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Fiber in rabbit nutrition

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ANIMAL NUTRITION
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Fiber in Animal Nutrition

a practical guide for monogastrics



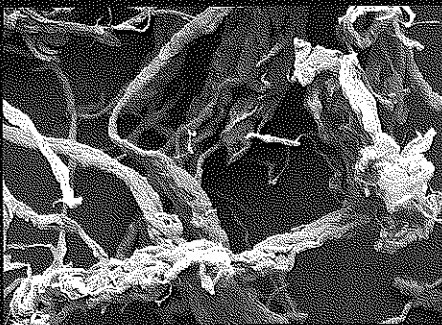
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Today there is rising awareness that moderate fiber levels are essential for gut health, gut motility and overall well being of monogastrics.

Fiber has been part of feed analytics since the development of the Weender analysis in the 19th century. In general considered an antinutritive factor in the feed for monogastrics, diluting the diets and reducing nutrient digestibility. But these negative attributes are determined by the fiber characteristics and their proportion in the diet. Today's emerging analytics give us a better understanding of the diverse fiber fraction and how to evaluate and employ fiber in the diets. However many questions concerning the effects of fiber in nutrition still remain unanswered.

This book reviews the state of the art knowledge about feeding fiber to monogastric livestock and companion animals, covering key issues surrounding analysis, definition, regulation and mode of action in the gut. The book places a special focus on current topics like animal welfare and functional health effects, making it interesting to all who are involved in animal nutrition and the animal feed business.

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Fiber in Animal Nutrition

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Preface

Gonzalo G. Mateos

This booklet presents in 5 chapters the last available research published by the scientific community on the effects of dietary fiber on animal feeding and production. The information provided gives in depth information on how dietary fiber contributes to ameliorate animal health and welfare of pets and domestic animals. Available data indicate that the improvements observed with the inclusion of additional fiber are due primarily to a physiological response of the animals, with better development of the gastrointestinal tract. A more functional digestive tract helps in the control of the growth and profile of the microbial population, resulting in productivity benefits. A great part of the book is dedicated to evaluate the structure, chemical composition, and physical characteristics of the different sources of fiber available in the market. The data help to understand why different fiber sources result in distinct effects in the physiology and normal function of the digestive tract of pets and domestic animals.

Dietary fiber is a key component in companion pet foods, with important benefits on satiety and eating behavior of the animals, as well as on teeth and mouth health. Also, dietary fiber play an important role in the improvement of the consistency and structure of the stools. As a result, the use of the adequate type of fiber will help in the control of obesity and in the reduction of certain pathologies, especially in senior cats and dogs.

The effects of dietary fiber on optimizing gastrointestinal tract function in rabbits and ruminants have been accepted for long by feed formulators. In fact, most diets for these species include a requirement for a minimal

amount of fiber. In contrast, dietary fiber was considered an antinutritional factor in diets for pigs and poultry, with negative effects on palatability and feed intake as well as on nutrient digestibility. Consequently, most nutritionists in these species formulated diets with a maximum amount of crude fiber, especially in young animals.

Recent studies conducted in poultry and in pigs have shown consistently that these species, although for different reasons to those of pets, rabbits, and ruminants, might also need a minimum level of dietary fiber for optimal gastrointestinal health and function. However, the information available on the recommended physico-chemical characteristics of the fiber sources to improve digestive tract function and animal growth and welfare is limited. Consequently, it is not easy to make a sound recommendation on the minimum amount of fiber required by these species under practical commercial situations. In particular, factors such as age, management conditions, and health status of the animal, as well as type and level of fiber source used, might affect these recommendations.

The information provided by the new booklet demonstrates that the judicious selection of the source and level of fiber of the diet results in benefits for the animal with reduced aggressiveness, better consistency of the excreta, and improved animal welfare. Consequently, animal welfare and productivity, and the quality of the end products will improve. The reading of this publication will allow nutritionists to better understand the utilization of dietary fiber in diets for all types of domestic species.

