-arid EMBRAPA was the supplier cactus pear (*Opuntia ficus indica* Mill), thus all local guidelines were adhered for the use of plants and its use for silage production. Study design, animal experiments, and reporting followed the ARRIVE guidelines.

Animals experimental design, and duration. Thirty-six castrated male crossbreed goats (F1 Boer × mixed breed), taken from the same property, with eight months of age and 18.25 ± 7.23 kg average body weight were distributed in a randomized block design in a 3 × 3 factorial arrangement [(three levels of cactus pear silage − 0, 21 and 42% total DM) and three water supply intervals (0, 24 and 48h)]. The animals have housed in individual stalls (1.0 by 2.0 m), that has equipped with water troughs and feed troughs.

The experimental period lasted 75 d, preceded by 12 d for adaptation of the animals to the environment and the pens, and during this period all animals were treated against internal and external parasites with Ivermectin (Ivomec gold; Merial, Salvador, Bahia, Brazil) and vaccinated against clostridiosis using Polivalente (Sintoxan; Merial), and orally supplemented with vitamins and minerals.

Cactus pear silage. Cactus pear (*Opuntia ficus-indica* Mill.) was obtained from a single rural property, and all the cladodes, except for the main and primary ones, were collected, processed in a stationary forage machine to a particle size of 3 cm and ensiled in polyethylene drums with a capacity of 200 L. Silos were sealed with plastic tapes and lids to promote the fermentation process. The silage was used after a minimum period of 60 days after preparation.

Silage samples were collected at the time of supplying the diets and every 15 days for analysis of ammonia nitrogen (NH_3-N)[65], organic acids[66] pH, DM recovery, and gas and effluent losses[67]. The silage presented the following fermentation characteristics: 3.81 pH; NH_3-N of 9.0% total nitrogen; 59.20 g/kg DM and 22.80 kg/t green mass, respectively, for gas and effluent losses; 92.30% DM recovery and 80.2 g/kg DM lactic acid; 22.5 g/kg DM acetic acid; 0.5 g/kg DM butyric acid and 8.10 g/kg DM propionic acid[32].

Diets and general procedures. Diets were formulated to meet the nutritional requirements of crossbred goats with estimated weight gain of 100 g/d following the recommendations[68] and its consisted of Tifton 85 hay, cactus pear silage, ground corn, wheat bran, soybean meal and mineral premix. The forage: concentrate ratio was 60:40, and cactus pear silage was used to replace three proportions of Tifton hay (0, 21 and 42% DM) in the diet (Table 1). The diet was provided twice a day (09:00 and 15:00 h), and the amount of feed was adjusted daily with an acceptable amount of leftovers corresponding to 10% total amount provided to ensure *ad libitum* intake.

Samples of ingredients, leftovers and silage were collected weekly and frozen (–20°C) for further chemical analysis.

The methods proposed by AOAC[69] were used to determine the concentrations of DM (method 934.01), CP (method 954.01), EE (method 920.39), ash (method 942.05) and lignin (method 920.39). The content of acid detergent fiber (ADF) and NDF were quantified according to Van Soest[70].

NDF was corrected for ash and protein (NDFap) according to Mertens[71]. Acid detergent insoluble nitrogen (ADIN) and neutral detergent insoluble nitrogen (NDIN) were measured using the recommendations of Licitra *et al.*[72].

Non-fiber carbohydrates (NFC) and total carbohydrates (TC) were estimated according to the method described by Mertens[73] and Sniffen *et al.*[74], respectively.

Total digestible nutrients (TDN) and metabolizable energy (ME) were calculated according to formulas proposed by the NRC[75].

The content of calcium (Ca), phosphorus (P), magnesium (Mg), potassium (K) and sodium (Na) were determined in the ingredients on a dry matter basis, as described by Silva & Queiroz[76].

Daily DM intake and gain averaged 650.67 g/day and 72.25 g/day, respectively and total water intake (drinking + feeding), total water excretion (feces + urine), and body water balance/retention had averages of 2.36; 0.87 and 1.49 respectively[32].

Performance and carcass traits. At the end of the experiment, after the animals were subjected to 16h fasting, slaughter weight (SW) and body condition score (BCS) were obtained by external palpation, considering the scales from 1 to 5, where 1 = very thin and 5 = very fat or obese, according to Cezar & Sousa[77].

In the slaughter procedure, animals were slaughtered by cerebral concussion using a captive dart pistol (Tec 10 P model, Ctrade®, Porto Alegre, RS, Brazil) followed by bleeding by sectioning the carotid and jugular vessels, for three minutes. After, animals were skinned and eviscerated, and the gastrointestinal tract (GT) was weighed full and empty.

