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Original article

Replacement of digestible fibre by starch in the diet of the growing rabbit. II. Effects on performances and mortality by diarrhoea

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Abstract — The effects of the level of dietary starch on growth performance and mortality were studied in six experimental sites on 2 328 growing rabbits (582 per diet). Four iso-lignocellulosic (ADF) diets (A12, A16, A20, A24) with increasing starch content (12, 16, 20, 24%) instead of digestible fibre (hemicelluloses and pectins) were compared. Diets were given ad libitum from weaning (28 and 35 d old, depending on the site) to slaughter (between 68 and 71 d old). The increase (12 points) of dietary starch level led to a double-rise of mortality rate by digestive disturbances: 4.6% and 10.1% respectively for A12 and A24 for the whole period. In parallel, the feed conversion ratio decreased slightly but significantly by 0.15 point between A12 and A24. The feed intake and the digestible energy intake was respectively reduced by only 4.5% and by 1.5% ($P < 0.01$), between the A12 and A24 diets. During the whole period the growth rate remained similar for the four diets (mean = 42.5 $g \cdot d^{-1}$). To ensure digestive security of the growing rabbit, it is recommended to maintain a dietary starch level below 14% during the post-weaning period, while for the end-fattening period dietary starch could reach 18%.

rabbit / feeding / starch / fibre / growth / diarrhoea / mortality

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Résumé —Apports d'amidon en remplacement de fibres digestibles dans l'alimentation du lapin en croissance. II. Conséquences sur les performances et la mortalité par diarrhée. Au total, 2 328 lapins en croissance ont été mis en expérience dans six stations expérimentales, afin d'étudier les effets d'un apport croissant d'amidon en substitution de fibres digestibles, sur les performances de croissance et la mortalité au cours de la période d'engraissement. Quatre aliments (A12, A16, A20, A24) renfermant de 12 à 24 % d'amidon (12 à 24 %) ont été comparés. L'amidon remplaçait des fibres digestibles (hémicelluloses et pectines) sans variation concomitante des teneurs en protéines et en lignocellulose. Les aliments ont été distribués à volonté depuis le sevrage (entre 28 et 35 j d'âge selon le site) jusqu'à l'abattage (entre 68 et 71 j d'âge). L'accroissement de 12 points du taux d'amidon entre les régimes extrêmes (A12 vs. A24) entraîne un doublement de la mortalité par troubles digestifs sur la période totale d'engraissement (respectivement 4,6 et 10,1 %). Parallèlement l'indice de consommation s'abaisse faiblement (mais significativement) de 0,15 point entre ces mêmes régimes (respectivement 3,16 et 3,01 kg d'aliment par kg de gain). Entre les régimes extrêmes (A12 vs. A24) et sur la période totale (28 à 71 j d'âge), l'ingestion d'aliment et d'énergie digestible baisse faiblement (resp. –4,5 % et –1,5 % ; $P < 0{,}01$) tandis que la vitesse de croissance ne varie pas significativement (42,5 $g{\cdot}j^{-1}$ en moyenne). Pour assurer la sécurité digestive du lapin en croissance, il est donc recommandé de limiter le taux d'amidon à 14 %, en période post-sevrage ; alors qu'en fin d'engraissement le taux d'amidon alimentaire peut atteindre 18 %.

lapin / alimentation / amidon / fibres alimentaires / croissance / diarrhée / mortalité

1. INTRODUCTION

A minimum dietary supply in plant cell walls is essential in the feed of the fattening rabbit to ensure normal digestive processes and to avoid deadly enteritis [13]. Several studies have shown the favourable role of the lignocellulosic fraction on the mortality of fattening rabbits [2, 15] and have quantified the needs for the components of lignocellulose itself by analysing the respective effects of lignins and cellulose [6, 7, 9, 16, 17].

In parallel, the recommendations on starch supply remain insufficiently supported by experimental results and the interactions between starch and fibre, in particular the non lignocellulosic fraction, have been scarcely studied [1, 2, 4].

Thus, a concerted study associating INRA, Itavi and five feed manufacturers was carried out to analyse the effects of increasing the starch/digestible fibre ratio (with similar ADF level) on digestion and retention of nutrients (see part 1 of the study, [8]), and on the performances and mortality of the fattening rabbits (present study). This work consisted in managing a high number of animals during several experiments under various breeding conditions and with the same diets, in order to obtain results transposable to commercial breeding.

