

NOV 2024



Nutritional Guidelines

For Feeding Pet Rabbits





Table of Contents

Acknowledgements	02	6.4.1 Composition, Additives and Analytical Constituents	24
1 Glossary	03	6.4.2 Feeding Instructions	25
2 Introduction	05	6.5 Feeding Rabbits	25
2.1 Objectives	05	6.5.1 Forage	26
2.2 Scope	06	6.5.2 Fresh Foodstuffs	27
3 Basic Nutrition Principles	06	6.5.3 Contaminants	30
3.1 The Rabbit	06	6.5.4 Selective Feeding	31
3.2 Energy	09	6.6 Dietary Enrichment	31
3.2.1 Calculation of the Energy Content of Foods for Pet Rabbits	09	7 Annexes	32
3.2.2 Calculation of the Energy Requirements of Pet Rabbits	11	7.1 Body Condition Score	32
3.2.3 Factors Influencing Energy Requirements	12	7.2 List of Safe Greens	33
3.2.4 Obesity	12	7.3 List of Potentially Toxic Foodstuffs	34
4 Nutrient Recommendations	13	8 Changes Versus Previous Version	35
4.1 Use of the Table	13	8.1 Adaptations in the Nutritional Guidelines 2024 vs. 2013	35
4.2 Table of Nutrient Recommendations	13	9 References	36
4.3 Substantiation of Nutrient Recommendations	15	Disclaimer	40
4.4 Fibre	16		
4.4.1 Quantification of Fibre	17		
4.4.2 Fibre Requirements of Pet Rabbits	19		
4.5 Water	19		
5 Analytical Methods	20		
6 Practical Formulation And Feeding	20		
6.1 Safe Production of Pet Rabbit Food	20		
6.2 Different Rabbit Food Formats	20		
6.3 Types of Ingredients	23		
6.3.1 Common Feed Materials for Rabbit Foods	23		
6.3.2 Common Additives for Rabbit Foods	23		
6.4 Labelling of Pet Rabbit Foods	24		

Acknowledgements

These guidelines were originally drafted, on behalf of FEDIAF, by UK Pet Food (formerly PFMA), and finalised with guidance from external experts and within FEDIAF. This revised version was initiated by FEDIAF and with support from UK Pet Food has been updated by guest contributors and reviewed by external experts.

FEDIAF wishes to acknowledge the contribution of the following in writing and finalising these guidelines:

- Dr. Christine Huggett
- Dr. John Lowe
- Prof. Anna Meredith
- Dr. Suzanne Moyes
- Penny Ormsby
- Ellie Parkes
- Marion Turnbull
- Dr. Donna Snellgrove (Co-Chair FEDIAF Small Pets Working Group)
- Dr. Molly Varga-Smith

FEDIAF would also like to thank the following external experts for giving their time to review these guidelines:

- Prof. Julian Wiseman, Division of Animal Sciences, University of Nottingham, United Kingdom.
- Prof. Jürgen Zentek, Institut für Tierernährung, Freie Universität Berlin, Germany.

1.0 Glossary

The glossary contains definitions of key words commonly used in the context of rabbit nutrition and found within these guidelines. Where available the source of the definition is referenced, as is the section within the document where further information can be found.

Additive (feed additive). Substances, micro-organisms or preparations, other than feed material and premixtures, which are intentionally added to rabbit food or water in order to perform, in particular, one or more of the functions mentioned in Art. 5 (3) of Regulation (EC) No 1831/2003. (Regulation (EC) No 1831/2003 on additives for use in animal nutrition, Art. 2 (2) (a)). See also section 6.3.2.

ADF. Acid Detergent Fibre. See also section 4.4.1.

ADL. Acid Detergent Lignin. See also section 4.4.1.

Animal Feed. ‘Feed’ (or ‘feedingstuffs’) means any means any substance or product, including additives in animal feed, whether processed, partially processed or unprocessed, intended to be used for animal feeding. Loosely, food for food-producing animals (includes rabbits and horses).

Caecum of the rabbit. The unique musculature of the colon allows the intestinal tract of the rabbit to separate fibrous material from more digestible material; the fibrous material is passed as faeces, while the more nutritious material is passed into the caecum, then encased in a mucous covering and passed as a caecotroph (see caecotrophy).

Caecotrophy. Process by which soft faeces (caecotrophs) are excreted and systematically re-ingested from the anus, mainly in the early morning. These caecotrophs come direct from the caecum and have a high protein (essential amino acids), vitamin and mineral content.

Complementary feed. Compound feed which has a high content of certain substances but which, by reason of its composition, is sufficient for a daily ration only if used in combination with other foods (Regulation (EC) No 767/2009 on the marketing and use of feed, Art. 3 (2) (j)).

Complete feed. Compound feed which, by reason of its composition, is sufficient for a daily ration (Regulation (EC) No 767/2009 on the marketing and use of feed, Art. 3 (2) (i)).

Compound feed. Feed consisting of a mixture of at least two feed materials, whether or not containing additives, for oral feeding in the form of complete or complementary feed (Regulation (EC) No 767/2009 on the marketing and use of

feed, Art. 3 (2) (h)). BUT: A rabbit food may not be described as a compound food (Art. 15 (a)).

Daily ration. The average total quantity of feeding stuffs, calculated on a moisture content of 12%, required daily by an animal of a given species, age category and yield, to satisfy all its needs (Regulation (EC) No 1831/2003 on additives for use in animal nutrition, Art. 2 (2) (f)). The above-mentioned legal definition means the average total quantity of a specific food that is needed daily by a rabbit of a given breed, lifestage or activity to satisfy all its energy and nutrient requirements.

Digestible energy (DE). The gross energy of the food less the gross energy content of faeces (McDonald et al., 1995).

Dietary enrichment. Feed, ingredients or nutrients provided to the animal in addition to the ready-made diet. OR, in the context of environmental enrichment, presenting feed or forage in such a way that the animal must find, and work for it.

Dietary Fibre. A generic term that refers to lignin or a plant-derived carbohydrate component that cannot be broken up by intestinal enzymes of the foregut. See also section 4.4.

DM. Dry Matter.

Environmental enrichment. Any modification to the environment of a captive animal that enhances the level of physical and social stimulation and reduces stress, e.g. providing toys, climbing structures, hiding places or foraging tasks.

Feed materials. Products of vegetable or animal origin, whose principal purpose is to meet animals’ nutritional needs, in their natural state, fresh or preserved, and products derived from the industrial processing thereof, and organic or inorganic substances, whether or not containing feed additives, which are intended for use in oral animal-feeding either directly as such, or after processing, or in the preparation of compound feed, or as carrier of premixtures (Regulation (EC) No 767/2009 on the marketing and use of feed, Art. 3 (2) (g)).

Forage. Non-manufactured hay, grass and wild plants.

Maintenance energy requirement (MER). The energy required to support energy equilibrium (where maintenance energy equals heat production), over a long period of time (Blaxter, 1989).

Metabolizable energy (ME). The digestible energy less the energy lost in urine and combustible gases (McDonald et al., 1995).

NDF. Neutral Detergent Fibre. See also section 4.4.1.

NFC. Non-fibrous carbohydrates. The highly digestible carbohydrate fraction of feed including sugars, starch, organic acids and pectin (a carbohydrate that is part of the plant cell wall). NFC are also referred to as non-structural carbohydrates (NSC) i.e. carbohydrates other than cellulose and hemicellulose (constituents of the plant cell wall), but not including pectin. See also section 3.2.1.

NRC. National Research Council (USA). A council organised by the US National Academy of Sciences, Engineering and Medicine (NASEM). The NRC Sub Committee on Rabbit Nutrition compiled and published 'The nutrient requirements of rabbits (1977)'. www.national-academies.org

NSP. Non-Starch Polysaccharides. See also section 4.4.1.

Nutritional maximum limit. The maximum level of a nutrient in a complete rabbit food that, based on scientific data, has not been associated with adverse effects in healthy rabbits. Levels exceeding the nutritional maximum may still be safe, however, no scientific data are currently known to FEDIAF.

Pet. Any non-food producing animal.

Pet food. Any product produced by a pet food manufacturer, whether processed, partially processed or unprocessed, intended to be ingested by pet animals after placing on the market. (Regulation (EC) No 767/2009).

RA. Recommended Allowance. The concentration or amount of a nutrient in a diet formulated to support a given physiological state (NRC, 2006).

Recommendation. See RA.

SUL. Safe Upper Limit.

TDF. Total Dietary Fibre. See also section 4.4.1.

2.0 Introduction

FEDIAF represents the interests of 15 national pet food industry associations and 5 direct companies, and is the spokesperson for approximately 375 companies, across 18 countries, mostly within the European Union, but also Norway, Switzerland and the United Kingdom.

One of FEDIAF's main objectives is to maintain the well-being of pets through the provision of safe, well balanced and nutritionally sound pet food by its member companies. FEDIAF, with support from its British member UK Pet Food, therefore present 'Nutritional Guidelines for Feeding Pet Rabbits' which is based on the state-of-the-art knowledge on pet rabbit nutrition, providing pet food manufacturers with nutritional recommendations to ensure the production of well balanced and nutritionally sound diet and thus pet food for adult and growing pet rabbits. The guide does

not include detailed information on reproduction, but it is hoped to do so in future. It is also important to note that this is also a guide to the pet rabbit's daily diet, which can be delivered in a variety of ways i.e. through a commercially prepared complete feed or a combination of different food types e.g. commercially prepared complementary feed alongside forage and foliage.

These Guidelines are aimed at helping manufacturers develop and produce nutritionally balanced foods for pet rabbits, for a long and healthy life of these animals.

This document is reviewed regularly and updated whenever there are new relevant technological, scientific or legislative developments in pet rabbit nutrition.

2.1 OBJECTIVES

The objectives of FEDIAF's Nutritional Guidelines for Feeding Pet Rabbits are:

- i. To contribute to the production of nutritionally balanced foods for pet rabbits, while complying with relevant EU legislation on animal nutrition. To achieve this objective, the guidelines incorporate up-to-date scientific knowledge on rabbit nutrition to:
 - Provide practical nutrient recommendations for pet food manufacturers when formulating their products for adult and growing pet rabbits.
 - Help pet food manufacturers to assess the nutritional value of commercial rabbit foods for healthy animals.
 - Provide guidance on the unique aspects of pet rabbit nutrition such as fibre requirements for their unique digestive tract and dentition.
- ii. To be the reference document on pet rabbit nutrition in Europe for EU and local authorities, consumer organisations, professionals, and customers.
- iii. To enhance cooperation between pet food manufacturers, pet care professionals and competent authorities by providing scientifically sound information on the formulation and assessment of foods for pet rabbits.
- iv. To complement FEDIAF's Guide to Good Practice for the Manufacture of Safe Pet Foods and the FEDIAF's Code for Good Labelling Practice for Pet Food.



2.2 SCOPE

FEDIAF's Nutritional Guidelines provide information on several aspects of rabbit food, nutrition and feeding:

- i. Recommendations for adequate and safe nutrient levels for the design of commercial complete and complementary foods for pet rabbits;
- ii. Tools for the assessment of the nutritional value of pet rabbit foods;
- iii. Recommendations for energy intake;
- iv. Typical ingredients suitable for use in rabbit foods;
- v. Different types of fibres: sources, and their role for rabbits;
- vi. Specific topics for rabbit nutrition, including selective feeding and supplementation of foods.

FEDIAF's Nutritional Guidelines give nutrient recommendations for healthy rabbits eating typical commercial foods for pet rabbits.

- The levels in this guide reflect the amounts of essential nutrients to ensure adequate and safe nutrition in healthy individuals when consumed over its lifetime.
- These guidelines relate to pet rabbit foods manufactured from typical ingredients which are commonly used in rabbit feed.

- The nutrient levels include a safety margin for individual animal variation and nutrient interactions.
- It follows from the above statements that individual pet foods can be adequate and yet outside the recommendations, based on the manufacturer's own substantiation of nutritional adequacy and/or feeding recommendations for said specific commercial food.

Unlike for other pet animals, there is also a significant market for rabbit feed produced for animals that are bred and reared for commercial purposes, including as food for humans. In terms of nutrition, some basic requirements are similar for both pet and commercial rabbits, and much information about rabbit nutrition comes from studies with commercial rabbits. Some practical issues arise, in particular with product labelling and safe manufacture ensuring that animal proteins do not enter the human food chain.

Excluded from FEDIAF's Nutritional Guidelines are foods for particular nutritional purposes (such as diets fed under veterinary supervision) and some other specialised foods.

3.0 Basic Nutrition Principles

3.1 THE RABBIT

Rabbits are mammals belonging to the Clade Glires (includes Orders Rodentia and Lagomorpha) Order Lagomorpha (which includes hares and pikas), family Leporidae (rabbits). Lagomorphs are differentiated from rodents by the presence of a second maxillary incisor tooth. The earliest Lagomorph fossils date from the late Palaeocene 55-57 million years ago (Lacher et al., 2016), and they are thought to have evolved essentially to occupy the ecological niche now filled by small ungulates, developing physiological strategies to deal with a high fibre, nutrient dilute diet. There are 92 extant species of Lagomorphs, of which 23 are rabbit species (Mammal Society, 2024). There are rabbit species on most continents and islands (Australia and New Zealand being well known exceptions to this rule), with geographical spread being facilitated by humans. Interestingly rabbit populations are increasing in areas where they are an introduced species, while those populations in endemic areas are declining (Marin-Garcia al., 2023a).

