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Performance and carcass characteristics of lambs fed diets containing different types of carbohydrates associated with polyunsaturated fatty acids

Rafael Lopes Soares[1], Rita de Cássia Ramos do Egypto Queiroga[1], Rui José Branquinho Bessa[2], Francinilda Alves de Sousa[1], Beatriz Dantas Oliveira Fernandes[1], Anaiane Pereira Souza[3] and Ariosvaldo Nunes de Medeiros[1*]

[1]Departamento de Zootecnia, Centro de Ciências Agrarias, Universidade Federal da Paraíba, Rodovia PB-079, 58397-000, Areia, Paraíba, Brazil. [2]Centro de Pesquisa Interdisciplinar em Saúde Animal, Faculdade de Medicina Veterinária, Universidade de Lisboa, Lisboa, Portugal. [3]Instituto de Estudos do Trópico Úmido, Universidade Federal do Sul e Sudeste do Pará, Xinguara, Pará, Brazil. *Author for correspondence. E-mail: ariosvaldo.medeiros@gmail.com

ABSTRACT. This study aimed to evaluate the productive performance and carcass characteristics of lambs fed diets with different types of carbohydrates associated with polyunsaturated fatty acids. Thirty castrated male lambs (20.5 ± 7.6 kg) were used, distributed in a randomized block design under three experimental diets: High proportion of non-fibrous carbohydrates (NFC) diet; High NFC diet + spineless cactus (high proportion of NFC and spineless cactus) and Low NFC diet (low proportion of NFC), in a 60 day experimental period. The variables of nutrient intake, performance, and carcass characteristics were evaluated. The animals fed the High NFC + spineless cactus diet presented a higher dry matter intake, organic matter, mineral matter, crude protein, and total carbohydrates intake ($p < 0.05$). Carcass characteristics and weight of commercial cuts were improved in High NFC and High NFC + spineless cactus diets ($p < 0.05$), on the other hand we observed a total fat weight reduction in animals fed with High NFC + spineless cactus. The results indicate that high levels of NFC positively influence animal performance, where the type of carbohydrate influences nutrient intake, also affecting carcass characteristics.

Keywords: carcass yield; sheep production; weight gain.

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Introduction

Carbohydrates and lipids are important energy sources in the diet of ruminants. They are nutrients that allow sheep to gain weight and to improve quality carcasses (Soares et al., 2012; Romão et al., 2013). The types of carbohydrates and their sources influence the quality of the diet, as they can result in different fermentative characteristics, impacting nutrient degradability and animal productive performance (Sniffen, O'Connor, Soest, Fox, & Russell, 1992; Morgado et al., 2013b). Animals fed with diets containing high concentrations of starch, which is a soluble carbohydrate of rapid ruminal fermentation, can present a significant reduction in ruminal pH and fiber digestion, consequently reducing feed intake and presenting digestive disorders. On the other hand, pectin-rich foods, such as spineless cactus, enable a pattern of ruminal fermentation like diets with fibrous carbohydrates, maintaining a more favorable ruminal condition for fiber digestion (Ben-Ghedalia, Yosef, Miron, & Est, 1989; Morgado et al., 2013b).

Higher proportions of non-fibrous carbohydrates (NFC) in ruminant diets result in heavier carcasses and with higher fat content for providing a greater intake of digestible energy in the diet than when animals are fed with lower proportions of NFC (Moreno et al., 2010). A source of NFC constantly used in arid and semi-arid regions of the world is spineless cactus, the inclusion of cactus in sheep diets results in a decrease in the fat content in the carcass, without compromising animal performance (Pinto et al., 2011; Abreu et al., 2019). Studies evaluating the addition of oils together with carbohydrates demonstrate influence on the percentage of carcass components (Morgado, Ezequiel, Galzerano, & Sobrinho, 2013a; Urbano, Ferreira, Oliveira, Lima Júnior, & Andrade, 2014; Francisco et al., 2015), however, studies evaluating the use of spineless cactus as a source of NFC associated with oils in sheep diets are scarce.

Therefore, this study aimed to evaluate the productive performance and carcass characteristics of lambs fed diets with different proportions and types of carbohydrates associated with polyunsaturated fatty acids.

Material and methods

The study was conducted following ethical standards and was approved by the Ethics Committee on the Use of Animals (CEUA) of the Federal University of Paraíba - CEUA license - 7483280818.

Animals, diets, and experimental arrangement

The study was carried out at the Small Ruminants Research Unit, belonging to the Federal University of Paraíba, São João do Cariri - PB, Brazil. Thirty lambs with no defined racial pattern were evaluated, with an average body weight of 20.5 ± 7.6 kg and approximately five months of age, castrated, medicated against endoparasites and ectoparasites and vaccinated against clostridiosis. The experimental period lasted 60 days, with the first 15 days for adaptation to diets and facilities, and 45 days for data collection. The animals were allocated to a randomized block design, where three blocks were formed according to the initial body weight of the animals.

