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Live yeast (*Saccharomyces cerevisiae* var. *boulardii*) supplementation in fattening rabbit diet: Effect on productive performance and meat quality

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26 **Live yeast (*Saccharomyces cerevisiae* var. *boulardii*) supplementation in fattening rabbit diet:**
27 **Effect on productive performance and meat quality**

28

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37

38 **Abstract**

39 The effects of dietary supplementation with *Saccharomyces cerevisiae boulardii* (CNCM I-1079
40 strain, LSB) at 0, 300 and 600 mg/kg on apparent digestibility, growth performance, caecal
41 fermentation, carcass characteristics and meat quality of broiler rabbits were studied from 37 to 84
42 days of age. One hundred and fifty New Zealand White rabbits were single housed and randomly
43 allotted into three groups. Animals were fed isocaloric and isonitrogenous basal diets *ad libitum*,
44 supplemented with different levels of concentrated live yeast LSB (0, 3x10⁶ and 6x10⁶ colony
45 forming unit (CFU)/g diet, respectively). Protected LSB was resistant to the pelleting process and to
46 passage through the rabbit digestive tract as far as the caecum, where it showed an 86% survival
47 rate in the 600 mg/kg supplementation level group. Significant differences were found only for the
48 fibrous fractions digestibility that were lowest (P=0.001) in the animals fed 300 mg/kg
49 supplemented diet, while yeast and mould populations in the caecum increased (P=0.001) in the
50 animals fed 300 and 600 mg/kg supplemented diets (4.16 and 4.76 log CFU/g, respectively).

51 Mortality did not differ amongst dietary treatments being 10, 8 and 6% for groups fed LSB at 0, 300
52 and 600 mg/kg, respectively.

53

54 *Keywords:* Rabbit; Probiotic; Performance, *Saccharomyces cerevisiae boulardii*; Yeast

55

56 **1. Introduction**

57 In commercial production, health problems related to intestinal pathology are a major cause
58 of mortality and reduced growth rates, especially in growing rabbits. In 2006, a complete ban on the
59 use of antibiotics as growth promoters focused attention on probiotics as possible alternatives for
60 improving production and health status in livestock (Maertens et al., 2006).

61 Probiotic provision has been effective in rabbits and other species when the animals are
62 raised in unfavourable conditions (Zoccarato et al., 1995; Trocino et al., 2005), although the
63 mechanism underlying this improved performance and welfare remains partially unexplained. There
64 is evidence that probiotics act mainly by competing with enteric pathogens, balancing colonic
65 microbiota, modulating the systemic and mucosal immune systems and influencing the intestinal
66 barrier (Fortun-Lamothe and Boullier, 2007; Ng et al., 2009).

67 Among probiotic sources tested in rabbit rearing, many strains are of bacterial and yeast
68 origin, including the colonising (*Lactobacillus* and *Enterococcus* spp) and non-colonising (*Bacillus*
69 spp, *Saccharomyces cerevisiae*) microorganisms. Bovera et al. (2012) tested the effect of
70 *Lactobacillus plantarum* spray application on suckling New Zealand White rabbits and observed
71 changes in caecal microflora and a significantly lower mortality. Maertens et al. (1994) studied the
72 effect of dietary supplementation of *Bacillus cereus* (strain CIP5832) on caecal and growth
73 parameters of weanling rabbits. This work showed that the addition of this probiotic improved the
74 weaning weight and feed efficiency while no effect on mortality was observed. Oso et al. (2013)
75 reported poor growth response in growing rabbits fed a basal diet supplemented with 0.5 g/kg of

76 *Bacillus cereus* or *Pediococcus acidilactis*.