After removing the head, limb and tail, the carcass was weighed to obtain the hot carcass weight (HCW). The empty body weight (EBW) was calculated by the difference between the SW and the weight of the contents of the GT and the empty bladder and gallbladder.

A portable pH meter (Texto 205, Campinas, SP, Brazil) previously calibrated was used to measure the $pH_{initial}$ (45 min after slaughter) and the pH_{final} (24 hours after slaughter).

Carcasses were cooled for 24 hours at ± 4 ºC in a cold room. After this period, the carcasses were weighed to obtain the cold carcass weight (CCW) and water evaporation losses in cooling (WELC) according by equations (1). Subsequently, hot (HCY) and cold (CCY) and biological (BCY) yields were calculated according by equations (2), (3) and (4) respectively.

$$WELC = \frac{HCW - CCW}{HCW} \times 100$$

1

$$HCY = \frac{HCW}{SW}$$

2

$$CCY = \frac{CCW}{SW}$$

3

$$BCY = \frac{EBW}{SW}$$

4

Carcass morphometric measurements were obtained according to Cezar & Sousa[77]: based on the parameter length (external, internal and leg), rump perimeter, chest width, and depth of chest. The carcass compactness index (CCI) was calculated by Eq. (5), expressed in kg/cm.

$$\mathrm{CCI} = \frac{CCW}{\mathrm{internallength}}$$

5

Half carcasses were weighed and cut in five anatomical regions: shoulder (by disarticulating the scapula), leg (by the cut between the last lumbar vertebra and the first sacral vertebra), loin (between the first and the sixth lumbar vertebrae), ribs (between the first and the 13th thoracic vertebrae) and neck (region comprising the seven cervical vertebrae).

In the left half carcass, a cross section was made in the section between the 12th and 13th ribs to measure the loin eye area (LEA) of the *Longissimus thoracis* (LT) muscle and minimum subcutaneous fat thickness (Measure C), according to Cezar & Sousa[77]. The left *Longissimus lumborum* muscle were dissected, identified, packaged and frozen at -18 ºC for further analysis.

The left legs were dissected, and the leg muscularity index (LMI) was calculated using the weight in grams of the five muscles (W5M) that surround the femur (*Biceps femoris muscle, Semimembranosus muscle, Semitendinosus muscle, Adductor femoris muscle* and *Quadriceps femoris muscle*) and the length of the femur (LF) in cm, using the Eq. (6) described by Purchas *et al.*[78].

$$LMI = \frac{\sqrt{W5M/LF}}{LF}$$

6

Physical-chemical composition of the Longissimus lumborum **muscle.** Two steaks approximately 2.5 cm thick were exposed to the atmosphere for 50 min to determine the color indices for each animal: L*, the index related to lightness (L* = 0, black; = 100, white); a*, the redness index that ranges from green (−) to red (+); and b*, the yellowness index that ranges from blue (−) to yellow (+); in three different locations, using a chromameter

(MINOLTA CR-400, Osaka, Japan). The chromameter was calibrated with a white tile (Y = 93.2, x = 0.3137, y = 0.3257), Illuminant D-65, with 2° standard observer. The saturation index (*Chroma*) was determined according to the Eq. (7)

$$Chroma = \sqrt{a^2 + b^2}$$

7

Cooking losses were obtained according to the methodology described by American Meat Science Association-AMSA[79] and subsequently the shear force was measured, in which from the samples used in cooking losses (CL), at least three cylinders of each sample were removed, with a 1.27 cm diameter pourer, in the direction of muscle fibers. A texturometer equipped with a Warner-Bratzler stainless steel blade (G-R MANUFACTURING CO. 3000) with a 25 kgf load cell and a cutting speed of 20 cm/min was adopted, according to Wheeler *et al.*[80].

The concentration of moisture, ash, and protein were obtained according to the recommendations of AOAC[81]. For lipid extraction, the method described by Hara & Radin[82] was adopted, using n-hexane-isopropanol solution (3: 2 v/v) and after extraction, lipids were esterified and methylated[83].

Fatty acid profile of the Longissimus lumborum **muscle.** To determine the fatty acid profile, the lipids previously extracted from the *Longissimus lumborum* muscle and diets (Table 2) were converted to fatty acid methyl esters (FAME). To analyze the fatty acid profile, trans methylated samples were analyzed in a gas chromatograph (Focus GC AI 3000, Thermo Finnigan analyzer, Milan, Italy) with flame ionization detector and capillary column CP-Sil 88 (Varian) with 100 m length, 0.25 μm internal diameter and 0.20 μm film thickness.