Domestic rabbits are descended from the European rabbit (*Oryctolagus cuniculus*). This species has been closely associated with humans for over 2000 years, but domestication is only around 200 years old, meaning that behaviourally domestic rabbits are similar to their wild counterparts (PDSA, 2023). Rabbits may be farmed for meat, fur or fibre (wool) production, used as laboratory animals or show animals or kept as pets.

There are around 50 rabbit breeds, and more than 500 varieties of rabbit currently recognised by the British Rabbit Council. Rabbits are the third most popular pet in the UK, with around 1.1 million individuals being kept as companion animals. The intensive breeding of different rabbit varieties has led to some physical characteristics that can affect a rabbit's ability to display normal behaviour. Angora rabbits for example are unable to cope with their long fur without human intervention, while brachycephalic breeds such as Netherland Dwarfs struggle with normal dental attrition

due to the jaw conformation, and in extreme cases can have significant issues breathing as the nostrils are so narrow.

Behaviour varies between different species of rabbits. Domestic rabbits (the species most commonly held as pets) are a social species, living in small family or harem groups of 2- 8 animals (McBride, 1988) although these groups can be up to 30 individuals. Each family group lives in a complex of underground burrows (warrens) that give protection from predators and extremes of weather. Rabbits are crepuscular, active from dusk until dawn, using this time to feed, groom, mate and defend territories. These territories can be large, up to 20 hectares in size (Nowak, 1999). As prey animals, rabbits are adapted to run rather than to fight. Strong hind legs and a mobile spine allow rapid acceleration, however the comparatively small heart size and lung volume limit this to short bursts of speed, rather than prolonged aerobic activity (Pariault, 2009).

Much of the time outside of the burrow is spent feeding. Rabbits are 'concentrate selectors' and will naturally gravitate towards food items that provide the most benefit for the least effort (Marin-Garcia et al., 2023b) choosing nutrient rich leaves and young shoots over older plant material that is higher in fibre. Nevertheless, seasonal variation in food availability means that wild rabbits are dependent on a high-volume nutrient dilute diet for much of the year. Captive rabbits have a more consistent diet but remain dependent on dietary fibre to grind teeth down and promote normal gut motility.

The rabbits natural diet comprises of stems and leaves of various plants, the exact variety dependent on geographical location. The diet varies seasonally, as stems and leaves sprout, grow, mature and dry, and protein, sugar and other nutrient levels rise and fall with the growth cycle. The feeding choices also vary. This suggests that rabbits have a selective feeding strategy that attempts to maintain diet quality despite seasonal nutrient variability (Nowak, 1999). In terms of nutritional content, wild rabbits typically eat a diet that is (as a % of dry matter) 25% crude protein, 40% neutral detergent fibre, 25% fat, starch and soluble fibre and 8% ash (Nowak, 1999).

Rabbits must process a diet that is high volume and high fibre, so they have evolved both anatomic and physiologic adaptations to facilitate this. Rabbits are elodont mammals, meaning that their teeth grow constantly. Because their diet is abrasive and must be macerated before digestion, the structure of the teeth has evolved to deal with this constraint. Teeth that grow constantly allow for the prehension and grinding of foods that contain abrasive substances without a reduction in food intake and processing efficiency over time.

The digestive tract of the rabbit comprises approximately 30% of bodyweight, significantly more than carnivores of a similar size (Cruise and Brewer, 1994). The stomach and small intestines function in a similar manner to other mammals. The stomach has muscular and glandular portions where mechanical and chemical digestion start, while the small intestines contain enzymes that facilitate the digestion and absorption of simple carbohydrates, proteins and fats. The fibre component of the diet presents more challenges. Attrition by the occlusal surfaces of the teeth disrupts the plant cell walls, making cell contents available for digestion in the small intestine. This leaves both digestible and nondigestible fibre. As ingesta passes from the small intestine through the ileocaecocolic junction into the proximal large intestine separation of the two types of fibre particles occurs. The structure of the proximal large intestine moves the smaller digestible fibre particles to the periphery of the intestine where they are caught in the haustra (sacculae the lie between each taenia or strap) while the larger non-digestible fibre particles remain in the centre of the intestinal lumen. This non-digestible portion of the diet moves slowly aborally (away from the mouth) through the large intestine, water is reabsorbed, and this matter is eventually evacuated as hard faecal pellets. Periodically, (under control of the fusus coli) the digestible fibre is moved back up towards the caecum during a period of retrograde peristalsis. In the caecum the digestible fibre undergoes microbial fermentation. Once this is complete the caecum empties (again under control of the fusus coli) and the digesta moves rapidly through the large intestine, during which time a layer of mucus is secreted onto the surface of the soft faecal balls or caecotrophs. When these caecotrophs are voided, the rabbit is stimulated to eat them directly from the anus. Once eaten the mucus layer on the caecotrophs surface is removed in the stomach and then assimilation of nutrients occurs within the small intestines. Caecotrophy usually occurs five or more hours after feeding during a time when the rabbit is resting rather than actively eating.

What began as an evolutionary constraint for wild rabbits has become a dietary requirement for pet rabbits. Perhaps the most critical part of the pet rabbit diet is the fibre content, which rabbits rely on in order to grind down their teeth (Crossley, 1995), and to promote normal gut motility (Davies and Davies, 2003). The majority of pet rabbits are fed some form of commercial diet (whether that is a pellet-based ration or one that is muesli-based) with the expectation that additional fibre in the form of hay and fresh vegetables would be offered. Commercial rabbit rations typically contain around: 14% crude protein, 25% crude fibre, 4% crude oils and fats, 8% crude ash. It has been suggested that crude fibre is not

an appropriate indicator of total dietary fibre content (Molina et al., 2015).

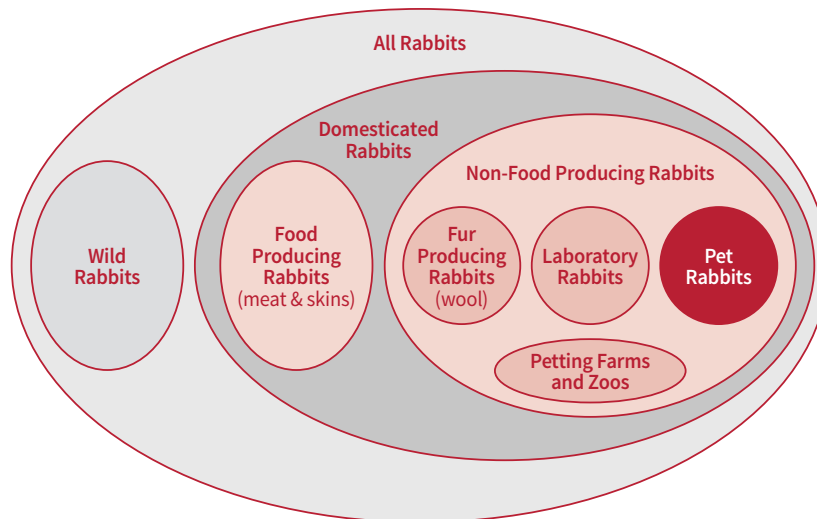
There are health consequences when rabbits are fed an inappropriate diet. One of the most commonly recognised clinical issues is acquired dental disease. While not solely caused by a lack of dietary fibre, diets that do not contain enough fibre can compound acquired dental disease by reducing that animal’s ability to grind its teeth down normally. Gastrointestinal stasis syndrome, a common clinical sign in rabbits that are in pain or unwell, can also be affected by dietary fibre levels. To maintain good gut motility, a rabbit is dependent on a diet that contains long stem fibre. While a lack of appropriate fibre in the diet will not necessarily result in a rabbit suffering from gastrointestinal stasis, it is one factor that can contribute to this.

Other factors related to diet can impact the welfare of pet rabbits. Obesity can be a consequence of inappropriate diet, where a rabbit is fed too many calories and does not have the opportunity (or often the space) to work these off. It is estimated that up to 35% of pet rabbits are overweight (Adji et al., 2022).

Rabbits have a unique calcium metabolism. In common with other hindgut fermenters, rabbits will take up calcium from the diet indiscriminately, so that the calcium and ionised calcium levels in the blood are higher than other species, and in the case of total calcium reflect the calcium levels in the diet. Rabbits, in contrast to many other hindgut fermenters, have a high fractional urinary excretion of calcium (Buss and Bourdeau, 1984). Where the dietary calcium levels are too high, conditions such as microurolithiasis (bladder sludge), urolithiasis, renolithiasis and soft tissue calcification resulting in pain and dysfunction can occur.

Rabbits are unique in the fact that they are a species that is both used commercially as well as being kept as pets and as such straddle two sets of nutritional and legal requirements. While some member states recognise rabbits as meat animals specifically it should be noted that the following guidance is for pet animals only. There are various special conditions pertaining to the labelling of food for pet rabbits, which will be highlighted later in this document. Ultimately rabbits have evolved to survive and thrive on a diet that is high in fibre, and while this can be challenging to replicate in captivity, the closer the diet offered is to that in the wild, the better the welfare of the pet rabbit.

Figure III-1. Graphic to illustrate the unique positioning of rabbits in society



3.2 ENERGY

Table III-1. Abbreviations

Kcal	Kilocalories	BW	Body Weight
MJ	Megajoules	BCS	Body Condition Score
Kg	Kilogram	CP	Crude Protein
GE	Gross Energy	EE	Ether Extract
DE	Digestible Energy	NFE	Nitrogen-Free Extract
ME	Metabolisable Energy	NFC	Non-Fibrous Carbohydrate
ME _n	ME Corrected for Zero Nitrogen Balance	ADF	Acid Detergent Fobre
MER	Maintenance Energy Requirement	NDF	Neutral Detergent Fibre

Energy is not a nutrient, but a property of the feed. It has been traditionally measured in kilocalories (kcal) or more commonly today in kilojoules (kJ) or megajoules (MJ), either of which are expressed per kilogram (kg) of diet. The conversion of kcal to MJ is (kcal x 4.184)/1000.

The provision of too much energy from the diet against the requirement of the rabbit is likely to result in obesity, too little resulting in weight loss.

The total energy in the diet as measured by calorimetry is termed gross energy (GE). Not all of this is useful to the

rabbit. Some is lost in the faeces, following digestion, leaving digestible energy (DE) and some more is lost in the excretion of waste nitrogen in the urine, leaving metabolisable energy (ME).

Unlike dogs and cats, where calculating the energy content of pet foods and energy requirements of pets centres around ME, DE remains a common and practical basis for energy calculations when feeding rabbits.

3.2.1 CALCULATION OF THE ENERGY CONTENT OF FOODS FOR PET RABBITS

Estimating the energy content of the rabbit diet is not without issue; similarly for a given energy content, the source of that energy within the diet (starch versus fat) can also impact upon body condition.

A number of equations have been proposed over the years for the prediction of the energy content of rabbit feeds. Whilst their accuracy of prediction is acceptable, it should be remembered that such equations should be based on actual chemical analyses of either the dietary components and/or the final diet, rather than relying on predicted values.

Further, there is a tendency for equations to over predict the energy content of diets with high levels of digestible

fibre, such as beet pulp, and underestimate those with high additional fat content. The latter are probably not appropriate for pet rabbit diets.

Similarly, using DE values from published tables such as INRA, whilst a good guide will not have the accuracy of predictions based on actual analytical data. They are however a good basis to begin diet design upon.

Where robust information or analytical facilities are available to provide data on the fibre fractions in a feed or a feeding stuff then the following equations can be used or estimating digestible energy:

DE MJ/kg	= 15.3 – 0.19 ADF
----------	-------------------

Where: ADF is acid detergent fibre; on a % DM basis. (Fernandez-Carmona et al., 2004).

Or,

DE MJ/kg	= 0.013 CP + 0.036 EE + 0.017 NFC + 0.006 NDF
-----------------	--

Where: CP is crude protein; EE is ether extract; NFC is non-fibrous carbohydrate (organic matter minus CP, EE and NDF); and NDF is neutral detergent fibre, assayed with a heat-stable amylase and expressed exclusive of residual ash; each on a g/kg DM basis. (Villamide et al., 2009).

Alternatively, if only basic analytical information is available the following equation can be used:

DE MJ/kg	= (-1801 + 7.10 CP + 12.01 EE + 5.59 NFE) x 0.004184
-----------------	---

Where: CP is crude protein; EE is ether extract; and NFE is nitrogen-free extract; each on a g/kg as-fed basis. If DE is in kcal/kg the correction factor of 0.004184 should be removed. (Lowe, 2020).

It is acknowledged that these equations can yield quite different DE values. For a typical mixed feed diet, it is suggested that the DE should be in the region of 9-10.5 MJ/kg. For situations where using ME is preferred (DE may overestimate energy value of protein-rich feeds), the following equation, corrected for nitrogen may be used:

MEn	= DE x (ME/DE)
------------	-----------------------

Where: MEn is corrected for zero nitrogen balance; DE is Digestible Energy; ME is Metabolisable Energy. (Maertens et al., 2002).

And where,

(ME/DE)	$\frac{= 0.995 - 0.0048 \times \text{digestible protein (g/kg)}}{\text{DE (MJ/kg)}}$
----------------	--

Or, can be assumed to be between 0.9 to 0.95.

