EFFECT OF XYLOOLIGOSACCHARIDES SUPPLEMENTATION IN DRINKING WATER AND FEED RESTRICTION ON FAECAL DIGESTIBILITY, GROWTH TRAITS AND ENERGY AND NITROGEN RETENTION EFFICIENCY IN GROWING RABBITS

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ABSTRACT

The objective of this work was to evaluate the effect of xylooligosaccharides supplementation in water (XOS) and its potential synergy with feed restriction on fecal apparent digestibility, nitrogen and energy retention efficiency. Four treatments in a factorial arrangement were used: 2 levels of XOS (0.0 and 7.5 g/L) × 2 feeding plans (*ad libitum* and restricted, from 32 to 51 d of age). A total of 106 32-d old rabbits weighing 687 ± 126 g were blocked by litter randomly assigned to the four treatments and caged individually. The restricted group was fed with 50% the feed eaten by the *ad libitum* group at weaning and the daily feed supply increased linearly until 100% of intake of the libitum group at 51 d of age. Fecal digestibility was determined between 39 and 43 d (D1) and between 59 and 62 d of age (D2) (9 rabbits/treatment), and energy and body composition at 32, 51 and 59 d of age using bioelectrical impedance technique. XOS supplementation improved energy and protein digestibility in D1 (by 4 and 5%; $P \leq 0.032$) but had no effect in D2. XOS supplementation had no influence on feed intake and mortality but tended to impair growth rate along the whole experimental period ($P = 0.076$), and nitrogen retention in the body and in the carcass from 32 to 51 d of age ($P \leq 0.079$) mainly due to the trend for a higher urinary nitrogen excretion ($P = 0.082$). It led to a reduction of nitrogen and energy retention efficiency in this period ($P \leq 0.046$). Feed restriction improved energy and protein digestibility in D1 (by 5 and 8%; $P \leq 0.011$), with no effect in D2. In the whole experimental period feed restriction resulted in a 82% of the *ad libitum* feed intake. It reduced mortality (20.0 *vs*. 0%; $P < 0.001$), improved the efficiency of nitrogen retention in the carcass (by 7%; $P < 0.001$) and tended to increase that of energy ($P = 0.090$), but impaired growth rate (by 8%; $P < 0.001$), nitrogen and energy retention in the carcass (by 5 and 9%; $P \leq 0.003$). In conclusion, XOS supplementation did not improve growth performance, and even impaired some traits, while gradual feed restriction helped to control mortality with a slight impairment of some growth traits.

Keywords: Xylooligosaccharides, Feed restriction, Energy and nitrogen retention efficiency, Rabbit.

INTRODUCTION

The oligosaccharides that are released by intestinal degradation of structural carbohydrates (Pedersen *et al*., 2015) could be related to the positive effects that soluble fibre has been observed in groups affected by enteropathy (Trocino *et al*., 2013; Delgado *et al*., 2018). In fact, xylooligosaccharides tended to reduce mortality rate just after weaning during the supplementation period (Farias-Kovac, 2021). In contrast, in the first part of the current study, the XOS supplementation reduced feed intake, and tended to reduce the growth rate and increase mortality (Farias-Kovac, 2021). On the opposite, feed restriction has demonstrated consistent positive results to minimize mortality and optimize feed efficiency after weaning, although has the disadvantage of the impairment of growth traits when the fattening period is short like in Spain (Romero *et al*., 2010; Gidenne *et al*., 2012), so that a progressive feed restriction plan might be of interest (Duperray and Guyonvarch, 2009; Birolo *et al*., 2016). The aim of this study is to evaluate the potential effects of XOS, as well as its possible synergy with the feed restriction on nitrogen and energy retention efficiency.

MATERIALS AND METHODS

Experimental design

Four treatments in a 2 x 2 factorial arrangement were used with two levels of XOS (0, and 7.5 g/L. minimum 95% XOS, Xi'an Chen Lang Biological Technology Co. Ltd., China) along the whole fattening period, and two feeding plans (*ad libitum*, AL, and restricted, R). Restriction started with a 50% of the AL group and increased progressively until 100% at 51 d of age inspired in the feeding plan studied by Duperray and Guyonvarch (2009) and Birolo *et al*. (2016). From 51 to 53 d restricted rabbits were offered the same feed eaten by the AL group, and from 53 to 59 d they were fed completely *ad libitum*. A control diet was formulated to meet the nutrient requirements for growing rabbits with 20.3% crude protein, 34.8% neutral detergent fibre, 9% soluble fibre, 15.1% starch and 19.0 MJ/kg gross energy (on DM basis). A total of 106 rabbits weighing 687 ± 126 g were weaned at 32 d of age, blocked by litter, randomly assigned to the four treatments and individually caged. Due to the design of the farm, treatments were not balanced (XOS-AL=29 rabbits, XOS-R=25, XOS+AL=26, XOS+R=26). No antibiotic was supplied. Rabbits had *ad libitum* access to water, and those that finished with 1.5 kg body weight or less were considered as morbids and excluded from the analysis. Faecal digestibility was determined (9/treatment) from 39 to 43 d of age (D1), and from 59 to 62 d of age (D2), and growth traits recorded (see Farias-Kovac, 2021). In vivo body and carcass chemical composition and energy content were estimated using the bioelectrical impedance analysis (BIA) technique (Saiz *et al*., 2013a, b and 2017). Measurements of resistance and reactance were done at 32, 51 and 59 d of age. Multiple regression equations according to Saiz *et al*. (2013a, b and 2017) were used to estimate water, protein, ash, fat and energy proportions both in the body and in the carcass. Nitrogen and energy retention efficiency were determined according to Delgado *et al*. (2018).

