Feeding programmes based on highly-digestible fibre weaning diets: effects on health, growth performance and carcass and meat quality in rabbits

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Abstract

The effect of three different dietary programmes on health, growth performance and carcass and meat quality in young rabbits weaned at 28 d was studied using a diet (F) rich in highly-digestible fibre, from 17 to 63 d of age (group FF); using diet F from 17 to 42 d followed by a diet poor in highly-digestible fibre and rich in starch and fat (S) until 63 d (group FS); and using a standard diet C with intermediate highly-digestible fibre and starch content, containing 100 ppm of zinc-bacitracin, from 17 to 63 d (group CC). A highly-digestible fibre diet could be useful to reduce the incidence of digestive disorders. However, it decreased slaughter weight (2294 g in FF vs. 2406 g in CC; $P<0.05$) and carcass and meat traits, e.g. dressing out percentage (55.4% in FF vs. 56.7% in CC; $P<0.05$), meat to bone ratio (5.73 in FF vs. 5.94 in CC; $P<0.05$) and hind leg fat content (3.81% in FF vs. 4.71% in CC; $P<0.05$) at 63 d of age. Switching to a high starch and fat diet at late fattening improved chilled carcass weight at 63 d of age (1339 g in FS vs. 1263 g in FF; $P<0.05$) mainly through the promotion of liver development (7.53% in group FS vs. 6.47% in group FF; $P<0.05$) and fat deposition (3.89% in FS vs. 2.63% in FF; $P<0.05$), and increased hind leg fat content (+1.2 points of fat percentage; $P<0.05$). However, this switch increased health risk (35.1% in FS vs. 17.6% in FF; $P<0.05$).

Keywords: highly-digestible fibre, growth performance, carcass, meat quality, health, rabbits.

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1. Introduction

Digestive disorders are the main factor responsible for reduced performance and health in growing rabbits, especially in recent decades when the incidence of Epizootic Rabbit Enteropathy (ERE) has increased. The inclusion of antimicrobials has often controlled the negative effects of ERE, but has increased the health costs. Moreover, high usage of antimicrobials increases the risk of presence of residuals in the meat and impairs consumer perception towards intensive rabbit farming. It is well known that adequate nutrition and feeding strategies can minimise the risk of these disorders (Gidenne et al., 2010). Among these strategies, the beneficial effect of increasing highly-digestible fibre (mainly soluble fibre and hemicelluloses) and reducing starch on the digestive health of growing rabbits is well established (Blas and Gidenne, 2010; Martínez-Vallespín et al., 2011a; Trocino et al., 2013a) and consequently widely used. Highly-digestible fibre promotes fermentative activity and induces favourable changes in caecal environment (Martínez-Vallespín et al., 2013; Trocino et al., 2013b).

Soluble fibre has high water holding capacity promoting the formation of gels. Its dietary inclusion instead of starch could thus reduce digestive rate of passage and feed intake, but negative effects on live weight (LW) gain of growing rabbits has not been reported (Trocino et al., 2011; Martínez-Vallespín et al., 2011a). However, as recently reviewed (Trocino et al., 2013a), an increase in full gastrointestinal tract weight and a consequent reduction in dressing percentage have been reported when rabbits were fed with diets

containing high levels of soluble fibre, usually from sugar beet pulp. This possible detriment on carcass yield could be alleviated by switching to a more concentrated diet in late fattening period, when the incidence of digestive disorders is usually lower.

Thus, the aim of this work was to compare two feeding programmes based on the use of a highly-digestible fibre diet from the beginning of feed intake to the end of the fattening period or switching at 42 d to a diet poor in highly-digestible fibre and rich in starch and fat. Their effect on health, growth performance and carcass and meat quality was evaluated in an ERE context, in comparison with a standard feeding programme with intermediate highly digestible fibre and starch content containing 100 ppm of zinc-bacitracin.

