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Effect of different feed grinding fineness on the performances and digestive efficiency of growing rabbits

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Abstract — In this study, two experiments were carried out. In the first experiment, we studied the effect of commercial feeds, differing in the grinding level of their constituents (group C was fed a diet milled with the process used for commercial feeds, group F and group G received the same diet ground more finely or coarsely, respectively), on the growth performances of rabbits and on some characteristics of the caecum and its content. The second experiment, an in vivo digestibility experiment, was carried out to study the influence of the same diets on the digestive efficiency of growing rabbits. The different particle sizes of the feeds did not significantly influence feed intake, weight gain and feed efficiency or slaughtering parameters of growing rabbits. The different grinding levels of the diets did not influence the apparent faecal digestibility of dry matter, organic matter and gross energy. The cell wall polysaccharides digestibility was, however, significantly decreased in the F group rabbits ($P < 0.01$). The different particle sizes had no effects on the caecal content characteristics nor were anatomohistopathological lesions found. Rabbits exhibit a great capacity to adapt to diets with somewhat different particle sizes.

growing rabbit / grinding fineness / performances / digestibility

Résumé — Influence de la finesse de broyage de l'aliment sur les performances zootechniques et l'efficience digestive chez le lapin en croissance. Deux essais ont été réalisés afin d'évaluer les effets de la finesse de broyage des ingrédients utilisés pour la formulation d'aliments destinés aux lapins en croissance. Pour le premier essai, 108 lapins sevrés à 35 jours, d'un poids moyen de 994 g répartis en trois lots de 36 chacun, ont reçu à volonté pendant 47 jours soit un aliment broyé selon les processus industriels traditionnels (lot C, servant de témoin), soit le même aliment dont les ingrédients

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avaient subi une mouture plus ou moins fine (lots F et G respectivement). Les aliments obtenus se sont révélés différents en ce qui concerne la distribution des particules dans les trois classes granulométriques considérées (∅ < 0,25 mm : F = 39,4 % ; C = 22,9 % ; G = 19,4 % ; ∅ = 0,25 – 1 mm : F = 53,09 % ; C = 52,26 % ; G = 50,03 % ; ∅ > 1 mm : F = 8,2 % ; C = 21,46 % ; G = 31,0 %). De même, la composition chimique des classes granulométriques a été différente. En particulier, la fraction la plus grossière des aliments (∅ > 1 mm) contenait 40,9 % de NDF pour le lot F et 27,7 % pour le lot G ; la fraction la plus fine (∅ < 0,25 mm) au contraire contenait 42 % de NDF pour le lot G et 32,5 % pour le lot F. Ces différences n'ont toutefois pas eu d'influence significative sur les performances de croissance (GMQ : 32 g) et l'indice de consommation alimentaire (3,6), ni sur les données d'abattage (rendement de carcasse : 62 %), le poids du caecum plein, le contenu caecal et le nombre de coliformes de celui-ci. Le pH du caecum s'est révélé semblable pour tous les lapins (5,84, 5,93 et 5,96 pour les lots G, F et C, respectivement) ainsi que la composition chimique du contenu caecal. Le deuxième essai, une épreuve de digestibilité fécale, prévoyait l'emploi de 24 lapins âgés de 49 jours, distribués en 3 lots de 8, recevant les mêmes aliments que dans l'essai 1. Aucun changement de l'utilisation digestive de la matière sèche, de la matière organique, des protéines brutes et de l'énergie brute n'a pu être constaté. En revanche, la digestibilité des fibres brutes et des fractions NDF et ADF s'est révélée significativement inférieure (P < 0,01) pour le groupe recevant l'aliment à plus fine mouture (F) par rapport aux lapins du lot G (FB : 10,6 % contre 14,8 % ; NDF : 31,8 % contre 36,5 % ; ADF : 10,5 % contre 18,3 %). La distribution granulométrique différente pourrait donc influencer la digestibilité des fibres alimentaires, même si les données obtenues dans le premier essai (relatives en particulier à la composition caecale et au pH) ne sont pas concluantes à cet égard. Cet aspect mérite donc d'être étudié ultérieurement.

lapin / finesse de mouture / performances / digestibilité

1. INTRODUCTION

In the rabbit, as in most species of zootechnical interest, feed particle size seems to influence caeco-colic motility, with possible effects on the digestibility of the diet. Previous research indicates that a fine grinding of diet constituents modifies the proximal colon motility, causing a local antiperistaltic activity [4] and longer retention times, particularly in the large bowel [10]. The results from different trials support a close relationship between diet particle size and digesta transit rate [8, 9, 13]. On the contrary, they do not univocally outline the effects on the performances and digestibility of dietary components [1, 3, 7, 15].