For a more comprehensive review of this subject a number of chapters in 'Nutrition of the Rabbit' 3rd Edition by De Blas and Wiseman (2020), could be consulted, especially the chapter on Energy and protein metabolism and requirements by Xiccato and Trocino (2020). Other helpful references include: Villamide et al., (2009), Mertens (2002),

Mertens (2003), Maertens et al., (2002), and INRA (2004) which contains published values for nutrient content of different feeds, and is a useful 'textbook' source for rabbit DE values for feed ingredients.

3.2.2 CALCULATION OF THE ENERGY REQUIREMENTS OF PET RABBITS

A good guide for calculating the appropriate energy intake for the adult pet rabbit is shown in Table III-2. Growth would be a multiple of 1.9 to 2.1 from this value, gestation a multiple of 1.35 to 2.00 as pregnancy progresses, and lactation a multiple of 3.00 (Tobin, 1996), as shown in Table III-3.

Table III-2. Average energy requirements of adult pet rabbits

DE		OR	ME	
DE (kcal/day)	105 kcal DE x BW ^{0.75}		ME (kcal/day)	100 kcal ME x BW ^{0.75}
DE (MJ/day)	0.44 MJ DE x BW ^{0.75}		ME (MJ/day)	0.42 MJ ME x BW ^{0.75}

Where: DE is digestible energy; ME is metabolisable energy; body weight is expressed in kg. (Tobin, 1996).

Table III-3. Average energy requirements during growth and reproduction in pet rabbits

	Times MER
Growth	1.9 – 2.1
Gestation	1.35 – 2.00
Lactation	3.0

Where: MER is maintenance energy requirement. (Tobin, 1996).

It may be assumed that for a pet rabbit a daily dry matter (DM) intake of 3-5% bodyweight would be typical, however a very wide variation exists between individuals and according to the energy density of the diet and environment, with intakes of as much as 8% having been observed on high forage-based diets.

Because of the wide variation in requirements resulting from the many factors that influence energy needs of the pet rabbit, it remains important to indicate that the feeding guide provided on-pack is just that, a guide. Encouragement should be given for the rabbit owner to adjust feeding rates to maintain a steady, appropriate weight and body condition score (See Annex 1).

Assuming a good quality hay or grass is available, the rabbit has been observed to be able to adjust feed intake of the hay (0.3-0.66 of dry matter intake) to manage the energy requirements of varying circumstances. However it has been observed that hay with an ADF of greater than 380 g/kg DM, appears to adversely affect this voluntary feed intake resulting in a healthy, but weight losing body condition of the rabbit (Lowe, personal communication).

3.2.3 FACTORS INFLUENCING ENERGY REQUIREMENTS

The energy requirement of the rabbit, expressed per kg of metabolic weight (body weight^{0.75}) varies according to:

- Age/Lifestage
- Vital and Productive Functions (maintenance, growth, gestation, lactation)
- Physical Activity
- Environment (temperature, humidity, air speed)
- Stress/Poor Health

Whilst there are values attributed to some of these factors, the actual energy requirement will vary both between different types, and even within the same type, of rabbit.

The feeding guide, whilst legally required, is actually of vital importance to help / guide the owner to feeding the rabbit(s) appropriately in order to maintain a healthy body weight (BW) and body condition score (BCS) for the type of rabbit. It is therefore important to state in the feeding guidelines on-pack that daily food intake may need to be adjusted to maintain body weight and condition.

Care should be taken to assess the energy content of the diet and the likely energy requirement of the rabbit for a set of circumstances. It is suggested to be cautious about over-estimating the needs and thus the amount of supplementary feed above forage to be supplied each day.

3.2.4 OBESITY

As with cats and dogs, obesity is an increasing issue for rabbits. This is why it is important to monitor how much food they are given and to watch both their weight and body condition. Regular monitoring is essential to pick up changes before they become problematic, and assess effectiveness of any remedial intervention.

The body weights of pet rabbits vary considerably, ranging from less than 1kg for a Netherland Dwarf to over 8kg for a Continental Giant. Typical body weights may be found in breed standards / body weight tables, but these don't represent the increasing number mixed breed (cross-bred)

rabbits kept as pets. Body weight tables can act as a guide where the breed is known, and regular weighing can help show whether the rabbit is gaining or losing weight, but neither provide any indication as to whether the rabbit is obese, overweight, or indeed underweight.

Body condition scoring (BCS) is a quick and simple technique which involves palpating (feeling) the natural bony protuberances of the rabbit (pelvis, ribs and spine) and assessing how much subcutaneous fat there is over them. Further information and a scoring chart are provided in Annex 7.1.



4.0 Nutrient Recommendations

4.1 USE OF THE TABLE

The table has been compiled following a review and interpretation by practising nutritionists and veterinarians of the published literature which is, in the main, for either commercial meat and/or laboratory rabbits.

Any commercially manufactured rabbit food should clearly state whether it is complete or complementary. The values suggested in the table are safe and practical amounts for the design of a complete rabbit food.

However, very few commercially manufactured foods for pet rabbits are 'complete' these days – most are 'complementary' and are designed to be fed alongside hay or fresh grass, fresh leafy greens, and fresh water – which when combined make the diet complete.

A complementary rabbit food, that is to be fed alongside forage sources, may in itself, not comply with the values in

the table. However, when nutrient intake is calculated from the feeding guide, based on the amount of rabbit food, forage and/or additional feedstuffs to be fed in the daily ration, the total / overall diet should fall within these values. To that end the values in the table, not only reflect those of a complete diet, but also the pet rabbit's total intake.

Current best feeding practices recommend that pet rabbits should have access to quality forage at all times for gut health, adequate dental wear and enrichment reasons.

The column entitled SUL in some cases consist of levels that should not be exceeded and are indicated by an asterisk, for example Calcium and vitamin D, whereas the others are levels at which no adverse effect has been observed in rabbits, higher levels may still be safe, but no scientific data are available.

4.2 TABLE OF NUTRIENT RECOMMENDATIONS

NB. It is important to note that these nutrient recommendations are for the pet rabbit's total diet.

The ration may comprise contributions from various sources including manufactured food, forage, fresh vegetables and treats.



Table IV-1. Nutrient Guidelines for Pet Rabbits. (Unit/kg feed, 12% moisture, assuming 10MJ DE/kg)

Component	Unit	Nutrient Level / kg feed at 12% moisture			Maxima		
		Adult Maintenance Recommendations		Growth, Minimum Requirements*		SUL	Legal Maxima
		Ranges		Ranges			
Protein	g	120 to ≤170		150	180	-	-
Arginine	g	8-9		7	n/d		
Glycine*	g	6.8		n/d	n/d		
Histidine	g	n/d		3	n/d		
Isoleucine	g	n/d		6	n/d		
Leucine	g	n/d		11	n/d		
Lysine	g	5-8		5†	9		
Methionine + Cystine	g	5.4-6.5		5.5	n/d		
Phenylalanine + Tyrosine	g	n/d		n/d	n/d		
Threonine	g	5.8-6.5		6	n/d		
Tryptophan	g	n/d		2	n/d		
Valine	g	n/d		7	n/d		
Carbohydrates		-		-	-	-	-
Starch *	g	≤200		n/d	135†	See * below	
ADF	g	170		n/d	n/d		
NDF	g	300 to 450		n/d	n/d		
ADL	g	55 to n/d		n/d	n/d		
((NDF + Pectins)-ADF): ADF		n/d to ≤1.3		n/d	n/d		
ADF-ADL	g	110 to n/d		n/d	n/d		
Crude Fibre*	g	140 to 250		140† to 160			
Fat	g	25-50		30 to 50			
Minerals	g	-		-		-	-
Calcium*	g	5		5		10	
Phosphorus	g	4		4		9†	
Ca / P ratio		1:5 to 2:1		1:5 to 2:1			
Potassium	g	6		2 to 6		16	
Sodium	g	2		1 to 2		8	
Chloride	g	1.7		1 to 5		4.8	
Magnesium	g	0.3 to 3		0.4 to 0.7		3.4‡	
Trace elements	mg	-		-		-	-
Copper	mg	5 to 20		3 to 6		25	25
Iodine	mg	0.4 to 0.5		n/d		2	10
Iron	mg	30 to 400		100 n/d			1250
Cobalt*	mg	0.25 mg§		0.1 to 1			10
Manganese	mg	8 to 15		20 to 40		75	150
Selenium	mg	0.05 to 0.32		0.1 to n/d		0.35	0.5
Zinc	mg	50 to 150		40 to n/d			150
Vitamins		-		-		-	-
Vitamin A	mg	10000 to 12000		6000 to 10000†			
Vitamin D	mg	800 to 1000		500 to n/d		2000	2000
Vitamin E	mg	50 to 160		50† to n/d			
Vitamin C*	mg	n/d	400	n/d		2000¶	
Vitamin K*	mg	1	2	n/d			
B-group*	mg	n/d	n/d	n/d	n/d		

n/d – not determined. * Please refer to Additional Notes on these nutrients. † Additional data from De Blas and Wiseman (2020) and Lebas (2000). ‡ Bulat, Z.P. et al., (2008). § Should be supplied when vitamin B12 is limited. ¶ Chen (1989).

4.3 SUBSTANTIATION OF NUTRIENT RECOMMENDATIONS

The values in the ranges are recommended values for typical diets based on the current best knowledge derived from published information including several scientific papers for adult rabbits, and the reference given below for growing rabbits. The limited published information accounts for some apparent discrepancies between the adult and growth values. In the future, some recommended values are likely to change as more information is published.

Growth

These data come from limited research, and we would encourage further work in this area. The majority of the data is taken from Kamphues et al., (2014). Additional data comes from De Blas and Wiseman (2020) and Lebas (2000) (see comment marked “†”).

Safe Upper Limit (SUL)

The safe upper limit is defined as the intake of a nutrient that can be consumed daily over a lifetime without significant risk to health on the basis of the available evidence. As a general principle it was agreed that no SUL will be stated in the Guidelines for nutrients for which no data on potential adverse effects are available. Gidenne et al., (2020) observe that whilst typically maximum acceptable levels are far higher than the recommended level, in rabbits there are some noticeable exceptions, such as potassium, phosphorus and vitamin D.

Legal Maxima

These list those additives with a maximum legal limit as authorised by the European Union. Maximum permitted levels have been determined by the legislator for several nutrients if added as a nutritional additive (i.e. trace-elements & vitamin D) (legal maximum). They are laid down in the Community Register of Feed Additives pursuant to Regulation (EC) No 1831/2003 of the Parliament and the Council, concerning additives in feedstuffs. The legal maximum levels apply to all life stages (Regulation (EC) No 1831/2003 in conjunction with EU register of feed additives). A legal maximum only applies when the particular trace-element or vitamin is added to the recipe as an additive, but relates to the “total” amount present in the finished product i.e. the sum of the amount coming from the additive plus the amount from feed materials (ingredients). If the nutrient comes exclusively from feed materials, the legal maximum does not apply, instead the nutritional maximum, when included in the relevant tables, should be taken into account.

Protein

Protein quantity and quality for pet rabbits is usually regarded as being met with conventional ingredients in compound foods and good quality forage, such as grass or hay. Indeed excess

protein over and above that suggested in the table is potentially likely to lead to digestive upsets.

Whilst lysine is considered the first limiting amino acid, followed by methionine, a typical raw material base of the pet rabbit diet is more likely to shortfall in sulphur amino acids as a first concern.

Glycine: The literature in general suggests that the rabbit requires ten essential amino acids, while Cheeke (1987) suggested that glycine could also be considered essential at levels similar to lysine, which would be typically found in a rabbit food anyway. The evidence suggests that this is only important in fast growing animals, but this is not what we’re seeking to achieve in pet rabbits. Never-the-less Fekete (2020) has suggested a value of 6.8 g/kg for adult maintenance in laboratory rabbits.

Carbohydrate

Starch: Whilst it is recognised that an upper starch limit may be unnecessary providing that adequate fibre fractions are supplied, the purpose of these recommendations is to provide a safe and efficacious guide to complete diet. An upper starch provides additional safety to the diet for a pet rabbit where, despite appropriate feeding guides, owners may inadvertently overfeed the compound fraction of the daily ration and thus inadvertently provide an imbalance of starch and fibre.

Dietary Fibre: Upper values for fibre fractions are provided as it is recognised that excessive inappropriate fibre fraction intake could reduce the energy supply thus compromise the health and well-being of the rabbit. For further information on fibre see Section 4.4.

Fat and Fatty Acids

There are limited data on the essential fatty acid requirements of rabbits. However given that in the wild their consumption of grass or similar forages would be rich in omega-3 fatty acid, linolenic acid, it would seem appropriate to mimic such intakes in the pet diet. A diet based on such forages would typically supply ~25 g fat per kg. Further weight constraint is an important consideration in the pet rabbit, consequently high fat diets per se should be avoided. Such materials as lucerne, grass and full fat linseed are rich sources of linolenic acid. It is suggested that the fat content of the compound feed should not exceed 50 g/kg.

Minerals

Calcium: The rabbit is particularly sensitive to calcium intake and whilst amounts as high as 19 to 25 g/kg total diet have been

fed without apparent problems during reproduction (Gidenne et al., 2020), for the pet rabbit a safer upper limit would be 10 g/kg.