The three diets evaluated were defined according to the amount of NFC: High NFC Diet (based on Tifton hay, corn, and soybean meal, NFC = 35.44%); High Diet NFC + spineless cactus (based on Tifton hay, forage spineless cactus, corn and soybean meal; NFC = 40.47%); and Low NFC Diet (diet based on Tifton hay, corn and soybean meal; NFC = 14.68%). All diets contained the same amount of sunflower oil (3%) and fish oil (1%) in their composition. Tifton 85 grass hay (Cynodon dactylon) was used as roughage feed. The cactus used was the cultivar *Miúda* (*Nopalea cochenillifera-Salm Dyck*). It was two years old at the time of cutting and was collected every two weeks throughout the experiment.

The experimental diets were isoproteic and formulated according to the NRC (2007) for an average daily gain of 200 g animal^{-1}. The chemical composition of the ingredients and their proportions in the experimental diets are presented in Tables 1 and 2.

Table 1. Chemical composition of experimental diet ingredients.

Composition g kg^{-1}	Ingredients			
	Tifton Hay	Ground corn	Soybean meal	Spineless cactus
Dry matter[1]	885.1	885.8	872.9	256.7
Organic matter[2]	940.4	965.1	931.1	931.1
Ash[2]	59.6	34.9	61.4	68.9
Crude protein[2]	89.1	92.0	487.8	19.6
Ethereal extract[2]	19.5	59.1	19.0	9.30
Fiber in Neutral Detergent[2]	728.0	278.7	158.7	194.1
Non-Fibrous Carbohydrates[2]	103.8	535.3	273.1	708.1
Total Carbohydrates[2]	831.8	814.0	431.8	902.2

[1]g kg^{-1} of natural matter; [2]g kg^{-1} of dry matter.

Table 2. The proportion of ingredients and chemical composition of experimental diets.

	Experimental diets g kg^{-1}		
Ingredients	High NFC	High NFC + spineless cactus	Low NFC
Tifton hay	250	250	730
Corn	532	60	50
Soybean meal	160	232	162
Spineless cactus	-	400	-
Sunflower oil	30	30	30
Fish oil	10	10	10
Mineral supplement	10	10	10
Limestone	8	8	8
	Chemical composition g kg^{-1}		
Dry Matter[1]	884.8	639.3	890.7
Ash[2]	61.3	76.8	73.2
Organic Matter[2]	938.7	923.2	926.8
Crude Protein[2]	149.3	148.8	148.7
Ether Extract[2]	79.0	56.1	59.9
Neutral Detergent Fiber[2]	355.7	313.2	571.1
Non Fibrous Carbohydrates[2]	354.4	404.7	146.8
Total Carbohydrates[2]	710.1	717.8	717.9

[1]g kg^{-1} of natural matter; [2]g kg^{-1} of dry matter.

Measurements and analytical methods

During the experimental period, samples of ingredients and orts were obtained, orts were weighed and sampled daily. These portions were homogenized to obtain a composite sample from each animal, then the material was pre-dried in a forced ventilation oven at 55°C for 72 hours and ground with Willey knives using a 1 mm mesh sieve.

The samples were analyzed according to the protocols described by the Association of Official Analytical Chemists [AOAC] (1997) for dry matter (DM; method 934.01), crude protein (CP; method 990.13), ether extract (EE, method 920.39), and ash (method 942.05). Neutral detergent fiber (NDF) was estimated by the method of Van Soest, Robertson, and Lewis (1991), with the addition of thermostable amylase, using ANKOM fiber analyzer (ANKOM200 Fiber Analyzer; ANKOM Technology Corporation, Fairport, NY, USA).

The proportions of total carbohydrates (TC) were estimated using the equation proposed by Sniffen et al. (1992): $[TC = 100 - (\%CP + \%EE + \%Ash)]$ while the proportions of NFC in the diet were estimated according to Van Soest et al. (1991), $[NFC = 100 - (\%CP + \%EE + \%Ash + \%NDF)$.

Intake, weight gain, slaughter, carcass yield, and commercial cuts

The voluntary intake of nutrients was measured by the difference between the food offered and the orts. The animals were weighed at the beginning of the experiment (initial weight) and at the end of the experiment (final weight) to obtain the results of average daily gain. All animals were fasted for solids for 16 hours before slaughter. After this time, they were weighed to obtain body weight at slaughter (BWS). Slaughter was carried out following the rules in force in the Regulation on Industrial and Sanitary Inspection of Products of Animal Origin (Brasil, 2000).

The animals were stunned by a stunning cerebral concussion in the atlas-occipital region, using a captive dart pistol, followed by bleeding by sectioning the jugular veins and carotid arteries. Blood was collected in a previously tared container for subsequent weighing. After bleeding, skinning, evisceration, removal of the head (section in the atlantooccipital joint) and extremities of the limbs (section in the carpal and tarsometatarsal joints) were performed, then recording the warm carcass weight (WCW), including the kidneys and pelvic-renal fat for the calculation of the warm carcass yield $[WCY = (HCW/BWS) \times 100]$.

