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Minimal dietary physical structure level for Belgian Blue double-muscled finishing bulls

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Abstract — The minimal amount of dietary physical structure for Belgian Blue double-muscled fattening bulls was investigated with four feeding regimens. The trial involved 52 bulls weighing 330 kg at the start and 680 kg at slaughter. All diets were fed ad libitum and consisted of concentrates and maize silage in different ratios. The structural value (SV), currently in use in Belgium as an index of dietary physical structure for dairy cattle, of the diets amounted to 0.79, 0.62 and 0.45 units per kg DM for the HSV (high), MSV (moderate) and LSV (low) group, respectively. The fourth group (LSVs) received the same diet as the LSV group, but additional straw was provided ad libitum, to evaluate whether bulls were capable of compensating for a possible lack of physical structure by eating straw. From the start until 600 kg no differences in growth rate were found. From 600 kg until slaughter (680 kg), the LSV group had the highest growth rate (1.35 vs. 1.14 $kg \cdot d^{-1}$). That same group also had the highest DM– and NEF-intake during the first 84 days of the trial. Although not significantly different, the MSV group had the highest amount of lean meat in the carcass (776 $g \cdot kg^{-1}$) and the lowest amount of fat (100 $g \cdot kg^{-1}$). The level of physical structure did not affect meat quality. Overall, no external signs of subclinical or clinical acidosis were observed. The length of the rumen papillae was not affected by the diets. Histological examination of the ruminal epithelium revealed that MSV and LSV exhibited the severest morphological changes. However, it is unclear whether the welfare of these animals was endangered by a shortage of physical structure. Based on the zootechnical performances, no adverse effects were found when feeding a diet with an SV of $0.45 \cdot kg^{-1}$ DM.

physical structure / roughage / double-muscled bulls / performance / rumen histology

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Résumé — Le seuil de fibrosité d'une ration chez les taurillons Blanc-Bleu Belge culards. Le seuil de fibrosité de la ration a été étudié chez des taurillons Blanc-Bleu Belge culards soumis à quatre régimes différents. L'essai a été réalisé sur 52 taurillons pesant au début de l'expérience 330 kg et à l'abattage 680 kg. Les animaux, nourris ad libitum, ont reçu des rations à base de concentré et d'ensilage de maïs dans des proportions variables. L'indice de fibrosité (actuellement utilisé en Belgique chez les bovins laitiers) des régimes a atteint respectivement 0,79, 0,62 et 0,45 unités par kg de MS pour le groupe HSV (haut), le groupe MSH (modéré) et le groupe LSV (bas). Le quatrième groupe LSVs a reçu le même régime que le groupe LSV, mais complémenté avec de la paille fournie ad libitum, afin d'évaluer si les taurillons sont capables de compenser, en mangeant la paille, la perte de fibrosité de la ration. Du début jusqu'à 600 kg, la vitesse de croissance n'a pas été significativement différente. De 600 kg jusqu'à l'abattage (680 kg) le groupe LSV a eu la vitesse de croissance la plus élevée (1, 35 vs. 1,14 kg·j^{-1}). Pour ce même groupe, les quantités de matière sèche et d'énergie nette ingérées ont été les plus élevées pendant les 84 premiers jours de l'essai. Bien que non significativement différent, le groupe MSV a eu la proportion la plus élevée de viande maigre dans la carcasse (776 g·kg^{-1}) et la proportion de gras la plus faible (100 g·kg^{-1}). La fibrosité des rations n'a pas affecté la qualité de la viande. De façon générale, aucun signe extérieur d'acidose subclinique ou clinique n'a été observé. La longueur des papilles ruminales n'a pas été affectée par le type de rations. L'examen histologique de l'épithélium du rumen a montré que les changements morphologiques ont été les plus sévères pour les groupes MSV et LSV. Cependant, il n'est pas démontré que le bien-être de ces animaux soit altéré par le manque de fibrosité des rations. Aucun effet négatif sur les performances zootechniques n'a été observé avec une ration ayant un indice de fibrosité de 0,45 unité par kg DM.