77 Supplementation with probiotic sources of yeast origin has been evaluated on rabbits
78 (Maertens and De Groot, 1992; Onifade et al., 1999). Only the NCYC Sc 47 strain of
79 *Saccharomyces cerevisiae* has been approved in the European Union for the fattening period
80 (Falcão-e-Cunha et al., 2007). *Saccharomyces cerevisiae boulardii* (CNCM I-1079 strain) is a non-
81 pathogenic yeast widely used in human medicine to prevent and treat intestinal disorders, such as
82 infectious and antibiotic-associated diarrhoea (Buts and De Keyser, 2006; Czerucka et al., 2007). Its
83 role in gut function has also been highlighted in physiological studies on swine, and trials as a feed
84 additive in husbandry conditions have shown its positive effects on weaned pigs (Le Bon et al.,
85 2010). The aim of this preliminary study was to investigate the effect of increasing dietary
86 supplementation of *Saccharomyces cerevisiae boulardii* (LSB, LEVUCCELL® SB10 ME TITAN,
87 Lallemand Sas, Blagnac, France) on the apparent digestibility, growth performance, caecal
88 fermentation, carcass characteristics and meat quality of broiler rabbits.

89

90 **2. Materials and Methods**

91 *2.1. Animals, housing and diets*

92 The study was carried out at the Department of Agriculture, Forest, and Food Sciences
93 experimental rabbitry in Carmagnola (Turin, Italy). One hundred fifty New Zealand White rabbits
94 were single housed in triple deck cages from 37 to 84 d of age. Rabbits were randomly allotted into
95 three groups and fed isocaloric and isonitrogenous diets *ad libitum*, supplemented with LSB [1×10^{10}
96 colony forming unit (CFU)/g] at 0, 300 and 600 mg/kg of diet, respectively. After pelleting, one
97 sample (500 g) of each diet was collected and stored in a plastic box at ambient temperature for
98 yeast analysis. The analyses showed a concentration corresponding to 0, 3×10^6 and 6×10^6 CFU/g
99 diet, respectively. The LSB strain utilised was the CNCM I-1079, that is a concentrated live yeast
100 supplied in a micro-encapsulated formulation and pre-mixed with barley meal. The ingredients and

101 composition of the basal diet are shown in Table 1. Diets did not contain antibiotics or
102 coccidiostatics.

103

104 *2.2. Digestibility trial*

105 The nutrient digestibility coefficients of each diet were determined in the second week of the
106 growing trial (with 10 rabbits aged 44d). The faeces were individually collected for five days using
107 a nylon net placed under the floor of each cage, to avoid urine contamination. The faeces were
108 collected daily, at approximately 0900 h, before the daily ration was provided. Each faecal sample
109 was immediately weighed and then placed in a two-layer plastic bag to prevent loss of moisture and
110 immediately frozen at -20°C. The frozen samples, upon arrival at the laboratory, were dried in a
111 draft oven at 80°C to constant weight and then ground in a homogenizer (Tecator, Herndon, VA,
112 USA) and stored at - 20°C for chemical analysis.

113 All the analyses were carried out according to recommendations of the European Group on
114 Rabbit Nutrition (EGRAN, 2001) on three replicates of each feed and two replicate of each faeces
115 sample. Diets and faeces were analyzed to determine total N content according to AOAC method
116 #984.13 (AOAC, 2000), ash by ignition to 550°C, and ether extract by AOAC method #945.16
117 (AOAC, 2000), using the Soxhlet method without previous acid hydrolysis. Neutral detergent fiber
118 (NDF) and acid detergent fiber (ADF) were determined according to Van Soest et al. (1991).

119 The apparent digestibility of the rations was calculated using total collection of faeces for
120 each rabbit and for each diet according to the following equation:

$$121 \text{ Digestibility} = (\text{ingested amounts} - \text{excreted amounts}) / \text{ingested amounts}$$

122

123 *2.3. Growth performance and carcass traits*

124 The rabbit weight and feed intake were recorded every 14 days, except for the last period
125 which lasted 17 days. Mortality was recorded daily throughout the experimental period. Average

126 daily feed intake (ADFI), average daily gain (ADG) and feed conversion ratio (FCR) were
127 calculated. Data from animals that died were excluded from the calculations of growth performance
128 parameters.

129 At the end of the experimental period, ten rabbits per group were weighed, stunned and
130 slaughtered. The carcasses were prepared by removing non edible parts, as recommended by Blasco
131 et al. (1993), and the gastrointestinal tract was weighed. After chilling for 24 h, weight of carcasses
132 (with head, liver, kidneys, thoracic organs) were recorded and dressing out percentage was
133 calculated. Liver, kidneys, heart and lungs were separated from the chilled carcass and weighed.
134 The weights of the full gastrointestinal tract, liver, kidneys, heart and lungs were expressed as a
135 percentage of slaughter weight (SW).