Hydrogen was used as carrier gas, at a flow rate of 1.8 mL/min. The initial oven temperature program was 70 ºC, with a waiting time of 4 min, 175 ºC (13 ºC/min), waiting time of 27 min, 215 ºC (40 ºC/min), waiting time of 9 min and then increasing 7 ºC/min to 230 ºC, remaining for 5 min, totaling 65 min. The vaporizer temperature was 250 ºC and the detector temperature was 300 ºC.

An aliquot of 1 μL of the esterified extract was injected into the chromatograph and the fatty acids (FA) were identified by comparing the retention times. The percentages of fatty acids were obtained using the Chromquest 4.1 software (Thermo Electron, Milan, Italy).

FAs were identified by comparing the retention times of methyl esters of the samples with FA standards (BCR-CRM 164, Anhydrous Milk-Fat Producer: BCR Institute for Reference Materials and Measurements; Supelco TM Component FAME Mix, cat 18919 Supelco, Bellafonte, PA). To quantify the FAME, a response factor was generated for each FA based on the standard sample. The results were quantified by normalizing the areas of methyl esters and expressed as mg/100 g fatty acid methyl esters (FAME). Only FAME representing > 0.01% of total FAME and in at least one of the treatments, were included in tables.

After FA identification, the sum of saturated fatty acids (SFA), branched chain fatty acids (BCFA), monounsaturated fatty acids (MUFA), polyunsaturated fatty acids (PUFA) and the MUFA/SFA, PUFA/SFA, PUFA/MUFA, n-6/n-3 ratios were calculated.

The nutritional quality of the lipid fraction was measured through the following indices: atherogenicity (AI) and thrombogenicity (TI) proposed by Ulbricht & Southgate[62].

Ratio of hypocholesterolemic to hypercholesterolemic fatty acids (h:H) was calculated according to Santos-Silva *et al.*[64] and the concentration of desirable fatty acids (DFA) according to Rhee[84].

The activity of the enzymes Δ9-desaturase C16, Δ9-desaturase C18, and elongase were estimated according to De Smet *et al.*[85].

Statistical analysis. The experimental design was a randomized block design, blocked according to animal' initial weight (n = 36), and the treatments were arranged in a 3 x 3 factorial, with three cactus pear silage inclusion levels (0%, 21% and 42% DM) and intermittent water supply (offers *ad libitum*, and 24 and 48 h water restriction) in the diets of goats, resulting in nine treatments and four replications per treatment.

Data were subjected to analysis of variance (ANOVA) and mean comparisons were done by Tukey's test, as well as the interaction between them, with statistical probability of up to 5% using the PROC GLM of SAS 9.2 software, according to the Eq. (8):

$$\mathrm{Yijk} = \mu + \alpha \mathrm{i} + \beta \mathrm{j} + (\alpha\beta)\,\mathrm{ij} + \mathrm{k} + \mathrm{eijk}$$

8

Where Y is the observed value of the variable ijk that refers to the k-th repetition of the combination of the i-th level of factor A with the j-th level of factor B, μ is the average of all experimental units for the variable, αi is the effect of the ratios of forage cactus silage (i = 0, 21, and 42%) at the observed value Yijk, βj is the effect of the intermittent water supply (j = 0, 24, and 48 h) at the observed value Yijk, αβij is the effect of the interaction between the ratio of forage cactus silage and intermittent water supply, k is the block effect on the observation Yijk, and eijk is the error associated with the observation of Yijk.

Declarations

Data availability

The datasets used and/or analyzed during the current study available from the corresponding author on request.

Acknowledgments

This work was supported by the Coordination for the Improvement of Higher Education Personnel (CAPES-Brazil – Finance Code 001) and National Council for Scientific and Technological Development (CNPq-Brazil) for the fellowship grant; and by the Maranhão State Research Foundation (FAPEMA-Brazil) and the Integrated Animal Science Doctoral Program in partnership with the Federal University of Paraíba-Brazil (UFPB).

Author Contributions

E.M.S, G.G.L.A, P.S.A and J.S.O designed the study. G.F.L.C, I.R.R.A and N.M.P performed the experiment and collected data. G.F.L.C, E.M.S, A.F.P, A.M.Z, D.J.F and A.G.V.O.L analyzed the data. E.M.S, A.F.P, A.G.V.O.L and J.S.O conducted statistical analysis. G.F.L.C, E.M.S, A.M.Z, A.F.P, D.J.F and A.G.V.O.L wrote the manuscript. All authors read and critically revised drafts for intellectual content and provided approval for publication.