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3.7 Literature

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Fiber in Rabbit Nutrition

Thierry Gidenne

4.1 Context – importance of dietary fiber in the rabbit nutrition

As an herbivorous and monogastric animal, the rabbit is adapted for a high fiber intake, and in traditional breeding systems, the rabbit is fed with forages, herbs and cereals. In more intensive breeding systems, the rabbit is usually fed with diets containing at least 45 to 60% of dietary fiber when measured with the TDF procedure (table 24). The rabbit could also be fed with high-energy/low fiber pelleted feeds, to improve its feed conversion. But, using too concentrated feeds increases the risks for digestive troubles (diarrhoea, growth troubles), particularly after weaning (Gidenne et al., 2010). Thus it is essential to understand, how dietary fibers act in rabbit nutrition, and how to optimise the fiber supply in rabbit feeding to preserve the health, without a too large impairment of the growth. Therefore in this chapter, we will first recall very briefly the structure of the main fiber classes, followed by a short description of analytical methods routinely used for dietary fibers analysis in rabbit feeding (Chapter 4.2). Then we will present examples of classical fiber sources for rabbit feeding (Chapter 4.3), since the adjustment of specific fiber classes in rabbit feed is essential to reduce the risk of digestive trouble. As for other monogastric animals, the importance of fibers is due to effects on intake, rate of passage and mucosa functionality (Monragne et al., 2003). In the rabbit, their role as substrate for caecal microflora and the effect on digestion will also be summarised in chapter 4.4. The rela-

Table 24: Fiber level and other main constituents in pelleted feed for the rabbit

Chemical criteria (g/kg as fed)	Mean range
Total dietary fiber (TDF)	450–600
Neutral detergent fiber (ANDFom)	280–460
Acid detergent fiber (ADFom)	150–230
Acid detergent lignin (ADL)	35–65
Crude fiber	120–180
Soluble fiber*	35–120
Other constituents	
Starch	80–130
Sugars	30–60
Crude protein (CP)	140–190
Ether extract (EE)	20–40

* Calculated as: OM-CP-EE-ANDFom-Starch-Sugars

relationship between specific fiber fractions and the digestive health of the growing rabbit has been analysed through a meta-analysis of a compilation of trials that do not use antibiotics (Gidenne, 2015a), since the EC policy strongly recommend to reduce the use of antibiotics in animal breeding (Chapter 4.5). Finally, we will propose new fiber requirements for the growing rabbit health based on several criteria and the Van-Soest procedure (Chapter 4.6).

4.2 Dietary fiber: definition and analytical criteria useful for rabbit feeds

The concept of dietary fibers is larger than the cell wall botanical definition, since in animal nutrition it includes not only the cell-wall polysaccharides (cellulose, hemicelluloses, pectic substances, etc.), but also other components that are only fermented by the microbiota, such as: oligosaccharides, gums, resistant starch, inulin, etc. According to their botanical origin, they may be associated with lignins and other non-carbohydrate components (e.g., polyphenols, waxes, saponins, cutin, phytates, resistant protein). Shortly, dietary

fibers could be defined as the sum of lignins and fermentable polysaccharides of the plant cell wall. The main fiber fractions present in rabbit feeds could be classed respective to their digestion in the rabbit gut (Chapter 4.4): 1- lignins and cellulose, that are slowly fermented and thus poorly digested in the rabbit caecum (although lignin is theoretically indigestible); 2- hemicelluloses and pectins that are more quickly fermented and thus well digested in the rabbit caecum.