2. MATERIALS AND METHODS

2.1. Animals and experimental conditions

The same protocol was applied at six locations, respectively in the experimental breeding unit of ITAVI (Rambouillet) and in five animal feeding companies: CCPA (Vienne-en-Arthies), Guyomarc'h (St-Nolff), Sanders (Sourches), UCAAB (Montfaucon) and UFAC (Vigny). All the experiments were carried out during the spring of 1993. They differed in the number of rabbits used, the genotypes and the housing conditions. The experimental conditions are summarised in Table I. On the whole, 2 328 rabbits were used (582 animals per diet).

2.2. Experimental diets

Four iso-proteic diets (A12, A16, A20, A24) containing increasing starch levels (respectively 12, 16, 20 and 24%) were

Table I. Experimental conditions in the different sites.

Site	Number of rabbits per diet	Number of rabbits per cage	Genotype	Age at weaning (days)	Weight at weaning (g)	Age at slaughter (days)	Weight at slaughter (g)
1	72	6	Hycole	28	676	70	2 285
2	84	7	Hyplus	31	748	68	2 457
3	192	6	Hyplus	34	841	69	2 362
4	84	7	Hyplus	35	953	71	2 413
5	78	6	Vitaline	31	801	67	2 289
6	72	6	Hyplus	30	695	71	2 437
Total	582						

compared. The cereal starch (from wheat and barley) replaced digestible fibres (from beet pulp and wheat bran mainly), without simultaneous variation of the lignocellulose level (ADF = 18%) provided by a common basis (alfalfa and straw). The theoretical DP/DE ratios were similar. The ingredients and the analytical characteristics of the experimental diets were reported in detail in the first part of this study [8]. The feeds (pellets of 4 mm diameter) were manufactured at one time (Sanders-Sourches) with the same batches of raw materials. They were distributed ad libitum from weaning (between 28 and 35 days of age according to the site, Tab. I) to slaughter (between 68 and 71 days of age). No prophylactic treatments were given to the animals in the diets nor in the drinking water.

2.3. Measurements on animals

In the 6 experimental sites, the animals were placed in collective wired cages, in closed units where the environment (temperature, ventilation) was controlled. Animals were allotted to diets according to weaning weight and litter origin. Rabbits were weighed at weaning, at 49 days of age and at slaughter. Feed consumption was measured per period and per cage. Mortality was controlled daily. In the event of mortality, the food remaining in the feeder was weighed to calculate the real feed intake, taking into account the duration of the presence and the number of rabbits remaining per cage. Cages having a mortality higher than 50% were not included in the statistical analysis of the growth performances or intake.

2.4. Statistical analysis

The results were initially analysed according to experimental location, using the techniques of covariance and variance analyses according to GLM procedure [19]. This analysis was followed by an overall data processing resulting from the data from the five sites, by taking into account “diet” and “site”, the “series intra-site” effect and the “site × diet” interactions in addition to the principal effects. One of the experimental sites (No. 5) was excluded from the final statistical analysis because of an abnormally high mortality (40%) without a relationship with feeding. The multiple comparisons of means were analysed using the Scheffe test. The results of mortality were analysed according to the K Pearson method (distribution of χ^2) and according to the CATMOD procedure [19]. The multiple comparisons were carried out by the method of contrasts and the significance of the linearity of the response to the diet effect was analysed using the Maentel-Henszel test.

3. RESULTS

3.1. Growth performances

Generally, we observed a significant effect of the “site” for all parameters. However, no significant interaction between the effect of the site and that of the diet was noticed whatever the criterion or the period considered (Tabs. II, III and IV). This absence of interaction allowed a common statistical analysis of the whole dataset.

During the initial phase of growth, from weaning to 49 days of age (Tab. II), the weight gain (in all sites) differed according to the diets ($P = 0.03$), but the differences between treatments were very weak (maximum deviation < 2 $g \cdot d^{-1}$). The diet effect on growth was significant only in two sites out of five. The initial weights varied according to the site, between 676 and 953 g depending upon weaning ages (28 to 35 days) and the genotypes used (cf. Tab. I). However, introducing the weight at weaning as a covariate in the statistical model did not affect the significance of the diet effect.