2. Material and methods

2.1. Diets

Three pelleted diets were used in the current study. Diet F was characterised by a high level of highly-digestible fibre [HDF, calculated as the sum of neutral detergent soluble fibre (NDSF) and hemicelluloses; 384 g per kg dry matter (DM)]. Diet S was formulated mainly replacing part of this HDF (–140 g per kg DM) with starch (+101 g per kg DM) and ether extract (+23 g per kg DM) (Table 1). A medicated commercial rabbit diet (including 100 ppm of zinc-bacitracin; Bacipremix 50, Pintaluba, Spain) was used as a control (diet C). The diets had similar crude protein (CP) and acid detergent fibre (ADF)

contents (178 and 217 g per kg DM, respectively), and included 66 ppm of robenidine (Cycostat 66G, Alpharma, Belgium) as coccidiostat.

Chemical analyses of diets were performed according to the methods of the Association of Official Analytical Chemists (2000): 934.01 for DM, 942.05 for ash, 976.06 for CP and 920.39 for ether extract, with acid-hydrolysis of samples prior to the extraction. Starch content was determined according to Batey (1982), by a two-step enzymatic procedure with solubilisation and hydrolysis to maltodextrins with thermo-stable α-amylase followed by complete hydrolysis with amyloglucosidase. The resulting glucose was measured by the hexokinase/glucose-6 phosphate dehydrogenase/NADP system. Neutral detergent fibre (NDF), ADF and acid detergent lignin fractions were analysed sequentially (Van Soest et al., 1991) with a thermo-stable α-amylase pre-treatment and expressed exclusive of residual ash, using a nylon filter bag system. The NDSF content was determined according to Hall et al. (1997), after adapting the method to the modifications proposed by Martínez-Vallespín et al., (2011b).

2.2. Experimental design

The experimental procedures were approved by the Committee of Ethics in Research of the Universitat Politècnica de València and followed the rules established by the Royal Decree 1201/2005 (BOE, 2005) on protection of animals used for scientific purposes. Rabbits were housed in an experimental farm affected by ERE with temperatures of 18 to 24ºC and a photoperiod of 16 h light:8 h darkness throughout the experimental period.

Rabbits came from a three way cross using synthetic lines reared at Universitat Politècnica de València (Baselga, 2002). Crossbred females from lines A and V selected for reproductive traits were inseminated with semen from males of the parental line R selected for growth rate. At 17 days of age, 300 suckling rabbits were distributed in litters standardised to 10 animals, housed separately from the does in adjacent (50×70×32 cm WHL) cages and randomly assigned and fed with diet F (18 litters, group F) or diet C (12 litters, group C). Feed intake of the litters until weaning (28 days of age) and individual LW at 17 and at weaning at 28 days were controlled. Animals had access to suckling once per day and milk intake was measured at days 21, 22, 23, 24, 25 and 28 of lactation, by weighing the does before and after suckling. Females were always fed *ad libitum* with a commercial diet for reproductive rabbit does.

After weaning, 128 rabbits from group F and 64 rabbits from group C were housed in individual cages (26×50×31 cm). Animals from group C continued with diet C until 63 days of age (group CC). However, half of the rabbits from group F were switched to diet S (group FS) at 42 days of age and the remainder followed the F diet (group FF) until 63 days of age. LW and feed intake were measured at 28, 42 and 63 days of age. The remaining weaned rabbits (52 and 56 from F and C groups, respectively) were housed in collective cages (50×80×32 cm; eight per cage), and continued receiving their respective diets until 42 days of age. Mortality and morbidity (animals showing signs of digestive disorders or poor growth rate) were recorded daily both in individual and collective cages.