With the sequential Van-Soest procedure we can estimate in animal feeds or raw materials, the lignins (ADL), the cellulose (ADFFom-ADL) and the hemicelluloses (aNDFFom-ADFFom). However, pectins are not estimated with this procedure. The major part of pectins in rabbit feeds is insoluble in water, and they cannot be measured easily in feeds. Thus they are estimated in raw material from specific tables, such as those by the EGRAN group (Maertens et al., 2002). Consequently, to estimate the digestible fibers (DF) in a rabbit diet, we must add the hemicelluloses (HC, analysed) and water insoluble pectins (WIP, calculated from tables). Whereas the poorly

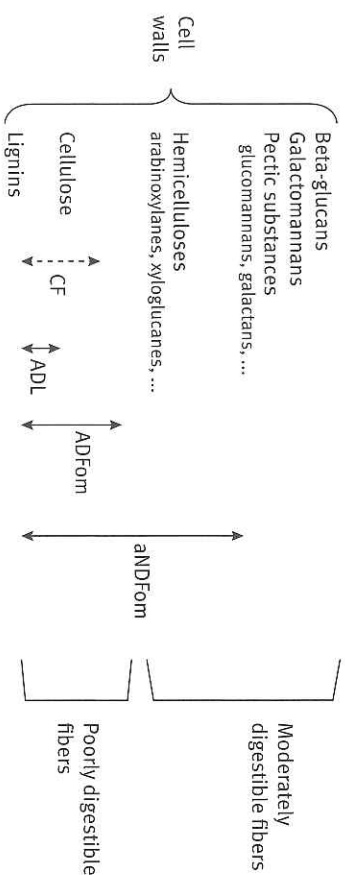


Figure 10: Main fiber fractions, analytical criteria and relative digestion by the rabbit. CF: Crude Fiber; aNDFFom: Neutral Detergent Fiber, assayed with a heat stable amylase and expressed free of ash; ADFFom: Acid Detergent Fiber expressed free of ash; ADL: Acid Detergent Lignin

digested fibers are more simply estimated by the ADF criterion (figure 10).

However, to these fiber fractions we should add other polysaccharides, belonging to the cell wall, but soluble in water, such as: soluble pectins, arabinoxylnes, beta-glucans, etc. The water solubility of polysaccharides is generally defined from solubility in hot water (80°C). These water soluble fibers (SF) could be analysed through a complex procedure but without enough reproducibility for routine laboratory analysis in animal feeding. Alternatively, SF could be evaluated by differences among two criteria "TDF-aNDFFom", since TDF procedure estimate the whole fiber content (soluble and insoluble), and also polysaccharides from the cell content (e.g. fructans, resistant starch, mannans). Using this procedure, soluble fiber ranges between 6 to 10% in rabbit feeds (Trocino et al., 2013).

4.3 Fiber sources routinely used in rabbit feed

To formulate a complete feed, balanced in fibers and other nutrients, several raw materi-

als are used to reach the requirements for the rabbit (Chapter 4.6); their fiber composition is listed below (table 25).

Quantitatively, the most important fiber supply is the poorly digested fiber fraction, namely the lignocellulose. Quantitatively, cellulose represents 40–50% DM in hulls of legumes and oilseeds, 10–30% DM in forages and beet pulps, 3–15% DM in oilseeds or legume seeds. Other classical sources of cellulose are wheat straw, alfalfa and sunflower meal. Lignin concentration is under 5% for most concentrate feeds and young forages. The degree of lignification of the plant cell wall may reach 12% with ageing in forages, or up to 59% in grape seed meal. A high lignin concentration is found in ingredients, such as buckwheat hulls, grape pomace or rapeseed meal. Other specific raw materials, rich in lignins and cellulose are available for rabbit feeding, such products are extracted from wood (Krieg et al., 2012), or a blend of ingredients "rich in fiber" ready to incorporate in a feed before pelleting.