Competing Interests

The authors declare no competing interests.

Additional Information

Correspondence and requests for materials should be addressed to A.M.Z.

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Tables

Table 1
Ingredients and chemical compositions of experimental diets (g/kg, DM basis)

Item	Cactus pear silage		
	0	21	42
Ingredients			
Ground corn	310	270	130
Soybean meal	70.0	90.0	90.0
Wheat bran	10.0	30.0	170
Tifton 85 hay	600	390	180
Cactus pear silage	0.00	210	420
Mineral premix [1]	10.0	10.0	10.0
Chemical composition, g/kg DM			
Dry matter, g/kg as fed	870	707	542
Ash	98.7	78.4	82.9
Crude protein	112	116	124
Ether extract	25.0	24.6	23.9
Neutral detergent fiber ap [2]	496	408	357
Neutral detergent insoluble nitrogen, g/kg CP	314	230	123
Acid detergent insoluble nitrogen, g/kg CP	78.0	63.0	42.9
Acid detergent fiber	263	225	196
Acid detergent lignin	55.3	50.3	46.9
Hemicellulose	233	183	161
Cellulose	208	175	149
Carbohydrate total	764	781	769
Non-fibrous carbohydrate	268	373	412
Metabolizable energy (Mcal/kg)	2.18	2.22	2.32
Total Digestible Nutrients	647	678	697
Macrominerals, g/kg DM			
Calcium, Ca	4.04	6.10	7.80

[1] Mineral premix provided the following per kilogram of diet: KI 43 g, Ca 190 g, Mg 16 g, S 35 g, Cu 1540 mg, Fe 2190 mg, Zn 2170 mg, Mn 1335 mg.

[2] Neutral detergent fiber corrected for ash and protein.

Item	Cactus pear silage		
	0	21	42
Phosphorus, P	2.44	2.44	2.44
Magnesium, Mg	3.21	3.47	3.70
Sodium, Na	3.75	4.51	5.56
Potassium, K	0.76	0.77	0.75
Ca: P Ratio	1.65:1	2.50:1	3.48:1
[1] Mineral premix provided the following per kilogram of diet: KI 43 g, Ca 190 g, Mg 16 g, S 35 g, Cu 1540 mg, Fe 2190 mg, Zn 2170 mg, Mn 1335 mg.			
[2] Neutral detergent fiber corrected for ash and protein.			

Table 2

Dietary fatty acid (g/100 g FAME) composition of experimental diets with cactus pear silage

Fatty acid (g/100g FAME)	Cactus pear silage		
	0	21	42
C12:0	0,32	0,35	0,35
C14:0	0,41	0,45	0,48
C16:0	19,1	19,2	19,5
C17:0	0,38	0,36	0,31
C18:0	2,16	2,17	2,26
C20:0	0,62	0,61	0,53
C22:0	0,43	0,38	0,35
C24:0	0,35	0,33	0,31
c9-C16:1	0,26	0,25	0,25
c9-C18:1	13,7	13,8	13,5
c11-C18:1	0,99	0,91	0,89
c12-C18:1	0,32	0,30	0,37
c9c12C18:2	44,0	44,0	42,9
C18:3 n-3	13,4	13,1	13,8
Other fatty acids	3,59	3,82	4,20

Table 3

Morphometric measurements and carcass traits of goats fed with cactus pear silage (CPS) and submitted to intermittent water supply (IWS)