The aim of this research was to verify the effect of different feed grinding fineness on the performances and digestive efficiency of growing rabbits. Normal commercial rabbit diets were realised in accordance with the technical constraints associated with industrial manufacturing processes. In addition, health status, caecal contents characteristics and anatomo-histopathological features were also evaluated.

2. MATERIALS AND METHODS

The research was carried out according to an experimental design providing for two single experiences.

Trial 1

One hundred and eight Provisal hybrid rabbits, half males and half females, were used. The trial took place in autumn in a farm with an air control temperature system. The rabbits were divided into 3 experimental groups of 36 each, according to homogeneity criteria including weight, sex and litter. At weaning (35 days) the rabbits were housed in 4 place cages (cm 56 × 41 × 28 h), the kind used on the farm. From that

Table I. Composition of the experimental diets.

Diets	F	C	G
Chemical composition (% DM):			
Dry matter (%)	91.0	90.7	90.2
Crude protein (N × 6.25)	17.5	17.3	17.9
Crude lipids	2.82	2.87	2.93
Crude fibre	16.8	15.5	16.1
Ash	8.57	8.90	8.70
Neutral detergent fibre	36.10	33.30	37.10
Acid detergent fibre	19.90	18.80	20.0
Digestible energy ($Mj{\cdot}kg^{-1}$)*	10.9	11.3	11.1

Composition (%): dehydrated lucerne meal (28.0), wheat fine bran (11.8), meadow hay (11.0), soybean meal (10.7), wheat middlings (10.0), maize meal (7.5), sunflower meal (6.0), barley (5.6), carobbeans (4.8), sugarcane molasses (2.0), animal fat (0.4), dicalcium phosphate (1.3), sodium chloride (0.3), choline (0.06), minerals and vitamins (0.54), robenidine (66 $mg{\cdot}kg^{-1}$).
* Calculated [17].

moment until the end of the experiment, which took 47 days on the whole, all the rabbits received, ad libitum, 1 of 3 pelleted diets of similar composition (Tab. I), differing only by the grinding level of their constituents. The rabbits in the control group (C) were fed a diet in which raw materials were milled by the process used for commercial feeds (1st milling with a ∅ = 7 mm grinder, 2nd milling with a ∅ = 2.5 mm), while the rabbits in the other two groups received a similar more finely ground diet (group F – 1st milling with a ∅ = 5 mm grinder, 2nd milling with a ∅ = 2.5 mm) or coarsely (group G – only 1 milling with a ∅ = 7 mm grinder). The average particle sizes and their distribution among the particle size classes (Fig. 1) were evaluated, after mixing the different diet constituents and before pelleting, according to a dry method using normalised sieves with square meshes (side of 2, 1, 0.5, 0.25 and 0.125 mm, in sequence) in conformity with the official methods for animal feed control [12]. This evaluation was done for five replicates of 50 g per diet. The particle size classes of the 5 replicates of each diet were then mixed and analysed twice according to standard methods [2] in order to determine their chemical composition (water, protein, lipids, ash, crude fibre and NDF, ADF, ADL determined with a non-sequential Van Soest procedure). During the trial, the individual live weight and the feed intake per replicate (4 rabbits) were recorded every 2 weeks. Dead animals underwent anatomopathological examination (necropsy including a detailed inspection and palpation of all the organs) in order to evidence any pathological features. At the end of the trial, and after a 4-hour period without feeding, all the animals were weighed and slaughtered. For each animal, the weight of the full gastrointestinal tract, the skin and the hot carcass (inclusive of the head, kidneys, liver, scapular and perirenal fat) were recorded. Furthermore, on 30 rabbits, 10 from each group (5 males and 5 females) were chosen at random, and the weight of caecum and its contents, together with pH and chemical composition (water, protein, lipids, ash, NDF, ADF and starch) of the latter, were evaluated [2]. Finally, from 30 other animals chosen according to the same criteria, the whole caecum was isolated, separated and immediately stored at + 4 °C. These samples were used in order to count the coliforms, diluting 1 g of fresh caecal contents into sterile peptonate physiological solution (0.8% NaCl + 0.1%

