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Original article

Effect of cereal sources and processing in diets for the growing rabbit. II. Effects on performances and mortality by enteropathy

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Abstract – The effects of the quality of the dietary starch on growth performance and mortality were studied on five experimental sites on 1784 growing rabbits (446 per diet). Four iso-fibre diets varying in starch nature (W-wheat, B-barley, M-maize, EM-Extruded maize) were compared. The diets were given ad libitum from weaning (30 to 35 d. of age, depending on the site) to slaughter (68 to 71 d). From weaning to 49 days of age, the weight gain did not differ significantly according to the starch source (mean = 48.6 $g \cdot d^{-1}$ on average). The feed intake was higher for the M diet compared to the other three diets (+5%, $P < 0.01$). During the finishing period (49 d to slaughter), the weight gain was significantly higher for the EM diet compared to the W or B diets (+2%). The feed consumption was 5% higher ($P < 0.01$) for the M diet, compared to other treatments. Thus, feed conversion was the worst for the M diet, while it was the lowest for the EM diet. During the whole fattening period, the weight gain was only slightly higher with extruded maize feed, compared to the others (meanly +0.8 $g \cdot d^{-1}$). Correlatively, feed intake and conversion index were significantly lower for the EM diet, while they were the highest for the M diet (–2 to –4% compared to B and W diets). On the five experimental sites, mortality was always caused by acute digestive disorders, without specific pathology. The mortality rate due to diarrhoea greatly varied among sites (between 1.7 and 19.4%). The mortality rate between weaning and 49 days of age and during the finishing period was not affected by the dietary starch origin. However, the mortality in the W group was 3 points lower than in the M group ($P = 0.07$).

rabbit / feeding / starch nature / extrusion / enteropathy / growth

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Résumé – Effet du type de céréale et de l'extrusion dans l'alimentation du lapin en croissance. II. Effets sur les performances de croissance et sur la mortalité par entéropathie non spécifique. Les effets de la nature de l'amidon sur les performances de croissance et l'état sanitaire du lapin en croissance ont été étudiés dans 5 sites expérimentaux, à raison de 446 lapins par traitement. Quatre régimes différant seulement par la nature de l'amidon ont été comparés : W = amidon de blé, B = amidon d'orge, M = amidon de maïs, EM = amidon de maïs extrudé. Les animaux ont été alimentés à volonté entre le sevrage (30 à 35 jours d'âge, selon le site) et l'abattage (68 à 71 jours d'âge). Du sevrage à 49 jours d'âge, la vitesse de croissance a été élevée et n'a pas différé significativement entre les 4 traitements (en moyenne = 48.6 $g \cdot j^{-1}$). L'ingestion d'aliment a été plus élevée pour le régime M (+5 %, P < 0,01). En période de fin d'engraissement (49 j à abattage), la vitesse de croissance a été plus rapide pour le régime EM, comparée aux régimes "Blé" ou "Orge" (+2 %). L'aliment à base de maïs a présenté le niveau d'ingestion le plus élevé (+5 %, P < 0,01), et aussi l'indice de consommation le plus haut, tandis que le régime EM a présenté la conversion alimentaire la plus efficace. Durant la totalité de la période de croissance, la vitesse de croissance a été seulement légèrement plus élevée pour le groupe EM (en moyenne +0,8 $g \cdot j^{-1}$ par rapport aux trois autres groupes), tandis que l'ingestion et l'indice de consommation ont été les plus faibles (–2 à –4 % respectivement comparé aux groupes B et W). Sur les 5 sites expérimentaux la mortalité a toujours été causée par une diarrhée aiguë, sans pathologie spécifique identifiable. Le taux de mortalité par diarrhée a beaucoup varié selon le site (entre 1,7 et 19,4 %). La mortalité post-sevrage ou en fin de croissance ne varie pas significativement en fonction des traitements. Cependant, on peut remarquer un taux de mortalité inférieur de 3 points pour le groupe B par rapport au groupe M (P = 0,07).