2.3. Carcass composition

Sixty animals from the collective cages (30 rabbits each of groups F and C) were slaughtered at 42 days. Thirty rabbits per group from the FF, FS and CC group individual cages were slaughtered at 63 days. All the animals were randomly selected and no fasting was practiced before slaughter. Rabbits were electrically stunned (90 V, 3 s, 50 Hz) and bled within 3 s. Skin and full gastrointestinal tract were removed and weighed. Small intestine and caecum were separated and emptied to obtain full and empty small intestine and caecum weight. Small intestine length was measured. Carcasses were suspended from the calcaneal tendon for 30 minutes in a ventilated area and then cooled in a refrigerated chamber at 3ºC. At 24 h post-mortem, carcasses were transported to the laboratory and weighed to obtain the chilled carcass weight (CCW). Liver, kidneys, scapular fat and perirenal fat where separated and weighed.

In rabbits slaughtered at 63 days, and according to the norms of the World Rabbit Science Association (Blasco and Ouhayoun, 1996), head and thoracic viscera (the set of lungs, thymus, oesophagus and heart) were also removed from the carcass and weighed. The carcass obtained was weighed to obtain the reference carcass weight (RCW). The thoracic cage, forelegs, intermediate part and hind part were weighed. To determine meat to bone ratio, one of the hind legs was dissected to separate bone from meat and the weight of these parts was recorded.

2.4. Meat characteristics

156 Meat traits were evaluated at 24 h post-mortem using carcasses from 63 day old
157 rabbits. *Longissimus lumborum* muscle pH was measured at the level of the
158 fourth lumbar vertebra at 20 ºC by penetrating 3 mm, with a Mettler Toledo
159 MP220 pH meter probe. Colour measurements in the CIELAB space (Lightness,
160 L*; redness, a* and yellowness, b*; CIE, 1976) were measured using a Minolta
161 CR-300 Minolta Chromameter (Minolta Camera, Osaka, Japan), which gives the
162 average of three measurements of L*, a* and b* at each point. Carcass colour
163 was determined on the external surface of the *longissimus lumborum*, at the level
164 of the fourth lumbar vertebra (Pla et al., 1995). Meat colour was measured in the
165 transverse section after cutting the *longissimus lumborum* muscle at the level of
166 the sixth lumbar vertebra. To study meat composition, meat dissected from one
167 hind leg was ground in a domestic mincer and scanned with a Near Infrared
168 Spectroscopy monochromator (model 5000, NIR Systems Inc., Silver Spring,
169 MD, USA). Two round sample cups with 3.8 cm diameter quartz windows
170 were filled from each hind leg. Two spectra rotating each cup 90 degrees were
171 recorded. The four reflectance spectra of each hind leg were averaged. Meat
172 protein, total lipids and moisture percentages were estimated by applying
173 equations previously obtained by Pla et al. (2004).

174 *2.5. Statistical analysis*

175 Data for growth performance and carcass and meat quality were analysed using
176 the general linear models procedure of SAS (2009). Data were presented as
177 least square means and standard errors. The model included the group (F and C
178 until 42 days; FF, FS and CC until 63 days), the weekly batch (three batches of

179 animals) and their interaction as fixed effects. Litter nested to the interaction
180 between group and weekly batch was included as a random effect in the
181 analysis of data from 28 to 42 days of age. For carcass and meat quality traits
182 of rabbits at 63 days of age, sex was also included as fixed effect in the model.
183 Mortality and health risk index (mortality + morbidity) were analysed
184 according to a generalised linear model (GENMOD of SAS), including the
185 group as fixed effect.

186

187 **3. Results**

188 *3.1. Growth performance*

189 LW at 17 days old was similar for all the groups [on av. 326±1 g (least square
190 mean ± standard error)]. The performance from 17 to 42 days old is shown in
191 Table 2. Milk intake was similar, but feed intake, LW gain and LW at 28 days
192 of age were lower in group F than in group C (–27, –9 and –4%, respectively;
193 $P<0.05$). From 28 to 42 days of age, feed conversion ratio was 12% lower
194 ($P<0.05$) in group F but feed intake and LW gain did not differ significantly.
195 No differences in mortality and health risk index between groups from 17 to 42
196 days of age were found.