Item	CPS (% DM)			IWS (hours)			SEM	*P-value*		
	0	21	42	0	24	48		CPS	IWS	CPS × IWS
Slaughter weight, kg	22.9	23.0	22.4	23.1	23.4	21.8	1.17	0.9300	0.6028	0.6283
Body condition score	2.36	2.43	2.47	2.46	2.40	2.40	0.15	0.8641	0.9596	0.7309
Body external length	51.5	52.8	52.6	52.4	52.3	52.2	0.78	0.4376	0.9829	0.2335
Body internal length	59.3	59.5	59.5	59.3	59.9	59.1	0.96	0.9753	0.8272	0.5982
Leg length	42.5	44.1	43.1	43.2	43.7	42.7	0.82	0.3927	0.7098	0.2370
Thorax width	13.5	13.7	13.6	13.6	13.5	13.6	0.50	0.9355	0.9973	0.1216
Rump width	17.5	18.3	16.8	17.4	18.0	17.3	0.73	0.3685	0.7552	0.8536
Thoracic perimeter	59.3	61.2	59.7	60.0	60.6	59.5	1.14	0.4792	0.7923	0.6481
Rump perimeter	49.1	51.2	49.9	49.4	50.9	49.9	1.39	0.5638	0.7468	0.7156
Depth of chest	24.3	25.0	25.7	24.6	25.3	25.0	0.44	0.1063	0.5494	0.4500
Carcass compactness index, kg/cm	0.16	0.17	0.17	0.17	0.17	0.16	0.01	0.4642	0.8658	0.4010
Empty body weight, kg	17.8	18.8	18.5	18.6	18.7	17.8	0.99	0.7435	0.7854	0.5919
Hot carcass weight, kg	9.67	10.4	10.4	10.3	10.4	9.71	0.56	0.5817	0.6323	0.4505
Cold carcass weight, kg	9.53	10.2	10.2	10.2	10.3	9.57	0.56	0.5949	0.6340	0.4507
Water evaporation losses in cooling, %	1.42	1.57	1.44	1.42	1.50	1.52	0.07	0.2428	0.5867	0.2185
Hot carcass yield, %	42.1^{b}	45.2^{a}	46.2^{a}	44.6	44.6	44.3	0.54	< 0.001	0.8878	0.1987
Cold carcass yield, %	41.7^{b}	44.5^{a}	45.6^{a}	44.0	43.9	43.8	0.57	< 0.001	0.9667	0.3605
Biological yield, %	54.6	55.2	55.9	55.3	55.9	54.7	0.80	0.5236	0.5898	0.8694
Measure C, mm	0.67	0.78	0.65	0.80	0.70	0.60	0.09	0.5625	0.2745	0.8783
Loin eye area, cm²	8.00	7.60	7.40	7.90	7.35	7.80	0.39	0.5132	0.4357	0.1952

$^{a, b}$Means within rows with different letter superscripts differ by Tukey test ($P < 0.05$).

Table 4
Half cold carcass and weight of commercial cuts of goats fed with cactus pear silage (CPS) and submitted to intermittent water supply (IWS)

Item	CPS (% DM)			IWS (hours)			SEM	*P-value*		
	0	21	42	0	24	48		CPS	IWS	CPS × IWS
Half carcass	5.29	5.28	5.01	5.23	5.37	4.99	1.04	0.7587	0.6538	0.3698
Commercial cuts, kg										
Shoulder	1.04	1.06	0.99	1.06	1.05	0.99	0.05	0.5857	0.5862	0.3800
Neck	0.54	0.51	0.48	0.51	0.52	0.50	0.03	0.5047	0.9025	0.4216
Ribs	1.30	1.26	1.23	1.26	1.30	1.24	0.08	0.8028	0.8449	0.1875
Leg	1.53	1.51	1.40	1.50	1.53	1.41	0.08	0.4915	0.5787	0.3931
Loin	0.50	0.53	0.54	0.52	0.55	0.50	0.04	0.7094	0.6916	0.5956
Cuts yield, %										
Shoulder	19.9	20.1	19.9	20.3	19.6	19.9	0.30	0.8009	0.2444	0.3829
Neck	10.2	9.66	9.70	9.69	9.83	10.1	0.30	0.3763	0.6874	0.1343
Ribs	24.6	23.9	24.5	24.1	24.1	24.8	0.54	0.6389	0.5515	0.4383
Leg	29.0	28.6	28.2	28.7	28.8	28.3	0.46	0.4636	0.7538	0.5163
Loin	10.1	10.1	9.86	10.0	10.2	9.86	0.32	0.8474	0.8321	0.8498

Table 5
Tissue composition and leg muscularity index of goats fed with cactus pear silage (CPS) and submitted to intermittent water supply (IWS)