136

137 *2.4. Caecal content analyses*

138 On five animals per group, the caecum was separated from the digestive tract, weighed and
139 the pH value of the fresh caecal content was determined directly using a Crison MicropH 2001 pH
140 meter (Crison Instruments, Barcelona, Spain). Caecal content was then removed, put into plastic
141 bottles, and stored at -20°C until chemical and microbiological analyses were performed. The
142 remaining empty caecum was washed with distilled water, dried with blotting paper and weighed.

143 Alcohol and volatile fatty acid (VFA) concentrations were determined on aqueous extracts
144 of caecal content. One g of sample was extracted with 5 mL of distilled water at 20°C. The mixture
145 was centrifuged for 5 min at 3000xg and then filtered through a Schleicher and Schull membrane
146 filter (BA-83, 0.2 µm). Using an on-column technique with an auto-sampler (Dani Instruments
147 SpA, ALS 1000, Cologno Monzese, Italy), a 1 µL aliquot of the extract was injected into a wide-
148 bore capillary column (SGE BP21 25m x 0.53 mm internal diameter and 0.5 µm film thickness; P/N
149 054474, SGE International, Ringwood, Victoria, Australia) installed in a gas chromatograph (Dani
150 GC 1000 DPC), running in a temperature-programmed mode and equipped with a flame ionization

151 detector and a PTV injection port, used in split mode, with a split vent flow of 100 mL/min. The
152 injector and detector ports were set at 230°C and 240°C, respectively. Helium was used as the
153 carrier gas and the oven temperature was programmed to increase from 60°C to 200°C at 5°C per
154 min and held for 2 min giving a run time of 30 min. The peak area was measured using a Dani Data
155 Station DDS 1000. Each peak was identified and quantified according to pure standards (Sigma
156 Chemical, St. Louis, MO, USA).

157 Microbiological analyses were carried out on 10 g of caecal content taken under sterile
158 conditions. Caecal content was weighed in a sterilized bag and homogenized in 0.90 g/L sterile
159 saline solution for 2 min in a stomacher (PBI International, Milan, Italy), in accordance with the
160 methods proposed by Kovács et al. (2006) and Mourão et al. (2006). From the resulting dilution,
161 decimal dilutions were prepared for yeast and moulds (10^{-2} , 10^{-3} , and 10^{-4}), for total viable counts
162 (TVC) and total anaerobes (10^{-3} , 10^{-4} , and 10^{-5}) using 0.90 g/L sterile saline solution and plated in
163 duplicate to enumerate the following microorganisms: yeast and moulds were enumerated using the
164 surface-plate method on Sabouraud Dextrose Agar (Oxoid Ltd, Cambridge, UK). Plates were
165 incubated at 25 °C for 72-110 h. TVC were enumerated by the pour-plate method using Plate Count
166 Agar (Oxoid Ltd, Cambridge, UK). Plates were incubated at 30 °C for 48 h. Total anaerobes were
167 enumerated by the inclusion method using Violet Red Bile Glucose agar (Oxoid Ltd, Cambridge,
168 UK). Plates were incubated at 37 °C for 24 h. The number of colonies was expressed as log CFU
169 per gram of chymus. All microbiological analyses were performed in duplicate.

170

171 2.5. Meat quality analyses

172 2.5.1. Sample preparation

173 After chilling for 24 h in a refrigerated room (+ 4°C), the carcasses were halved and the two
174 *longissimus dorsi* (LD) muscles were excised. The left LD muscle was divided into two parts. The
175 fore part was used to measure pH, colour and cooking losses. The hind part of the left LD and the

176 whole right LD were vacuum-packed, frozen and stored at -20°C until analyses were performed.

177 2.5.2. *pH and Colour measurements*

178 pH_{24} was measured on the LD with a Crison MicropH 2001 (Crison Instruments, Barcelona,
179 Spain) provided with a combined electrode and an automatic temperature compensator.