197 Growing rabbits in groups FF and FS had lower feed intake and LW gain from
198 42 to 63 days and lower LW at 63 days of age than those of group CC (–10,
199 –8, and –5%, respectively; $P<0.05$, Table 3). Although no significant
200 differences were found in mortality, the health risk index of group FS was
201 higher than that observed in group FF (+17.5%; $P<0.05$).

3.2. Carcass and meat quality

At 42 days of age (Table 4), animals fed with diet F were characterised by a heavier full gastrointestinal tract (+3.1% LW; $P<0.05$), as a result of heavier small intestines and caecums but especially of caecal content (+2.0% LW; $P<0.05$), and lighter skin (–0.5% LW; $P<0.05$) than those fed with diet C. CCW and dressing out percentage were lower in group F (–47 g and –2.5% LW, respectively; $P<0.05$), and F carcasses also showed less dissectible fat, mainly due to perirenal fat (–0.4 and –0.3% CCW, respectively; $P<0.05$).

Table 5 shows the effect of dietary group on carcass at 63 days of age. Animals that continued with diet F (group FF) had a heavier full gastrointestinal tract (+1.9% LW; $P<0.05$) than those that continued with diet C (group CC), mainly due to heavier caecum content (+1.5% LW; $P<0.05$), and lighter skin (–0.5% LW; $P<0.05$). CCW, dressing out percentage and RCW were lower in group FF compared to CC (–78 g, –1.3% LW and –51 g, respectively; $P<0.05$). FF carcasses also contained less liver and dissectible fat percentage and less meat to bone ratio (–1.1% CCW, –0.8% RCW and –0.21 g/g, respectively; $P<0.05$) and more head and hind part (+0.6% CCW and +0.9% RCW, respectively; $P<0.05$). On the other hand, animals that were changed to from the F to the S diets (group FS) were characterised by the lighter full gastrointestinal tract at 63 days of age (–3.4% LW compared to FF; $P<0.05$). Group FS had similar weight for caecum but higher for small intestine organ compared to FF (+0.2% LW; $P<0.05$). However, both small intestine and caecum contents were lower in group FS than in group FF (–0.3 and –1.3% LW, respectively; $P<0.05$).

225 CCW, dressing out percentage and RCW were higher in group FS compared to
226 FF (+76 g, +2.2% LW and +45 g, respectively; P<0.05). FS carcasses also
227 contained more liver and dissectible fat (+1.1% CCW, +1.3% RCW,
228 respectively; P<0.05) and less hind part (–0.9% RCW, respectively; P<0.05).

229 Meat quality at 63 days of age is shown in Table 6. The redness of the carcass
230 and meat of *longissimus lumborum* and the fat content in the meat of hind leg
231 was lower in group FF than in CC (–0.57 and –0.88 points of redness and
232 –0.9%, respectively; P<0.05). Hind leg meat had higher fat content in group FS
233 than in FF (+1.2 points of fat percentage; P<0.05).

234 **4. Discussion**

235 *4.1. Using a highly-digestible fibre diet over the entire growing period*

236 A high mortality rate was recorded during the trial (on av. 34% from 17 to 63
237 days of age), compatible with the history of ERE outbreaks on this
238 experimental farm. Under these conditions, the use of highly-digestible fibre
239 diets has been associated with reduced mortality rate (Soler et al., 2004;
240 Gómez-Conde et al., 2009; Martínez-Vallespín et al., 2011a; Grueso et al.,
241 2013). Animals fed with a diet including a high level of highly-digestible fibre
242 during the whole trial showed the lowest values for health risk index, achieving
243 a mortality rate (30%) similar to that obtained with a commercial diet including
244 a intermediate level of highly-digestible fibre and supplemented with zinc-
245 bacitracin (33%).