Phosphorus: Whilst amounts as high as 8 g/kg total diet have been fed without apparent problems, at 10 g/kg signs of toxicity were observed during reproduction (Gidenne et al., 2020). Excess phosphorus (>9 g/kg) may depress feed intake and impair prolificacy in does (Chapin and Smith, 1967).

Magnesium: The magnesium requirements for growing rabbits vary from 0.3 (NRC, 1977; INRA, 1989) to 3 g/kg (Lebas, 2004; Maertens and Luzi, 2004). Evans et al., (1983a,b) found that 3.4 g/kg fulfilled requirements, but 1.7 g/kg was insufficient. Excess dietary magnesium is eliminated through the urine, and therefore, extra supplementation with magnesium rarely induces severe side effects (Bulat et al., 2008).

Cobalt: The cobalt requirement of the rabbit is principally to ensure supply to the hind gut microbiota for the synthesis of vitamin B12. It is however recommended to include sufficient vitamin B12 into the rabbit’s diet, and thus to remove the need

for any additional cobalt, above that supplied from background levels found in the raw materials. The intestinal microbiota of the rabbit has been shown to be very efficient at utilising any cobalt present in the diet. If however vitamin B12 is not provided, a cobalt content of 0.25 mg/kg is recommended.

Vitamins

Vitamin C: Vitamin C has only been found to be of benefit during periods of stress, otherwise it is assumed that the rabbit is capable of synthesis from glucose. Extremely high levels of vitamin C are not advised, and may potentially be a prooxidant if vitamin E levels are not adequate (Chen, 1989).

Vitamin K: Vitamin K is only suggested as required in the absence of caecotrophy.

B-group Vitamins: The B-group of vitamins is generally regarded as being supplied from synthesis within the hind gut of the rabbit. However in many cases dietary supplements or dietary fortification/enrichment of these vitamins are commonplace to ensure sufficient vitamin supply in case of insufficient synthesis. For Vitamin B12 see note on cobalt.

4.4 FIBRE

Table III-1. Abbreviations

TDF	Total Dietary Fibre	NDF	Neutral Dietary Fibre
SDF	Soluble Dietary Fibre	ADF	Acid Detergent Fibre
IDF	Insoluble Dietary Fibre	ADL	Acid Detergent Lignin
NSP	Non-Starch Polysaccharides	CF	Crude Fibre

For pet rabbits, whilst it is entirely plausible to manufacture complete feeds with appropriate amounts of dietary carbohydrate (‘fibre’ and ‘starch’) to meet the nutritional and gastrointestinal physical and physiological needs, the physical nature of the fibre present in the product is

the most important factor for dental wear rather than its chemical nature. An appropriate statement as to the need to supply this form of material should appear on all rabbit feed packs along the lines of ‘For the health and wellbeing of your rabbit good quality hay should be fed at all times’

4.4.1 QUANTIFICATION OF FIBRE

Fibre is essential to the rabbit on a daily basis, to maintain normal gut function, dental wear, and to provide substrate for normal fermentation in the caecum; all these factors are key to nutrient supply, normal health and behaviour in the rabbit.

The term fibre embraces a wide range of plant components, and it is important key to quantify the minimum amounts and relative proportions of these that are important to the rabbit.

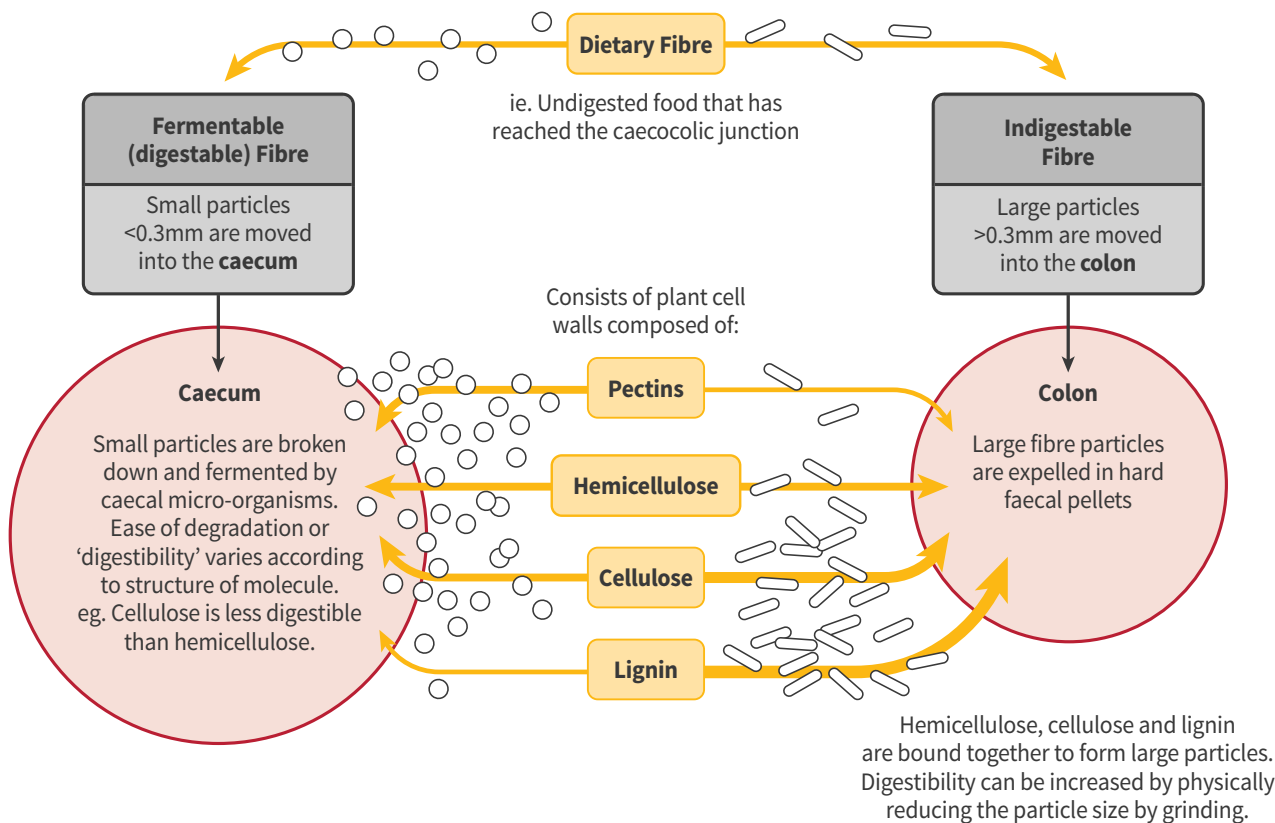
Fibre comes, in the main, from plant cell walls. Plant cell walls are not uniform and are extremely complex structures. Their type, size and shape depend upon the functionality of that cell wall within the plant. This in turn affects the functionality of the material in the rabbit and how it will be metabolized in the rabbit's gut.

In general, plant cell walls are a series of polysaccharides often associated with glycoproteins, phenolic compounds, acetic acid and in some cells, lignin.

A young growing plant cell has a primary cell wall, which contains few cellulosic fibrils and some non-cellulosic components. During ageing, the plant develops a secondary cell wall consisting of mainly cellulose and lignin.

In simple terms, primary cell wall (fermentable, sometimes referred to as digestible, fibre) supports the caecal fermentation needs, whilst secondary cell wall (often termed indigestible fibre) maintains gut motility and function (Figure IV-1). In absence of structured indigestible fibre, diarrhoea may develop. Plant cell walls (lignin, cellulose and silicate phytoliths) are also important in enhancing salivation and in providing dental abrasion and maintaining normal dental occlusion through extended chewing time, appropriate chewing patterns and force of the chew action.

Figure IV-1. Digestion of fibre in Rabbits (Varga-Smith, 2023; adjusted with the author's permission)



Fibre measurement is complex and remains incomplete. Further, the terminology is also often confusing and inconsistent. However, an approach to the fibre needs of rabbits can broadly be based on the following categories, and as illustrated in Figure IV-2:

Total Dietary Fibre (TDF)

Refers to the total cell wall components in a plant. TDF represents all Non-Starch Polysaccharides (NSP), pectic substances, hemicellulose, cellulose and lignin. TDF is the sum of soluble and insoluble fibres (SDF and IDF) that refer to the dietary fibre components that are soluble and insoluble in water, respectively.

Neutral Detergent Fibre (NDF)

Equates to most of the hemicellulose and lignocellulose and all the cellulose.

Acid Detergent Fibre (ADF)

Equates to cellulose and most of the lignin. Consequently NDF minus ADF represents the hemicellulose content of the diet. (AOAC, 2000, method 973.18).

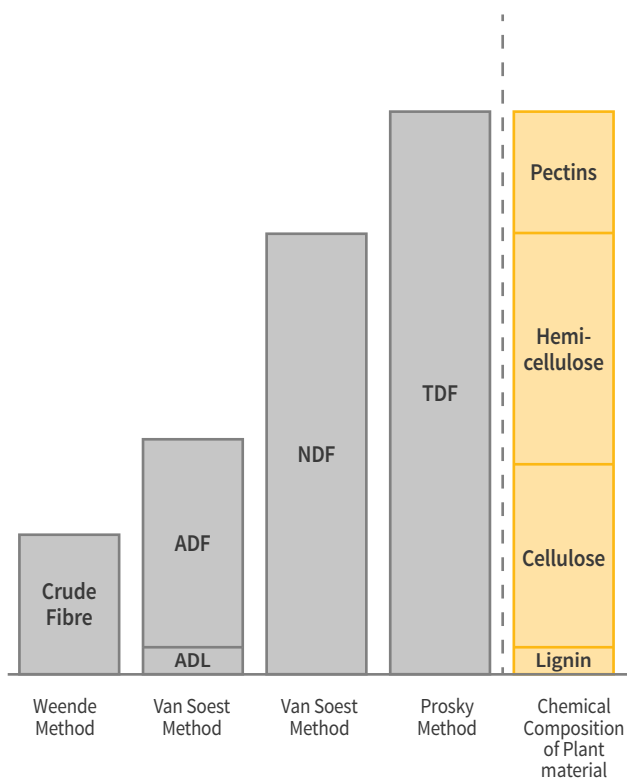
Acid Detergent Lignin (ADL)

Is nearly all lignins.

Crude Fibre (CF)

CF represents 20-90% of the lignin and 30-100% cellulose depending upon the plant ingredient being analysed. Consequently, it could be considered as a poor analytical measure on which to base sound formulation of the complete diet for a rabbit (Meredith and Prebble, 2012; Molina et al., 2015). That said, legislation (See section 6.4.1.) stipulates that CF must never-the-less be declared on-pack.

Figure IV-2. The non-starch polysaccharide content of plant material



Note: The figure shows the relative proportions of each of the chemical constituents of plants measured by each method; crude fibre, acid detergent fibre (ADF), acid detergent lignin (ADL), neutral detergent fibre (NDF) and total dietary fibre (TDF).

Consequently an estimate of pectins can be derived from TDF - NDF (Hall et al., 1997)

4.4.2 FIBRE REQUIREMENTS OF PET RABBITS

The rabbit needs a minimum fermentable (digestible) and a minimum non-fermentable (indigestible) fibre component in the complete diet (which may include both a compound food and forage material such as hay). Rather than formulating to crude fibre, it is strongly suggested that the formulation should be based upon values for the various non-starch polysaccharide (fibre) fractions of the diet. In practical terms values for minima / maxima for NDF¹, ADF² and lignin are recommended at the stated DE content of the diet, so as to better reflect the important balance of digestible and indigestible fibre, irrespective of its origin in terms of ingredients in the complete diet. Formulating using appropriate values for these criteria are likely to result in a crude fibre content of the complete diet of 140 g/kg when the diet is enriched with other sources of fibre (such as hay) or in the region of ≥ 160 g/kg. The corollary of this is that if the NDF, ADF and lignin values are ignored or unavailable to the formulator, a reasonable 'safe' value for crude fibre would be in the order of 140 g/kg to 160 g/kg, irrespective of the ingredient matrix of the complete diet.

Research has indicated that a minimum NDF of 300 g/kg total diet, a minimum ADF of 170 g/kg total diet would meet the needs of the rabbit at adult maintenance. For growing rabbits, an additional constraint of a maximum starch of 135 g/kg total diet is recommended, whilst for the adult

200 g/kg may be acceptable or even 250 g/kg providing the minimum 'fibre' values are exceeded (Gidenne and Garcia, 2006).

These fibre components may come from a wide range of ingredients that are incorporated into the feed either in the form of ground material, as in pelleted or extruded feeds, or as additional loose fibre components. In respect of ground material, evidence indicates that if the indigestible fibre fraction was finely ground (less than 1mm) then the diet behaved as if containing insufficient dietary fibre, inducing adverse caecal patterns and scouring (Pairet et al., 1986; Bouyssou et al., 1988).

The values for the carbohydrate fractions of the diet should fall within those suggested in the table of these guidelines and should be used in conjunction with the ratio indicated. Such an approach should meet the needs of the rabbit and reduce as far as possible the likelihood of digestive upsets.

A further improvement on quantifying fibre fraction involves the addition of pectin. This follows studies indicating differing fermentation rates of diets with similar NDF values. The effect is considered to be the pectin and other soluble fibre fractions (Hall et al., 1997; Gidenne and Garcia, 2006).

¹ Fermentable needs.

² Indigestible, motility needs.