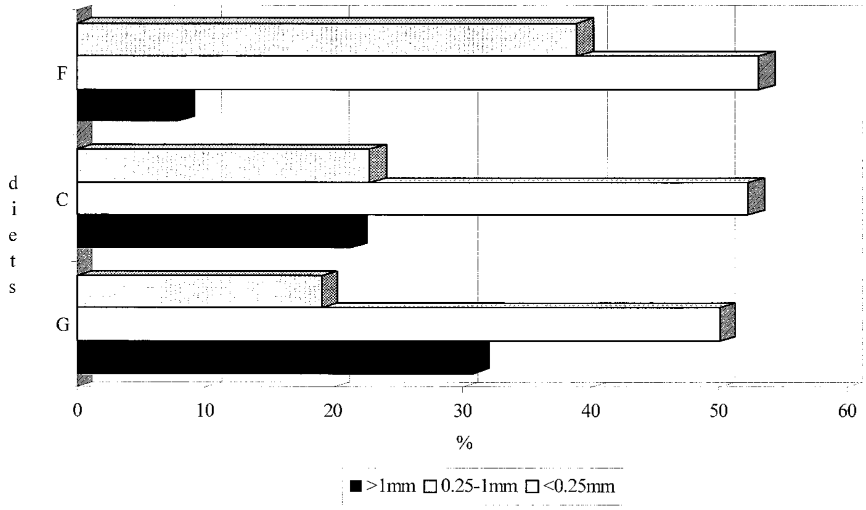

Figure 1. Particle distribution among the size classes for the three experimental diets.

peptone) and using Violet Red Bile Agar as culture medium.

Trial 2

In the 2nd experiment, 24 Provisal hybrid rabbits of the 2 sexes were used, divided into 3 homogeneous groups of 8 individuals each. The rabbits were weaned between 30 and 33 days of age and from the 49th day of life were put into individual digestibility crates. The animals were fed with the same diets as in the 1st trial, given ad libitum. During the 9th week, the faeces of each rabbit were collected daily for 7 days, weighed and stored at –18 °C. In the end, the total frozen individual faecal excretion was dried at 80 °C for 24 h. Half of these faeces were then dried at 103 °C for 24 h to determine the total excretion of dry matter (DM). The other part of the dried faeces was ground and a sample was used for chemical analysis (organic matter, OM; crude protein, CP; ether extract, EE; crude fibre, CF; acid detergent fibre, ADF; neutral detergent fibre, NDF; gross energy) in conformity with standard methods [2]. The experimental feeds were analysed in the same way. Then, the apparent faecal digestibility values of the diets were calculated from faeces excretion and feed intake ratio according to Perez et al. [18]. The animals were then slaughtered as in trial 1 and they underwent an anatomopathological examination. Ten samples were also collected from each rabbit for histological examination: 3 from the stomach, 2 from the small gut, and 5 from the large bowel in order to evaluate proliferative and inflammatory lesions which could be related to the treatments. Each sample was fixed in buffered formaline (10%), dehydrated in an increasing ethanol series, and then embedded in paraffin. The 6 μm thick sections obtained were stained with haematoxilin-eosin.

All the data, except those concerning the coliform number and the histological features, were analysed according to the GLM procedure of the SAS statistical package [19]. The model included the effects of treatment and sex (without interaction because not significant). The differences between males and females were always very slight and are consequently not reported in the different tables. When the F test analysis of variance was significant ($P < 0.05$), differences among means were compared using the SNK test. Mortality rate among the different groups was compared using the χ^2 test [5].

3. RESULTS

3.1. Feed characteristics

The different screens used for milling the 3 experimental diet constituents resulted in a substantial difference in particle distribution among the size classes (Fig. 1). In fact, particles with ∅ < 0.25 mm were 39.4% of the totality in diet F and 19.4% in diet G. On the contrary, the latter had 31.0% of the particles with ∅ > 1 mm which were only 8.2% in the former. In the control diet (C), particles of these two classes (∅ < 0.25 mm and ∅ > 1 mm) were equally present (22.9% and 21.46% respectively). Particles with a medium size (∅ = 0.25 – 1 mm) were in the same proportion in the 3 experimental diets (F = 53.09%; C = 52.26%; G = 50.03%).