The second important supply in fiber corresponds to the digestible fiber fractions

Table 25: Fiber fractions (% DM) in raw materials classically used in rabbit feeds, according to several methods of analysis

Ingredients	Wheat straw	Wheat bran	Dehydrated alfalfa	Sugar-beet pulp	Sunflower meal	Soybean hulls	Grape pomace
aNDFFom	80	45	46	47	38	62	64
ADFFom	54	11	34	22	32	44	54
ADL	16	3	8	2	11	2	34
Crude fiber	40	10	27	19	26	36	26
WIP	2.2	2.9	7.6	27	8	10	8
TDF	85	46	48	68	42	68	72
SF (TDF-NDP)	5	1	2	21	4	6	8
Crude protein	3	15	16	9	31	11	13

WIP: water-insoluble pectins (uronic acids + neutral sugars of pectins insoluble in hot water)

“DF”, corresponding mainly to hemicelluloses (HC) and insoluble pectins (WIP). HC are a group of several polysaccharides, estimated by difference between NDF & ADF (see table 25). Quantitatively HC constitute 10–25 % of the DM in forages and agro-industrial by-products (brans, oilseeds and legume seeds, hulls and pulps) and about 2–12 % DM of grains and roots. The WIP are in dicotyledonous plants, such as in legume seeds (4–14% DM in soybean, pea, faba bean, white lupin), and also in fruits and pulps.

Finally, water-soluble polysaccharides and oligosaccharides are usually in low level in ingredients for animal feeding. For instance, soluble hemicelluloses such as arabinoxylans (in wheat, oat and barley) range between 2–4% DM, and β -glucans range between 1–3% DM in barley or oat. Oligosaccharides such as α -galactosides are found in lupin, pea or soya seeds (5–8% DM). But the most important fraction of SF is soluble pectic substances, that could reach from 10 to 40% DM, in pulps of fruits or beets.

4.4 Impact of fibers on digestion and performances

The importance of fibers is due to effects on intake, rate of passage and role as substrate for caecal microbiota (Combes et al., 2013). But, for the growing rabbit one of the main challenges is to provide fiber recommendations for digestive trouble prevention and without a too large impairment of performance (growth, feed efficiency).

4.4.1 Dietary fibers level and intake regulation of the growing rabbit.

The domestic rabbit fed a pelleted balanced diet is able to regulate its feed intake to reach a constant DE (digestible energy) intake when the dietary DE concentration ranges between 9.0 and 11.5 MJ/kg (figure 11). But a higher correlation is obtained with the Acid Detergent Fiber (ADF) level when between 10 and 25 % in a diet. The voluntary feed intake is more related to the dietary ADF level because of the low digestion of this fraction, and probably because the ADF level

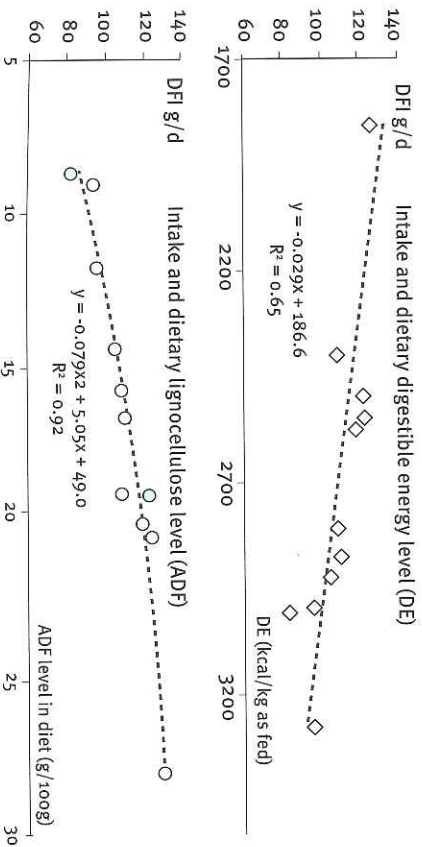


Figure 11: Feed intake of the growing rabbit, according to the ADF or the digestible energy content of the diet DFI: daily feed intake measured between weaning (4 weeks) and 11 weeks old

also corresponds to a “ballast” value that limits the intake. Thus fiber deficient diets (<12% ADF) led to low nutrient intake and to low and variable growth performances. The replacement of starch by digestible fibers fractions (hemicelluloses or pectins), without changing the ADF level, did not greatly affect the intake. First results of the effects of SF on the intake behaviour suggest a 5 to 10 % impairment (Jacquier et al., 2014). In return, when the dietary fibers level is very high (>25 % ADF), the animal cannot increase its intake sufficiently to meet its energetic needs, thus leading to a lower growth rate, but without digestive problems.