180 Meat colour was measured at room temperature (20°C) using a portable Minolta CR-331C
181 Minolta Colorimeter (Minolta Camera, Osaka, Japan) with D_{65} illuminant and 2° standard observer.
182 The results were expressed in terms of lightness (L^*), redness (a^*) and yellowness (b^*) in the
183 CIELAB colour space model (CIE, 1976). Chroma [$C^* = (a^{*2} + b^{*2})^{1/2}$] and Hue [$H^0 = \tan^{-1}(b^*/a^*)$]
184 were calculated according to Boccard et al. (1981). Values were the mean of two different
185 measurements per meat sample.

186 2.5.3. *Cooking losses*

187 Samples of LD from each rabbit were weighed (F), vacuum packed in plastic bags and
188 cooked at 80°C for 1 h by immersion in a water bath (Ramírez et al., 2004). Cooked samples were
189 cooled under running water for 30 min. The samples were then removed from the bags, blotted and
190 weighed (C). Cooking losses were calculated as $(F - C) \times 100/F$.

191 2.5.4. *Chemical composition*

192 LD muscles were analyzed to determine moisture according to AOAC method #950.46
193 (AOAC, 2000), total N content by AOAC method #928.08 (AOAC, 2000), ether extract by AOAC
194 method #960.39 (AOAC, 2000), and ash by AOAC method #920.153 (AOAC, 2000). Values were
195 expressed on a fresh matter basis.

196

197 2.6. *Statistical analysis*

198 Statistical analyses were performed using the SPSS software package (IBM SPSS, 2012).
199 Mortality rate differences amongst groups were tested with the Fisher exact test (R Core Team,
200 2013). Bacterial numbers were not normally distributed and were log transformed to create a

201 normal distribution prior to analysis. Analysis of variance was used to evaluate the effect of
202 different LSB levels on the nutrient digestibility coefficients, growth performance, caecal activity,
203 carcass characteristics and meat quality of broiler rabbits. Differences among treatment means were
204 determined using Duncan's test at a probability level of 0.05.

205

206 **3. Results and discussion**

207 *3.1. Digestibility trial*

208 Apparent digestibility coefficients are reported in Table 2. The results show that the
209 supplementation of LSB does not modify the dry matter intake and digestibility of dry matter,
210 organic matter, EE, and CP. Differences ($P < 0.001$) were found for both NDF and ADF. Animals
211 fed 300 mg/kg supplemented diet had the lowest value of both fibrous fraction digestibilities, while
212 the ADF digestibility coefficient of animals fed 600 mg/kg supplemented diet showed an
213 intermediate value between the other two groups.

214 Kimsé et al. (2012) found that adding live yeast (*Saccharomyces cerevisiae* NCYC Sc 47)
215 did not modify the total digestibility of nutrients. Similarly, Chaudary et al. (1995) found that oral
216 administration of yeast culture had no effect on the digestibility of nutrients in rabbits fed diets with
217 different fibre content. Kamra et al. (1996) reported that feeding probiotics (*Lactobacillus*
218 *acidophilus*, *L. casei* and *Saccharomyces cerevisiae* ITCCF 2094) have no significant effect on
219 growth performance and NDF, ADF, hemicellulose and cellulose digestibilities in New Zealand
220 White rabbits under Indian hot climate environmental conditions. Oso et al. (2013) found that ADF,
221 NDF and other nutrient digestibility values were not affected by dietary inclusion of probiotics of
222 bacterial origin (*Pediococcus acidilactis* or *Bacillus cereus*) in mixed breed weaner rabbits. In
223 contrast, in weaned piglets in a feeding trial lasting 35d, Giang et al. (2010) found that a basal diet
224 supplemented with 0.2% yeast and a mixture of lactic acid bacteria improved the apparent total tract
225 digestibility of CP, crude fibre and organic matter.