Item	**CPS (% DM)**			**IWS (hours)**			**SEM**	***P-value***		
	0	**21**	**42**	**0**	**24**	**48**		**CPS**	**IWS**	**CPS × IWS**
Leg, kg	1.51	1.50	1.39	1.48	1.52	1.39	0.08	0.5082	0.5402	0.4425
Muscle, kg	0.95	0.95	0.87	0.92	0.95	0.89	0.20	0.5572	0.7409	0.5085
Fat, kg	0.17	0.15	0.13	0.18	0.14	0.13	0.02	0.1663	0.0784	0.8562
Bone, kg	0.30	0.29	0.28	0.29	0.29	0.29	0.01	0.5223	0.9462	0.2984
Other tissues, kg	0.07	0.08	0.07	0.07	0.08	0.07	0.02	0.7867	0.1134	0.1092
Muscle:bone	3.15	3.26	3.13	3.18	3.28	3.08	0.12	0.7187	0.5045	0.6210
Muscle:fat	6.43	6.93	7.55	5.96	7.45	7.55	0.67	0.4938	0.1869	0.2062
Muscle, %	62.3	63.0	62.8	62.0	62.8	63.3	1.17	0.9092	0.7056	0.3523
Fat, %	11.0	10.0	9.23	12.3^{a}	8.80^{b}	9.07^{b}	0.96	0.4511	0.0321	0.3609
Bone, %	20.2	19.4	20.2	19.5	19.3	21.0	0.61	0.6376	0.1223	0.7869
Leg muscularity index	0.36	0.30	0.35	0.37	0.34	0.30	0.03	0.3425	0.2693	0.7895

$^{a, b}$Means within rows with different letter superscripts differ by Tukey test ($P < 0.05$).

Table 6
Physicochemical composition of the *Longissimus lumborum* muscle of goats fed with cactus pear silage (CPS) and submitted to intermittent water supply (IWS)

Item	**CPS (% DM)**			**IWS (hours)**			**SEM**	***P-value***		
	0	**21**	**42**	**0**	**24**	**48**		**CPS**	**IWS**	**CPS × IWS**
$pH_{initial}$	6.56	6.62	6.59	6.56	6.54	6.66	0.06	0.7988	0.3545	0.8728
pH_{final}	5.73	5.76	5.73	5.68	5.87	5.68	0.11	0.9887	0.3935	0.6294
Color parameter										
L* (lightness)	38.8	38.6	39.5	40.4	37.4	39.1	0.91	0.7767	0.1013	0.7531
a* (redness)	16.8	17.1	17.3	16.6	17.4	17.2	0.61	0.8393	0.6271	0.5790
b* (yellowness)	9.29	10.4	10.3	9.99	9.45	10.4	0.51	0.2841	0.4658	0.6827
Chroma (saturation index)	19.2	20.0	20.2	19.4	19.9	20.1	0.71	0.6159	0.7908	0.6500
Cooking losses, %	32.3	31.3	32.5	33.0	29.6	33.3	1.57	0.8516	0.2220	0.0123
Shear force, N	20.7	19.5	19.9	19.3	19.3	21.6	0.11	0.7852	0.2898	0.0180
Chemical composition, %										
Moisture	73.9	74.6	75.0	74.7	74.8	73.9	0.45	0.2369	0.3225	0.7068
Protein	22.4	21.9	21.9	22.0	21.9	22.2	0.44	0.5848	0.8860	0.8709
Total lipids	2.06	2.11	2.12	2.14	2.04	2.12	0.03	0.9418	0.8493	0.8956
Ash	3.63^{b}	3.79^{b}	4.46^{a}	3.99	3.88	3.98	0.11	< 0.001	0.7394	0.3982

[a, b]Means within rows with different letter superscripts differ by Tukey test (*P* < 0.05).

Table 7
Saturated fatty acid from *L. lumborum* muscle of goats fed with cactus pear silage (CPS) and submitted to intermittent water supply (IWS)