4.5 WATER

Rabbits have a comparatively high water intake (100-150ml/kg BW/day), drinking largely at night. Water intake is affected by age, environmental temperature, reproductive status, husbandry and diet. Water requirements can be met by the diet only if water content is above 55%. In pet rabbits, the relationship between food and water intake has a linear relationship – as dry matter (DM) intake increases, freshwater intake increases (Cizek, 1961). Free water intake is higher in diets containing higher fibre levels, with a correlation between hay intake rather than concentrate (prepared feed) intake, highlighting the importance of hay in ensuring adequate water intake when feeds with low water content are fed (Prebble and Meredith, 2014).

Water consumption in excess of 100-150ml/kg BW/day may indicate play behaviour, or polydipsia (excessive water

intake) due to health issues or feed deprivation (insufficient feed intake) which can result in loss of sodium and induced sodium deficiency (Cizek, 1961).

Access to ad libitum water is essential and pet rabbits demonstrate a preference for drinking from a bowl compared to a bottle/nipple drinker (Tschudin et al., 2011a,b). Heavy earthenware bowls are suitable, but if these are routinely fouled, bottle drinkers in a frame outside the pen and a small trough inside, or a 6mm diameter drinking tube may be more practical. A note on-pack to this effect could be considered as critical as the one stating that the rabbit must always have access to fresh, clean drinking water.

5.0 Analytical Methods

In order to obtain representative results, samples must be collected and treated according to the general principles of Regulation (EC) No 152/2009 of 27 January 2009 laying down the methods of sampling and analysis for the official control of feed (latest consolidated version 04 April 2024).

The analysis of only one sample may not reflect the level declared in the average analysis of the product. To obtain a representative analysis, multiple samples coming from different batches have to be analysed. A composite sample made from multiple samples is also valid. When evaluating the results of a single-sample analysis, deviation from the declared values of analytical constituents is permitted provided it is within the tolerances outlined in Annex IV Part A of Commission Regulation (EU) 2017/2279 of 11 December 2017 (amending Annexes II, IV, VI, VII and VIII to Regulation (EC) No 767/2009 of the European Parliament and of the Council on the placing on the market and use of feeds), and tolerances for analytical latitude.

In section 4.4.1 three analytical methods were compared to highlight the different fibre fractions determined by each and show that Crude Fibre was a poor analytical measure for fibre levels in rabbit foods and ingredients. Many commercial laboratories use the Fibertec™ system which determines not only crude fibre, but also the detergent fibres (NDF, ADF and ADL).

Analysis of rabbit foods, where Vitamin D levels are approaching the minimum recommendation, say between 500 and 1000 IU/kg DM, is difficult and unreliable. The detection limit for HPLC methods is approximately 3000 to 5000 IU/kg. Analysis is not required if supplementation is practised, and it is unlikely that un-supplemented products with adequate levels of vitamins A and E will be deficient in vitamin D.

6.0 Practical Formulation and Feeding

6.1 SAFE PRODUCTION OF PET RABBIT FOOD

These guidelines are written for pet rabbits. But as already stated, manufacturers should be aware that unlike most other domestic pets, rabbits are also reared as food animals.

Pet rabbit feed producers and industry in general considers that farmed rabbit and pet rabbit feeding have two entirely different aims – pet rabbits are fed for a long and healthy life; meat production rabbits are fed for rapid growth.

The production of safe pet rabbit foods follows essentially the same requirements as for all pet foods. These requirements are discussed fully in the separate FEDIAF Guide to Good Practice for the Manufacture of Safe Pet Foods.

6.2 DIFFERENT RABBIT FOOD FORMATS

Commercially prepared rabbit foods can be presented in a variety of ways, and there is often confusion in the terminology used to describe the different product formats.

Coarse mixes

Coarse mixes can be described as a dry (moisture content <14%) multi-component pet food where a variety of different ingredients are combined. They can be complete or complementary.

These mixes can include whole, flaked, or rolled cereals and legumes, fruits, seeds, nuts, forage stalks and other composite products (extrusions or pellets), which may be forage-based, and/or be a vehicle for adding micro-nutrients (vitamins, minerals, and trace elements) to the food. They are often referred to as ‘muesli’, ‘muesli-style’ products, which implies high cereal and dried fruit inclusion, but this is not always the case.

Coarse mixes offer a variety of textures and tastes to rabbits, but selective feeding may be a problem in bowls that are over-filled and/or continually topped up or where more than one rabbit occupies the pen/cage. Differences in ingredient dimensions and densities may cause settling during transit and storage, and may alter the composition of the mix, and hence nutritional profile.

Compressed pellets

Pellets are dense compressed products, formed when ingredients are ground, mixed, gently conditioned with steam (heat and moisture) and pressed through holes in a metal die plate. They are most often cylindrical, but they can be other shapes (less variety than with extruded nuggets). Their diameter can affect acceptance. Pellets typically break off naturally as they leave the die plate, which means there can be some variation in their length. The external surface of the pellet is smooth and shiny, but the ends are often ragged. Pellets are cooled before being put into packaging.

Typical temperatures for pelleting are ~70-75°C. Those described as cold- or cool-pressed may be processed at lower temperatures of ~40°C, which can help retain levels of the more thermally sensitive nutrients, but the losses at higher temperatures can be compensated for by adding more to the formulation.

Pellets can be complete or complementary, and presented as a mono-component diet or included in coarse mixes. There should be minimal variation in ingredient and nutritional composition between pellets within a batch.

Extruded nuggets

Nuggets are to rabbits, as kibbles are to dogs and cats. Nuggets are mostly extruded expanded products, BUT can also occasionally be baked.

Extruded nuggets are formed when ingredients are ground, mixed, conditioned with steam, and forced through holes in a metal die plate under high pressure. As the product exits the die it expands due to the release of pressure, and a blade then slices through it to create a nugget of a specific size. Holes in the die plate determine the shape of the extrusion (huge variety of shapes), and the speed of the rotating blade alters the depth / length of the extrusion. Typical temperatures for extrusion are ~110-130°C. Products are cooled before being packaged.

Nuggets can be complete or complementary. They can be forage-based, cereal-based and may even contain meat by-products. Although mostly sold as mono-component products, extruded nuggets can be included

in coarse mixes. Variation in ingredient and nutritional composition between nuggets within a batch should be minimal. Ingredients undergo high pressure, friction and heat. Losses of less thermally stable nutrients can be compensated for by elevating levels in the formula.

Forages

Traditionally 'forages' were limited to a few different types of hay (dried grass), but more recently the term has also come to include a variety of different types of grasses, and also dried plant leaves, herbs, and flowers.

Broadly speaking there are 3 types of hay: grass (ryegrass, fescues, timothy), legume (alfalfa, clover, vetch), and cereal (barley, wheat, oat). However, cereal hay is more often called straw and used as bedding (except for green oat hay, which is harvested with seed-heads intact).



The most commonly available forage is 'meadow hay', a hay composed of a variable mixture of grasses (mainly ryegrass, fescue, occasionally clover) and other naturally occurring meadow plants / flowers. Timothy is one of the most popular hays. Hays are typically dried in the field, with regular turning, but barn- and air-dried products are becoming more popular. Further, more detailed information on hay can be found in Section 6.3.1.

Forages are a vital aspect of the pet rabbit's diet. There can be tremendous variation in nutrient levels between forages, based on species, season, harvesting and storage conditions, and ratio of stalk to leaf.

Foliage and flowers

Also falling under forages (and perhaps natural treats) are various dried plant leaves, herbs, and flowers, which can be presented as individual products and/or within forage mixes. These were traditionally found growing within natural meadows, hedgerows and verges, and often fed fresh to small herbivores, but in recent years are being specially cultivated, harvested and barn- or air-dried. Leafy green vegetables are also considered as foliage, but are fed fresh.

The list of plants is diverse and growing. Examples include:

- Plant Leaves – soft fruit (blackberry, blackcurrant, raspberry, strawberry), tree (apple, mulberry, pear)
- Herbs – coriander, chervil, dandelion, lemon balm, mint, nettle, parsley
- Flowers – chamomile, cornflowers, echinacea, hibiscus, lavender, mallow, marigold, rose

Plant leaves, herbs & flowers are 'complementary' feedstuffs. There can be tremendous variation in nutrient levels depending on species used (and combinations thereof), season and storage conditions.

Roots, stems, twigs and bark

Often classed under both forages and treats, wood products, twigs and bark, stems and roots are also often offered to rabbits and rodents. Whilst they may be ingested, they are not typically classed as foodstuffs, but rather as natural gnawing treats or chews.

Safe materials include:

- Roots – dandelion
- Stems – reeds, seagrass, willow, water hyacinth
- Twigs, Wood & Bark – apple, pear, birch, hazel, willow

Materials like willow and strong grass stems from water hyacinth, seagrass and reeds are often woven, to create interesting wicker shapes – like balls, baskets, tunnels, hideaways etc. The fibre content of these materials can be quite high and can contribute to the overall fibre intake of the rabbit, but the far greater benefits are in dental attrition and dietary enrichment.

Treats

Often the differentiation between chews and treats is the amount of time it takes for the pet to consume the treat – a

treat is typically consumed quickly, whereas a chew lasts longer. In rabbits and other small pets, chews tend to be called gnawing treats.

Treats can be natural or manufactured:

- Natural – dried foliage & flowers, nuts, seeds, dried fruits & vegetables.
- Manufactured – extruded or baked (different colours, shapes, dimensions, textures, with and without pockets), vegetable drops

Treats are 'complementary' feedstuffs. Because of the diversity of treat types there can be tremendous variation in nutrient levels. Care must be taken when feeding any higher calorie treats to rabbits. The size of each treat, relative to the size of the rabbit, means that they can easily consume far more calories than they actually need.

Gnawing treats

Gnawing treats are designed to be nibbled at persistently over longer periods of time. They can either be natural or manufactured:

- Natural – products like twigs, bark and roots
- Manufactured – products that are compressed or formed in moulds. They can be cube-, cookie- or stick-shaped, layered or filled, and may be forage-, cereal- or seed-based. These products may, but not always, contain binders (including syrups, starches and oils) to hold the ingredients together. 'Stickle' treats are a type of gnawing treat, which consists of a mixture of ingredients (like oats, seeds, nuts, dried fruit and vegetables) formed around a central stick.

Manufactured gnawing treats are 'complementary' feedstuffs. There can be tremendous variation in nutrient levels between different gnawing treats depending on ingredients and recipe. Gnawing treats can be quite large and should therefore be fed infrequently. 'Stickle' treats are hung in cages to encourage small pets to work for their reward, a little bit at a time, rather than eat it in one sitting. They are more suited to rodents than rabbits, and consumption must be monitored daily to avoid overconsumption, especially when first introduced which can upset the small pet's sensitive digestion.

A helpful factsheet containing further definitions and illustrating these different formats can be found on the UK Pet Food website at: <https://www.ukpetfood.org/resource/dietary-formats-definitions-for-small-mammals.html>.

6.3 TYPES OF INGREDIENTS

The table of nutrient recommendations in Section 4.2 defines the nutrients and levels required either in a complete food for pet rabbits, or in the rabbit's total daily diet. These nutrients need to be presented to the rabbit as a palatable food,

and are delivered in the ingredients within the food(s). This section describes the more common ingredients (termed 'feed materials' and 'feed additives' by the EU).

6.3.1 COMMON FEED MATERIALS FOR RABBIT FOODS

Feed materials are ingredients typically used in larger quantities in animal feeds or pet foods, and can be of animal, vegetable or mineral in origin. They can be in their natural state, fresh or preserved, or be derived from processing of other materials. To be used in rabbit food they must be in the EU Catalogue of Feed Materials and comply with any conditions.

Their principal purpose is to meet animals' nutritional needs. Rabbits need a high level of fibre in their diet, and whilst hay, grass and lucerne are the most common feed materials for supplying this, several other high fibre feed materials can be used. Other feed materials can be added as good sources of particular nutrients like proteins (e.g. soybean meal) and omega-3 fatty acids (e.g. linseed).

At the time of writing the latest update to the Catalogue of Feed Materials was in July 2022 (Commission Regulation

(EU) 2022/1104 of 1 July 2022 amending Regulation (EU) No 68/2013 on the Catalogue of feed materials). The catalogue is updated every few years, and in recent years new additions to Part C. List of Feed Materials, have been in favour of rabbit foods.

It is important to note that some feed materials (e.g. specific herbs) which whilst not appearing in the EU catalogue, may still be in the Register of Feed Materials (<http://www.feedmaterialsregister.eu>), and therefore also legitimately used for rabbit foods, provided they are safe and accurately described on the label. The GB Register of Feed Materials (<https://gbfeedmaterialsregister.org.uk>) was published in September 2024, and is a list of feed materials that are notified by UK feed business operators for placing on the GB market.

6.3.2 COMMON ADDITIVES FOR RABBIT FOODS

In contrast to feed materials, feed additives are ingredients typically used in smaller quantities in animal feeds or pet foods. Additives can be substances, micro-organisms or preparations, other than feed material and premixtures, which are intentionally added to rabbit food or water in order to perform specific functions. Of the five recognised groups of feed additives four are relevant for use in pet rabbit foods: nutritional, technological, sensory and zootechnical. To be used in rabbit foods, they must be on the EU Register of Feed Additives and be approved for use in rabbits.