4.4.2 Fiber digestion in the rabbit and hind gut microbial activity.

Cell wall polysaccharides are hydrolysed and then fermented only by bacterial enzymes, whereas lignins are considered totally undegradable. The fibers are an energy source derived from the activity of the microbiota. This takes place mainly in the caecum and proximal colon of the rabbit. The extent of the fiber digestion is rather different according to the fraction (table 26), and is ultimately de-

Table 26: Digestibility of some fiber fractions by the growing rabbit

Dietary fiber criteria	Mean range, %
Neutral detergent fiber (aNDFom)	10 to 60
Cellulose (ADFom-ADL)	5 to 25
Hemicelluloses (ANDFom-ADF)	20 to 60
Water insoluble pectins	30 to 80
Uronic acids	30 to 85
Soluble fibre (TDF-ANDFom)	70 to 90
Lignin (ADL)	-15 to 15

termined by the time necessary for microbiota to hydrolyse and ferment the polysaccharides. Because the retention time in the caecocolic segment of the rabbit is relatively short (8–12h), only the most rapidly fermentable polysaccharides are highly digested: such as uronic acids (pectins) or soluble fibers (table 26). Lignocellulose is degraded at a smaller extent ranging from 5 to 25%. Obviously, the fiber digestion is lower than that of protein or starch, and high fiber levels correspond to a lower digestive efficiency. However, adding DF in place of starch moderately reduces the digestive efficiency of the rabbit.

For the adult rabbit, fed a high fiber diet, the energy provided by the caecal VFA absorption could represent up to 50% of the maintenance energy. But, increasing the fiber intake (and lowering that of starch) either increases or has no effect on the fibrolytic activity and caecal VFA concentration (ranging from 80 to 100 mM), while a lower butyrate molar proportion is generally observed.

The quality of fibers, particularly their fermentability, modulates the microbial activity. For instance, increasing the levels of pectins through the incorporation of beet pulps in a diet increases the VFA concentration in the caecum. Conversely, increasing the lignin level reduces the VFA concentration (Krieger et al., 2012). Besides, the morphology of the caecal mucosa seems modified by the quality of the fibers. For example, increasing the ratio lignin/cellulose reduces the crypt depth and width (Krieger et al., 2012).

4.4.3 Impact of fiber on performance and health of the growing rabbit

Digestive pathology of the growing rabbit is the major cause of losses after weaning. Moreover, digestive disorders are responsible

for important morbidity characterized by growth depression and poor feed efficiency. Till the eighties, only the crude fiber criterion was used to define the fiber requirements for the growing rabbit, and the value ranges from 6 to 18% according to the authors. Consequently, the precise assessment of the fiber requirements with more "adequate" criteria is essential to reduce the risk of digestive troubles without a too large impairment of the growth and feed efficiency.

The respective effects of fibers and starch on the incidence of diarrhoea in the growing rabbit have been subject to many studies comparing the fiber: starch ratio, since in complete feed formulations one nutrient is substituted by another one. Since ileal flow of starch is very low (<2 g/d) in the rabbit, compared to that of fiber (>40g TDF/d) an overload of starch appears very unlikely linked to digestive pathology. This was demonstrated by large-scale studies showing that only the fiber level plays a

role in digestive trouble occurrence, and not the starch level (Gidenne, 2015). Thus in France, large-scale studies were performed to validate the relationships among dietary fiber fractions and digestive health, and to analyse the relevance of the Van-Soest criteria for elaborating new requirements for the growing rabbit.