246 When compared with a standard commercial diet for growing rabbits, and
247 independently of milk supply (Martínez-Vallespín et al., 2011a), early

248 introduction of a diet with high NDSF (without varying other fibre fractions)
249 decreased feed intake and nutrient supply, reducing growth performance until
250 weaning. In contrast, animals fed with the high NDSF diet achieved a similar
251 LW at 42 days, showing an improvement in feed conversion ratio. However,
252 these results are mainly due to a greater development of the full gastrointestinal
253 tract, particularly of the caecum, resulting in a lower chilled carcass weight and
254 dressing out percentage at 42 days of age. When growing rabbits were kept on
255 the highly-digestible fibre diet until slaughter, not only chilled carcass weight
256 and dressing out percentage but also LW were impaired. Martínez-Vallespín et
257 al. (2013) reported that diets rich in pectins, usually from sugar beet pulp, led
258 to a higher caecal weight independently of simultaneous wide variations in the
259 level of insoluble fibre and/or starch. These results confirm that raising highly-
260 digestible fibre content of diet might impair both performance and carcass
261 yield of growing rabbits, although negative effects might be overestimated in
262 the current study because of a possible positive effect of zinc-bacitracin on
263 animals fed with the commercial diet.

264 Highly-digestible fibre diet resulted in a lower dissectible fat (already detected
265 at 42 days of age) and lower fat percentage in the meat of the hind leg,
266 probably as a consequence of lower energy intake with a higher protein to
267 energy ratio diet. A reduction in fat content of the empty body has been
268 observed when replacing barley by sugar beet pulp (García et al., 1993).
269 Trocino et al. (2013b) also found a lower dissectible fat percentage when using
270 growing rabbit diets with increased highly-digestible fibre content at the
271 expense of starch, in spite of a similar digestible energy intake. However,

Xiccato et al. (2011) did not find any effect of the level of soluble fibre to starch ratio on the dissectible fat percentage. To the authors' knowledge, there are no reports about the effect of dietary fibre on liver percentage in rabbits. In pigs, Weber et al. (2010) reported a reduction in liver weights when increasing dietary hemicelluloses at the expense of starch, concomitant with lower glycogen and triglyceride liver content, suggesting that there is a repartitioning of these nutrients from the liver when high fibre diets are used.

A possible lower degree of maturity of animals fed with the high NDSF diet, which were characterised by a lower LW at slaughter, could underlie their higher proportions of head and hind part as well as lower meat to bone ratio in the hind leg (Pascual et al., 2008), which has been reported to be a good predictor of the meat to bone ratio of the whole carcass (Hernández et al., 1996).

The effect of highly-soluble fibre level on carcass and meat colour seems controversial. According to our results and others from the literature (Trocino et al., 2010), this dietary change had no effect on meat colour. However, Xiccato et al. (2011) observed lighter meat colour when soluble fibre replaced starch. It could be hypothesised that dietary effects on meat colour might be more due to changes in ingredients than nutrients per se, which could explain the higher redness of meat from animals fed with the commercial diet.

4.2. Switching to a diet richer in starch and fat at late growing period

This switch to a more concentrated diet at late fattening, when the incidence of digestive disorders is usually lower, was proposed to alleviate the detriment on

carcass yield when using high NDSF diet. According to our results, this strategy was effective. Although animals apparently showed similar growth performance (feed intake, LW gain and FCR) with both diets, carcass weight was higher when animals were shifted to a more concentrated diet resulting in a higher dressing out percentage. The nutrient change to starch and fat instead of highly fermentable fibre explains the promotion of small intestine development and the reduction of caecum content which is the main factor responsible for full gastrointestinal tract development decrease. Ledin (1982) found that growing rabbits fed with a more concentrated diet had a longer small intestine.

However, the delay of maturity observed with the high NSDF diet was not alleviated when switching to a concentrated diet at late fattening, as deduced from a persisting high head proportion and low meat to bone ratio. In addition, improvement on chilled carcass weight observed was mainly due to the promotion of the liver development and fat deposition, both dissectible (Pla and Cervera, 1997; Fernandez and Fraga, 1996) and meat fats (Christ et al., 1996), when an energy enriched diet was introduced. The increase in fat percentage in carcass and meat could be considered negative from the point of view of consumer health. However, rabbit carcass and meat can be considered low in fat (Ouhayoun, 1989; Pla et al., 2004) compared to other species, and an increase of fat percentage in meat could have a positive effect on meat quality because juiciness is improved (AMSA, 1978).

