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Soluble fibre, starch and protein level in diets for growing rabbits: Effects on digestive efficiency and productive traits

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ABSTRACT

From 29 d of age until slaughter (78 d), 246 hybrid rabbits were divided into six experimental groups and fed six diets *ad libitum* according to a bi-factorial arrangement with two soluble fibre-to-starch ratios (0.5 and 1.1), obtained by replacing starch (from 178 to 130 g/kg) with soluble fibre (from 84 to 141 g/kg), and three levels of crude protein (139, 154, and 172 g/kg diet). Growth traits were recorded on all rabbits; total tract apparent digestibility coefficients (CCTAD) were measured on 72 rabbits. Gut traits were obtained from further 36 rabbits slaughtered at 38 d of age. The increase in the soluble fibre-to-starch ratio increased ($P < 0.001$) the CTTAD of the dry matter (0.605–0.670) and almost all nutrients and decreased ($P < 0.001$) feed intake (7.0%) and feed conversion (8.4%) over the whole trial. The increase in the soluble fibre-to-starch ratio decreased the pH (5.87–5.71, $P < 0.05$) and the ammonia-N level (4.72–2.33 mmol/L; $P = 0.001$), and increased the total volatile fatty acid (VFA) content (64.0–78.4 mmol/L; $P < 0.01$) of the caecal contents. When the crude protein concentration was increased, the CTTAD of almost all nutrients increased linearly ($P < 0.01$), the daily growth rate (5.3%; $P < 0.001$) increased, and the feed conversion decreased (4.7%; $P < 0.001$). At slaughter, a higher dietary protein level was associated with a greater live weight of animals (2729–2840 g; $P < 0.01$) and carcasses. The proportion of the gastro-intestinal tract decreased (190–184 g/kg slaughter weight; $P < 0.05$) and the dressing percentage increased (60.1–60.7% slaughter weight; $P < 0.05$). In the caecum, the total VFA level linearly increased from rabbits fed low-protein diets to rabbits fed high-protein diets (61.2–78.4 mmol/L; $P < 0.01$). Neither the dietary soluble fibre-to-starch ratio nor the protein level affected the health status of the rabbits or the morphology of the gut mucosa. In conclusion, the use of diets with high soluble fibre concentrations (141 g/kg) and low starch concentrations (130 g/kg) enhanced the digestive efficiency, growth performance, and caecal fermentation of growing rabbits, despite the moderate level of acid detergent fibre (ADF: 164 g/kg). In contrast, reducing the amount of dietary protein from 172 to 139 g/kg decreased the growth performance and caecal fermentation activity of rabbits. In the tested range, the soluble fibre-to-starch ratio and the protein level did not show relevant interactions, and the health status was not affected by these dietary treatments.

Abbreviations: ADF, acid detergent fibre; aNDF, neutral detergent fibre assayed with a heat-stable amylase and expressed inclusive of residual ash; CTTAD, coefficient of total tract apparent digestibility; DE, digestible energy; DM, dry matter; DP, digestible protein; ERE, epizootic rabbit enteropathy; L, probability of the linear component of variance; LW, live weight; RC, reference carcass; RSD, residual standard deviation; SW, slaughter weight; TDF, total dietary fibre; VFA, volatile fatty acids.

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1. Introduction

In rabbit feeding, the insoluble fibre (hemicelluloses, cellulose and lignin) (Mertens, 2003) and the less lignified fibre fractions influence the rate of passage of the digesta, are substrate for microorganisms, and thus affect and regulate the growth performance and digestive health of rabbits (Gidenne et al., 2010a; Gidenne et al., 2010b). The insoluble fibre is recognised as the most effective fibre fraction since a long time, whereas the role of the less lignified fractions has been investigated later. Among these latter fractions, "digestible fibre" (hemicelluloses and pectins) has been firstly proposed by Gidenne (2003) as a reference in rabbit nutrition. However, the digestive utilisation of hemicelluloses may greatly vary according to their nature because of different lignification and complexity of the cell walls or different hemicelluloses constituents (Gidenne, 1992; Carabaño et al., 2001; García et al., 2002). Therefore, besides insoluble fibre, soluble fibre (SF; pectins, β-glucans) is going to be used to evaluate fibre quality in diets for rabbits as for other species (Hall, 2003; Mertens, 2003; Xiccato et al., 2012).