The gastrointestinal tract (GIT), as well as the bladder and gallbladder, were weighed full and empty to determine the empty body weight (EBW). The EBW values were used to determine the biological or true yield $[BY = (HCW/EBW) \times 100]$.

After slaughter, the carcasses were stored in a cold chamber for 24 hours at ± 4°C, and hung by the common Achilles tendon. After this period, the carcasses were weighed to obtain the cold carcass weight (CCW) and to obtain the values of cold carcass yield $[CCY = (CCW/BWS) \times 100]$ and the cooling weight loss $[\text{Cooling weight loss} = (HCW - CCW) / HCW \times 100]$. The carcasses were divided longitudinally and the left half-carcass was sectioned into six sections: leg, loin, rib, breast, neck and shoulder. Each section was weighed to obtain the cut weights.

A cross-section was made, in the section between the 12 and 13th ribs, where the ribeye area of the *Longissimus Dorsi* muscle was determined, in which the muscle was traced on a transparency sheet to determine the ribeye area with the help of graph paper.

Determination of tissue composition

The determination of tissue components was made following the methodology described by Brown and Williams (1979). The legs were thawed under refrigeration at a temperature around 8°C for 24 hours. After this period, the dissection started with the aid of a scalpel and tweezers. To obtain tissue components, dissection divided the leg into fat (pelvic, subcutaneous, and intermuscular), and the five main muscles that cover the femur (*semimembranosus*, *semitendinosus, adductor, quadriceps femoris, and biceps femoris)*.

The other muscles that did not directly involve the femur were weighed to obtain the weight of the total muscles and other tissues (unidentified tissues composed of tendons, blood vessels, nerves, glands, aponeurosis, fascia) and all the leg bones.

All components were weighed separately and the length of the femur was measured. From these data, percentages of the yield of fat, muscles, and leg bones were measured, in addition to determining the muscle and bone ratio (sum of muscles/total sum of bones), muscle and fat ratio (sum of muscle/total sum of fat) and leg muscle index (LMI) was also determined; (Purchas, Davies, & Abdullah, 1991) through the following Equation 1:

$$LMI = (\sqrt{(W5M/LF)}/LF \quad (1)$$

On what: W5M = weight of five main muscles that cover the femur in g (*semimembranosus*, *semitendinosus, adductor, quadriceps femoris, and biceps femoris)*; LF = length of the femur in cm.

Statistical analysis

Data were subjected to analysis of variance with the aid of the SAS statistical package 9.2 software (SAS Institute Inc., Cary, NC USA) using PROC MIXED. The comparison of means was performed using the Tukey Test, adopting 0.05 as the critical level of probability for type I error and using the mathematical model described below (Eqution 2):

$$Yij = m + Ti + bj + eij \quad (2)$$

Where: Yij = value observed for the variable under study referring to the i- eleventh treatment in the j-eleventh repetition; m = average of all experimental units for each variable under study; Ti = effect fixed the treatment of treatment i on the observation value of the variable Yij; ti=mi-m; bj = random effect of block j on the observed value Yij; bj=mj-m; eij = is the error associated with observation Yij.

Results and discussion

Lambs fed with the High NFC + spineless cactus diet had a higher intake of DM, OM, Ash, and CP ($p < 0.05$) when compared to the others. The EE intake was higher for animals fed with the two diets characterized by a high proportion of NFC ($p = 0.003$; Table 3). The intake of NDF was higher in the High NFC + spineless cactus and Low NFC diets compared to the High NFC diet ($p = 0.0194$). The High NFC + spineless cactus diet had a higher NFC intake ($p < 0.0001$; Table 3) compared to the others, however, the High NFC had a higher intake of NFC compared to Low NFC. The intake of TC was higher for the High NFC + spineless cactus diet ($p < 0.0001$) when compared to the others.

Table 3. Nutrient intake by lambs fed with different sources and types of carbohydrates in experimental diets.

Variables	Experimental diets			SEM[10]	p-value[11]
	High NFC	High NFC+ Spineless cactus	Low NFC		
DMI $BW^{0.75}$ g kg^{-1}	79.9b	131.6a	78.69b	4.39	<0.001
DMI BW %[2]	3.4b	5.8 a	3.52b	0.180	<0.001
Intake					
DM[3] (g day^{-1})	996.3b	1574.3a	894.3b	95.8	<0.001
OM[4] (g day^{-1})	933.7b	1459a	828.9b	88.6	<0.001
Ash (g day^{-1})	62.5b	115.21a	65.4b	7.20	<0.001
CP[5] (g day^{-1})	153.9b	230.6a	138.6b	13.32	<0.001
EE[6] (g day^{-1})	79.21 to	89.14a	54.4b	5.42	0.003
NDF[7] (g day^{-1})	369.2b	488.7a	439.5 to	32.88	0.0194
NFC[8] (g day^{-1})	330.8b	649.9a	142.0 c	39.60	<0.001
TC[9] (g day^{-1})	700.1b	1138.6a	635.5b	70.05	<0.001

[1]Dry matter intake by metabolic weight; [2]Dry matter intake by body weight; [3]Dry matter; [4]Organic matter;[5]Crude protein; [6]Ether extract; [7]Neutral fiber detergent; [8]Non fibrous carbohydrates; [9]Total carbohydrates; [10]Standard error of the mean; [11]Probability; a and b differ from each other by Tukey's test ($p < 0.05$).