317 Furthermore, this switch impaired the health status of growing rabbits in late
318 fattening. This finding, similar to that reported by Soler et al. (2004), could be
319 mainly associated with a negative change in the substrate available for caecal
320 fermentative activity (Gidenne et al., 2010).

321

322

5. Conclusions

Highly-digestible fibre diets can be useful to reduce the incidence of ERE, but they impaired growth performance as well as carcass yield and quality. Switching to a high starch and fat diet at late fattening can help to improve chilled carcass weight, but mainly through promotion of liver development and fat deposition, and at the expense of a higher health risk.

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Table 1. Ingredients and chemical composition (g/kg DM) of the experimental diets.

	F	S	C[1]
Ingredients			
Wheat		240	
Beet pulp	280		
Wheat bran	150		
Soybean hulls		100	
Wheat straw		50	
Animal fat	30	60	
Cane molasses		10	
Basal mix [2]	540	540	
Chemical composition			
Dry matter (DM)	911	914	908
Ash	78	68	68
Crude protein	178	177	178
Ether extract	48	71	36
Starch	69	170	146
Neutral detergent fibre (NDF)	374	329	368
Acid detergent fibre (ADF)	217	219	215
Acid detergent lignin	58	53	48
Hemicelluloses (as NDF-ADF)	157	110	153
Neutral detergent soluble fibre	227	134	161

[1] Commercial diet for growing rabbits (Nanta, Spain) including 100 ppm of zinc-bacitracin (Bacipremix 50, Pintaluba, Spain). Ingredient composition not available.
[2] Alfalfa, 250 (g/kg DM); Sunflower meal, 200; Soybean meal, 60; L-Lysine HCl, 3; DL-Methionine, 1; L-Threonine, 1; Calcium hydrogen phosphate, 12; Calcium carbonate, 2; Sodium chloride, 5; Vitamin/Trace element mixture (L-510, Trouw Nutrition, Spain), 5; Cycostat 66G (Robenidine, Alpharma, Belgium), 1.

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Table 2. Performance of young rabbits from 17 to 42 days of age (least square means ± standard errors).

		Group[1]	
	No.[2]	F	C
Pre-weaning (17 to 28 days):			
Milk intake, g/rabbit d	29	25.9±0.9	26.2±1.1
Feed intake, g/rabbit d	29	7.30±0.27[a]	10.0±0.32[b]
Individual live weight gain, g/d	29	21.2±0.4[a]	23.2±0.5[b]
Individual live weight at 28 d, g	29	559±4[a]	582±5[b]
Post-weaning (28 to 42 days):			
Feed intake, g/d	143	83.6±2.8	89.3±4.3
Live weight gain, g/d	143	48.5±1.6	46.3±2.5
Feed conversion ratio	143	1.72±0.02[a]	1.96±0.04[b]
Live weight at 42 d, g	143	1246±26	1236±41
Mortality from 17 to 42 days, %	290	15.6	15.6
Health risk index from 17 to 42 days, %	290	21.9	25.0

[1] F: diet rich in highly-digestible fibre; C: medicated commercial diet.
[2] Number of litters for milk and feed intake during the pre-weaning period or number of young rabbits for the rest of variables.
Means in the same row with unlike superscripts differ (P<0.05).

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Table 3. Performance of growing rabbits from 42 to 63 days of age (least square means ± standard errors).

		Group[1]		
	No.[2]	FF	FS	CC
Feed intake, g/d	112	152±4[a]	155±3[a]	170±3[b]
Live weight gain, g/d	112	49.7±1.2[a]	49.1±1.1[a]	53.6±1.1[b]
Feed conversion ratio	112	3.09±0.06	3.18±0.06	3.19±0.06
Live weight at 63 d, g	112	2294±41[a]	2275±38[a]	2406±39[b]
Mortality, %	143	17.6	28.1	20.4
Health risk index, %	143	17.6[a]	35.1[b]	25.9[ab]

[1] FF: diet rich in highly-digestible fibre (F) from 17 to 63 days; FS: diet F from 17 to 42 days and diet S (where part of highly-digestible fibre has been replaced by starch and ether extract) from 42 to 63 days; C: medicated commercial diet from 17 to 63 days.
[2] Number of rabbits at 63 days old.
Means in the same row with unlike superscripts differ (P<0.05).