fibrosité / fourrage / taurillons culards / performance / histologie du rumen

1. INTRODUCTION

Due to the intensive beef production systems in Belgium and the high energetic demands of the Belgian Blue (BB) double-muscled (dm) bulls [8, 9], the amount of roughage in fattening diets is often rather limited and consequently large amounts of readily fermentable carbohydrates are provided. This may result in subclinical or clinical acidosis, which is often associated with rumenitis [17, 20] resulting in reduced performance [22]. For beef cattle, the recommendations for a minimal level of physical structure are scarce and mostly empirical.

In 1996, a physical structure evaluation system was introduced in Belgium for dairy cattle [7]. It is based on research determining the physical structure value of numerous feedstuffs as well as the physical structure requirements of dairy cows. The requirements were determined with trials in which the roughage part of the diet of Holstein cows was decreased weekly until symptoms of a physical structure deficiency appeared (mainly a decrease in milk fat content). The roughage part in the diet just above the level at which the problems occurred was called the critical roughage part (CRP). As such, for each experimental diet, the physical structure requirements were met precisely when the CRP was fed. For practical reasons, the minimal physical structure value (SV) of a diet for a standard cow (25 kg milk in 1st, 2nd or 3rd lactation) was assumed equal to 1 unit per kg dry matter (DM). For each experimental diet, an equation could be formulated based on the assumed value for the physical structure requirements and the derived portions of the feedstuffs of each diet at the CRP:

Physical structure requirement = (SV of the feedstuff$_{1...i}$ × portion of the feedstuff$_{1...i}$ at CRP)$_{1...i}$

or

$$1 \,/\, \text{kg DM} = (a_{1...i} \,/\, \text{kg DM} \times X_{1...i})_{1...i}$$

where: i = the number of feedstuffs involved in each diet type; a_i = the SV that had to be derived from the different equations and X_i = the portion of each feedstuff at the CRP.

The structural values of different feedstuffs were derived from an extensive database of diets providing just enough physical structure. The system is currently in use in Belgium and The Netherlands and is being introduced in Germany and France.

In determining the physical structure requirements for dairy cattle, a decrease in milk fat content was an easily observable sign of a lack of physical structure [7]. In beef cattle, however, less manifest parameters have to be evaluated. Reduced feed intake [22], decreased dressing proportion [3, 20] and histomorphological changes of the ruminal wall [22] can indicate subclinical or clinical acidosis.

The structural values, as determined for dairy cattle [7], are considered to be a characteristic of the feedstuff, and hence independent of the animal type. Therefore, the same values are also used for beef cattle.

The objective of this trial was to determine the minimal SV of diets for beef bulls in order to avoid clinical and subclinical acidosis. As such, efficiency can be increased, performance optimised and the welfare of the animal improved.

2. MATERIALS AND METHODS

2.1. Animals and management

To investigate the effects of the SV of the diet on zootechnical performance and on carcass and meat quality, 52 BB dm bulls were used. The animals were purchased at the market at a mean weight of 277 kg. After an adaptation period of about 2 months with a diet based on grass silage, the animals were divided into four homogeneous groups. Therefore, at assignment of the bulls to one of the four groups, equal mean values and standard deviations for the body weight at the start, growth rate during the adaptation period, body conformation, age and the weight/age ratio were achieved for the four groups. At the start of the experiment, animals were weighed on three consecutive days. Thereafter, weight was determined once every four weeks and on two consecutive days at the end of a subperiod (at 84, 168 days and before slaughter). Fasted live weight was determined prior to slaughter, after a fasting period of 20 hours (deprived of food and water). The mean slaughter weight for each group was 680 kg.

The 13 bulls of each group were housed in two pens (one with 8 animals and one with 5). Two bulls from two different groups had to be removed: the first after 8 weeks due to a spine injury, the second after 7 weeks with several tumours.