lapin / nature d'amidon / extrusion / entéropathies / croissance

1. INTRODUCTION

Feeds with high starch and low fibre content favour the incidence of enteropathy in the growing rabbit [2, 4] without identification of a specific pathogenic agent. The flow of nutrients reaching the caecum modifies the balance of the caecal ecosystem [1], and thus may alter the sensibility of the animals to enteropathy. Dietary fibre constitutes the main part of the nutrient ilea flow, and thus plays a key role in this enteropathy syndrome [8]. However, since the young rabbit incompletely digests starch till 7 weeks of age [5], a significant quantity of starch would reach the caecum and may interact with digestive health, particularly for starch sources resistant to digestion in the small intestine such as maize. However, there is a lack of references on the effect of the source and processing of starch on growth and digestive health in the young rabbit [2, 3]. Some studies have tried to address this problem by using varying sources of starch [9, 13], to compare diets having similar levels of starch and other nutrients. However, the effects of starch nature on mortality by non-specific enteropathy have, to our knowledge never been studied using a powerful procedure, such as a network of experimental sites involved in studies on the role of dietary fibre/starch supply [12], in order to include a large number of rabbits in the experiment, and thus to assess more precisely the health status of the animal. Therefore, the establishment of recommendations on starch remains incomplete and it must be supported by experimental results, particularly to assess the potential effects of the cereal sources on mortality by digestive troubles.

A concerted study associating a research centre (INRA), an extension centre (ITAVI) and five feed manufacturers was thus carried out to analyse the effects of varying the origin of starch (with similar fibre levels) on the digestion of nutrients (see part I of the study [7]), and on the performances and mortality of the fattening rabbits (present study). The concerted study consisted in managing repeated assays on a high number of animals, under various breeding conditions while using the same protocol, in order to obtain results transposable to commercial breeding.

Table I. Experimental conditions in the different sites.

Site	Number of rabbits per diet	Rabbits per cage / cages per diet	Genotype	Age at weaning (days)	Age at slaughter (days)
1	98	7 / 14	Hyplus	31	68
2	120	6 / 20	Hyplus	34	68
3	84	7 / 12	Hyplus	35	71
4	72	6 / 12	Vitaline	31	70
5	72	6 / 12	Hyplus	30	71
Total	*446*	*Cages = 70*			

2. MATERIALS AND METHODS

2.1. Animals and experimental conditions

The same procedure was applied in five French experimental breeding units: ITAVI (Rambouillet), Evialis (St Nolff), Cybelia (Groupe Glon, Sourches), INZO (UCAAB, Montfaucon), Trouw Nutrition (Vigny). The five replicates of this study were carried out in spring 1995. In the five experimental sites, the rabbits were housed in collective wire net cages, with the same density (0.06 m^2 per rabbit, 6 or 7 rabbits per cage), in closed units where the environment (temperature, ventilation) was controlled. However in each location, the experimental conditions differed by the number of rabbits used, the genotypes and the housing conditions (Tab. I). Overall, 1784 rabbits were used (446 animals per diet). The animals were allotted to diets according to weaning weight and litter origin.

2.2. Experimental diets

The four diets varied only in the origin of the starch incorporated or by the processing of starch (extrusion), without changes in starch level (meanly 20.8%), or in protein or fibre level. Starch was supplied by three different cereal sources, wheat (diet W), barley (diet B), maize (diet M), and by extruded maize (diet EM). The level of lignocellulose (ADF = 16.3%) was slightly below recent recommendations [4], while the level of starch was chosen about 5 points over the usual post-weaning recommendations [4]. The ingredients and the analytical characteristics of the experimental diets were reported in detail in the first part of this study [7]. The four diets were manufactured and pelleted at one time (CCPA, Osny), using the same batches of raw materials. They were distributed ad libitum from weaning (between 30 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, neither in the diets nor in drinking water (antibiotic or coccidiostatic).

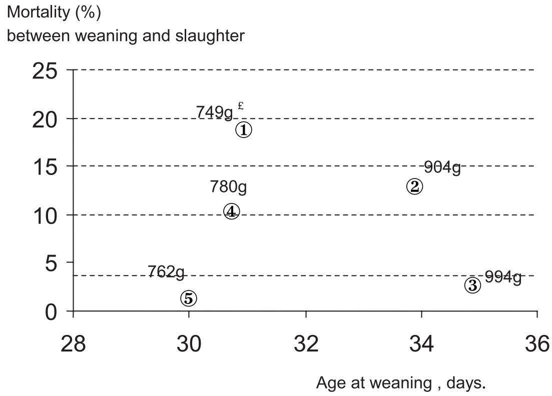
The nutritive value of the diets was determined in the first part of this study [7]. The digestible energy contents were 11.49, 12.24, 11.68, 11.97 $MJ \cdot kg^{-1}$ (air dry basis) respectively for W, B, M, and EM diets.