Variable (mg/g FAME)	CPS (% DM)			IWS (hours)			SEM	*P- value*		
	0	21	42	0	24	48		CPS	IWS	CPS×IWS
∑SAF	421	436	435	432	426	434	11.7	0.5784	0.9922	0.7094
C6:0	0.20	0.15	0.15	0.15	0.19	0.15	0.02	0.2072	0.0831	0.5328
C8:0	0.15	0.12	0.12	0.13	0.14	0.12	0.01	0.2279	0.5001	0.6477
C10:0	0.96	0.88	1.01	0.95	0.95	0.95	0.05	0.9197	0.7699	0.9032
C11:0	0.03	0.03	0.03	0.03	0.03	0.03	> 0.01	0.7873	0.3410	0.7861
C12:0	0.49	0.44	0.46	0.46	0.47	0.47	0.02	0.4867	0.9926	0.5718
C13:0	0.04	0.04	0.04	0.04	0.04	0.04	> 0.01	0.5160	0.4092	0.1915
C14:0	13.4	13.3	14.4	13.5	13.2	14.4	0.01	0.4436	0.1590	0.2270
C15:0	2.43	2.45	2.53	2.41	2.68	2.31	0.11	0.7699	0.0567	0.1965
C16:0	228	230	230	225	222	241	5.49	0.9391	0.0547	0.2836
C17:0	12.7	15.6	15.3	14.4	16.2	13.1	0.97	0.0750	0.0824	0.1971
C18:0	154	166	163	168	161	154	8.70	0.5327	0.5558	0.4516
C20:0	0.32	0.33	0.31	0.34	0.36	0.25	0.03	0.9079	0.1155	0.0532
C21:0	0.00	0.06	0.04	0.03	0.06	0.02	0.03	0.2990	0.6309	0.6692
C22:0	1.10^{a}	0.76^{ab}	0.52^{b}	0.87	0.89	0.63	0.01	0.0089	0.2890	0.4026
C23:0	0.21	0.18	0.17	0.13^{b}	0.26^{a}	0.18^{ab}	0.03	0.7669	0.0123	0.0649
C24:0	0.04	0.00	0.03	0.01	0.05	0.03	0.02	0.5533	0.4279	0.3010
∑BCFA	7.15^{a}	6.02^{b}	6.25^{b}	6.68	6.51	6.21	0.27	0.0264	0.2593	0.6880
C13:0 *anteiso*	0.51^{a}	0.34^{b}	0.31^{b}	0.39	0.44	0.33	0.05	0.0263	0.0508	0.6833
C14:0 *iso*	0.20	0.15	0.17	0.18	0.18	0.17	0.01	0.1031	0.7507	0.4461
C15:0 *iso*	0.85	0.72	0.81	0.82	0.76	0.80	0.05	0.2047	0.6745	0.2502
C15:0 *anteiso*	1.07^{a}	0.78^{b}	0.83^{b}	0.90	0.93	0.85	0.06	0.0012	0.3785	0.1554
C16:0 *iso*	1.27	1.01	1.07	1.23	1.07	1.04	0.07	0.0694	0.1219	0.9264
C17:0 *iso*	3.25	3.01	3.05	3.16	3.13	3.02	0.14	0.6959	0.7163	0.6380

[a, b]Means within rows with different letter superscripts differ by Tukey test ($P < 0.05$)

Table 8
Monounsaturated fatty acids (MUFA) from *Longissimus lumborum* muscle of goats fed with cactus pear silage (CPS) and submitted to intermittent water supply (IWS).

Variable (mg/g FAME)	CPS (% DM)			IWS (hours)			SEM	*P- value*		
	0	**21**	**42**	**0**	**24**	**48**		**CPS**	**IWS**	**CPS×IWS**
∑MUFA	528	521	523	524	528	520	11.9	0.8141	0.9900	0.6997
C10:1	0.01	0.01	0.01	0.01	0.01	0.01	> 0.01	0.9197	0.7699	0.9032
C17:1	8.91	9.05	9.21	8.99	9.90	8.27	0.51	0.9491	0.1767	0.3510
C20:1	1.20[a]	0.90[b]	1.16[ab]	1.14	1.08	1.04	0.07	0.0258	0.6885	0.2863
C22:1 n-9	4.62	3.76	4.02	4.00	4.57	3.83	0.35	0.1782	0.1734	0.1727
C24:1	1.52	1.44	1.43	1.56	1.43	1.39	0.09	0.8657	0.2460	0.2216
Σc-MUFA	506	500	501	502	505	500	11.7	0.8385	0.9891	0.7091
*c*9-C14:1	0.73	0.64	0.63	0.60	0.68	0.73	0.05	0.3704	0.2230	0.0828
*c*9-C16:1	23.7	21.5	21.5	21.4	22.0	23.3	1.22	0.3154	0.4836	0.2614
*c*9-C18:1	413	422	422	417	424	416	9.82	0.9329	0.9847	0.8802
*c*11-C18:1	41.2	32.8	33.4	37.4	34.6	35.4	2.43	0.0513	0.5628	0.7345
*c*12-C18:1	17.1	15.2	15.1	16.0	15.6	15.7	0.97	0.2951	0.8656	0.6161
*c*13-C18:1	9.32[a]	7.62[b]	7.70[b]	8.62	7.96	8.06	0.42	0.0108	0.2628	0.4490
*c*15-C18:1	0.64	0.61	0.67	0.64	0.59	0.71	0.08	0.7794	0.6382	0.1973
Σt-MUFA	6.00	5.80	6.00	6.20	5.40	6.10	0.45	0.8802	0.3929	0.1731
trans-C18:1	2.71	2.63	2.61	2.99	2.40	2.56	0.26	0.9929	0.3608	0.3872
*t*16-C18:1	3.34	3.13	3.39	3.25	3.03	3.59	0.31	0.7352	0.1901	0.1094