Feed intake decreased slightly as the starch level increased in the diets (–6.3%, between A12 and A24; $P < 0.01$). This could be attributed to the slight variations in digestible energy (DE) concentration recorded between the extreme diets (10.1 vs. 10.4 MJ) in the first part of this study [8]. In fact, expressed on a DE basis, intake is logically less affected by the diet, even if significant differences remained between A12 and A24 for the DE intake. The latter was associated by similar variations of the growth rate. The energetic conversion index remained unaffected among the diets (23 MJ of DE on average per kg gain).

During the finishing period (Tab. III), the weight gain was not significantly different for the four diets. Feed consumption was slightly but significantly reduced for the two extreme diets (–3.6% between A12 and A24; $P < 0.01$). Since the growth rate was similar, the conversion index varied concurrently to the intake (–0.25 units between A12 and A24; $P = 0.01$). The DE intake, and correlatively the energetic conversion index were unaffected by the treatments.

Table II. Zootechnical performances from weaning to 49 days of age.

Diets	A12	A16	A20	A24	Statistical level			
Starch (%)	12.3	16.1	20.0	23.5	RMSE[2]	Site	Diet	Site × Diet
n[1]	*492*	*486*	*473*	*470*				
Weight at weaning (g)	797	796	794	797	*57*	*<0.01*	*1.00*	*1.00*
Weight at 49 d (g)	1 550	1 552	1 539	1 529	*88*	*<0.01*	*0.27*	*0.99*
Weight gain ($g \cdot d^{-1}$)	46.0^{ab}	46.3^{a}	45.3^{ab}	44.6^{b}	*3.6*	*<0.01*	*0.03*	*0.63*
Feed intake								
($g \cdot d^{-1}$)	105.1^{a}	102.1^{a}	101.6^{ab}	98.5^{b}	*7.9*	*<0.01*	*<0.01*	*0.73*
(MJ $DE \cdot d^{-1}$)	1.06^{a}	1.04^{ab}	1.03^{ab}	1.02^{b}	*0.08*	*<0.01*	*0.01*	*0.76*
Feed conversion								
($kg \cdot kg^{-1}$ gain)	2.29	2.21	2.28	2.23	*0.27*	*<0.01*	*0.36*	*0.66*
(MJ $DE \cdot kg^{-1}$ gain)	23.1	22.5	23.0	23.1	*2.7*	*<0.01*	*0.39*	*0.64*

[1] Number of rabbits used in the statistical analysis.
[2] Root mean square error.
[a, b] Means having a common superscript are not different at the level $P = 0.05$.

Table III. Zootechnical performances from 49 d of age to slaughter.

Diets	A12	A16	A 20	A 24	Statistical level			
Starch (%)	12.3	16.1	20.0	23.5	RMSE^{2}	Site	Diet	Site × Diet
n^{1}	*481*	*479*	*464*	*453*				
Final weight (g)	2 380	2 382	2 389	2 383	*117*	*< 0.01*	*0.85*	*0.98*
Weight gain ($g \cdot d^{-1}$)	39.9	39.8	40.8	41.0	*3.8*	*< 0.01*	*0.19*	*0.92*
Feed intake								
($g \cdot d^{-1}$)	155.8^{a}	151.6^{ab}	152.3^{ab}	150.2^{b}	*9.5*	*< 0.01*	*< 0.01*	*0.89*
($MJ\ DE \cdot d^{-1}$)	1.57	1.54	1.54	1.56	*0.10*	*< 0.01*	*0.16*	*0.90*
Feed conversion								
($kg \cdot kg^{-1}$ gain)	3.93^{a}	3.86^{ab}	3.76^{ab}	3.68^{b}	*0.41*	*< 0.01*	*0.01*	*0.99*
($MJ\ DE \cdot kg^{-1}$ gain)	39.6	39.1	38.0	38.3	*4.2*	*< 0.01*	*0.16*	*0.99*

[1, 2] See Table II.

Table IV. Zootechnical performances during the whole fattening period.