The increase of dietary SF has been shown to improve intestinal mucosa integrity and to modulate the intestinal microbiota of rabbits (Gómez-Conde et al., 2007; Gómez-Conde et al., 2009). Besides soluble fibre may also replace starch in diets for growing rabbits without negative effects on diet utilisation and growth performance when the insoluble fibre level is kept constant (Trocino et al., 2011), because it contributes to increase the energy value of diets (De Blas and Carabaño, 1996; Perez et al., 2000; García et al., 1993). However, the effects of increasing the soluble fibre level in rabbit feed and the interactions between soluble fibre and other dietary nutrients have not been fully elucidated (Trocino et al., 2013). In a rather restricted range of dietary crude protein (152–162 g/kg), Xiccato et al. (2011) found that feeding growing rabbits with low-protein, high-soluble fibre-to-starch ratio diets reduced mortality, increased digestive efficiency, and improved the intestinal environment without affecting growth performance.

A high dietary protein level (>160 g/kg) guarantees the best growth performance, but increases the nitrogen excretion of rabbits (Maertens et al., 1997; Xiccato and Trocino, 2010), may impair caecal fermentation and alter the composition of the gut microflora, and is also considered a risk factor of increased mortality in rabbits (De Blas et al., 1981; Carabaño et al., 2009).

This study aimed to determine whether decreasing the crude protein concentration from high to low values (from 172 to 139 g/kg) and increasing the soluble fibre-to-starch ratio (from 0.5 to 1.1) by replacing starch (from 178 to 130 g/kg) with soluble fibre (from 84 to 141 g/kg) could affect the feed efficiency, growth performance, and slaughter results, in addition to the gut conditions, of fattening rabbits.

2. Materials and methods

2.1. Animals and diets

The trial was approved by the Italian Ministry of Education, University and Research and by the Ethical Committee of the University of Padova, and all animals were treated humanely according to the principles stated by EC Directive 86/609/EEC regarding the protection of animals used for experimental and other scientific purposes.

A total of 282 rabbits of both sexes from a hybrid line (Eurolap, Hyla, Gosné, France) were reared in individual cages from weaning at 29 d of age until their slaughter, at 78 d. Out of the initial number, 246 rabbits were used to assess growth performance, digestibility, and slaughter traits, and the remaining 36 rabbits were slaughtered at 38 d to sample the caecal contents and the intestinal mucosa. The rabbits were kept in a brick shed equipped with forced heating and ventilation systems to maintain a temperature within the range 18–25 °C. The rabbits were exposed to a natural photoperiod (11–13 h) during the months of March and April.

Four diets were formulated with the combination of a low (LP, 139 g/kg) or high (HP, 172 g/kg) crude protein concentration and a low (LR, 0.5) or high (HR, 1.1) soluble fibre-to-starch ratio, that is diets LP–LR, HP–LR, LP–HR, HP–HR (Tables 1 and 2). A dilution technique was used to obtain two more diets with intermediate levels of crude protein (154 g/kg): diet MP–LR (0.5 LP–LR + 0.5 HP–LR) and diet MP–HR (0.5 LP–HR + 0.5 HP–HR). All diets were supplemented with synthetic amino acids (lysine, methionine and threonine), minerals, and vitamins to satisfy the nutritional requirements of growing rabbits (De Blas and Mateos, 2010), and with a coccidiostat (Robenidine). No antibiotic treatment was administered in the feed or water.

From 29 d of age until slaughter, the rabbits were divided into six groups (47 rabbits per experimental diet) that did not differ with respect to live weight and variability, and the rabbits were given access to the six experimental diets *ad libitum*.

Individual live weight and feed intake were recorded once per week. The health statuses of the rabbits were controlled daily.

2.2. Sampling of the caecal contents and the intestinal mucosa

Thirty-six rabbits out of the 282 initial rabbits were slaughtered at 38 d of age (6 rabbits per experimental diet) to sample the caecal contents and the intestinal mucosa. The slaughtered animals were representative of their corresponding experimental groups in terms of the average live weight and variability. The rabbits were slaughtered between 08:00 and 12:00 h. They were weighed immediately before slaughtering by cervical dislocation. Thereafter, the full gut and then the stomach and the caecum were separated and weighed. The caecum was removed, and the pH of the caecal contents was