The highest DM intake for High NFC + spineless cactus diet can be attributed to the proportion of NFC and its carbohydrate type. In addition to the high proportions of NFC, the pectin present in spineless cactus promotes an increase in the passage rate, due to its rapid fermentation, and consequently, results in a higher intake (Wanderley et al., 2012; Felix et al., 2016; Costa, et al., 2017; Oliveira et al., 2018a). This result corroborates a study evaluating levels of inclusion of spineless cactus in the diet, in which DM intake by lambs also increased with the inclusion of cactus (Cardoso et al., 2019). On the other hand, when there is a greater proportion of fibrous carbohydrates in the feed, there is a reduction in the passage rate thus resulting in a lower intake of the diet 'Low NFC' when compared to the High NFC + spineless cactus diet. Diets with high contents of cellulose and hemicellulose, result in a decrease in the rate of passage due to the inability of the rumen to digest large fractions of fibrous carbohydrates quickly and, in this way, decrease the DMI (Sniffen et al., 1992; Kammes & Allen, 2012; Galvani, Pires, Hübner, Carvalho, & Wommer, 2014; Claffey et al., 2018). Unlike expected, the DM intake values did not differ between the High NFC and Low NFC diets, this difference was possibly not observed due to the higher EE content in the High NFC diet, which possibly limited the feed intake.

Regarding the DM intake in the diet High NFC + spineless cactus has been higher than the High NFC, it can be a physical limitation related to food degradation since carbohydrate fermentation differs as to the source used (Morgado et al., 2013b). Pectin-rich foods do not produce significant amounts of lactic acid, tending to maintain a higher ruminal pH and thus enabling a high acetate: propionate ratio, forming a more favorable ruminal condition for fiber digestion (Ben-Ghedalia et al., 1989).

The highest intake of OM, ash, CP, and TC with the use of High NFC + spineless cactus is possibly related to cactus in diet. The addition of spineless cactus also causes an increase in the intake of other nutrients in the diet, considering that its composition has high concentration of minerals such as calcium and phosphorus (Andrade et al., 2016; Felix et al., 2016). Based on these results, it is possible to indicate a favorable relationship between pectin from spineless cactus and nutrient intake. Although the diet High NFC + spineless cactus has a low concentration of EE in its composition, the higher DMI by animals on this diet resulted in high EE intake.

Average daily gain, EBW, WCW, and CCW and kidney fat of lambs fed with the high NFC diets were higher ($p < 0.005$; Table 4) compared to animals fed with the Low NFC diet. However, the HCY ($p = 0.9528$); BY ($p = 0.5068$); weight loss by cooling ($p = 0.0706$) and rib eye area ($p = 0.0799$), did not differ between the diets evaluated.

The high proportion of NFC in the High NFC and High NFC + spineless cactus diets resulted in greater average daily gain, reflecting in higher BWS, EBW, HCW, CCW, and higher CCY (Table 4). The proportion of carbohydrates in the diet influenced the average daily gain of the finishing lambs. Probably the provision of the high content of NFC in the diet for sheep in feedlot works as an animal growth promoter, improving carcass characteristics (Arvizu et al., 2011; Pereira Filho et al., 2014).

The shoulder, neck, rib, breast, and leg weights were similar between the two High NFC diets and were higher than the Low NFC diet ($p < 0.001$; Table 5). The highest weights of commercial cuts in the High NFC and High NFC + spineless cactus diets showed the effect of the diet on the body weight of the animals, reflecting on the weight of these cuts individually. As for cut yields, the shoulder yield ($p = 0.277$); neck ($p = 0.277$); rib ($p = 0.613$); breast ($p = 0.657$) and loin ($p = 0.332$) did not differ between the diets (Table 5).

Table 4. Performance and carcass characteristics of lambs fed with different sources and types of carbohydrates in experimental diets.

Variables	Experimental diets			SEM[1]	p-value[2]
	High NFC	High NFC +Spineless cactus	Low NFC		
Initial weight (kg)	20.5	20.5	20.5	0.99	0.9597
Final weight (kg)	35.9a	35.3a	30.6b	1.21	<0.0001
Average daily gain (g)	252a	226a	168b	0.01	<0.0001
Slaughter body weight (kg)	34.8a	32.0a	27.8b	1.07	<0.0001
Empty body weight (kg)	30.9a	28.6y	23.4b	1.05	<0.0001
Warm carcass weight (kg)	17.7a	16.5a	14.1b	0.62	<0.0001
Cold carcass weight (kg)	17.3a	16.1a	13.1b	0.63	<0.0001
Kidney fat (g)	200 to	175 to	103b	0.01	0.0057
Warm carcass yield (%)	51.5	51.3	50.8	0.93	0.9528
Cold carcass yield (%)	50.3a	49.9a	46.7b	0.52	<0.0001
Biological yield (%)	59.1	57.5	60.6	1.12	0.5068
Cooling weight loss (%)	2.60	2.74	2.86	0.04	0.0706
Ribeye area (cm^2)	11.9	11.8	10.3	0.39	0.0799

[1]Mean standard error; [2]Probability; a and b differ from each other by the Tukey test ($p < 0.05$).