Diets	A12	A16	A20	A24	Statistical level			
Starch (%)	12.3	16.1	20.0	23.5	RMSE^{2}	Site	Diet	Site × Diet
n^{1}	*481*	*479*	*464*	*453*				
Weight gain ($g \cdot d^{-1}$)	42.4	42.5	42.7	42.5	*2.4*	*< 0.01*	*0.68*	*0.79*
Feed intake								
($g \cdot d^{-1}$)	133.5^{a}	129.9^{b}	129.9^{b}	127.4^{b}	*7.4*	*< 0.01*	*< 0.01*	*0.98*
($MJ\ DE \cdot d^{-1}$)	1.35^{a}	1.32^{ab}	1.31^{b}	1.33^{ab}	*0.08*	*< 0.01*	*0.04*	*0.98*
Feed conversion								
($kg \cdot kg^{-1}$ gain)	3.16^{a}	3.06^{b}	3.06^{b}	3.01^{b}	*0.15*	*< 0.01*	*< 0.01*	*0.78*
($MJ\ DE \cdot kg^{-1}$ gain)	31.9^{a}	31.0^{b}	30.9^{b}	31.3^{ab}	*1.5*	*< 0.01*	*< 0.01*	*0.76*

[1, 2] See Table II.

During the whole fattening period (Tab. IV), the weight gain was strictly identical between the groups (42.5 $g \cdot d^{-1}$ on average). Feed consumption decreased ($P < 0.01$) when the dietary starch level reached 16% (diet A16) and dropped an average 5% between A12 and A24. Since the growth rate remained similar, the conversion index varied concurrently to the intake (–0.15 unit between A12 and A24; –5% in relative value). The DE intake and the energetic conversion index, although significantly different between the 2 extreme diets because of the effect recorded in the first period, were not greatly affected by the diet.

3.2. Mortality

On the 5 experimental sites kept for the analysis, mortality was always caused by acute digestive disorders, without any

Table V. Mortality from enteritis.

Diets	A12	A16	A20	A24	Effect diet[1]	
Initial number	(n = 504)	(n = 504)	(n = 504)	(n = 504)	χ^2	*P level*
Period: weaning – 49 days						
Number of dead	12^b	18^{ab}	31^a	34^a	14.5	< 0.01
Mortality rate (%)[2]	2.4	3.6	6.1	6.7		
Period: 49 days – slaughter						
Number of dead	11	7	9	17	5.2	0.16
Mortality rate (%)[2]	2.2	1.4	1.8	3.4		
Whole period						
Number of dead	23^b	25^b	40^a	51^a	16.2	< 0.01
Mortality rate (%)[2]	4.6	5.0	7.9	10.1		

[1] Chi^2 test according to K. Pearson.
[2] Mortality rate expressed in percent of the initial number of rabbits (n = 504).

identification of a specific pathology at autopsy (such as coccidiosis or colibacillosis). Independently of the diet, the mortality rate by digestive disorders varied strongly according to the experimental site (between 3.3 and 9.9%). This "site" effect was not related to the age at weaning nor to the initial weight of the young rabbits.

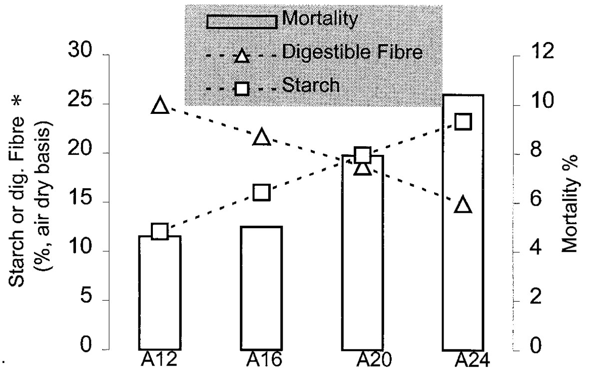
Between weaning and 49 days of age, a very strong negative influence of the dietary starch level was recorded for the mortality rate of animals, by digestive disorders (χ^2 value = 14.5; $P < 0{,}01$). In fact, during this period, mortality evolved linearly ($P = 0.003$) and almost tripled (6.7 vs. 2.4%) between the extreme diets (A24 vs. A12). During the finishing period, mortality remained higher with the A24 diet, but the differences between the diets were not significant (χ^2 value = 5.2; $P = 0.16$).

During the whole fattening period, the diet had a clear effect on mortality (χ^2 value = 16.2; $P < 0.01$). In fact, the mortality recorded for the A24 diet (10.1%) was twice higher than that observed for the A12 or A16 diets (4.8% on average). This increase in mortality evolved linearly ($P = 0.001$; Fig. 1) within the range of the diets tested.