226

227 3.2. Health status and growth performance

228 Mortality percentages were: 10, 8 and 6% for groups fed 0, 300 and 600 mg/kg LSB
229 respectively. There were no significant differences among dietary treatments. Kimsé et al. (2012)
230 stated that on growing rabbits from day 35 to day 70, the supplementation of 10^6 CFU/ g of
231 *Saccharomyces cerevisiae* NCYC Sc 47 strain (Activesaf®) significantly halved mortality over the
232 whole fattening period, compared to the control.

233 No growth performance parameters were affected by live yeast addition (Table 3) There
234 were also no differences in carcass characteristics among treatments (Table 4).

235 In a recent trial, aiming to study the response to *Escherichia coli* lipopolysaccharide
236 administration, Collier et al. (2011) reported greater ADG than the controls in pigs whose diet was
237 supplemented with 222 g/t of active dry yeast, *Saccharomyces cerevisiae boulardii*. Similarly, in the
238 same species, Le Bon et al. (2010) found that dietary supplementation of *Saccharomyces cerevisiae*
239 *boulardii* CNCM I-1079 strain (2×10^9 kg/feed) followed by *Pediococcus acidilactici* significantly
240 improved FCR. On the contrary, Oso et al. (2013) found poor growth response in rabbits fed diets
241 containing the probiotic of bacterial origin *Pediococcus acidilactis* or *Bacillus cereus*, while the
242 inclusion of the prebiotics mannan and arabinoxylans oligosaccharides showed an improved growth
243 and gut morphology in growing rabbits. Giang et al. (2010) showed that a mixture of lactic acid
244 bacteria complex and *Saccharomyces boulardii* improved overall live performance. In an exhaustive
245 review, Falcão-e-Cunha et al. (2007) summarized that dietary inclusion of feed additives containing
246 yeast generally improve ADG in rabbits, although results concerning FCR and mortality were
247 partially contradictory. *Saccharomyces cerevisiae* (5×10^8 CFU per d) orally supplemented as yeast
248 culture, did not improve growth performance in 6-week-old New Zealand White mash-fed rabbits
249 (Chaudary et al., 1995). Similarly, Maertens and De Groote (1992) reported no significant
250 difference in rabbit performance. Conversely, Onifade et al. (1999) found that rabbits fed 3.0 and

251 1.5 g/kg of *Saccharomyces cerevisiae* (Yeastacc¹⁰²⁶¹®), had higher body weight and feed intake with
252 a better feed conversion than the un-supplemented group.

253 In addition to growth performance, there is a lack of specific studies for rabbits on the effect
254 of *Saccharomyces cerevisiae boulardii* on carcass characteristics, as most of the works are related to
255 probiotic mixtures or generally indicate *Saccharomyces cerevisiae* supplementation. Onbaşilar and
256 Yalçın (2008) found no differences in weight percentages of lung, heart, kidney and small intestine
257 in New Zealand White rabbits fed 1g of probiotic (BioteksinTM)/kg diet, but the liver percentage
258 was affected in animals fed 1g of probiotic + 66 mg of anticoccidial agent (Robenine
259 hydrochloride)/kg diet. Similarly, Tripathi and Karim (2011) showed that carcass traits did not
260 change in lambs fed diets supplemented by *Saccharomyces cerevisiae* and other yeast cultures.

261

262 3.3. Caecal activity

263 Caecum content characteristics and its contents were reported in Tables 5 and 6,
264 respectively.

265 The full and empty weights of the caecum and its contents were not affected by treatment
266 and these values were similar to those reported by Cesari et al. (2009) and Gallois et al. (2005) on
267 growing rabbits. The pH value of the caecum content was about 6.3–6.5, similar to values obtained
268 by Bónai et al. (2008) who studied the effect of *Bacillus cereus* var. *toyoi* on caecal microflora in
269 growing rabbits. The concentration of total VFA and the individual VFA values were unaffected by
270 the treatment and were in accordance with those reported by Gidenne et al. (2000) who pointed out
271 that acetic acid concentration of the caecum ranged between 78.0 and 82.5%, while butyric acid and
272 propionic acid concentrations ranged from 13.1 to 16.9% and from 3.9% and 4.7%, respectively.
273 Similar values were observed by Kimsé et al. (2009) in rabbit: acetate (77%), butyrate (17%) and
274 propionate (5%).