Statistical Analysis

Data of nitrogen and energy balances were analyzed as a completely randomized design considering XOS level, feed restriction and their interaction as the main sources of variation and considering the heterogeneity of variances caused by the feed restriction. For this reason, two SEM values were reported in tables, one for mean values of *ad libitum* groups and another one for mean values of restricted groups (even when in some cases variances were homogeneous). Weaning weight was included as covariate. All data were presented as least-squares means.

Chemical Analyses

Methods of the AOAC (2000) were used to determine crude protein (method 968.06), and gross energy was measured by adiabatic bomb calorimeter (model 356, Parr Instrument Company, Moline, IL).

RESULTS AND DISCUSSION

In the first digestibility of this study (D1) XOS supplementation improved energy (62.9 *vs*. 60.3%) and protein (75.8 *vs*. 72.4%) ($P \leq 0.032$) digestibility but had no effect in D2 (data not shown). In the whole experimental period, XOS supplementation had no influence on mortality and feed intake (Table 1), although using a higher number of rabbits Farias-Kovac (2021) reported a reduction of 5% of feed intake. XOS tended to impair growth rate along the whole experimental period ($P = 0.076$) and tended to reduce nitrogen retention in the body and in the carcass from 32 to 51 d of age ($P \leq 0.079$), mainly due to the trend for a higher urinary nitrogen excretion ($P = 0.10$. Data not shown). It led to a reduction of digestible nitrogen and energy retention efficiency in this period ($P \leq 0.044$), that was lost in the second phase of fattening, resulting in a trend in the whole experimental period ($P \leq 0.082$). These results resemble partially those of xylose supplementation in pigs. It reduced nitrogen retention and increased nitrogen and xylose losses in urine (Schutte *et al*., 1991; Huntley and Patience, 2018). Together with the minor effects of XOS on ileal and caecal volatile fatty acids (Farias-Kovac, 2021) suggest that at least part of XOS might be absorbed as xylose. The latter might be accounted for the potential β-xylosidase activity in the stomach/duodenum/jejunum according to their optimal enzyme conditions defined in vitro (Lagaert *et al*., 2011), and assuming its presence in the soft faeces, rather than for a solubilization in the stomach acidic conditions (Courtin *et al*., 2009).

Table 1: Effect of xylooligosaccharides supplementation (XOS) and feeding plan (*Ad libitum vs.* Restricted -Rest-) on energy and nitrogen retention efficiency.