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Table 4. Carcass composition of rabbits at 42 days of age (least square means ± standard errors; n=58).

	Group[1]	
	F	C
Live weight, g	1089±22	1121±24
Blood, %[2]	3.56±0.09	3.48±0.10
Skin, %[2]	12.8±0.2[a]	13.3±0.2[b]
Full gastrointestinal tract, %[2]	29.8±0.5[b]	26.7±0.5[a]
Full small intestine, %[2]	6.32±0.13[b]	5.59±0.16[a]
Small intestine organ, %[2]	3.09±0.06[b]	2.71±0.06[a]
Small intestine content, %[2]	3.29±0.13	2.86±0.17
Small intestine length, cm	292±5	288±5
Small intestine weight to length ratio, g/100 cm	12.0±0.3[b]	11.0±0.03[a]
Full caecum, %[2]	10.7±0.3[b]	8.5±0.3[a]
Caecum organ, %[2]	1.51±0.04[b]	1.28±0.04[a]
Caecum content, %[2]	9.17±0.25[b]	7.18±0.26[a]
Chilled carcass weight, g	545±15[a]	592±16[b]
Dressing out percentage[2]	48.3±0.4[a]	50.8±0.4[b]
Liver, %[3]	7.01±0.17	7.23±0.18
Kidneys, %[3]	1.59±0.02	1.55±0.02
Scapular fat, %[3]	0.38±0.02	0.43±0.02
Perirenal fat, %[3]	0.78±0.03[a]	1.10±0.03[b]
Dissectible fat, %[3,4]	1.16±0.03[a]	1.53±0.03[b]

[1] F: diet rich in highly-digestible fibre; C: medicated commercial diet.
[2] Relative to live weight.
[3] Relative to chilled carcass weight.
[4] Scapular + perirenal fat.
Means in the same row with unlike superscripts differ (P<0.05).
Rabbits housed in collective cages from 28 to 42 days of age.

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Table 5. Carcass composition of rabbits at 63 days of age (least square means ± standard errors; n=88).