2.3. Measurements on animals

The rabbits were individually identified and 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 presence and the number of rabbits remaining per cage. If mortality exceeded 50% within a cage, the data were not included in the statistical analysis of the feed intake.

2.4. Statistical analysis

The results were first analysed by experimental location, using the techniques of covariance and variance analyses according



£ : live-weight at weaning
① : Site number

Figure 1. Weight at weaning and mortality according to experimental sites.

to the GLM procedure of SAS [14]: $Y = \mu + D + P + P \times D + Ww + \varepsilon$, with D = diet effect, P = period effect, Ww = weight at weaning (covariate). This analysis was followed by an overall data processing resulting for the five sites : $Y = \mu + D + S + P(S) + S \times D + Ww(S) + \varepsilon$, by taking into account in addition to the principal effects the diet and site "S", the effect period intra-site "P(S)", the interaction between site and diet "S × D", and the intra site weight at weaning "Ww(S)" as a covariate. The multiple comparisons of means were analysed using the Scheffe test. The mortality results were analysed according to the Pearson method (distribution of χ^2) and using the CATMOD procedure [14]. Contrast analysis was used to test the effect of extrusion on maize starch (diets M vs. EM). Low values of weight or weight gain of animals having digestive troubles were not discarded from the statistical analyses.

3. RESULTS

3.1. Growth performances

The initial weights varied according to the sites (from 749 to 994 g), depending on the weaning ages (28 to 35 days) and genotypes used (Fig. 1 and Tab. I). However, introducing the weight at weaning as a covariate in the statistical model did not affect the diet effect.

Generally, we observed a significant effect of the "site" for all variables. On the contrary, no interaction between the effect of the site and that of the diet was noticed whatever the criterion or the period considered (Tab. II), except for the growth rate in the post-weaning period (in one site the growth rate was slightly lower for the W diet, compared to the others). This situation allowed a common statistical analysis of the whole dataset.

From weaning to 49 days of age (Tab. II) the weight gain differed very weakly (maximum deviation under 1 $g \cdot d^{-1}$) among the four treatments. Post-weaning growth rate was analysed on each site (significant interaction with the diet): it differed significantly only in one site out of five, and was higher for W and EM diets compared to B and M diets (46.0 vs. 44.3 $g \cdot d^{-1}$).

The feed intake was higher with the M diet compared to the other three diets (+5%). This was not related to the dietary digestible energy (DE) concentration [7]. Expressed on a DE basis, differences in intake were more significant among diets, with the highest value for M and B diets,

Table II. Feed intake and growth performances according to the starch source.

Diets	W (wheat)		B (barley)		M (maize)		EM (extr. maize)		Statistical level			
n[1]	*414*		*404*		*403*		*408*		SEM[2]	Site	Diet	S × D
Weight at weaning (g)	844		840		843		844		*4.8*	*<0.01*	*0.94*	*1.00*
Weight at 49 d (g)	1646		1630		1641		1641		*8.1*	*<0.01*	*0.64*	*0.63*
Slaughter weight (g)	2538	ab	2512	b	2543	ab	2559	a	*10.9*	*<0.01*	*0.033*	*0.44*
Weight gain (g·d^{-1})												
From weaning to 49 d	49.0		48.0		48.7		48.7		*0.23*	*<0.01*	*0.41*	*0.014*
From 49 d to slaughter	43.0	b	42.5	b	43.5	ab	44.3	a	*0.31*	*<0.01*	*<0.01*	*0.69*
Weaning-slaughter	45.7	ab	45.0	b	45.9	ab	46.2	a	*0.23*	*<0.01*	*0.010*	*0.105*
Feed intake (g·d^{-1})												
From weaning to 49 d	105.5	b	104.1	b	110.7	a	103.1	b	*0.46*	*<0.01*	*<0.01*	*0.45*
From 49 d to slaughter	157.0	b	158.9	b	165.3	a	156.1	b	*0.56*	*<0.01*	*<0.01*	*0.37*
Weaning-slaughter	134.3	b	134.7	b	141.3	a	132.7	b	*0.46*	*<0.01*	*<0.01*	*0.65*
Energy intake (MJ DE·d^{-1})												
From weaning to 49 d	1.21	c	1.27	ab	1.29	a	1.23	bc	*0.005*	*<0.01*	*<0.01*	*0.46*
From 49 d to slaughter	1.80	c	1.95	a	1.93	ab	1.87	bc	*0.006*	*<0.01*	*0.01*	*0.36*
Weaning-slaughter	1.54	b	1.65	a	1.65	a	1.59	b	*0.005*	*<0.01*	*0.01*	*0.68*
Feed conversion (kg/kg gain)												
From weaning to 49 d	2.15	b	2.16	b	2.26	a	2.11	b	*0.007*	*<0.01*	*<0.01*	*0.22*
From 49 d to slaughter	3.66	b	3.77	ab	3.81	a	3.52	c	*0.014*	*<0.01*	*<0.01*	*0.061*
Weaning-slaughter	2.94	b	2.99	b	3.08	a	2.87	c	*0.007*	*<0.01*	*<0.01*	*0.93*
Energy conversion (MJ DE·kg^{-1} gain)												
From weaning to 49 d	24.7	b	26.4	a	26.4	a	25.3	b	*0.086*	*<0.01*	*0.01*	*0.19*
From 49 d to slaughter	42.1	c	46.2	a	44.5	b	42.2	c	*0.16*	*<0.01*	*<0.01*	*0.060*
Weaning-slaughter	33.8	b	36.6	a	35.9	a	34.3	b	*0.084*	*<0.01*	*<0.01*	*0.94*