275 Oso et al. (2013) found that rabbits fed diets containing probiotics (*Pediococcus acidilactis*

276 and *Bacillus cereus*) had the lowest VFA concentration compared to dietary inclusion of prebiotics
277 and symbiotics, while the concentrations of the acetic, propionic and butyric acid produced were not
278 affected by dietary inclusion of probiotics.

279 There was no live yeast in the caecal contents of the rabbits fed the LSB 0 diet while, as
280 expected, rabbits consuming LSB-supplemented diets showed higher ($P<0.001$) yeast
281 concentrations of 4.16 and 4.76 log CFU/g of chyme, respectively (Table 6).

282 Live yeast concentration fell slightly after pelleting (-0.7 log CFU/g DM), at 70–80°C. Yeast
283 survival rate, measured as the ratio between yeast intake and yeast excreted, was high and increased
284 significantly from 81 to 86% with increasing yeast addition. A similar result was observed by
285 Kimsé et al. (2012) who found that the survival rate of yeast increased from 90 to 97% with
286 increasing yeast supplementation in rabbit digestive tract.

287 Luick et al. (1992) found that yeast culture and fructooligosaccharides did not affect caecal
288 fermentation. Similarly, addition of probiotics (yeast or lactobacilli) seemed to not greatly modify
289 caecal fermentation as measured *in vivo* by Kermauner et al. (1994). The germ counts of total
290 anaerobes growing on Schaedler agar in caecal content were similar to those in previous
291 experiments (Bónai et al., 2008).

292 Gidenne et al. (2002) found that the microflora in the caecum of rabbits is established at
293 weaning, and only minor changes occur with age. Abecia et al. (2005) demonstrated by molecular
294 microbiological tools that bacteria are the main constituents in the rabbit caecum, but Bennegadi et
295 al. (2003) also reported a significant community of archaea among other constituents of gut
296 microbiota in rabbits.

297

298 3.4. Meat quality traits

299 Meat traits and chemical composition of LD muscle of rabbits are reported in Table 7. No
300 significant effects of LSB supplementation were observed. Chemical composition of LD muscle fell

301 within the normal range for rabbit meat (Dalle Zotte and Szendro, 2011).

302

303 **4. Conclusions**

304 Protected live yeast (*Saccharomyces cerevisiae boulardii*, CNCM I-1079 strain) was
305 resistant to the pelleting process and to the passage through the rabbit digestive tract as far as the
306 caecum where it showed an 86% survival rate in the 600 mg/kg supplementation level group.
307 Although the caecal population of yeast increased in the rabbits fed LSB supplemented diets, the
308 supplementation at a dose of up to 600 mg/kg did not affect the productive performance, carcass
309 characteristics, caecal fermentation and meat quality of broiler rabbits reared in standard farming
310 conditions. No significant differences were found for nutrient digestibilities except for NDF and
311 ADF values. These were lowest in animals fed a 300 mg/kg supplemented diet.

312

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317

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443

444 Table 1

445 Ingredients and proximate composition of basal diet

Ingredients	%
Alfalfa meal (16% CP)	30
Barley meal	20
Dried beet pulp	14
Wheat bran	20
Soybean meal (44% CP)	6
Sunflower meal (30% CP)	6
Soybean oil	1
Molasses	1.5
Dicalcium phosphate	0.5
Vitamin-mineral premix ¹	0.94
DL-methionine	0.06
Proximate composition on dry matter basis	
Dry matter, %	90.2
Crude protein, %	16.5
Ether extract, %	3.1
Ash, %	7.0
Neutral detergent fibre, %	33.7
Acid detergent fibre, %	22.3
Digestible energy ² , MJ/kg DM	10.2
Digestible protein ³ , g/kg	114.8
DP/DE ⁴ , g/MJ	11.3

446 ¹ per kg of diet: Vit. A 200 IU; α -tocopheryl acetate 16 mg; Niacin 72 mg; Vit. B6 16 mg; Choline
447 0.48 mg;; Ca 500 mg; P 920 mg; K 500 mg; Na 1 g; Mg 60 mg; Mn 1.7 mg; Cu 0.6 mg