At the time of writing the latest update to the Feed Additives legislation was in July 2019 (Regulation (EC) No 1831/2003 on additives for use in animal nutrition). The Commission regularly updates the European Union Register of Feed Additives, and as of 5 April 2023, replaced the register in PDF format with a new searchable online version (<https://ec.europa.eu/food/food-feedportal/screen/feed-additives/search>). There is also an electronic register that sets out a list of feed

additives permitted for use in Great Britain (https://data.food.gov.uk/regulated-products/feed_authorisations). This does not replace assimilated Regulation (EC) No 1831/2003 which is the legal basis for the placing on the market and use of individual feed additives.

Pet rabbits require vitamins, minerals and trace elements. Some are provided via natural feed materials, but many are supplemented by using a premix, to meet the required intake. For example, alfalfa is a good source of the mineral calcium, which may also be added separately via a premix in one of its mineral forms, such as calcium carbonate or di-calcium phosphate.

Trace elements (zinc, iron etc.) and certain vitamins (e.g. fat-soluble Vitamin A) are classified as 'Additives', whereas sources of the major minerals such as calcium carbonate and di-calcium phosphate are classified as 'Feed materials' (and not additives). Additional functional ingredients, sometimes referred to as nutraceuticals, may be added to the rabbit's diet – these may fall under 'Additives' or 'Feed Materials'.

Note, not all feed additives may be used in rabbit feeds e.g. certain colourants. Just because an additive is approved for use in dog and cat food doesn't mean they are approved for use in rabbit foods. When using additives in rabbit food it is therefore essential to check they are approved for use before using them.

Further information on the use of additives in rabbit food can be found in a 'Pet Food Additives' factsheet on the UK Pet Food website at: <https://www.ukpetfood.org/resource/additives-factsheet.html>.

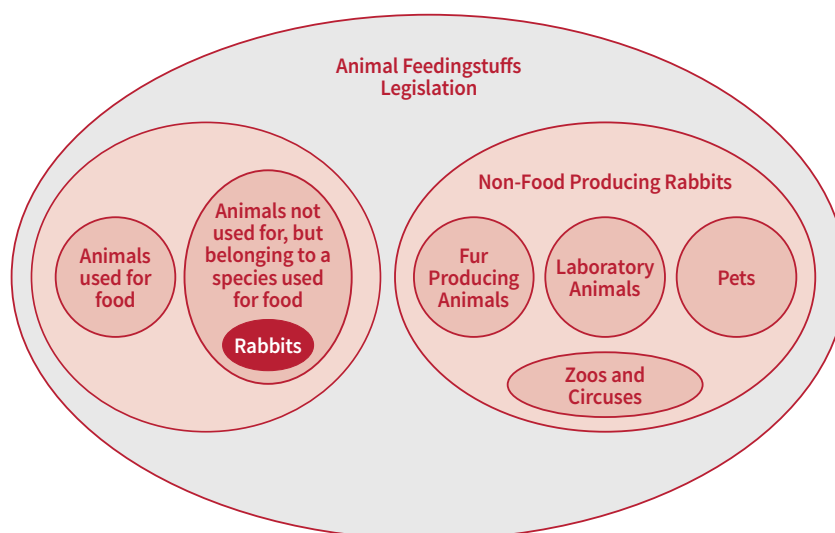
6.4 LABELLING OF PET RABBIT FOODS

Despite being pets (and therefore non-food producing animals), in animal feedingstuffs legislation rabbits are seen as animals not used for, but belonging to a species that is used for food. Hence, food for pet rabbits must be labelled according to the rules for food-producing animals, as illustrated in Figure VI-1, and documented in Regulation (EC) No 767/2009 on the marketing and use of feed.

As a 'food-producing animal', rabbit food must therefore be labelled differently from a 'pet food' for dogs, cats and indeed other small mammals. For example:

- Pet rabbit food cannot be labelled as 'pet food'. The label must specify 'rabbit food' – use of the term 'pet food' is NOT allowed. The term 'pet' only applies to any non-food producing animal (Art. (2)(f)) and the derogation to use the word 'food' only applies to 'pet food', so technically it should be called rabbit 'feed'. However, the authorities don't seem to be concerned by this.
- The label must specify 'complete' or 'complementary'. The use of the term 'compound' is not allowed (Art. 15 (a)).

Figure VI-1. Graphic to illustrate the rules that apply to the labelling of rabbit foods



6.4.1 COMPOSITION, ADDITIVES AND ANALYTICAL CONSTITUENTS

Composition

As a food-producing animal, each ingredient of a rabbit food must be listed by their specific name in the Composition, in descending order by weight. In addition, the % inclusion needs to be listed with the ingredient name if attention is drawn to it on the label or in marketing text e.g. contains mint. (Art. 17 (1)(e)).

Category labelling of feed materials is NOT allowed (unlike for pet animals, Art. 17 (2)(c)). For example, each specific cereal must be listed e.g. wheat, and not the category of 'cereals'.

Additives

Additives with a legal maximum for food producing species, must be labelled by name and ID number (unlike 'and/or' in pet animals), and the amount and chemical composition

stated. (Annex VI Chapter I (1)(a)). This is also the case if attention is drawn to the inclusion of an additive on the label or in marketing text e.g. contains high levels of Vitamin E.

Terms such as 'colourants', 'flavourings', 'preservatives', 'antioxidants' are NOT allowed – they must be fully labelled if there is a legal maximum for food-producing species.

Analytical Constituents

Analytical constituents must be labelled according to Annex VI Chapter II (1) unless the feed is composed only of whole plant

grains, seeds and fruit. Unlike pet food where only the nutrients protein, fibre, fat and ash must be declared, certain minerals must also be declared on rabbit food labels. For complete feeds calcium, sodium and phosphorus must be declared; for complementary feeds sodium must be declared, calcium only if levels are $\geq 5\%$ and phosphorus only if levels are $\geq 2\%$.

It should also be noted that tolerances on analytical constituents differ between food-producing and non-food-producing animals (Annex IV).

6.4.2 FEEDING INSTRUCTIONS

Regulation (EC) No 767/2009 on the marketing and use of feed also makes provision for the instructions for proper use of feed, including instructions on how it should be fed (Annex II (4)). This is especially important where rabbit foods are complementary, and represent only a proportion of the daily food intake. And it is suggested that feeding guides should favour reduced commercial food and encourage forage intakes in a pet rabbit situation.

The on-pack feeding guidelines for pet rabbit food are crucial. Owners should be advised that in addition to the prepared rabbit food, the daily diet should include forage (at least half of the daily feed dry matter intake), suitable fresh vegetables and fresh water.

Overconsumption of rabbit food can lead to obesity and guidance to owners (via a variety of media including websites, help lines etc.) may describe the health implications for the animal. Current guidance on the quantity of commercial rabbit food to feed in the UK is set deliberately low at 15g per kg of ideal body weight per day (APGAW, 2023).

For further detailed information on all other aspects of product labelling, see the FEDIAF Code of Good Labelling Practice for Pet Food. However, it must be remembered that this code is for pet food, whereas rabbits are food-producing animals, so other sources of information may need to be consulted too.

6.5 FEEDING RABBITS

The guidance given by many welfare organisations and manufacturers to pet rabbit owners, certainly in the UK, is that an adult pet rabbit is best fed a dietary regime where the vast majority (~85%) consists of hay and/or grass (fresh or dried), and the rest consists of greens (vegetables and wild plants, ~10%), and commercial rabbit food (~5%) (APGAW, 2023). This '85/10/5' ratio is often incorporated into simple visual representations and accompanied by educational messages that emphasise the importance of hay and grass in providing the coarse fibre essential for keeping teeth in trim and digestive system healthy, that the greens provide environmental enrichment (variety of taste and texture) and additional natural nutrients, and the commercial rabbit food provides supplemental nutrients like vitamins and minerals. Owners are further encouraged to adjust the quantity of greens and commercial rabbit food offered depending on the weight of their rabbits, but never to restrict the amount of hay or grass. And, also advised to take care when feeding greens to especially young rabbits.

The simplicity of these guidelines is helpful to guide and convey the important messages appropriately to most pet rabbit owners. However, practically, and technically, it is unlikely that such a one-size-fits-all approach works for every pet rabbit, and some reservations have been expressed by the contributing experts. Whereas smaller breeds of rabbits may be able to thrive on this regime, large breeds and growing rabbits typically require less hay and either a little more commercial rabbit food, or a more nutrient-dense commercial rabbit food – thereby deviating from the '85/10/5' ratio – indeed, variations from this, and different iterations of the 'Rabbit Food Pyramid' can also be found online. Further, in many depictions it is unclear as to whether the ratio should be applied on a 'volumetric' or 'weight' basis, and to-date, the origins of the ratio within the scientific literature, remain unidentified, and in some cases appear to be a combination of both. Section 3.2.3 outlines the various factors that influence energy (and thereby nutrient) requirements of rabbits – there can be wide differences depending on the

rabbit and their individual physiology and circumstances. There is also a physical limit to the quantity of food that each rabbit can consume daily (dry matter intake). The following sections 6.5.1 and 6.5.2 highlight the plethora of forages and fresh foodstuffs that can be fed to rabbits – there can be significant variations in the composition of different hays, grass, vegetables and wild plants in terms of energy and nutrient content, on a fresh, dry matter and also bulk density basis. The same quantity of hay and fresh grass cannot be used interchangeably, as is often suggested.

6.5.1 FORAGE

Hay plays a crucial role in the diet of pet herbivores. Hay is important for digestive and dental health along with enrichment and mental stimulation. Hay and dried grasses can vary and there are several types suitable for pet rabbits. Grass hay includes meadow and timothy hay; these are the two most popular and nutritionally appropriate options for small herbivores. Alfalfa, also known as lucerne, is also available depending on the rabbit's lifestage.

Timothy hay is a premium quality perennial grass hay, rich in indigestible fibre and naturally low in calcium. Timothy grass helps support the motility of the gut contents and helps to support dental health and attrition.

Meadow hay is a generic term for hay which is harvested from a permanent pasture and may include a mix of grasses as well as other plants and flowers. Meadow grass is often softer than timothy grass and nutritional content may vary depending on the combination of plants and grasses.

Alfalfa hay differs to the grass hays as it is a legume crop. The nutritional profile also differs; this crop is higher in protein and calcium. These higher levels are great for supporting the growth of young rabbits however is not recommended as a forage source for adult rabbits at maintenance.

The quality of the feeding hay provided to domestic rabbits is incredibly important, poor hay quality will lack the correct balance of nutrients needed for pet rabbits to thrive. Poor quality hay may also have a negative odour, contain dust or mould which may cause health issues and reduce intake.

Hay quality can vary depending on hay type, along with other factors which include the growth stage at the time of harvest, handling and storage. First cut timothy hay has higher levels of fibre than second and third cuts. The first cut has a higher stem proportion whereas the second and third cuts have a higher leaf content and in turn lower fibre levels. The nutrient requirements of first cut timothy grass

As part of the UK Rabbit Welfare Strategy (<https://rabbitwelfare.co.uk/rabbit-welfare-strategy>), UK Pet Food has committed to leading the Action Plan to 'Determine and promote optimal dietary advice', and is establishing a working group of experts to review this approach. Significant progress in the area of best feeding practice will be reviewed and either issued as an addendum to these guidelines, or incorporated in the next version.

often meets the requirements of pet rabbits better than subsequent cuts.

Hay quality may deteriorate significantly if it is not handled or stored correctly. Post harvest, hay should be dried quickly until moisture content is at optimum levels for the product. It should then be stored off the ground in a well-ventilated space away from moisture.

Identifying good quality feeding hay should include assessment of colour, odour, and its contents. Good quality feeding hay should be green or a golden-green colour, hay that is pale may indicate a poorer quality hay with a lower nutritional value. Good quality hay should also be dry to the touch. Loss of colour to the hay may be due to cutting at late stages of maturity, sun-bleaching, rain, and/or fermentation in the bale, all of which can alter the nutritional value. The aroma of good quality hay should be the traditional smell of freshly mown hay; musty smells are indicators of poorer quality hay and signs that the hay was not fully dried prior to storing. A good quality feeding hay should be free of any organic or foreign matter, dust and mould. Many hays are dust extracted to reduce respiratory disease risk. Visual inspections give a good indication of the quality of the hay, however, to assess the correct nutritional value, forage analysis is necessary.

Higher hay intake in rabbits is associated with greater faecal output and fewer uneaten caecotrophs and may assist in preventing gastrointestinal stasis (Meredith and Prebble, 2015). Owners should be advised to offer their rabbits quality hays from several different sources over a single source, to provide choice, encourage intake and potentially negate / compensate for any nutritional deficiencies in one source.

A helpful factsheet explaining the importance of hay for rabbits and other small herbivores may be found on the UK Pet Food website at: <https://www.ukpetfood.org/resource/the-importance-of-hay-for-small-herbivores.html>.

In addition to hay, chopped dried grass is also available and may also be fed to rabbits. The grass is cut, dried quickly at high temperatures and immediately sealed in air-tight waterproof packaging. This technique allows the grass to retain its nutritional value, natural colour and aroma, and is a useful alternative for fussy rabbits. However, it should be

stressed that, freshly mown grass / lawn clippings should NOT be fed to rabbits. These start to ferment immediately after cutting, and fermentation can accelerate when temperatures are elevated (summertime, heat from lawnmower). If ingested these can be harmful.