	Group[1]		
	FF	FS	CC
Live weight, g	2286±26^{a}	2323±26^{ab}	2365±25^{b}
Blood, %[2]	3.46±0.11	3.48±0.11	3.37±0.11
Skin, %[2]	14.1±0.2^{a}	14.8±0.2^{b}	14.6±0.2^{b}
Full gastrointestinal tract, %[2]	22.1±0.4^{c}	18.7±0.4^{a}	20.2±0.4^{b}
Full small intestine, %[2]	4.27±0.10^{b}	4.12±0.10^{ab}	3.85±0.10^{a}
Small intestine organ, %[2]	1.77±0.05^{a}	1.96±0.05^{b}	1.68±0.05^{a}
Small intestine content, %[2]	2.50±0.10^{b}	2.17±0.10^{a}	2.24±0.10^{ab}
Small intestine length, cm	368±6	380±6	371±6
Small intestine weight to length ratio, g/100 cm	11.0±0.2^{a}	12.0±0.2^{b}	10.7±0.2^{a}
Full caecum, %[2]	7.80±0.22^{b}	6.44±0.22^{a}	6.20±0.21^{a}
Caecum organ, %[2]	1.21±0.02^{b}	1.17±0.02^{b}	1.11±0.02^{a}
Caecum content, %[2]	6.59±0.21^{b}	5.27±0.21^{a}	5.09±0.20^{a}
Chilled carcass weight, g	1263±18^{a}	1339±18^{b}	1341±17^{b}
Dressing out percentage[2]	55.4±0.3^{a}	57.6±0.3^{c}	56.7±0.3^{b}
Head, %[3]	8.73±0.10^{b}	8.48±0.10^{b}	8.14±0.09^{a}
Liver, %[3]	6.47±0.18^{a}	7.53±0.18^{b}	7.54±0.17^{b}
Kidneys, %[3]	1.24±0.02	1.30±0.02	1.29±0.02
Thoracic viscera, %[3]	2.64±0.05	2.61±0.05	2.57±0.05
Reference carcass weight, g	1014±15^{a}	1059±15^{b}	1065±15^{b}
Reference carcass, %[3]	80.2±0.2^{b}	79.1±0.2^{a}	79.4±0.2^{a}
Scapular fat, %[4]	0.74±0.04^{a}	0.98±0.04^{b}	0.94±0.04^{b}
Perirenal fat, %[4]	1.90±0.09^{a}	2.91±0.10^{c}	2.45±0.09^{b}
Dissectible fat, %[4,5]	2.63±0.12^{a}	3.89±0.12^{c}	3.39±0.11^{b}
Thoracic cage, %[4]	11.5±0.1	11.6±0.1	11.4±0.1
Forelegs ,%[4]	16.2±0.1^{ab}	16.0±0.1^{a}	16.3±0.1^{b}
Intermediate part, %[4]	31.3±0.2	31.2±0.2	31.6±0.2
Hind part, %[4]	38.1±0.2^{b}	37.2±0.2^{a}	37.2±0.2^{a}
Meat/bone ratio, g/g	5.73±0.07^{a}	5.61±0.07^{a}	5.94±0.07^{b}

[1] FF: diet rich in highly-digestible fibre (F) from 17 to 63 days; FS: diet F from 17 to 42 days and diet S (where part of highly-digestible fibre has been replaced by starch and ether extract) from 42 to 63 days; C: medicated commercial diet from 17 to 63 days.
[2] Relative to live weight.
[3] Relative to chilled carcass weight.
[4] Relative to reference carcass weight.
[5] Scapular + perirenal fat.
Means in the same row with unlike superscripts differ (P<0.05).
Rabbits housed in individual cages from 28 to 63 days of age.

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Table 6. Meat quality of rabbits at 63 days of age (least square means ± standard errors; n=88).

		Group[1]		
		FF	FS	CC
Longissimus lumborum:				
pH		5.65±0.01^{ab}	5.63±0.01^{a}	5.66±0.01^{b}
Carcass colour[2]:	L*	54.36±0.29	53.96±0.29	54.27±0.28
	a*	3.50±0.19^{a}	3.49±0.19^{a}	4.07±0.18^{b}
	b*	1.01±0.26^{ab}	0.37±0.26^{a}	1.59±0.25^{b}
Meat colour[3]:	L*	50.35±0.37	49.97±0.37	49.63±0.36
	a*	5.83±0.26^{a}	6.29±0.27^{ab}	6.71±0.26^{b}
	b*	2.77±0.17	3.06±0.17	3.19±0.16
Hind leg meat:				
Protein, %		21.1±0.1	21.1±0.1	21.2±0.1
Fat, %		3.81±0.15^{a}	5.00±0.15^{b}	4.71±0.14^{b}
Moisture, %		73.7±0.2^{c}	72.2±0.2^{a}	72.9±0.2^{b}

[1] FF: diet rich in highly-digestible fibre (F) from 17 to 63 days; FS: diet F from 17 to 42 days and diet S (where part of highly-digestible fibre has been replaced by starch and ether extract) from 42 to 63 days; C: medicated commercial diet from 17 to 63 days.

[2] Carcass colour was determined on the external surface of the *longissimus lumborum* using the CIELAB space (Lightness (L*), redness (a*) and yellowness (b*)).

[3] Meat colour was measured in the transverse section after cutting the *longissimus lumborum*.

Means in the same row with unlike superscripts differ (P<0.05).

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