The leg yield ($p < 0.0001$) was higher in animals fed with the Low NFC diet, with an average of 31.83%.The values were similar between High NFC and High NFC+ spineless cactus diet that showed an average value of 30.3 %. The BWS is a determining factor in the weight of commercial cuts in sheep (Oliveira et al., 2018a). Likewise, Jacques, Berthiaume, and Cinq-Mars, (2011) reported a better classification of loin of lambs fed *ad libitum* when compared to those in a restricted amount of concentrate (40% DM), corroborating the results obtained in the present study for the Low NFC diet, which also presented lower weights of tissue components.

Regarding tissue composition, greater muscle and bone weight was observed for the High NFC and High NFC + spineless cactus diets ($p < 0.001$; Table 6). Subcutaneous fat, intermuscular fat and other tissues were higher in animals fed with the High NFC diet compared to the animals fed with the Low NFC diet ($p < 0.001$).

Table 5. Commercial cuts in the carcass of lambs fed with different sources and types of carbohydrates.

Variables	Experimental diets			SEM[1]	p-value[2]
	High NFC	High NFC +Spineless cactus	Low NFC		
Shoulder (kg)	1.43a	1.35a	1.14b	0.05	<0.0001
Neck (kg)	1.02a	0.96a	0.72b	0.05	<0.0001
Rib (kg)	1.29a	1.20a	0.95b	0.06	<0.0001
Breast (kg)	1.17a	1.08y	0.89b	0.05	<0.0001
Loin (kg)	0.75a	0.74a	0.57b	0.03	<0.0001
Leg (kg)	2.45a	2.31a	1.96b	0.08	<0.0001
Yield of commercial cuts					
Shoulder (%)	17.79	17.66	18.38	0.21	0.2775
Neck (%)	17.79	17.66	18.38	0.21	0.2775
Rib (%)	15.81	15.72	15.22	0.26	0.6126
Breast (%)	14.39	14.0	14.41	0.20	0.6572
Loin (%)	9.23	9.68	9.19	0.14	0.3325
Leg (%)	30.43b	30.26b	31.83a	0.28	<0.0001

[1]Mean standard error; [2]Probability; a and b differ from each other (p <0.05) by the Tukey test.

The carcasses of lambs fed with the High NFC diet had a higher total fat weight compared to the other diets (p <0.001). Pelvic fat (p =0.0826), muscle:fat ratio (p =0.1006) and muscle:bone ratio (p =0.2313) did not differ between the experimental diets. Leg muscle index (p <0.0001) was higher in the High NFC + spineless cactus diet than in the Low NFC diet.

Among the main tissue components of the leg evaluated, the fact that the muscles presented greater weight, followed by bones and fat, is explained by the fact that these components show different orders of growth. Similar values were also found by Moreno, Sobrinho, Leão, Loureiro, and Perez (2010), Costa et al. (2012), and Urbano et al. (2015). The highest LMI in lambs fed the High NFC diets indicates greater development of these issues regardless of the source of NFC. The leg muscle index was lower than that observed by Abdullah, Kridli, Shaker, and Obeidat (2010) and similar to the values found by Costa et al. (2011), indicating that the animals obtained a lower muscle deposition compared to the bone length.

Table 6. Tissue composition and leg muscle index of lambs fed with different sources and types of carbohydrates.

Variables	Experimental diets			SEM[1]	p-value[2]
	High NFC	High NFC +Spineless cactus	Low NFC		
Muscles (g)	1569a	1500a	1313b	53.89	<0.001
Pelvic fat (g)	32.2	28.1	22.9	2.44	0.083
Subcutaneous fat (g)	85.6a	61.4ab	36.5b	5.18	<0.001
Intermuscular fat (g)	142a	118ab	103b	9.98	<0.001
Total fat (g)	260a	208b	162b	14.07	<0.001
Bones (g)	397a	403a	345b	10.69	<0.001
Other tissues (g)	133a	109ab	80.8b	129.1	<0.001
Muscle:fat ratio	6.55	7.49	8.57	0.38	0.106
Muscle:bone ratio	3.99	3.70	3.77	0.08	0.231
Leg Muscle Index	0.37ab	0.38a	0.35b	0.01	<0.001

[1]Mean standard error; [2]Probability; a and b differ from each other by the Tukey test (p <0.05).