2.2. Feeding and feed characteristics

The bulls were fed once daily to appetite and received a total mixed ration (TMR) based on maize silage and concentrate. Water was freely available. Supply of concentrate and maize silage was recorded daily for each pen. The SV of the diets was 0.79 units per kg DM for the HSV group (high SV), 0.62 for MSV (moderate) and 0.45 for LSV (low), while the fourth group (LSV + straw; LSVs) received the same diet as LSV, but long wheat straw was always available in the hayrack, to evaluate whether bulls are capable of compensating a possible lack of physical structure by eating straw. All animals were kept on wood shavings. The four groups received the same maize silage and although the concentrates differed between the groups, they were formulated to all have an SV of $0.2 \cdot kg^{-1}$ DM. The SV of the maize silage was estimated according to De Brabander et al. [7], and amounted to $1.82\ units \cdot kg^{-1}$ DM. The different SV of the groups were obtained by varying the ratios of maize silage/concentrate. The three diets contained 64, 74 and 84% concentrates on a DM-basis, respectively. Since all diets needed to be iso-nitrogeneous and iso-energetic and to have comparable amounts of minerals, trace-elements and vitamins, the ingredients in the concentrates differed (Tab. I). The concentrates were ground (sieve width 6 mm), but not pelleted to optimise the homogenisation of the concentrates with the silage. Chemical composition (Weende scheme and sequential fibre analysis, [30]) and nutritive value of the concentrates and the maize silage are shown in Table II. Energy values (NEF; net energy for fattening; [29]) were calculated from regression equations based on in vitro digestibility [5]. Protein values (DVE (true protein digested in the small intestine) and OEB (degraded protein balance)) were calculated based on the Dutch protein system [28].

2.3. Carcass and meat quality and rumen histology

After a chilling period of 24 hours, carcass quality parameters were determined. The carcasses were classified according to the SEUROP scheme [1] and dressing proportion (cold carcass weight divided by fasted live weight) was recorded. Carcass composition (bone, fat and lean) was assessed by dissection of the 8th rib-cut [31]. The *m. longissimus thoracis* (LT) surface area was estimated using a digitizer and a specific computer program to calculate the surface of the muscle starting from a photographic image. To assess the quality of the meat, a sample of the LT was taken from the 8th rib cut. Ultimate pH, waterholding capacity and colour were determined according to Boccard et al. [2]. Near Infrared Spectroscopy was used to estimate the chemical composition of the meat [6].

After slaughter, a sample of the ruminal wall (± 100 cm^2) was taken at a standardised spot in the *recessus ruminis* of the ventral ruminal sac and divided into four subsamples. One subsample, after fixation in 10% phosphate buffered formaldehyde solution, was used for histological examination of ruminal pathologies. The examination concerned: acanthosis of the ruminal epithelium, "rete pegs" formation (=epithelial ingrowths of the ruminal epithelium) into the lamina propria, parakeratotic

Table I. Ingredients of the concentrates ($kg \cdot t^{-1}$ as fed).

	Concentrate for group[1]		
	HSV	MSV	LSV and LSVs
Coconut meal	117.8	240.0	157.0
Protected soybean meal	179.6	111.6	71.3
Maize glutenfeed	47.5	54.2	–
Soybean meal	146.3	50.7	–
Rapeseed oilmeal	–	50	193.3
Wheat	300.0	200.0	226.0
Tapioca	–	134.3	150.0
Sugarbeet pulp	134.2	–	113.6
Pollards	–	112.9	52.9
Beef tallow	8.2	–	–
Trace elements	20.0	15.0	12.5
Vitamin mix (A, D_3 and E)	12.0	9.2	7.5
Salt	4.3	3.1	2.5
Limestone	17.7	19.0	13.4
Feed phosphate	12.4	–	–

[1] HSV = high physical structure value (SV = 0.79), MSV = moderate physical structure value (SV = 0.62), LSV = low physical structure value (SV = 0.45), LSVs = LSV + ad libitum straw in the hayrack.

Table II. Chemical composition and nutritive value of the feeds.