4.4.4 Quantity and quality of lignocellulose (ADFom).

A too low intake of ADF produced by fiber deficient diets (<12% ADF) is associated to a low intake and lower growth performances. In addition, the beneficial effect of a high dietary ADF level on digestive disorders and mortality in fattening rabbits was demonstrated independently by several studies. However, when correlating ADF dietary level to the health risk index (HRI=mortality+morbidity) only 41% of the variations of HRI are explained by those of ADF (figure 12). Thus a single criterion,

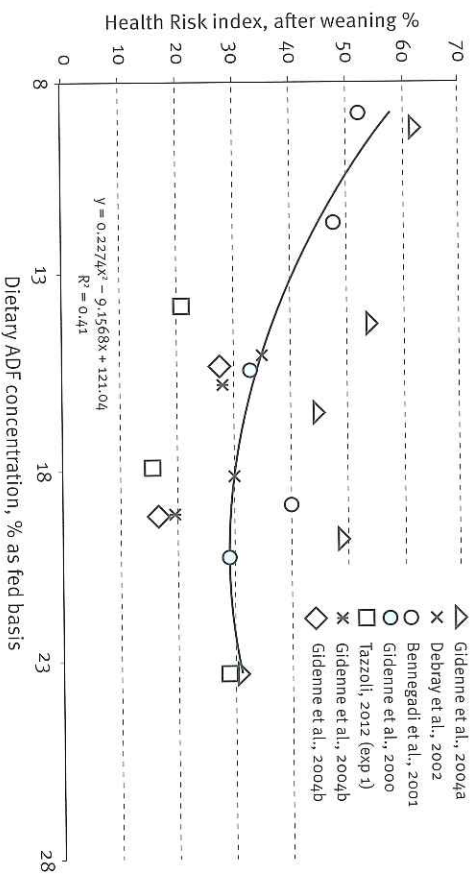


Figure 12: The risk of digestive trouble for the growing rabbit is reduced according to the dietary lignocellulose "ADF" level
Health risk index= mortality+morbidity, from weaning to slaughter

such as the supply of lignocellulose (or crude fiber) is not sufficient enough to relate the fiber supply and the "level of security" of a feed for the growing rabbit.

Thus apart from the quantity of lignocellulose, the quality of the ADF, i.e. the respective effects of lignins and cellulose have an impact on digestive health. Increasing the intake of lignins (criterion ADL = Acid Detergent Lignin) involves a rise of the feed conversion ratio, but reduces the risk of diarrhoea, as demonstrated in figure 13: a linear negative relationship ($R^2=0.77$, $n=6$ study) between ADL and HRI. Moreover, an increase of the ratio lignins/cellulose (L/C) is associated with a lower HRI (Gidenne et al., 2001). Therefore it seems beneficial to incorporate in diets raw material having a high lignin and cellulose level, as reported in several trials for doe and growing rabbits (JRS, 2007). Globally, to reduce the risk of post-weaning digestive disorders, the lignin intake (ADL)

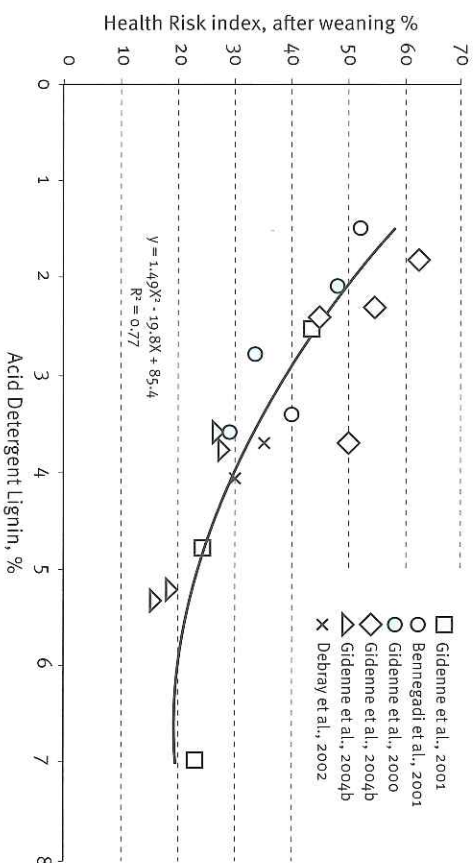


Figure 13: The risk of digestive trouble (HRI) in the growing rabbit is dependent of lignin "ADL" level

for the growing rabbit, can be assumed to be 5 to 7 g/d, and that of cellulose from approximately 11 to 12 g/d.