The different grinding fineness influenced not only the percentage of particles in the different size classes but also their chemical composition (Fig. 2). It is

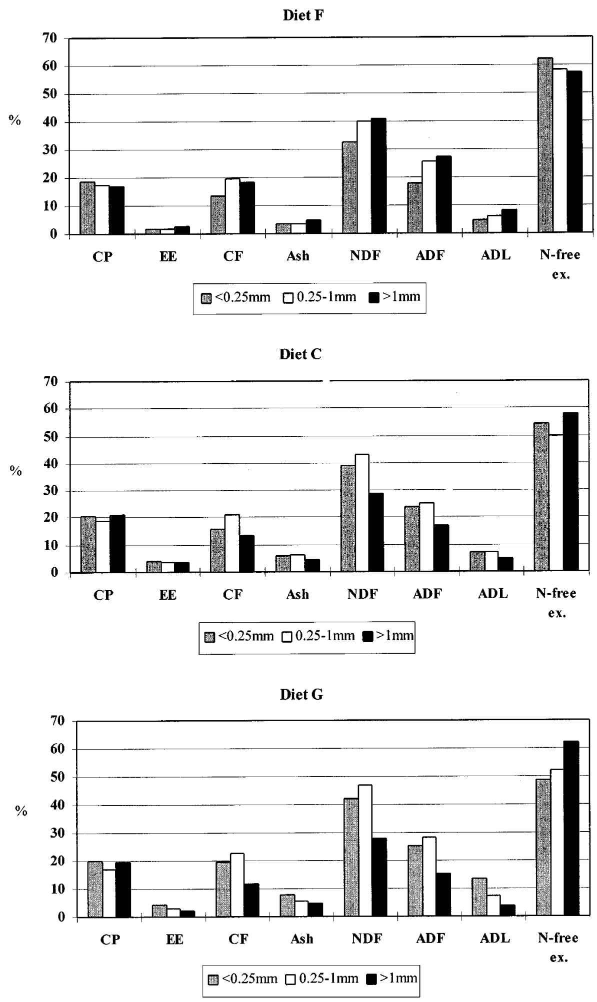

Figure 2. Chemical composition of the different particle size classes of the three experimental diets.

particularly interesting to note that in the fraction with the larger diameter ∅ > 1 mm), there was 40.9% NDF for feed F and 27.7% for feed G while in the finest fraction (∅ < 0.25 mm) there was 42% NDF for feed G and 32.5% for feed F. The chemical composition of the different particle size classes of the control diet (C) was more similar to that of feed G than that of feed F.

3.2. Health status, growth performances and feed efficiency

Health status during trial 1 was substantially good and average mortality rate was about 7.4%, mainly due to respiratory diseases, as necropsy of dead rabbits showed. There were 1 (2.8%), 3 (8.3%) and 4 (11.1%) dead rabbits for groups F, C and G, respectively which did not significantly differ with the χ^2 test. Anatomo- and histopathological features of rabbits slaughtered at the end of trial 2 did not disclose any abnormalities or differences between the animals of the different experimental groups.

Live weight and growth performances (Tab. II), as well as feed consumption and feed/gain ratio (Tab. III) did not differ significantly at any time from one group to another.

3.3. Slaughtering data and caecal contents

No differences in slaughtering data were found (Tab. IV). However, it is interesting to note that the dressing out percentage was quite high (> 62%) when compared to the expected range for rabbits. This was probably a consequence of the reduction of the digestive tract contents due to the time elapsed before slaughtering.

Rabbits that received the finest (F) and the coarsest (G) feeds had the same proportion of full gastrointestinal tract, caecal weight and caecal contents, compared with the control group (C) (P > 0.05 – Tab. V).

Chemical composition of the caecal contents did not differ significantly among the groups. Furthermore, the caecum pH was similar (5.84, 5.93 and 5.96 for G, F and C groups respectively – Tab. VI) for all the groups (P > 0.05). The coliform number in the caecal contents of all the rabbits was generally low ($< 1 \times 10^4$ g^{-1}) and within the physiological range for this species. Only 2 rabbits in group F, and 1 in groups C and G exceeded this level.

3.4. Digestibility data

Digestibility of DM, OM, CP, EE and gross energy did not differ among the groups

Table II. Growth performances (mean values).