6.5.2 FRESH FOODSTUFFS

Fresh grass is the ideal food, and rabbits have evolved to live on it (Varga-Smith, 2023). And certainly the adults of smaller rabbit breeds (those the size of their wild counterparts), can maintain themselves on a diet of predominantly grass. Fresh grass can be a valuable part of any rabbit's diet, when available.

In winter months when natural vegetation, like grass, wild plants and flowers are scarce, vegetables and herbs can be good alternatives.

Vegetables

The value of feeding vegetables to rabbits is long-established. During domestication, and whilst being bred and reared for meat and wool, rabbits were raised on many different foodstuffs, including kale, turnips, swedes, and mangolds (fodder beet). As rabbits started to be kept as pets, vegetable leftovers (peelings, carrot tops, cabbage leaves etc) were a

staple. In recent years once traditionally seasonal vegetables have become available all year round, as have more 'exotic' vegetables (e.g. butternut squash, pumpkin).

There is much debate over which vegetables can and can't be safely fed to rabbits. Online, lists of vegetables are presented as being 'safe', but in reality, many may not necessarily be suitable for rabbits. Vegetables tend to be classified by type, depending on the part of the food which is edible (Table VI-1). It can be helpful to be familiar with the different types or groups of vegetables, as 1) it can help when differentiating which ones are safe and suitable for feeding to rabbits (e.g. bulbs should be avoided), and 2) from a nutritional perspective (certainly in terms of selected nutrient contents for rabbits), the vegetables are generally quite similar within these groups (Table VI-2) and their profiles can help determine frequency of feeding and to vary and balance what is offered on a daily basis.

Table VI-1. Different groups/types of vegetables

Classification	Types	Examples
Culinary Vegetables	Bulbs*	Garlic, Onion, Shallots
	Tubers	Potato, Sweet Potato, Yam
	Roots	Beetroot, Carrot, Parsnip, Swede, Turnip
	Stems	Celery
	Leaves	Brussel Sprouts, Cabbage, Kale, Lettuce, Spinach, Spring Greens, Watercress
	Flower Buds	Broccoli, Cauliflower
Culinary Vegetables BUT Botanically Fruits	Seeds	Bean, Pea
	Fruit	Courgette, Cucumber, Gourd, Marrow, Pepper, Pumpkin, Squash, Tomatoes

* Bulbs, vegetable or flower, are not suitable for feeding to rabbits.

Table VI-2. Typical nutrient composition of selected vegetables (g/100g)

Nutrient Content (g/100g)		As Is					Dry Matter				
		Moisture	Protein	Fat	Ca	P	Ca:P	Oxalate	Fibre	Starch	Sugars
Tubers	Yam	67.2	5	1	0.05	0.08	0.56	0.65	11	84	2
	Sweet Potato	73.7	0	1	0.09	0.19	0.48	0.91	9	59	22
	Potatoes (old)*	79.0	10	1	0.02	0.18	0.14	0.24	8	79	3
	Potatoes (new)*	81.7	9	2	0.03	0.19	0.18	0.27	7	81	7
Roots	Swede	91.2	8	3	0.60	0.45	1.33	0.34	31	1	56
	Turnip	91.2	10	3	0.55	0.47	1.17	2.39	8	2	1
	Carrots (old)	89.8	6	3	0.25	0.15	1.67	4.90	25	3	73
	Carrots (young)	88.8	6	4	0.30	0.22	1.36	4.46	23	2	50
	Beetroot (leaves)	87.1	13	1	0.16	0.40	0.39	4.73	22	5	54
	Parsnip	79.3	9	5	0.20	0.36	0.55	0.19	21	30	28
Stems	Celery	95.1	10	0	0.84	0.43	1.95	3.88	33	N	8
Leaves	Spring Greens	86.2	22	7	1.52	0.66	2.31	3.26	44	3	20
	Watercress	92.5	40	13	2.27	0.69	3.27	4.13	40	N	5
	Spinach	89.7	27	8	1.65	0.44	3.78	9.42	38	1	15
	Cabbage (green)	89.7	17	4	0.66	0.45	1.48	3.88	30	1	37
	Lettuce (iceburg)	95.6	16	7	0.43	0.41	1.06	7.50	30	N	43
	Curly kale	88.4	29	14	1.12	0.53	2.13	0.17	28	1	11
	Cabbage (white)	90.7	15	2	0.53	0.31	1.69	1.08	26	1	53
	Brussel Sprout	84.3	22	9	0.17	0.49	0.34	2.29	24	5	20
	Lettuce (round/flat)	94.4	16	11	0.95	0.77	1.23	5.89	23	N	18
	Chicory	94.3	9	11	0.37	0.47	0.78	3.68	16	4	12
Flower Buds	Broccoli	88.2	37	8	0.47	0.74	0.64	1.61	22	1	13
	Cauliflower	88.4	31	8	0.18	0.55	0.33	1.29	16	3	22
Seeds	Peas (mangetout)	88.7	32	2	0.39	0.55	0.71	0.44	37	7	30
	Beans (French/green)	90.7	20	5	0.41	0.41	1.00	3.87	32	10	25
Fruits	Peppers (green)	93.3	12	4	0.12	0.28	0.42	0.60	28	1	36
	Marrow	95.6	11	5	0.41	0.39	1.06	N	25	2	48
	Peppers (red)*	90.4	10	4	0.08	0.23	0.36	0.42	20	1	64
	Cucumber	96.4	19	3	0.50	1.36	0.37	0.56	19	3	39
	Courgette	93.7	29	6	0.40	0.71	0.56	N	14	2	27
	Butternut Squash	85.2	7	1	0.32	0.23	1.41	0.14	14	1	15
	Pumpkin	95.0	14	4	0.58	0.38	1.53	N	10	6	34
	Tomatoes	84.4	4	2	0.04	0.15	0.29	0.32	8	Tr	20
Grains	Sweet Corn (baby)	76.0	21	8	0.01	0.37	0.02	0.04	11	0	21

Where: * See text below; 0 = None of the nutrient is present; Tr = Trace; N = The nutrient is present in significant quantities but there is no reliable information on the amount. Data from: McCance and Widdowson's The Composition of Foods 5th Edition 1998 and USDA's Agriculture Handbook 8-11, Composition of Foods: Vegetables and Vegetable Products, 1984. All values stated are for raw vegetables. (Huggett, 2015). Note fibre: Analysed using the Southgate Method.

Nutrient content can vary considerably between season and within different varieties of the same vegetable. A little knowledge on the profile of certain nutrients and anti-nutritional factors can help steer selection, frequency of feeding and how different vegetables may be 'mixed and matched'. As a general rule:

- **Bulbs:** Garlic, onion, shallots. Should never be fed to rabbits.
- **Tubers:** Have the lowest fibre and highest starch levels of all vegetables, and an inverse Ca:P ratio. Should be fed sparingly. Potatoes should be cooked prior to feeding to remove solanine*. More of the carbohydrate in sweet potato is sugars, which makes them appealing to rabbits.
- **Root Vegetables:** Contain moderate levels of fibre and low starch, but contain high levels of sugar, and should again be fed sparingly. Current guidance is to dissuade owners from feeding root vegetables due to their high sugar content, over dental (cariogenic), digestive and weight concerns. Caries is rare in rabbits, but may be a consequence of reduced dental eruption and/or abrasion rates in older rabbits or those with underlying dental conditions. Carrots also contain appreciable levels of oxalates**. Parsnips have a nutritional profile similar to tubers – higher levels of starch and an inverse Ca:P ratio.
- **Stems:** Celery. Contains a high level of fibre and moderate sugar. Can be fed a little more frequently.
- **Leaves:** Essentially the 'leafy greens'. Contain the highest levels of fibre for vegetables, and little starch, but vary considerably in sugar content. Darker-coloured greens (kale, spinach, spring greens etc.) have higher calcium and oxalate contents, and contain glucosinolates***, so they should be fed less often and rotated. Lettuce, because of its high moisture content, offers little nutrition. It also contains appreciable levels of oxalate on a DM basis, and contains lactucarium which can have a soporific (causes drowsiness) or opiate-like effect on rabbits.
- **Flower Buds:** Broccoli and cauliflower. Contain moderate levels of fibre, negligible starch, and low levels of sugar and calcium. They have an inverse Ca:P ratio, relatively high levels of oxalate, and also contain glucosinolates. They can be fed in small amounts, less frequently.
- **Seeds:** Peas and Beans. Contain high fibre, moderate sugar and low levels of starch and calcium. Peas contain higher levels of protein and have an inverse Ca:P ratio. Beans have a higher oxalate content. They can be fed in small amounts, less frequently.
- **Fruit:** Vegetables from a culinary perspective but botanically fruits, and are pushing the boundaries on suitability for rabbits so careful selection is paramount. Contain variable levels of fibre and sugar, and low levels of starch. To avoid any confusion, peppers are the heatless (i.e. do not contain capsaicin) varieties, often called 'sweet peppers', 'green' or 'red' peppers etc. and

not 'chili peppers'. Green peppers are recommended over red peppers – they have higher fibre and lower sugar levels. Can be fed in small amounts, less frequently, but the softer salad vegetables like tomatoes and cucumbers should be fed sparingly.

- **Grain:** Essentially sweetcorn. Contains low levels of fibre, no starch and moderate sugar. Inverse Ca:P ratio and negligible oxalate levels.

Care should be taken where vegetables contain low fibre and high starch and sugar levels, which may lead to transient uneaten caecotrophs and/or soft malformed stools, or at worst diarrhoea; and where vegetables contain extremely high levels of calcium in rabbits predisposed to urolithiasis or renal disorders.

Vegetables may contain anti-nutritional factors, some of which have already been highlighted:

- ***Solanine:** The Nightshades, which includes potatoes, aubergines, peppers and tomatoes can contain solanine – a toxic green-pigmented glycoalkaloid. It is known to accumulate under certain conditions in the potato (plant, sprouts and tuber), and is present in the leaves of tomato plants (not fruit), which is why potato and tomato haulm is not suitable for feeding to rabbits. Solanine can act as a local irritant and is poorly absorbed from the digestive tract, so can cause gastrointestinal disturbances. It can also cause neurological disturbances.
- ****Oxalates (oxalic acid):** Found especially in dark leafy greens – may reduce the availability of certain nutrients.
- *****Glucosinolates:** The Brassicas, which includes cabbage, cauliflower, broccoli, Brussels sprout, kale, spring greens, turnips etc. contain glucosinolates – biologically active, plant secondary metabolites – which in themselves are nontoxic but can be metabolised within the animal to thiocyanates which interfere with the availability of iodine and hence its uptake by the thyroid (Tripathi, et al., 2003; Tripathi and Mishra, 2007).
- **Phytate (phytic acid):** Binds minerals in the digestive tract, reducing their availability – found in legumes like beans and peas, and other vegetables to a lesser extent.
- **Phytoalexins/Psoralens:** Structurally related to coumarin (anti-coagulant / blood thinner) – found in carrot, celery, parsnip – levels of which can increase 10-fold in the plant with storage.
- **Tannins (Polyphenols):** Bitter compounds which may hinder digestion and absorption of nutrients.
- **Tomatine (an alkaloid glycoside similar to solanine):** Found in tomatoes.
- **Trypsin Inhibitors:** May impair protein digestion/ utilisation of dietary amino acids – found in legumes like beans.

Although limited information is available as to the exact effects of anti-nutritional factors in rabbits, and it's unlikely that they would be ingested in sufficient quantity to cause toxic levels, it's worth bearing in mind that some vegetables may contain more of some (and/or different ones) than others, so is generally recommended that a variety of vegetables is offered to the rabbit, rather than just one or two consistently. Similarly any nutrient deficiency in one can be compensated for by the constituents of another. A list of vegetables that can be safely fed can be found in Annex 7.2.

Vegetation

A variety of natural fresh foliage may also be fed to rabbits. This can include grass, the leaves of specific trees, leaves of soft fruits, herbs, wild plants and flowers. The selection will vary by country and their availability depend on season. Examples include:

- Grass (but not cuttings)
- Leaves of trees: Apple, hazel, mulberry, willow
- Leaves of soft fruits: Blackberry, raspberry, strawberry
- Culinary Herbs: Basil, Coriander, Dill, Mint, Parsley, Thyme
- Wild plants: Coltsfoot, Cow parsley, Dandelion, Knapweed, Plantain, Shepherd's Purse, Sow thistle
- Flowers: Echinacea, Marigold

A list of the foliage that can be safely fed to rabbits can be found in Annex 7.2.

Practical plant feeding

When providing fresh foodstuffs, prudence is the key to feeding rabbits safely. It is recommended that new items are introduced gradually to avoid digestive upsets and determine tolerance levels. Introduction to fresh grass in spring should be very gradual, as should introduction of new fresh foodstuffs – starting by feeding small pieces of the new material, say an approximately 5 cm x 5 cm

square of leaf, or a small baton, and building up gradually. Irrespective of source (supermarket, garden, hedgerows) they should be washed before being offered to rabbits – supermarket vegetables may have been sprayed with pesticides (some agrochemicals can be toxic to rabbits); hedgerow plants may be contaminated by the faeces of wild birds and animals, and potentially car fumes if harvested by the side of a road. And to avoid yellowing leaves and mouldy vegetables.

Foodstuffs to avoid

Feeding preferences in rabbits are learned from an early age, around weaning. Wild rabbits may learn from their mothers, their colony (group wisdom), and what is available around their warren, but pet rabbits are only exposed to what is offered to them, which may be relatively limited.