XOS supplementation	**XOS –**		**XOS +**		SEM[1]		P-value[2]	
Feeding plan	*Ad libitum*	Rest.	*Ad libitum*	Rest.	*Ad libitum*	Rest.	XOS	Feeding plan
n[3]	**29**	**25**	**26**	**26**				
32 - 51 d of age (restriction period)								
Growth rate, g/d	64.3	50.8	59.5	48.8	2.82	0.78	0.106	<0.001
Feed intake, g/d	154	106	149	101	7.50	1.03	0.370	<0.001
[4]Water intake, ml/d and rabbit	228	256	214	216	-	-	-	-
[4]Ratio water/feed intake	1.68	2.44	1.55	2.18	-	-	-	-
[4]XOS intake per animal, g/d	0.0	0.0	1.60	1.62	-	-	-	-
Mortality, %	17.2	0.0	11.5	0.0	-	-	0.50	0.001
Body weight (BW)$^{0.75}$	1.22	1.13	1.19	1.12	0.019	0.005	0.108	<0.001
Digestible N intake, g/kg BW$^{0.75}$ d, DN_i	2.795	2.243	2.896	2.286	0.119	0.021	0.398	<0.001
N retained, g/kg BW$^{0.75}$ d, NR								
NR body	1.361	1.165	1.284	1.124	0.045	0.014	0.079	<0.001
NR carcass	0.890	0.743	0.821	0.717	0.031	0.014	0.052	<0.001
Nitrogen efficiency								
NR body/DN_i	0.496	0.519	0.451	0.492	0.017	0.008	0.009	0.022
NR carcass/DN_i	0.324	0.331	0.288	0.313	0.012	0.006	0.006	0.101
DE intake, MJ/ kg BW$^{0.75}$ ·d, DE_i	1.30	1.01	1.33	1.03	0.056	0.009	0.49	<0.001
Energy retained, kJ/kg BW$^{0.75}$ ·d, ER								
ER body	446	316	398	316	21.6	7.47	0.141	<0.001
ER carcass	261	189	233	189	12.8	4.35	0.155	<0.001
Energy efficiency								
ER body/DE_i	0.348	0.314	0.305	0.308	0.015	0.008	0.044	0.21
ER carcass /DE_i	0.204	0.188	0.178	0.184	0.009	0.004	0.033	0.492
32 - 59 d of age (total period)								
Growth rate, g/d	61.0	56.7	59.3	54.2	1.41	0.89	0.076	<0.001
Feed intake, g/d	164	136	160	130	5.24	1.73	0.183	<0.001
[4]Water intake, ml/d and rabbit	266	295	276	276	-	-	-	-
[4]Ratio water/feed intake	1.76	2.15	1.84	2.19	-	-	-	-
[4]XOS intake per animal, g/d	0.0	0.0	2.07	2.07	-	-	-	-
Mortality, %	24.1	0.0	15.4	0.0	-	-	0.38	<0.001
Metabolic weight, BW$^{0.75}$	1.366	1.327	1.350	1.304	0.013	0.008	0.081	<0.001
Digestible N intake, g/kg BW$^{0.75}$ d, DN_i	2.687	2.369	2.695	2.366	0.069	0.020	0.962	<0.001
Nitrogen retained, g/kg BW$^{0.75}$ d, NR								
NR body	1.181	1.123	1.156	1.090	0.018	0.012	0.065	<0.001
NR carcass	0.786	0.761	0.778	0.723	0.015	0.011	0.077	0.003
Nitrogen efficiency								
NR body/DN_i	0.444	0.474	0.430	0.462	0.009	0.006	0.082	<0.001
NR carcass/DN_i	0.296	0.322	0.289	0.306	0.007	0.005	0.058	<0.001
DE intake, MJ/ kg BW$^{0.75}$ ·d, DE_i	1.237	1.095	1.238	1.078	0.032	0.009	0.752	<0.001
Energy retained, kJ/kg BW$^{0.75}$ ·d, ER								
ER body	428	381	412	365	11.0	7.22	0.094	<0.001
ER carcass	255	238	250	224	6.78	4.95	0.107	<0.001
Energy efficiency								
ER body/DE_i	0.349	0.349	0.333	0.339	0.007	0.006	0.063	0.647
ER carcass/DE_i	0.208	0.218	0.202	0.208	0.005	0.004	0.064	0.075

[1] Due to variance heterogeneity, a SEM value was included for each mean of the *ad libitum* groups, and another one for the means of restricted groups.[2] The interactions XOS × Feeding plan were not significant (P > 0.10). [3] Dead rabbits were not considered for nitrogen/energy balances, as well as other rabbits that had digestive troubles or aberrant values of intake or impedance (3, 1, 4, 3, in each treatment, respectively). [4] Data derived from Farias-Kovac (2021).

In D1 feed restriction improved digestibility of energy (63.2 *vs*. 60.0%) and protein (76.9 *vs*. 71.2%) ($P \leq 0.011$), with no effect in D2. In the whole experimental period, feed restriction resulted in an 82% of the *ad libitum* feed intake. In this period, it reduced mortality (20.0 *vs*. 0%; $P < 0.001$) and improved the efficiency of nitrogen retention in the carcass (by 7%; $P < 0.001$) and tended to increase that of energy ($P = 0.075$), but growth rate impaired (by 8%; $P < 0.001$), as well as the nitrogen and energy retention in the carcass (by 5 and 8%; $P \leq 0.003$). Nevertheless, restricted rabbits showed a great compensatory growth in the last week considering they had a slower growth during the restriction period (19% reduction in growth rate). Previous results of this experiment indicated no modification of the dressing out performance with feed restriction (57.8% on average; Farias-Kovac, 2021), in agreement with the proportional reduction of the energy and nitrogen losses in the skin and viscera with the energy and nitrogen retained in the carcass. These results are mostly in agreement with those associated with feed restriction reviewed by Gidenne *et al*. (2012) and reported by Birolo *et al*. (2016). The reduction of growth rate due to feed restriction was similar in this study than that reported by Romero *et al*. (2010) (where rabbits had access to feeders for 8 h/d), although the higher growth rate of the *ad libitum* group allowed in this study that rabbits attained the market weight at 59 d of age. There was no relevant interaction between XOS and feed restriction.

CONCLUSIONS

XOS supplementation did not improve and even tended to impair growth traits and nitrogen and energy balance, while a gradual feed restriction helped to control mortality with a slight impairment of some growth traits. No relevant synergism existed between XOS and feed restriction.

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