The greater weight of subcutaneous fat and intermuscular fat in the High NFC diet compared to the Low NFC diet is a result of the diet composition and the interaction of NFC and oils, reflecting in greater energy uptake offered to animals (Rosa et al., 2013). The higher weight of total fat in animals fed with the High NFC diet indicates the association of diet on carcass composition, the excess NFC results in lipogenesis and carcass fat deposition (Pereira et al., 2010; Santos et al., 2011). These results also show the relationship of carbohydrate type with the addition of oils in the diet, influencing higher fat content. Differently from Ferreira et al. (2014), that did not observe differences in the total fat weight of lambs. The carcasses of lambs fed with the High NFC + spineless cactus diet showed lower fat content than carcasses of lambs fed with the High NFC diet. It is suggested that although spineless cactus is rich in NFC, pectin behaves differently compared to monosaccharides, disaccharides, and starch (Morgado et al., 2013a), therefore, the pectin possibly modifies the extention of lipogenesis and reduces carcass fat deposition.

Conclusion

Based on this study, high levels of NFC positively influence animal performance, promoting better results for performance and carcass characteristics, where the type of carbohydrate influences the nutrient intake, also interfering positively with carcass characteristics.

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References

Abdullah, A. Y., Kridli, R. T., Shaker, M. M., & Obeidat, M. D. (2010). Investigation of growth and carcass characteristics of pure and crossbred Awassi lambs. *Small Ruminant Research, 94*(1-3), 167-175. DOI: https://doi.org/10.1016/j.smallrumres.2010.08.05

Abreu, K. S. F., Véras, A. S. C., Ferreira, M. A., Madruga, D. M. , Maciel, M. I. S., Félix, S. C. R., ... Urbano, S. A. (2019). Quality of meat from sheep fed diets containing spineless cactus (Nopalea cochenillifera Salm Dyck). *Meat Science, 148*(1), 229-235. DOI: https://doi.org/10.1016/j.meatsci.2018.04.036

Andrade, S. F. J., Batista, Â. M. V., Carvalho, F. F. R., Lucena, B. Y., Andrade, R. D. P. X., Lima Júnior, D. M., ... Batista, Â. M. V. (2016). Fresh or dehydrated spineless cactus in diets for lambs. *Acta Scientiarum. Animal Sciences, 38*(2), 155. DOI: https://doi.org/10.4025/actascianiDMci.v38i2.29329

Arvizu, R. R., Domínguez, I. A., Rubio, D. M., Bórquez, J. L., Pinos-Rodríguez, J. M., González, M., & Jaramillo, G. (2011). Effects of genotype, level of supplementation, and organic chromium on growth performance, carcass, and meat traits grazing lambs. *Meat Science, 88*(3), 404-408. DOI: https://doi.org/10.1016/j.meatsci.2011.01.018

Association of Official Analytical Chemists [AOAC]. (1997). *Official methods of analysis*). Gaithersburg, MD: AOAC International.

Ben-Ghedalia, D., Yosef, E., Miron, J., & Est, Y. (1989). The effects of starch- and pectin-rich diets on quantitative aspects of digestion in sheep. *Animal Feed Science and Technology, 24*(3-4), 289-298. DOI: https://doi.org/10.1016/0377-8401(89)90150-8

Brasil. Ministério da Agricultura e do Abastecimento. Secretaria de Defesa Agropecuária. (2000). *Instrução Normativa nº 3, de 17 de janeiro de 2000. Aprovar o regulamento técnico de métodos de insensibilização para o abate humanitário de animais de açougue*. Brasília, DF: Ministérios da Agricultura e do Abastecimento.

Brown, A. J., & Williams, D. R. (1979). *Sheep carcass evaluation: measurement of composition using a standardized butchery method*. Langford, CA: Agricultural Research Council.

Cardoso, D. B., Carvalho, F. F. R., Medeiros, G. R., Guim, A., Cabral, A. M. D., Véras, R. M. L., ... Nascimento, A. G. O. (2019). Levels of inclusion of spineless cactus (*Nopalea cochenillifera* Salm Dyck) in the diet of lambs. *Animal Feed Science and Technology, 247*(1), 23-31. DOI: https://doi.org/10.1016/j.anifeedsci.2018.10.016

Claffey, N. A., Fahey, A. G., Gkarane, V., Moloney, A. P., Monahan, F. J., & Diskin, M. G. (2018). Effect of breed and castration on production and carcass traits of male lambs following an intensive finishing period. *Translational Animal Science, 2*(4), 407-418. DOI: https://doi.org/10.1093/tas/txy070

Costa, R. G., Silva, N. V., Azevedo, P. S., Medeiros, A. N., Carvalho, F. F. R., Queiroga, R. C. R. E., & Medeiros, G. R. (2011). Meat quality of lambs fed silk flower hay (*Calotropis procera* SW) in the diet. *Revista Brasileira de Zootecnia, 40*(6), 1266-1271. DOI: https://doi.org/10.1590/S1516-35982011000600015

Costa, R. G., Treviño, I. H., Medeiros, G. R., Medeiros, A. N., Pinto, T. F., & Oliveira, R. L. (2012). Effects of replacing corn with cactus pear (*Opuntia ficus indica* Mill) on the performance of Santa Ines lambs. *Small Ruminant Research, 102*(1), 13-17. DOI: https://doi.org/10.1016/j.smallrumres.2011.09.012