Contrary to common belief, rabbits don't avoid naturally poisonous plants, and given access will eat most vegetation even if it is known to be toxic in other species. Some plants contain irritants as their defence mechanism which may dissuade consumption of large quantities. Unlike dogs and cats, rabbits are unable to vomit, so have no mechanism / reflex to be able to get rid of foodstuffs / potential toxins that may be harmful to them. Toxicity of a plant varies, depending on the part (and age) of that is eaten, and how much and how frequently it is consumed – effects may be immediate or cumulative.

Rabbits appear to be resistant to some plant toxins like ragwort, deadly nightshade, comfrey and laburnum (Varga-Smith, 2023). The plants to avoid are typically house plants and anything that grows from a bulb, but a variety of garden plants do pose a risk. For further information on plants and their toxic principles Varga-Smith (2023) should be consulted.

A list of plants that can be toxic to rabbits can be found in Annex 7.3.

6.5.3 CONTAMINANTS

As with other pet foods and animal feeds, the components of rabbit foods may harbour undesirable substances. These may include heavy metals, dioxins, pesticides and mycotoxins. Whilst the first two are more associated with meat, dairy and fish products, the last two can be important in rabbits.

Mycotoxins are toxic metabolites produced by fungi/moulds, and are a growing concern in the feed industry. Contamination of ingredients, food and feed with mycotoxins

is unpredictable, sporadic and often considered to be unavoidable even with robust harvesting, storage and processing practices. They are resistant to many thermal and physical treatments, surviving standard production processes. Aflatoxin is one of the more prevalent mycotoxins, and although most commonly associated with peanuts may be found in mouldy feeds, cereals and grains. Aflatoxin acts as an immune suppressant. Rabbits don't always reject mouldy or contaminated feed and are susceptible to aflatoxin toxicity, which can ultimately be fatal.

Physical contaminants may also be a problem in rabbit foods. In the late 1990s there were reports of a few cases of gastrointestinal obstruction caused by locust bean seeds and dried maize kernels, which escaped processing. In the case of the locust bean seeds, these hard, shiny, dark brown seeds would have ordinarily been removed from the locust

bean pods, and the dried maize kernels flattened during the maize-flaking process. For this reason locust bean pods are no longer used in rabbit foods, and manufacturers should be aware that using flaked maize, and also flaked peas (similar potential to escape processing) carries a similar risk in coarse mixes.

6.5.4 SELECTIVE FEEDING

Rabbits as foraging animals have highly developed senses of taste and smell to assist in selecting the correct dietary components in their wild environment – indeed, selective feeding is a natural behaviour. When kept as pets, rabbits may exhibit selective feeding of commercially prepared coarse mixes (i.e. eating certain components, yet avoiding others), potentially leading to ingestion of a diet low in essential nutrients (Harcourt-Brown, 1996). Pet rabbits offered such diets were shown to favour components high in starch and low in calcium and therefore may be at risk of poor bone and tooth quality if permitted to feed this way (Harcourt-Brown, 1996). In addition, the high starch components are lower in fibre such that uncontrolled selective feeding or a diet lacking supplementary fibre, such

as hay, can lead to poor tooth quality, insufficient dental wear and digestive conditions.

Pet owners may not be aware of the occurrence of selective feeding as food components may be scattered around the animal's environment, mixed with bedding. Where companies make coarse mixes / non-pelleted or non-extruded products, they can optimise such products by ensuring the recipe is high in fibre ingredients, has a suitable calcium content, is well balanced for palatability of components and that clear instructions on correct feeding (not feeding more until the previous portion is finished) are on-pack, so as to reduce or eliminate selective feeding (Cheeke, 2005).

6.6 DIETARY ENRICHMENT

Dietary enrichment stimulates a variety of natural behaviours that improve overall health and quality of life. Rabbits lacking dietary enrichment, in particular foraging opportunities, may exhibit undesirable activities (Morton et al., 1993) consistent with stereotypic behaviour (Odberg, 1978). This is regarded as an indicator of poor welfare, boredom, deprivation and frustration (Mason, 2006). Repetitive oral activities may represent frustrated foraging in rabbits with limited access to high fibre forages. Barren or poorly enriched environments can also lead to other undesirable behaviours (Gunn, 1994; Jackson, 1991; Stauffacher, 1992; Wallace, 1990). Enabling and encouraging activities such as chewing and foraging has been shown to have a positive effect on behaviour (Berthelsen, 1999; Prebble et al., 2015), with the provision of hay proving to be the most effective in reducing abnormal behaviour (Lidfors, 1997). Providing a block of wood for gnawing can also be effective, provided it is a soft wood such as willow or horse chestnut.

A rabbit should be provided with ample opportunity to forage and chew, through the provision of quantities of high fibre forage (hay, dried grasses) and supplementary snacks or treats high in indigestible fibre (gnaw sticks

or similar). Placing food in different locations and using different presentations (e.g. hay racks, cardboard tubes or baskets, hanging devices), provides mental stimulation, encourages natural behaviours and movements such as stretching and digging, and prolongs feeding time. Increased chewing time benefits dental health through provision of dental wear (Meredith, Prebble and Shaw, 2015). Dietary enrichment can also be useful for training purposes to improve bonding between pet and owner.

Dietary enrichment is thus important for a healthy rabbit. UK Pet Food have created a useful factsheet entitled 'Feeding Enrichment for Small Mammals', which also contains ideas for rabbits and can be found at: <https://www.ukpetfood.org/resource/feeding-enrichment-for-small-mammals.html>.

7.0 Annexes

7.1 BODY CONDITION SCORE

Body condition scoring (BCS) is a quick, simple and repeatable technique used in many animals (and indeed humans) to assess whether they have a healthy, or 'ideal', body condition, or are obese or too thin. Although no official body condition scoring system exists for rabbits, it can be evaluated in rabbits using methods adapted from those in dogs, cats and farm animals.

The method relies on palpating (feeling) prominent points on the body e.g. the pelvis, ribs and spine, and assessing the coverage of subcutaneous fat over these areas. Visual assessment is insufficient – in rabbits with long, dense coats, the pelvis, ribs and spine may not be obvious; in those with

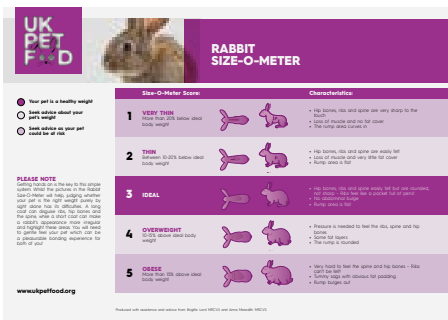
short coats e.g. Rex breeds, they may naturally appear more protuberant. The ribs should be felt just behind the rabbit's elbows. The amount of pressure needed will increase if the rabbit is overweight, and it may be difficult to feel the rib edges. Little pressure is needed in thin or emaciated rabbits, and the ribs' edges will feel sharp and pointed. The process should be repeated on the pelvis and spine.

The ribs are the area most indicative of changes in fat deposition. Fat coverage on the pelvis and spine tends to change less, and only in extremely overweight / obese or thin rabbits.

Table VII-1. 5-Point body condition scores in rabbits

Score	Description	Location Characteristics
1	Emaciated ≥ 20% below ideal body weight	Pelvis, ribs and spine are very easily felt (very sharp). Obvious loss of muscle; minimal fat cover. Ribs prominent and feel like a pocket full of rulers. Rump area is concave (curves in). Abdomen looks tucked up.
2	Underweight 10-20% below ideal body weight	Pelvis and ribs are easily felt and feel sharp. Slight loss of muscle; little fat cover. Ribs prominent, but less sharp. Rump area is flat. Abdomen looks slightly tucked up.
3	Ideal	Pelvis, ribs and spine are easily felt but have rounded edges. Ribs feel like a pocket full of pens. Rump area is flat. Abdomen looks flat (no abdominal bulge).
4	Overweight 10-15% above ideal body weight	Pressure is needed to feel the pelvis, ribs and spine. Some fat layers. Ribs and shoulders have some fat padding. Rump area is rounded, and there is a slight abdominal bulge.
5	Obese ≥ 15% above ideal body weight	Very hard to feel the pelvis and spine. Ribs can't be felt. Obvious fat padding over the ribs and in the shoulder area. Rump area is convex (bulges out). Significant abdominal bulge.

UK Pet Food have created a handy tool, the Rabbit Size-O-Meter, to help pet owners and pet professionals help rabbits maintain a healthy weight and body condition: <https://www.ukpetfood.org/resource/rabbit-size-o-meter.html>.



7.2 LIST OF GREENS

The following tables contains a list of foods that can be easily obtained or wildflowers and plants that can be foraged for, and are safe for rabbits in the UK (RWF, 2024a).

Table VII-2. List of safe greens for rabbits

Foods easily obtained	Wildflowers and Plants	
Beetroot greens	Agrimony	Mulberry
Broccoli	Apple Leaves and Twigs	Nasturtium
Brussel Sprouts	Avens	Plantain (Broad Leaf and Ribwort)
Cabbage	Blackberry Leaves	Pear Leaves and Twig
Carrots tops (as treats)	Blackcurrant Leaves	Raspberry Leaves
Cauliflower Leaves	Burdock	Rosebay Willowherb (Fireweed)
Celeriac	Camomile	Roses (Leaves and Flowers)
Celery	Calendula	Shepherd's Purse
Courgette	Cleavers (Goosegrass or Sticky Weed)	Sow Thistle
Corncobs (fresh only)	Cornflower	Strawberry Leaves
Culinary herbs – Basil, Coriander, Dill, Mint, Parsley, Thyme	Common Mallow	Sunflowers
Curly Kale	Chamomile	Willow Leaves
Fennel	Currant	Yarrow
Marrow	Dandelions	
Pea Pods	Echinacea	
Pepper (sweet, not chili)	Goats Rue	
Pumpkin	Golden Rod	
Radish Greens	Hawkbit	
Rocket	Hawthorn	
Spinach	Hazel	
Spring Greens	Lemon Balm	
Squash	Lady's Mantle	
Watercress	Marigold	
	Melilot	



7.3 LIST OF POTENTIALLY TOXIC FOODSTUFFS

Lists of toxic plants for rabbits vary by source. The following table contains toxic plants found in the UK (Varga-Smith, 2023; RWF, 2024b).

Table VII-3. List of potentially toxic foodstuffs for rabbits

Varga-Smith (2023)		RWF (2024b)	
Aconite (Monkshood, Wolf's Bane)	Laburnum	Aconite	Ivy
	Lily of the Valley	Arum	Lily of the Valley
Amaranthus	Linseed - >4 g/kg toxic in other species	Aubergine Plant	Lords and Ladies
Antirrhinums		Bluebell	Monks Hood
Arum	Lupins	Bryony	Onion Plant
Bracken	Milkweed	Bryony Red Berries	Periwinkle
Bryony	Nightshade	Bryony Black or Purple Berries	Poppy
Buttercups (fresh)	Oleander	Buttercup	Potato Plant
Cabbage	Poppies	Celandine	Primrose
Celandines	Potato Plants	Columbine/Aquilegia	Privet
Charlock	Potatoes	Comfrey	Ragwort
Comfrey	Privet	Corncockle	Ragwort Second Year Growth
Convolvulus	Ragwort	Cowslip	Rhubarb Leaves
Crotalaria	Scarlet Pimpernel Speedwell	Crocus	Russian Comfrey
Dahlia	Spurges (Euphorbia)	Daffodil	Snowdrop
Evergreens (except Conifers)	Toadflax	Deadly Nightshade	Spurge
Figwort	Tomato Plants	Delphinium	Tomato Plant
Foxglove	Travelers' Joy (Clematis Vitalba)	Dock	Traveller's Joy
Hellebore (Christmas Rose)	Wild Celery	Fool's Parsley	Tree Lupin
Hemlock	Yew	Foxglove	Tulip
Henbane		Grape Hyacinth	Wild Garlic
Horsetails	Plants from Bulbs: Bluebell, Crocus, Daffodil, Dahlia, Grape Hyacinth, Hyacinth, Lily of the Valley, Snowdrop, Tulip)	Hedge Garlic	Wood Sorrel
Irises		Hellebore	Woody Nightshade
Ivy		Hemloc	Yew
Kale		Henbane	
		Holly	
		Hyacinth	

8.0 Changes versus Previous Version

The following changes have been made to the previous version:

8.1 ADAPTATIONS IN THE NUTRITIONAL GUIDELINES 2024 VS. 2013

a. New terms in Glossary

b. Basic Nutrition Principles

- New section introducing 'The Rabbit'
- Revised 'Energy' sections

c. Nutrient Recommendations

- Removal of text within tables, creation of notes
- Addition of glycine in the table.
- SUL Magnesium changed from 3.5 to 3.4 (Evans et al., (1983a,b))
- New section on water

d. Analytical Methods

- Removal of table listing analytical methodologies

e. Practical Formulation and Feeding – new section

- New section on dietary formats
- Removal of Feed Material tables

- Additives text updated
- New section on labelling of pet rabbit foods
- New section on feeding rabbits – including forage, fresh foodstuffs & contaminants
- Revised 'Dietary Enrichment' section

f. Annexes

- New annex on Body Condition Scoring
- New list of safe greens
- New list of potentially toxic foodstuffs

g. References

- New references included; revisions to some existing references



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