[1] Number of rabbits used in the statistical analysis;
[2] Pooled standard error of the mean;
a, b: means having a common superscript are not different at the level $P = 0.05$.

while the lowest DE intake was recorded for the W diet. The latter were not associated with similar variations of the growth rate. Since growth rates were almost unaffected, the feed conversion and the energetic conversion index followed the same trend as intake. The extrusion of maize led to a 5% lower intake (feed or DE) compared to M, either in the post-weaning or finishing period.

Between 49 d and slaughter (68 to 71 d according to the site, Tab. II), the weight gain was significantly higher for the EM diet compared to the W or B diets. The feed consumption was 5% higher ($P < 0.01$) for the M diet, compared to the other treatments. Thus, feed conversion was the worst for the M diet, while it was the lowest for the EM diet. In return, the DE intake, and correlatively the energetic conversion index were significantly higher for B, and were similar for the W and EM diets.

During the whole growth period, weight gain was only slightly higher with EM feed, compared to the others (+0.8 g·d^{-1} on average). Accordingly, feed intake and conversion index were significantly lower for the

Table III. Mortality from non-specific enteropathy, according to the source of starch.

	Diets				*P level*[2]
	W	B	M	EM	Diet Effect
Initial number of rabbits	*446*	*446*	*446*	*446*	
Period: weaning – 49 days					
Number of dead	18	22	23	20	*0.86*
Mortality rate (%)[1]	*4.0*	*4.9*	*5.2*	*4.5*	
Period: 49 days – slaughter					
Number of dead	7	10	16	10	*0.27*
Mortality rate (%)[1]	*1.6*	*2.2*	*3.6*	*2.2*	
Period: weaning – slaughter					
Number of dead	25	32	39	30	*0.33*
Mortality rate (%)[1]	*5.6**	*7.2*	*8.7**	*6.7*	

[1] Mortality rate expressed as the percent of the initial number of rabbits (n = 446);
[2] Chi[2] test according to K. Pearson (CATMOD procedure, [14]);
*: contrast W vs. M, $P = 0.07$.

EM diet, while it was the highest for the M diet (+2 to +4% compared to the B and W diets), but the differences remained low.

3.2. Mortality

On the five experimental sites, mortality was always caused by acute digestive disorders, without any identification of a specific pathology at autopsy (such as coccidiosis or colibacillosis). Independently of the diet, the mortality rate due to non-specific enteropathy strongly varied according to the experimental site (between 1.7 and 19.4%). This "site" effect was not related to the age at weaning nor to the initial weight of the young rabbits (Fig. 1). The mortality rate was about half-higher during the two weeks after weaning compared to the 49-d-slaughter period.

Between weaning and 49 d, no influence of the dietary starch origin was recorded on the mortality rate of the animals (Tab. III, $P = 0.86$). Similarly, between 49 d and slaughter, the mortality rate remained unaffected by the dietary treatments. However, on the whole fattening period, the mortality in the W group tended to be lower than in the M group (–3 units, contrast W vs. M, $P = 0.07$).