Costa, R. G., Almeida, M. D. A., Cruz, G. B. Y., Beltrão Filho, E. M., Ribeiro, N. L., Madruga, D. M., & Queiroga, R. C. R. (2017). The fatty acid profile of fat depots from Santa Inês sheep fed spineless cactus (*Opuntia ficus-indica* Mill.). *Journal of the Science of Food and Agriculture, 97*(13), 4438-4444. DOI: https://doi.org/10.1002/jsfa.8303

Felix, S. C. R., Pessoa, R. A. S., Andrade Ferreira, M., Soares, L. F. P., Lima Silva, J., Abreu, K. S. F., & Melo, A. C. C. (2016). Intake, performance, and carcass characteristics of lambs fed spineless cactus replacing wheat bran. *Tropical Animal Health and Production, 48*(2), 465-468. DOI: https://doi.org/10.1007/s11250-015-0969-2

Ferreira, E. M., Pires, A. V., Susin, I., Gentil, R. S., Parente, O. M. M., Nolli, C. P., … & Ribeiro, C. V. D. M. (2014). Growth, feed intake, carcass characteristics, and meat fatty acid profile of lambs fed soybean oil partially replaced by fish oil blend. *Animal Feed Science and Technology*, *187*(1), 9–18. DOI: https://doi.org/10.1016/j.anifeedsci.2013.09.016

Francisco, A., Dentinho, M. T., Alves, S. P., Portugal, P. V., Fernandes, F., Sengo, S., ... Santos-Silva, J. (2015). Growth performance, carcass and meat quality of lambs supplemented with increasing levels of a tanniferous bush (Cistus ladanifer L.) and vegetable oils. *Meat Science, 100*(1), 275-282. DOI: https://doi.org/10.1016/j.meatsci.2014.10.014

Galvani, D. B., Pires, C. C., Hübner, C. H., Carvalho, S., & Wommer, T. P. (2014). Growth performance and carcass traits of early-weaned lambs as affected by the nutritional regimen of lactating ewes. *Small Ruminant Research, 120*(1), 1-5. DOI: https://doi.org/10.1016/j.smallrumres.2014.03.008

Jacques, J., Berthiaume, R., & Cinq-Mars, D. (2011). Growth performance and carcass characteristics of Dorset lambs fed different concentrates: forage ratios or fresh grass. *Small Ruminant Research, 95*(2-3), 113-119. DOI: https://doi.org/10.1016/j.smallrumres.2010.10.002

Kammes, K. L., & Allen, D. M. (2012). Rates of particle size reduction and passage are faster for legume compared with cool-season grass, resulting in lower rumen fill and less effective fiber. *Journal of Dairy Science, 95*(6), 3288-3297. DOI: https://doi.org/10.3168/jds.2011-5022

Moreno, G. M. B., Sobrinho, A. G. S., Leão, A. G., Loureiro, C. M. B., & Perez, H. L. (2010). Rendimentos de carcaça, composição tecidual e musculosidade da perna de cordeiros alimentados com silagem de milho ou cana-de-açúcar em dois níveis de concentrado, *Arquivo Brasileiro de Medicina Veterinária e Zootecnia, 62*(3), 686-695. DOI: https://doi.org/10.1590/S0102-09352010000300025

Morgado, E. S., Ezequiel, J. M. B., Galzerano, L., & Sobrinho, A. G. S. (2013a). Performance and carcass characteristics of lambs fed with carbohydrate sources associated with sunflower oil. *Bioscience Journal, 29*(3), 712-720.

Morgado, E. S., Ezequiel, J. M. B., Galzerano, L., Malheiros, E. B., Santos, V. C., & Cattelan, J. W. (2013b). Fermentação, cinética e degradação ruminal em ovinos alimentados com fontes de carboidratos associadas ao óleo. *Semina: Ciências Agrárias, 34*(6), 3081-3092. DOI: https://doi.org/10.5433/1679-0359.2013v34n6p3081

National Research Council [NRC]. 2007. *Nutrient requirements of small ruminants*. Washington, DC: National Academy Press.

Oliveira, J. P. F., Ferreira, M. A., Alves, A. M. S. V., Melo, A. C. C., Andrade, I. B., Urbano, S. A., ... Melo, T. T. B. (2018a). Carcasses characteristics of lambs fed spineless cactus as a replacement for sugarcane. *Asian-Australasian Journal of Animal Sciences, 31*(4), 529-536. DOI: https://doi.org/10.5713/ajas.17.0375

Oliveira, F. G., Sousa, W. H., Cartaxo, F. Q., Cunha, M. G. G., Ramos, J. P. F., Cezar, M. F., ... Oliveira, A. B. (2018b). Carcass characteristics of Santa Ines sheep with different biotypes and slaughtering weights. *Revista Brasileira de Saúde e Produção Animal, 19*(3), 347-359. DOI: https://doi.org/10.1590/s1519-99402018000300011

Pereira, E. S. , Pimentel, P. G., Fontenele, R. M., Medeiros, A. N., Regadas Filho, J. G. L., & Villarroel, A. B. S. (2010). Characteristics and yields of carcass and cuts in Santa Inês sheep fed with different concentrations of metabolizable energy. *Acta Scientiarum. Animal Sciences, 32*(4), 431-437. DOI: https://doi.org/10.4025/actascianiDMci.v32i4.9684

Pereira Filho, J. M., Silva, A. M. A., Silva, D. S., Cézar, M. F., Bezerra, L. R., Rufino, S. R. M., ... Bayão, G. F. V. (2014). Carcass characteristics of Santa Inês lambs finished on native pasture and subjected to different types of supplementation. *Journal of Agricultural Sciences, 37*(4), 456-462.