	Concentrates for group[1]			Maize silage	Straw
	HSV	MSV	LSV and LSVs		
Dry matter ($g \cdot kg^{-1}$)	874	873	874	298	856
Chemical composition ($g \cdot kg^{-1}$ DM)					
Crude protein	257	213	196	69	52
Ether extract	44	47	40	25	10
Crude fibre	90	91	113	206	400
Ash	82	75	72	39	107
NDF	258	294	300	419	744
ADF	103	122	142	223	446
Starch	218	275	276	237	–
Nutritive value					
SV ($units \cdot kg^{-1}$ DM)	0.20	0.20	0.20	1.82	4.30
DVE[2] ($g \cdot kg^{-1}$ DM)	181	148	131	51	18
OEB[3] ($g \cdot kg^{-1}$ DM)	25	10	7	–40	–35
NEF[4] ($MJ \cdot kg^{-1}$ DM)	8.61	8.31	8.14	6.85	3.27

Data are mean values of three analyses (one pooled sample per period).
[1] See footnote Table I.
[2] DVE = true protein digested in the small intestine.
[3] OEB = degraded protein balance.
[4] NEF = net energy for fattening.

hyperkeratosis, and infiltration of inflammatory cells. The score varied from 0 to 8, with 8 being very severe damage and 0 being no damage. The four parameters were first evaluated separately; afterwards a total score of damage to the ruminal wall was calculated by summation.

The other three subsamples of the ruminal wall were used to determine the length of the ruminal papillae. A mean value was calculated for each animal based on thirty measurements (10 randomly selected papillae from each subsample).

2.4. Statistical analysis

The significance of the treatments was tested using one-way analysis of variance, with treatment as the fixed factor following the model: $Y_i = \mu + T_i + e_i$ where μ is the overall mean, T_i is the effect of the treatment (4 treatments) and e_i is the residual error. Differences between groups were based on the Duncan test ($\alpha = 0.05$) [26]. The experimental units were individual data for live weight, liveweight gain, meat and carcass quality, ruminal histological pathology and length of rumen papillae, while pen data were the experimental units for feed intake and conversion.

3. RESULTS AND DISCUSSION

3.1. Animal performance

Table III shows the effect of the four treatments on the duration of the trial, live weight and growth rate. The total period averaged 230 days. The total trial length was shorter ($P = 0.01$) for the LSV group (213

Table III. Effect of dietary physical structure value on live weight and growth rate.

	Treatments[1]					
	HSV	MSV	LSV	LSVs	SEM	*P*
Number of bulls	13	12	13	12		
Experimental days	233[a]	234[a]	213[b]	238[a]	3	0.01
Live weight (kg)						
Initial	331	330	332	331	2	NS
Day 84	482	484	488	480	3	NS
Day 168	597	597	608	600	5	NS
Final	678	670	668	674	6	NS
Growth rate (kg·d^{-1})						
Start – day 84	1.80	1.83	1.85	1.77	0.03	NS
Day 85 – 168	1.37	1.34	1.43	1.43	0.04	NS
Day 169 – slaughter	1.23[ab]	1.12[ab]	1.35[a]	1.06[b]	0.04	0.10
Total period	1.48	1.45	1.58	1.44	0.03	NS

[a,b]: Means in a row with different letters differ significantly ($P < 0.05$).
[1] See footnote Table I.

vs. 235 days). This was mainly due to a higher growth rate during the third period. As intended, the four groups had comparable weights at the start and at slaughter. Growth rate was comparable for the four groups during the first and second subperiod averaging 1.81 and 1.39 kg·d^{-1} respectively. The higher growth rate during the third period of the LSV group compared with LSVs, indicates that free access to straw does not always guarantee better performance. By eating straw, the bulls of the LSVs group may have reduced the energy concentration of the diet and hence energy intake. Surprisingly, the growth rate of the HSV and MSV groups, was not higher than that of the LSV group during any of the three periods.