448 ² The digestible energy content of the basal diet was calculated according to Fernández-Carmona et
449 al. (1996)

450 ³ The digestible protein content of the basal diet was calculated as crude protein content multiplied
451 by the apparent digestibility coefficient of the protein

452 ⁴ DP/DE= Digestible protein/Digestible energy

453

454 Table 2

455 *In vivo* apparent digestibility (means \pm S.E.) of rabbits (n=10 per group) fed experimental diets

	LSB ¹ (mg/kg)			<i>P</i> -value
	0	300	600	
Dry matter, %	62.6 \pm 0.4	60.6 \pm 0.4	61.0 \pm 1.0	0.051
Organic matter, %	62.0 \pm 0.2	60.7 \pm 0.6	61.9 \pm 0.9	0.297
Crude protein, %	67.6 \pm 1.3	68.2 \pm 1.1	68.1 \pm 1.3	0.934
Ether extract, %	69.6 \pm 3.0	74.2 \pm 1.7	71.8 \pm 3.1	0.497
Neutral detergent fibre, %	29.1 \pm 0.9 ^a	23.8 \pm 0.6 ^b	27.7 \pm 1.1 ^a	0.001
Acid detergent fibre, %	29.5 \pm 1.0 ^a	22.2 \pm 0.6 ^c	25.9 \pm 1.3 ^b	0.001

456 ¹ LSB= yeast commercial product (LEVUCCELL[®] SB10 ME TITAN)

457 ^{a,b,c} Means in the same row with unlike superscripts differ (*P*<0.05)

458

459 Table 3

460 Mortality and growth performance (means \pm S.E.) of rabbits (n=50 per group) fed experimental
461 diets

	LSB ¹ (mg/kg)			P-value
	0	300	600	
<i>Mortality</i>				
37-84d, %	10	8	6	1.00
<i>Growth performance</i>				
IBW ² , g	1240 \pm 26	1218 \pm 23	1266 \pm 27	0.407
FBW ³ , g	2870 \pm 54	2864 \pm 48	2911 \pm 52	0.805
ADFI ⁴ , g	141.1 \pm 2.6	140.9 \pm 2.6	138.1 \pm 3.0	0.699
ADG ⁵ , g	34.7 \pm 0.9	35.0 \pm 0.9	35.0 \pm 1.0	0.996
FCR ⁶	4.2 \pm 0.1	4.2 \pm 0.2	4.0 \pm 0.1	0.675

462 ¹ LSB= yeast commercial product (LEVUCCELL[®] SB10 ME TITAN)

463 ² IBW: initial body weight

464 ³ FBW: final body weight

465 ⁴ ADFI: average daily feed intake

466 ⁵ ADG: average daily gain

467 ⁶ FCR: feed conversion ratio

468

469 Table 4

470 Carcass characteristics (means \pm S.E.) of rabbits (n=10 per group) fed experimental diets

	LSB ¹ (mg/kg)			<i>P</i> -value
	0	300	600	
Slaughter weight (SW), g	2801 \pm 40	2829 \pm 52	2974 \pm 69	0.076
Dressing out, %	56.4 \pm 0.7	55.5 \pm 0.7	56.4 \pm 0.6	0.673
Full gastrointestinal tract, g/100g SW	17.1 \pm 0.4	17.8 \pm 0.4	17.0 \pm 0.5	0.377
Liver, g/100 g SW	2.70 \pm 0.08	2.95 \pm 0.15	2.85 \pm 0.18	0.481
Kidneys, g/100 g SW	0.58 \pm 0.02	0.62 \pm 0.03	0.58 \pm 0.03	0.504
Heart and lungs, g/100 g SW	1.17 \pm 0.08	1.23 \pm 0.06	1.28 \pm 0.15	0.295

471 ¹LSB= yeast commercial product (LEVUCCELL[®] SB10 ME TITAN)