4. DISCUSSION

The methodological interest of this study lies in the statistical reliability of the experimental design (446 animals per diet), in the diversity of the breeding conditions (5 locations) organised in a research network, and in the application of a standardised protocol to control growth performances. The study was performed under good breeding conditions, as attested by the relatively high level of performances, either for weight gain (meanly 45.7 $g \cdot d^{-1}$), feed intake (135.8 $g \cdot d^{-1}$), or for feed conversion. The post-weaning period corresponded to a strong expression of the growth potential (growth rate close to 50 $g \cdot d^{-1}$). It also corresponds to an increased sensitivity to the breeding conditions and to digestive troubles, since the mortality by non-specific enteropathy was higher after weaning compared to the finishing period, as reported in previous studies on fibre supply [10–12].

4.1. Dietary starch nature and growth performances

The digestible energy level of the 4 experimental diets differed slightly (maximum deviation = 0.7 $MJ \cdot kg^{-1}$, first part of the study [7], and was in the classical range where the rabbit is able to regulate its feed intake (between 9.2 and 13.4 MJ·kg^{-1} of DE). However, we observed a variation in feed intake (± 5%) not precisely related to dietary DE content. Thus, growth rate remained higher for the maize-based diet compared to barley, whereas its DE content was 0.4 MJ lower. Surprisingly, the DE content of the wheat-based diet appeared lower than that of barley, while growth rates were similar during the whole fattening period. Variations in growth rate were unlikely affected by the health status of rabbits, since mortality rate was globally low and similar among treatments.

Variations in feed conversion during the post-weaning period could be expected, taking into account that starch from maize was more resistant to digestion in the small intestine compared to barley or wheat. However, in the first part of this study [7] we observed that the ileal starch levels were similar among diets (except for extruded maize), and thus feed conversions were similar. However, during the finishing period, larger differences in ileal starch content were observed, with lower levels of ileal starch for the barley-based diet compared to maize. Accordingly, we observed lower feed conversion for the barley-based diet.

During the whole fattening period, the weight gain was similar among the three cereal sources. Xiccato et al. [16] also did not observe a significant effect of starch source (barley vs. maize) on rabbit growth, neither for a low nor a high inclusion level. The large size of the experimental design allowed identifying small differences among groups. Thus, a significant impact of the cereal source on intake and feed conversion was observed in favour of wheat and barley compared to maize.

4.2. Impact of starch nature on the digestive health status

The unfavourable effect of a high starch supply on the young rabbit health status is hypothesised in the literature [2, 3], but not demonstrated. Sanitary risk would be higher, for the young rabbit (period post-weaning) since the data of digestive physiology indicate that the secretion of amylolytic enzymes still develops until 42 d of age [5, 15]. Thus, an excessive starch flow entering the caecum could be unfavourable to the fibrolytic flora, itself in a phase of development [1, 6]. However, almost no studies have correctly addressed this question, since variations in starch supply are always associated with fibre supply variations. We here try to maximise the starch supply in the diets (≈20%), but we did not observe a significant effect on the digestive trouble incidence of the growing rabbit, nor in the post-weaning nor finishing period. The determination coefficient (R^2) between post-weaning mortality rate and ileal starch content at 49 d old was only 0.29, and it was 0.44 between whole fattening mortality and ileal starch level. Even with extruded maize, when the level of undigested starch was low, the mortality rate was not significantly lower than for the other diets. However, Pinheiro and Gidenne [13] found a higher *morbidity* for diets containing 14% of crude potato starch (resistant to digestion), but the ileal starch level was only 1.3% in 6 wk old rabbits. At the end of rabbit fattening, the mortality was generally lower and was supposed to be related to the low starch ileal flow (<2 g·d^{-1}) observed at this age, even with a high starch/low fibre diet [8]. Nevertheless, no relationship was found here between mortality and ileal starch concentration. Therefore, we suggest that the lower sensibility of older rabbits to enteropathies would be rather due to a more complete maturation and stability of its caecal microbial ecosystem, than to a better digestion of starch in the small intestine.

5. CONCLUSION

Such a concerted study within a research network is of high interest to obtain reliable results on the interactions between nutrition and digestive pathology of the rabbit. Our results indicate that the nature of the dietary starch could affect growth performances, but to a low extent. The extrusion of maize led to a lower intake without a change in rabbit growth, and accordingly feed conversion was improved.

Without an effect of fibre level or quality, the starch nature did not seem to have a major impact on the incidence of enteropathies, neither during the post-weaning nor during the finishing period. Accordingly, a high flow of undigested starch in the caecum would not greatly affect the digestive health status of the rabbit. Therefore, recommendations for a low starch level did not seem to prevent enteropathies. However, since starch is incompletely digested in the small intestine until 7 weeks of age, the diet of the young rabbit should contain another energy source, such as lipids.

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