The data on intake and feed conversion are shown in Table IV. Few significant differences were found between the four groups concerning feed intake or feed conversion. Although, during the first period, DM- and NEF-intake of the LSV group was higher than that of the HSV and MSV group, these differences did not result in differences concerning feed conversion.

During the second and third period, the LSV group always had the highest intake numerically, but the differences were never significant.

Steen and Kilpatrick [27] compared ad lib. fed grass silage based diets with different amounts of supplemental barley: 0, 120, 240 and 360 g·kg^{-1} DM intake. They found energy intake and growth rate to increase with increasing proportions of barley. In a comparable trial, Patterson et al. [23] increased the concentrate (mainly barley meal) proportion in the diet from 0 to 850 g·kg^{-1} DM intake and found the same results. In our trial however, diets were iso-energetic, and therefore fewer differences were found concerning growth rate and intake.

Daily straw intake of LSVs averaged 170, 220 and 260 g during the three subperiods, respectively and represented 2.3, 2.6 and

Table IV. Influence of dietary physical structure value on daily intake and on feed conversion.

	Treatments[1]					
	HSV	MSV	LSV	LSVs	SEM	*P*
			Feed Intake			
DM (kg)						
Start – day 84	7.39[a]	7.36[a]	7.76[b]	7.60[ab]	0.08	0.08
Day 85 – 168	8.30	8.12	8.63	8.46	0.12	NS
Day 169 – slaughter	8.45	8.53	8.96	8.67	0.11	NS
Total period	8.01	7.96	8.36	8.21	0.08	NS
NEF[b] (MJ)						
Start – day 84	58.8[a]	58.8[a]	62.1[b]	59.9[ab]	0.63	0.08
Day 85 – 168	66.0	63.7	68.6	66.1	1.02	NS
Day 169 – slaughter	68.2	68.3	70.8	67.4	0.88	NS
Total period	64.1	63.2	66.5	64.3	0.62	NS
			Feed conversion			
DM (kg·kg^{-1} growth)						
Start – day 84	4.11	4.01	4.18	4.30	0.05	NS
Day 85 – 168	6.06	6.06	6.04	5.89	0.08	NS
Day 169 – slaughter	6.88	7.65	6.65	8.21	0.27	NS
Total period	5.40	5.48	5.29	5.70	0.07	NS
NEF[b] (MJ·kg^{-1} growth)						
Start – day 84	32.7	32.0	33.5	33.9	0.40	NS
Day 85 – 168	48.2	47.6	48.0	46.1	0.66	NS
Day 169 – slaughter	55.6	61.3	52.6	63.8	2.07	NS
Total period	43.1	43.5	42.1	44.6	0.46	NS

[a,b]: Means in a row with different letters differ significantly ($P < 0.05$).
[1,2] See footnote Table I.

3.0% straw on a DM-basis. The SV of this diet amounted to 0.54, 0.56 and 0.56 during the three periods, respectively.

The straw intake in this trial was relatively low, because the LSVs group also had 15% of maize silage in the diet. Mayombo et al. [19] reported BB dm bulls fed a concentrate diet with straw available in the rack, having a straw intake of 12.5% DM during the fattening period. Boucqué et al. [4] measured a straw intake of 6.8% of DM for BB normal conformation bulls fed a concentrate diet with straw available in the rack.

Few influences of the feeding regimens were found on carcass and meat characteristics (Tab. V). A significant difference was found in fasting weight loss. However, the differences between the groups were difficult to explain. The group receiving most concentrates in the diet was expected to have the smallest weight loss after fasting. In this trial, this was most certainly not the case. The mean dressing proportion of the four groups equalled 704 g·kg^{-1}. The mean conformation score for the four groups was 17.8. Statistical analysis indicated only a very slight tendency (P = 0.16) towards more fat with increasing amounts of concentrates in the diet. Increasing fatness with decreasing SV was expected based on the increasing proportion of concentrate in the diets. Rumen fermentation then shifts towards more propionic acid. Propionic acid increases insulin concentration [16], which in

Table V. Effect of dietary physical structure value on carcass and meat (m. longissmus muscle; LT) characteristics.