4. DISCUSSION

The methodological interest of this study lies in the statistical reliability of the experimental design (582 animals per diet), in the diversity of the breeding conditions (6 locations) organised in a research network, and in the application of a standardised protocol to control growth performances. Let us underline the high level of weight gain results: an average 43 $g \cdot d^{-1}$ for a daily feed intake of 130 g, leading to a feed conversion of approximately 3 kg per kg gain.

The digestible energy level of the 4 experimental diets was similar (an average 10.2 MJ $DE \cdot kg^{-1}$, first part of the study [8]) and was in the classical range of the feed intake regulation for the rabbit (ranging between 9.2 and 13.4 MJ of DE). We, however, observed a significant reduction of the intake (–5%) from A12 to A24, which could correspond to a metabolic adjustment (non measurable through faecal digestibility), but which was not detected by measurements of energy retention. The growth of rabbits differed only in the post-weaning period, where a slight reduction of growth occurred for the highest starch supply. This



* Digestible fibre = hemicellulose (NDF-ADF) + pectins (calculated).

Figure 1. Replacement of digestible fibre by starch in the diet of growing rabbits: effect on mortality by digestive troubles (period 28–71 d old).

unfavourable effect of a high starch/DF ratio was associated with a rise in mortality observed during this period. Similarly, in previous studies on fibre supply [16, 17, 18], the post-weaning period corresponded to a strong expression of the growth potential and also to an increased sensitivity to the breeding and feeding conditions. The reduction of growth was thus probably the consequence of a more precarious health status of rabbits consuming the diets rich in starch (or lowest in DF), since we did not exclude any animals with abnormal weight gain. Besides, we did not perform any health status control (signs of transitory diarrhoea etc.) to evaluate the morbidity level according to the diets.

The variations of the feed conversion index were very weak, in spite of a wide variation in the origin of the nutrients: starch vs. DF. This suggested a high valorisation of the hemicellulosic and pectic fractions (compared to cereal starch) by the rabbit, as already mentioned in the first part of this study for a limited number of animals [8]. This high energy valorisation from hemicelluloses and pectins has been mentioned recently by Carabaño et al. [3] and by Jehl et al. [12].

Concerning the health status of young rabbits during fattening, this work demonstrated that a reduction of the digestible fibre supply to the benefit of a starch supply involved a quasi linear rise of mortality (Fig. 1), particularly in the post-weaning period. This effect was associated with a higher retention time of digesta (+25% in duration) and with growth disturbances. Moreover, it confirmed the results of a previous study carried out with the same diets, indicating that the rise of mortality was associated with a reduction of the caecal microbial activity [11].

The unfavourable effect of starch on health status, more marked in the young rabbit (post-weaning period), was in agreement with the recent data of digestive physiology indicating that the secretion of amylolytic enzymes develops at least until 42 d of age [20]. Thus an excessive starch flow entering the caecum could be unfavourable to the fibrolytic flora (also in a phase of development). In the end-fattening rabbit (10 wks of age), the effect of starch on health seems less marked, which is coherent with a recent study showing that ileal starch flow is very low (< 2 g·d^{-1}) at this age [10].

Concerning the objective of limiting enteritis risks, these results indicate that it is convenient to limit the dietary starch level to 14% for post-weaning rabbits (prior to 42 d of age), in agreement with Maertens [14].

During the finishing period, it is possible to level up the starch supply to 18%, without a major impact on the digestive security of the animals. Nevertheless, let us underline, that it is also advisable to respect the lignocellulose supply (in quality and quantity). These fibre/starch recommendations have been subjected to a recent synthesis [5].

5. CONCLUSION

Such a concerted study within a research network is of high interest and originality so that reliable results may be obtained concerning the interactions between nutrition and digestive pathology of the rabbit. Our results indicate that the use of a single criterion such as ADF is insufficient to characterise the security level of a feed. It is necessary to associate a criterion for starch and digestible fibre supply. The negative role of an excessive starch intake on non specific enteritis incidence was shown mainly in the post-weaning period, independently of the quantity of dietary lignocellulose.

Conversely, with a constant ADF level, substituting digestible fibres for starch reduced the incidence of digestive troubles without main changes in growth or feed efficiency. These original results constitute a first response to one of the main problems in rabbit nutrition: how to reduce the incidence of digestive disorders without altering the performances.

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