4.4.5 Role of digestible fibers fractions "DF".

Hemicelluloses and water-insoluble pectins "WIP", well valorise for rabbit growth, also modulate the digestive health. This new "combined" fiber criterion, called "digestible fibers (DF = HC + WIP) was studied, and the favourable effect of the DF on HRI, compared to starch intake, was demonstrated in several studies. However, from a set of 15 diets (5 studies) when ADF and the ratio DF/ADF are varying within a study (figure 14), we observed a close relationship ($R^2=0.69$) between the ratio DF/ADF and the HRI. This suggests that a too high incorporation of DF, with respect to lignins and cellulose, should be avoided to minimise the HRI during fattening. We thus recommend that the ratio DF/ADF remain under 1.3 for diets

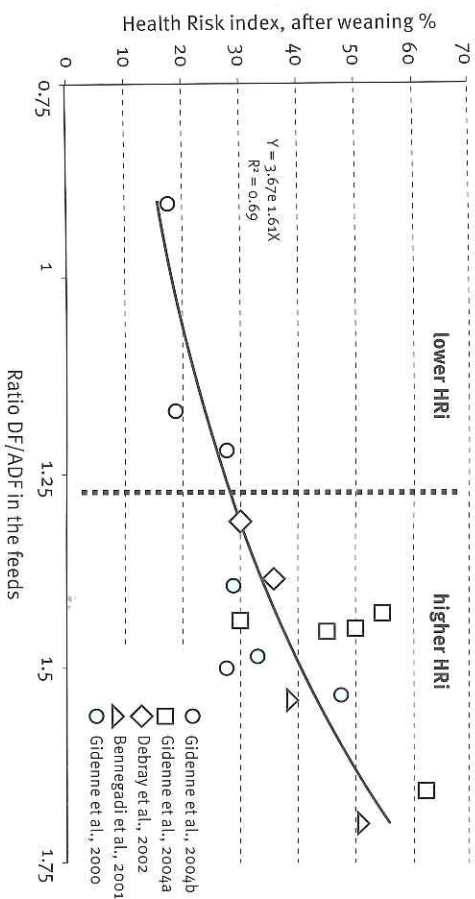


Figure 14: The risk of digestive trouble (HRI) in the growing rabbit is dependent of the ratio DF / ADF

having an ADF level over 15% (see table 27). When a sufficient supply of lignocellulose (at least 18%) is provided, it is advisable to replace some starch or protein by digestible fibers fractions. The HRI is reduced and the feed efficiency is weakly modified (Gidenne, 2015).

4.5 Dietary fiber requirements to reduce the risk of digestive disorders after weaning

We here proposed a summary of the fiber requirement for post-weaned and growing rabbits, to reduce the risk of digestive troubles after weaning, without a too large impairment of growth performances. One criterion is not sufficient to define the fiber requirements of complete balanced feed. Three key points must be controlled (table 27):

- 1- The level of ADF should be over 19%.
- 2- The quality of the lignocelluloses plays also a role in the digestive health, and the minimum level of lignins should be 5% in a feed.

- 3- The balance between the poorly digested "ADF" and high digested fibers "DF" fractions should be respected. The ratio DF/ADF should be under 1.3, to avoid an unbalanced intake of highly fermentable polysaccharides.

Recent data about SF revealed contrasting results and at present it appears not consistent enough to deserve a supplementary requirement.