	Treatments[1]					
	HSV	MSV	LSV	LSVs	SEM	*P*
Fasted live weight (kg)	658	654	647	657	5.7	NS
Fasting weight loss ($g \cdot kg^{-1}$)	30^{bc}	25^{ab}	31^{c}	24a	1.0	0.02
Cold carcass weight (kg)	462	462	455	462	3.9	NS
Dressing proportion ($g \cdot kg^{-1}$)	702	707	703	703	1.6	NS
LT surface (cm^2)	158	160	161	158	2.9	NS
SEUROP-classification						
conformation [2]	17.5	17.8	18.0	17.8	0.1	NS
fatness [3]	5.6	5.7	5.9	5.8	0.1	NS
Carcass lean meat ($g \cdot kg^{-1}$)	770	776	767	759	0.3	NS
Carcass fat ($g \cdot kg^{-1}$)	106	100	108	117	0.3	NS
Carcass bone ($g \cdot kg^{-1}$)	124	123	124	124	0.1	NS
LT colour: L*	44.1	45.7	45.2	46.6	0.7	NS
LT colour: a*	17.2	17.4	17.9	18.1	0.2	NS
LT colour: b*	14.4	15.1	14.9	15.2	0.3	NS
Moisture in LT($g \cdot kg^{-1}$)	753	752	752	754	0.5	NS
Protein in LT($g \cdot kg^{-1}$)	227	228	228	227	0.7	NS
Fat in LT($g \cdot kg^{-1}$)	11	12	11	11	0.2	NS
Drip loss ($g \cdot kg^{-1}$)	69	73	72	63	1.7	NS
Cooking loss ($g \cdot kg^{-1}$)	240	235	234	242	2.6	NS
Ultimate pH	5.5	5.5	5.5	5.5	0.01	NS
Shear force (N)	42.9	54.9	52.9	42.6	2.5	NS

[a,b]: Means in a row with different letters differ significantly ($P < 0.05$).
[1] See footnote Table I.
[2] S = 18, E = 15, U = 12, ..., P = 3 points.
[3] Class 1 = 3 (very lean), Class 2 = 6, ..., Class 5 = 15 points (very fat).

turn is correlated with the degree of fatness of an animal [25]. As such the fat covering (SEUROP-grading) of the carcasses of the LSV and LSVs groups are somewhat (not significant) higher in comparison with the two other groups. Fiems et al. [13] found a negative relation between fat content in the carcass and SV of the diet with bulls being fed high amounts of starch. However, fat covering was not influenced. Patterson et al. [23] found a linear relationship between the proportion of concentrates in the diet and the fat covering of the carcass as well as with the separable fat in the carcass.

Fat content in the carcass increased from 100 (MSV) to 117 $g \cdot kg^{-1}$ (LSVs). Although a low fat content is typical for the double-muscled strain of the BB breed [10, 12], carcasses containing less than 110 g $fat \cdot kg^{-1}$ are quite exceptional. Fiems et al. [11] found the fatty tissue of BB dm bulls to vary between 121 and 133 $g \cdot kg^{-1}$, after a comparable fattening period (370–690 kg). Surprisingly, their figures on fat covering (SEUROP; between 5.4 and 6.1) were not different from those found here (5.6–5.9). It is not clear why the carcass fat contents in this study were that low.

None of the meat quality characteristics indicated a significant influence of the physical structure level. This is in agreement with Patterson et al. [23] who found no effect of increasing the proportion of concentrates on meat quality.

3.2. Rumen pathology

In Table VI, the results of the histological parameters of the ruminal wall are listed. The height of the papillae of the four groups was comparable. Mayombo et al. [19] found higher papillae in the rumen of bulls fed a concentrate diet mixed with chopped straw in comparison with the same concentrate diet with ad libitum long straw. This suggests a more abrasive effect of the long straw in comparison with chopped straw, causing a smaller absorption surface in the rumen of the first group, since the papillae are shorter. In this study, no abrasive effect of long straw was found, possibly because the straw intake was only 3% of total DM intake compared to 12.5% in the trial of Mayombo et al. [19].