[a, b]Means within rows with different letter superscripts differ by Tukey test ($P < 0.05$)

Table 9

Polyunsaturated fatty acids (PUFA) from *Longissimus lumborum* muscle of goats fed with cactus pear silage (CPS) and submitted to intermittent water supply (IWS)

Variable (mg/g FAME)	**CPS (% DM)**			**IWS (hours)**			**SEM**	***P- value***		
	0	**21**	**42**	**0**	**24**	**48**		**CPS**	**IWS**	**CPS×IWS**
∑PUFA	50.7	43.2	42.3	44.2	46.5	45.4	3.12	0.1464	0.7817	0.0822
c9,t11-C18:2 + isomers	0.69	0.81	0.74	0.80	0.67	0.77	0.09	0.6447	0.4643	0.3336
∑n3	10.1	7.5	6.73	7.67	8.67	7.97	1.08	0.1248	0.4503	0.1617
C18:3 n3	0.88	0.52	0.78	0.62	0.69	0.88	0.10	0.0719	0.1902	0.8090
C20:3 n3	0.03	0.08	0.06	0.05	0.06	0.05	0.02	0.1385	0.7403	0.2961
C20:5 n3	3.00	2.41	2.08	2.27	2.79	2.43	0.43	0.4378	0.4580	0.6028
C22:5 n-3	4.95	4.04	3.51	3.87	4.66	3.98	0.64	0.4091	0.2613	0.1434
C22:6 n3	1.21	0.45	0.30	0.86	0.47	0.63	0.21	0.0610	0.5881	0.6761
∑n6	40.1	34.9	34.8	35.8	37.3	36.6	2.39	0.2608	0.9370	0.1317
c9,c12-C18:2 n-6	20.1	19.3	19.9	19.0	20.3	20.0	1.27	0.8003	0.8994	0.4369
C18:3 n6	0.20	0.23	0.22	0.23	0.21	0.22	0.03	0.8048	0.9593	0.9003
C20:2 n-6	0.01	0.00	0.03	0.00	0.02	0.02	0.01	0.1892	0.6192	0.5055
C20:3 n6	0.45	0.48	0.43	0.43	0.55	0.38	0.08	0.8162	0.0551	0.0558
C20:4 n6	19.3	14.9	14.2	16.1	16.2	16.0	1.55	0.0854	0.9684	0.2150

[a, b]Means within rows with different letter superscripts differ by Tukey test ($P < 0.05$)

Table 10
Fatty acid ratio and nutraceutical parameters from *Longissimus lumborum* muscle of goats fed with cactus pear silage (CPS) and submitted to intermittent water supply (IWS).

Variable (mg/g FAME)	**CPS (% DM)**			**IWS (hours)**			**SEM**	***P- value***		
	0	**21**	**42**	**0**	**24**	**48**		**CPS**	**IWS**	**CPS×IWS**
∑PUFA: ∑SFA	0.12	0.10	0.10	0.10	0.11	0.10	0.01	0.0838	0.8249	0.1084
∑PUFA ∑MUFA	0.10	0.08	0.08	0.08	0.09	0.09	0.01	0.3436	0.7698	0.1061
∑MUFA: ∑SFA	1.25	1.19	1.20	1.21	1.24	1.20	0.06	0.7197	0.9831	0.6979
n6/n3	3.98	4.65	5.17	4.66	4.30	4.59	0.59	0.2672	0.2716	0.4074
Desirable fatty acids	732	730	729	735	736	720	5.75	0.8535	0.1237	0.3088
Atherogenicity index	0.29	0.29	0.29	0.29	0.28	0.31	0.01	0.8636	0.2950	0.5285
Thrombogenicity index	0.79	0.83	0.82	0.82	0.79	0.83	0.04	0.6863	0.9758	0.7807
h:H index	1.91	1.92	1.89	1.94	1.98	1.79	0.08	0.9690	0.3508	0.6720
Δ9-dessaturase C16	9.38	8.58	8.55	8.75	8.97	8.81	0.48	0.3889	0.9922	0.6809
Δ9-dessaturase C18	72.9	71.7	72.1	71.3	72.5	72.9	1.47	0.7724	0.7318	0.5625
Elongase	69.2	70.1	70.0	70.4^{ab}	70.6^{a}	68.3^{b}	0.67	0.6608	0.0453	0.2212

$^{a,\,b}$Means within rows with different letter superscripts differ by Tukey test ($P < 0.05$)