Parameters	Groups			S.D. error	P values
	F	C	G		
Live weight at weaning (g)	994.03 (36)	993.61 (36)	993.75 (36)	105.63	0.99
Slaughtering weight (g)	2 541.57 (35)	2 543.18 (33)	2 525.78 (32)	309.59	0.97
Daily weight gain (g)					
0 – 14 days	27.50	28.71	29.90	8.16	0.44
15 – 28 days	30.20	30.97	32.00	8.18	0.65
29 – 42 days	37.97	37.19	36.64	6.81	0.68
43 – 47 days	39.74	35.67	36.84	12.31	0.35
0 – 47 days	32.23	32.24	31.86	5.62	0.95

In parenthesis: number of animals.

Table III. Feed intake and feed to gain ratio per replicate[1] (mean values).

Parameters	Groups			S.D. error	P values
	F	C	G		
Feed intake ($g \cdot d^{-1}$)					
0 – 14 days	339.25	345.63	351.29	22.83	0.56
15 – 28 days	490.12	491.21	494.29	26.71	0.95
29 – 42 days	573.37	562.77	572.65	50.91	0.90
43 – 47days	615.37	622.00	611.20	49.36	0.93
0 – 47 days	486.61	489.98	488.61	23.29	0.98
Feed gain ratio:					
0 – 14 days	3.17	3.02	3.03	0.42	0.65
15 – 28 days	4.11	4.00	4.07	0.52	0.90
29 – 42 days	3.80	3.68	3.94	0.30	0.30
43 – 47 days	3.82	4.03	4.09	0.51	0.61
0 – 47 days	3.65	3.67	3.64	0.22	0.98

[1] Nine replicates of four rabbits each per group.

Table IV. Slaughtering data (mean values).

Parameters	Groups			S.D. error	P values
	F	C	G		
Hot carcass weight (g)	1 546.71	1 552.00	1 525.00	191.64	0.83
Dressing out percentage (%)	62.34	62.45	61.70	1.70	0.17
Skin weight (%)[1]	14.25	14.36	14.26	1.10	0.89
Full gastrointestinal tract weight (%)[1]	15.43	16.03	16.28	1.78	0.14

[1] On live weight.

Table V. Caecal weight and chemical composition of its content (mean values).

Parameters	Groups			S.D. error	P values
	F	C	G		
Caecal weight (%)[1]	38.10	40.48	37.35	4.95	0.36
Caecal content weight (%)[2]	66.04	65.95	65.08	5.05	0.90
Water (%)	79.40	76.59	78.87	2.81	0.58
Crude protein (%)	34.61	33.26	33.92	3.54	0.16
Lipids (%)	2.95	2.70	2.69	0.57	0.28
Ash (%)	10.47	10.50	10.69	1.77	0.49
Neutral detergent fibre (%)	47.54	48.08	47.56	4.17	0.24
Acid detergent fibre (%)	26.92	29.61	29.75	4.08	0.38
Starch (%)	1.50	1.35	1.23	0.30	0.60

[1] On the full gastrointestinal tract weight; [2] on the caecal weight.

Table VI. Caecal contents pH and number of rabbits per coliform class (mean values).

Parameters	Groups			S.D. error	P values
	F	C	G		
pH	5.93	5.96	5.84	0.22	0.49
Coliforms ($n \cdot g^{-1}$ fresh content):					
$< 10^2$	6	8	6	–	–
$10^2 – 10^3$	2	0	2	–	–
$10^3 – 10^4$	0	1	1	–	–
$> 10^4$	2	1	1	–	–

Table VII. Apparent faecal digestibility values (%) of the diets (mean values).

Parameters	Groups			S.D. error	P values
	F	C	G		
Dry matter	62.6	64.3	63.6	1.94	0.25
Organic matter	62.7	64.9	63.9	2.02	0.13
Crude protein (N × 6.25)	80.8	79.4	80.5	2.13	0.49
Ether extract	68.6	71.0	68.3	4.74	0.47
Crude fibre	10.6B	14.6A	14.8A	2.73	0.01
Neutral detergent fibre	31.8B	31.6B	36.5A	2.98	0.01
Acid detergent fibre	10.5B	16.6A	18.3A	3.12	0.01
Gross energy	62.5	64.6	63.7	2.10	0.15

A vs. B: $P < 0.01$.