472

473 Table 5

474 Caecal content characteristics (means \pm S.E.) of rabbits (n=5 per group) fed experimental diets

	LSB ¹ (mg/kg)			P-value
	0	300	600	
Full caecum, %BW ²	6.13 \pm 0.46	6.52 \pm 0.36	5.96 \pm 0.45	0.903
Empty caecum, %BW	1.94 \pm 0.03	1.99 \pm 0.13	2.04 \pm 0.12	0.347
Caecal content, %BW	4.20 \pm 0.43	4.53 \pm 0.29	3.92 \pm 0.33	0.802
pH	6.3 \pm 0.1	6.3 \pm 0.1	6.5 \pm 0.1	0.292
DM caecal content, %	22.7 \pm 0.4	22.5 \pm 0.5	23.0 \pm 0.3	0.903
Propanol, mg/kg DM	0.44 \pm 0.06	0.57 \pm 0.03	0.50 \pm 0.03	0.301
Total VFA ³ , mg/kg DM	12.0 \pm 2.8	12.0 \pm 1.3	11.0 \pm 1.3	0.268
Acetic acid, mg/kg DM	8.96 \pm 2.00	9.36 \pm 0.88	8.62 \pm 0.94	0.269
Propionic acid, mg/kg DM	1.02 \pm 0.17	0.92 \pm 0.07	0.83 \pm 0.06	0.132
Butyric acid, mg/kg DM	1.82 \pm 0.73	1.61 \pm 0.32	1.43 \pm 0.29	0.406
Valeric acid, mg/kg DM	0.22 \pm 0.06	0.13 \pm 0.02	0.12 \pm 0.01	0.114

475 ¹ LSB= yeast commercial product (LEVUCCELL[®] SB10 ME TITAN)

476 ² BW= Body Weight

477 ³ VFA: volatile fatty acids

478

479 Table 6

480 Caecum microflora population (log CFU/g; means \pm S.E.) of rabbits (n=5 per group) fed
481 experimental diets

	LSB ¹ (mg/kg)			P-value
	0	300	600	
Yeast and moulds	0.00 ^a	4.16 \pm 0.18 ^b	4.76 \pm 0.16 ^c	0.001
Total Viable Counts	4.24 \pm 0.13	4.49 \pm 0.13	4.73 \pm 0.24	0.159
Total anaerobes	4.49 \pm 0.16	4.27 \pm 0.18	4.57 \pm 0.14	0.287

482 ¹ LSB= yeast commercial product (LEVUCCELL[®] SB10 ME TITAN)

483 ^{a,b,c} Means in the same row with unlike superscripts differ (P<0.05)

484

485 Table 7

486 Meat traits and chemical composition (on a fresh matter basis; means \pm S.E.) of *longissimus dorsi*

487 muscle of rabbits (n=10 per group) fed experimental diets

	LSB ¹ (mg/kg)			<i>P</i> -value
	0	300	600	
pH ₂₄	5.74 \pm 0.02	5.74 \pm 0.03	5.76 \pm 0.02	0.632
L* ²	56.9 \pm 0.5	57.1 \pm 0.4	57.9 \pm 0.5	0.616
a* ³	2.68 \pm 0.23	2.61 \pm 0.26	2.50 \pm 0.20	0.395
b* ⁴	2.81 \pm 0.20	2.41 \pm 0.20	2.96 \pm 0.20	0.517
Chroma	3.92 \pm 0.28	3.64 \pm 0.29	3.93 \pm 0.25	0.698
Hue	47.2 \pm 1.8	44.4 \pm 2.9	50.6 \pm 1.9	0.158
Cooking losses, %	32.2 \pm 0.4	32.4 \pm 0.5	31.4 \pm 1.1	0.626
<i>Chemical composition</i>				
Moisture, %	74.3 \pm 0.5	74.9 \pm 0.1	74.7 \pm 0.2	0.334
Crude protein, %	22.5 \pm 0.3	22.2 \pm 0.3	22.6 \pm 0.5	0.164
Ether extract, %	0.56 \pm 0.15	0.67 \pm 0.16	0.75 \pm 0.16	0.184
Ash, %	1.24 \pm 0.06	1.23 \pm 0.03	1.23 \pm 0.03	0.625

488 ¹ LSB= yeast commercial product (LEVUCCELL[®] SB10 ME TITAN)

489 ² L*: lightness

490 ³ a*: redness

491 ⁴ b*: yellowness