The histological examination of the ruminal wall indicated that in general the animals of the MSV and LSV group demonstrated somewhat more ruminal pathology than the other groups. They had a significantly higher score for acanthosis of the ruminal epithelium and for "rete pegs" formation in the lamina propria than the HSV group. The total score was also much lower for the HSV group than for the MSV and LSV groups. However, it is unclear whether the histological damage as found in our study causes physical suffering and implicates a welfare problem. No aberrant behaviour was noted in any of the groups.

Due to the straw intake of the LSVs group, the SV of the diet increased. Tendencies for less severe pathology scores for the LSVs group were found in comparison with the MSV and LSV groups. However, somewhat more (not significant) infiltrations of inflammatory cells were found in LSVs bulls. Additional research (De Bosschere; personal communication) indicated that the inflammatory reactions consisted mainly of lymphocytes, especially organised in foci, located at the bottom of the papillae. Occasionally, foci of lymphocytes were observed in the lamina propria of the papillae. Additionally, sometimes mild to moderate amounts of eosinophils were also observed. The exact nature (immunologic and/or allergic) of the inflammatory reaction remains unclear, however, ruminal acidosis is unlikely to be at the origin of it.

The ruminal mucosa of adult animals fed on adequate amounts of roughage normally has numerous long, gray-white papillae protruding from its surface [17]. These are lined by a thin layer of keratinized stratified

Table VI. Effect of dietary physical structure value on characteristics of the rumen papillae.

	Treatments[1]					
	HSV	MSV	LSV	LSVs	SEM	*P*
Mean height of papillae (cm)	1.35	1.39	1.44	1.43	0.02	NS
Histology						
Acanthosis of ruminal epithelium	1.1[a]	3.2[ab]	3.9[b]	2.2[ab]	0.4	0.04
Rete pegs in lamina propria	0.8[a]	3.8[b]	3.4[b]	2.2[ab]	0.4	0.01
Parakeratotic hyperkeratosis	3.3	2.9	3.2	3.0	0.2	NS
Infiltration of inflammatory cells	1.4	1.8	1.3	2.6	0.3	NS
Total score	6.5[a]	11.8[b]	11.8[b]	9.9[ab]	0.9	0.10

[a,b]: Means in a row with different letters differ significantly ($P < 0.05$).
[1] See footnote Table I.

squamous epithelium [15]. The papillae in animals fed diets high in concentrate, barley, or pelleted alfalfa become black, blunted, hard, and form clumps [17]. Microscopically, the epithelium of these altered papillae is acanthotic, hyperkeratotic and parakeratotic. These symptoms inhibit the rate of VFA absorption [15, 18, 21]. The pathogenesis of these mucosal changes involves changes in the concentrations, type, and relative proportions of the volatile fatty acids produced in the rumen, in the ruminal pH and in the amount and quality of the roughage being fed [17]. Increased concentrations of propionic and butyric acids, reduced levels of acetic acid and lower ruminal pH initiate keratinisation of the epithelium [14]. Hyper– and parakeratosis of the ruminal epithelium do not cause clinical illness as far as it is known, but rather interfere with weight gains and productivity [24] due to a reduced absorption. The somewhat higher histological damage found in the MSV and LSV group had no consequences on the zootechnical results.

4. CONCLUSION

Based on a similar growth rate, feed conversion and carcass and meat quality, no adverse effects were found on feeding a diet with an SV of 0.45. However, somewhat higher histological damage was found in the MSV and LSV groups, probably indicating a shortage of physical structure. Further research is needed to confirm earlier reports that such histological damages have no impact on the welfare of ruminants. In this case, this trial indicates that a diet with a SV of 0.45 can guarantee optimal performances for finishing Belgian Blue double-muscled bulls, without inducing welfare problems.

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