(Tab. VII). On the contrary, rabbits that received diet F showed a significant reduction ($P < 0.01$) of digestibility for crude fibre (CF), NDF and ADF when compared to group G. Digestibility of CF and the lignocellulosic fraction in the control rabbits (C) was substantially similar to the latter group (G), while NDF digestibility was similar to the former one (F).

4. DISCUSSION

As expected, the diet that was ground more finely showed a higher percentage of fine particles. However it is interesting to note that not only the percentage but also the chemical composition of the different particle size classes was influenced by the grinding fineness: in particular, the NDF content was larger in the ∅ > 1 mm class for feed F and in the ∅ < 0.25 mm class for feed G.

Health status and mortality rate do not seem to be practically influenced by the particle size classes of the diets used. Laplace and Lebas [13] found an increased digestive pathology in relation to feeds only composed of very small particles (∅ < 0.25 mm). On the contrary, Morisse [15] observed a significant reduction of mortality rate using a diet with a particle size distribution similar to our F diet. In our work, neither anatomical nor histological examination revealed any problems related to the different treatments.

Concerning growth performance and feed efficiency, literature data from different trials carried out with feedstuffs containing particles of different sizes exhibit some discrepancies, probably due to a wide variety of particle diameters that are not always clearly defined. Alicata et al. [1] and Diaz Arca et al. [7] did not find any improvement of these parameters using feeds with a finer particle size. In other trials, feeds with smaller particles than those currently used were able to improve feed/gain ratio [3, 13] or induce a better growth in the first breeding period [6]. On the contrary, diets with very small particles sizes (∅ < 0.25 mm) induced a significant reduction of growth rate [15]. So, the different grinding level we used was probably not effective in modifying weight gain and feed efficiency.

Slaughtering data did not show any difference between the groups in our trials. Furthermore, dressing out percentage was the same in all the rabbits, in contrast with our expectations and those of other authors who found an increased weight of total digestive tract in rabbits fed more finely ground diets [13, 15]. Their results were related to an increased antiperistaltic action of the proximal colon due to smaller particles [4] as confirmed by Gidenne [9] who showed that only particle sizes ∅ < 0.315 mm are carried back to the caecum, with consequently longer retention times and higher total digestive tract weight. However, no differences neither in caecal weight nor caecal contents were evidenced between the rabbits in our trials.

Furthermore, according to Gidenne [9], if only the finest class of the different feeds should be carried back to the caecum, we would expect some differences in the chemical analysis of the caecal contents as a consequence of the different compositions of the diets (especially for NDF contents). No significant differences were, however, available on this point. So, digestion and absorption in the small gut may have reduced the differences between the particles that reached the large gut; and even pelleting, that may also have a grinding effect [14], could have influenced our findings.

The significant improvements in CF, NDF and ADF digestibility, for rabbits fed the G diet, are probably related to a different fibrolytic activity of the caecal flora in these rabbits [10]; the lack of differences in the caecal content composition or pH do not, however, allow any supposition on this point and need further studies. Anyway, according to our results, a reduction of fibre digestibility with finely ground feeds has been shown by the same authors [8, 10]. Recently, Gidenne et al. [11] showed that rabbits are able to digest the lignocellulosic fraction of diets containing different amounts of ADF without differences, probably as a consequence of a different fibrolytic activity in the caecum. Therefore, the differences we found in our work can probably be more ascribed to the different composition of the different particle size classes in the diets used. However, a different fibre digestibility did not change the digestibility of the whole diet.

The physiological number of coliforms we found was related to a similar low caecal pH among the groups. Data concerning the rabbits that exceeded the values usually indicated as "within the physiological range" for this species, are probably not so important. In fact, in a recent study, Morisse et al. [16] found a high number of coliforms in healthy rabbits fed in a traditional way, with very high fibre components, even if their caecal contents showed low pH values.

5. CONCLUSIONS

The different feed grinding fineness, obtained following different manufacturing processes did not substantially influence health status, mortality rate, growth performances, slaughtering data and digestive tract incidence of the rabbits used in our experiment. Even if cell wall polysaccharides digestibility changed in relation to the different particle sizes, digestive efficiency was the same for the different diets used. In conclusion, we can affirm that rabbits exhibit a great capacity to adapt to diets with different particle sizes. Further studies need to be carried out, however, in order to investigate the exact relation between small particles, caecal content characteristics and fibrolytic activity.

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