Pinto, T. F., Costa, R. G., Medeiros, A. N ., Medeiros, G. R., Azevedo, P. S., Oliveira, R. L., & Treviño, I. H. (2011). Use of cactus pear (Opuntia ficus indica Mill) replacing corn on carcass characteristics and non-carcass components in Santa Inês lambs. *Revista Brasileira de Zootecnia, 40*(6), 1333-1338. DOI: https://doi.org/10.1590/S1516-35982011000600023

Purchas, R. W., Davies, A. S., & Abdullah, A. Y. (1991). An objective measure of muscularity: changes with animal growth and differences between genetic lines of southdown sheep. *Meat Science, 30*(1), 81-94. DOI: https://doi.org/10.1016/0309-1740(91)90037-Q

Romão, C. O., Carvalho, G. G. P., Leite, V. M., Santos, A. S., Chagas, D. M. T., Ribeiro, O. L., ... Oliveira, R. L. (2013). Fracionamento de carboidratos e degradabilidade ruminal da cana-de-açúcar tratada com óxido de cálcio. *Arquivo Brasileiro de Medicina Veterinária e Zootecnia, 65*(2), 537-546. DOI: https://doi.org/10.1590/S0102-09352013000200033

Rosa, B. L., Sampaio, A. A. M., Henrique, W., Oliveira, E. A., Pivaro, T. M., Andrade, A. T., & Fernandes, A. R. M. (2013). Performance and carcass characteristics of Nellore young bulls fed different sources of oils, protected or not from rumen degradation. *Revista Brasileira de Zootecnia, 42*(2), 109-116. DOI: https://doi.org/10.1590/S1516-35982013000200005

Santos, J. R. S., Cezar, M. F., Sousa, W. H., Cunha, M. G. G., Pereira Filho, J. M. , & Sousa, D. O. (2011). Carcass characteristics and body components of Santa Inês lambs in feedlot fed on different levels of forage cactus meal. *Brazilian Journal of Animal Science, 40*(10), 2273-2279. DOI: https://doi.org/10.1590/S1516-35982011001000030

Sniffen, C. J., O'Connor, J. D., Soest, P. J. V., Fox, D. G., & Russell, J. B. (1992). A net carbohydrate and protein system for evaluating cattle diets: II. Carbohydrate and protein availability. *Journal of Animal Science, 70*(11), 3562-3577. DOI: https://doi.org/10.2527 / 1992.70113562x

Soares, S. B., Furusho-Garcia, I. F., Pereira, I. G., Alves, D. O., Silva, G. R., Almeida, A. K., Lopes, C. M., & Sena, J. A. B. (2012). Performance, carcass characteristics and non-carcass components of Texel × Santa Inês lambs fed fat sources and Monensin. *Revista Brasileira de Zootecnia, 41*(2), 421-431. DOI: https://doi.org/10.1590/S1516-35982012000200027

Urbano, S. A., Ferreira, M. A., Oliveira, J. P. F., Lima Júnior, D. M., & Andrade, R. P. X. (2014). Fontes de gordura sobre a modulação do perfil de ácidos graxos da carne de pequenos ruminantes. *Arquivos de Zootecnia, 63*(241), 147-171. DOI: https://doi.org/10.21071/az.v63i241.596

Urbano, S. A., Ferreira, M. A., Véras, R. M. L., Azevedo, P. S., Santos Filho, H. B., Vasconcelos, G. A., & Oliveira, J. P. F. (2015). Carcass characteristics and tissue composition of Santa Inês sheep fed with manipueira. *Brazilian Journal of Agricultural Sciences, 10*(3), 466-472. DOI: https://doi.org/10.5039/agraria.v10i3a4812

Van Soest, P. J., Robertson, J. B., & Lewis, B. A. (1991). Methods for dietary fiber, neutral detergent fiber, and nonstarch polysaccharides in relation to animal nutrition. *Journal of Dairy Science, 74*(10), 3583-3597. DOI: https://doi.org/10.3168/jds.S0022-0302(91)78551-2

Wanderley, W. L., Ferreira, M. D. A., Batista, Â. M. V., Véras, A. S. C., Bispo, S. V., Silva, F. M., & Santos, V. L. F. (2012). Consumo, digestibilidade e parâmetros ruminais em ovinos recebendo silagens e fenos em associação à palma forrageira. Revista *Brasileira de Saúde e Produção Animal, 13*(2), 444-456. DOI: https://doi.org/10.1590/S1519-99402012000200013