Table 27: Fiber requirements to prevent digestive troubles for the growing rabbit

Unit:	Post weaning (28-42d old)	End of fattening (42-70d old)
Lignocellulose "ADFom"	≥19	≥17
Lignins "ADL"	≥5.5	≥5.0
DF/ADFom**	≤1.3	≤1.3

** Digestible fibers fractions = [hemicelluloses (NDF-ADF) + water-insoluble pectins]

4.6 Conclusion

The favourable impact of quantity and quality of low-digested fiber fractions on digestive health has been demonstrated and fiber requirements are now more precise. However, the analysis of the cell wall polysaccharides that are quickly fermented remains a challenge for the future. A criterion, such as TDF-aNDFom, needs to be validated in terms of reproducibility and reparability for feed analyses. Its nutritional role (mucosa protection, etc.) and its relationship with the performance and

digestive health of the young rabbit should be more deeply explored.

In perspective, the fiber requirements of the young rabbit before weaning should also be studied and specified. The nutritional preparation of the young before weaning is probably a key step to determining the digestive health of the growing rabbit. However, our knowledge of the digestive maturation, including the microbiota implantation in the young rabbit needs to be improved, to provide new concepts for the nutrition of the young in relation to dietary fibers.

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Fiber in Dog and Cat Nutrition

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5.1 Introduction

Many petfood formulas contain powdered cellulose, but the cellulose fibers may differ in length, diameter, chemical composition and water-binding capacity. Preparations may consist of lignocellulose or purified cellulose. Fibrillated cellulose that forms an insoluble fiber network can be produced by modern and sophisticated milling technology.

Cellulose fiber can be added to petfood as nutrient and/or functional ingredient. As nutrient, cellulose may support healthy gut mobility and function. As functional ingredient, cellulose at higher inclusion levels provides specific health benefits beyond basic nutrition. Technological functionality of cellulose lies in improving the food's texture.

A relatively low dietary level of cellulose meets the fiber intake that accommodates optimum feces quality, which might relate to comforting gut mobility. Higher cellulose levels are found in low-calorie products such as light and weight-reduction foods. Likewise, petfoods intended for hairball, dental and diabetes control are enriched with cellulose.

For petfood labeling, the analysis of crude fiber is used as quantitative measure. The analytical method yields variable proportions of dietary cellulose, hemicelluloses and lignin, whereas it may exclude other fibers. The crude fiber content of many cellulose preparations is around 70%. Regular dry dog and cat foods contain between 1.5 and 4% crude fiber, whereas wet foods have concentrations of 0.3 to 1%. The crude fiber content of

veterinary, weight-reduction diets for dogs in dry form can be as high as 20%.

5.2 Cellulose

5.2.1 Cellulose as nutrient

In truncated form, the National Research Council (2006) states that although dietary fiber is not a required nutrient, it is directly involved in maintaining gut health of dogs and cats. This view is substantiated by the observations that the diarrhea caused by fiber-free diets is nullified by supplemental cellulose. The basis of this beneficial cellulose effect is unknown, but it could relate to normalizing gut motility, enhanced water absorption by the hind gut, water binding by cellulose in feces or a combination. Anyhow, adding cellulose to a fiber-free diet elevates the dry matter content of feces.

Dogs fed fiber-free diets consisting of partially purified proteins, hydrogenated vegetable fat, minerals, vitamins and sucrose had diarrhea, making fecal collections difficult (Mabee and Morgan, 1950). It was helpful to feed cellulose two or three days preceding as well as during the collections. In another dog study, a fiber-free semipurified diet containing 40% albumin caused severe diarrhea which was overcome by incorporating of 10% cellulose and 10% agar into the diet (Morgan et al., 1951).

Wichert et al. (2002) fed dogs on an essentially fiber-free, wet diet consisting of cooked greaves, cooked starch, sunflower oil and a mineral-vitamin supplement. On the fiber-free diet, the dogs' feces had a liquid/pasty appearance. The feces became solid/