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Chapter 13

Feeding behaviour in rabbits

Thierry GIDENNE[1, *] , François LEBAS[2] , Laurence Fortun-Lamothe[1]

[1] INRA, UMR1289 Tissus Animaux Nutrition Digestion Ecosystème et Métabolisme, F-31326 Castanet-Tolosan, France
[2] Cuniculture, 87a Chemin de Lassère, 31450 Corronsac, France
* Corresponding author: thierry.gidenne@toulouse.inra.fr; INRA, Centre de recherche de Toulouse, UMR 1289 TANDEM, BP 52627, F-31326 Castanet-Tolosan, France

Introduction

As a monogastric herbivore, the rabbit presents a unique feeding behaviour compared to other domestic animals, since he belongs to the *Lagomorpha* order (*Leporidae* family: rabbits and hares, Grassé and Dekeuser, 1955), and consequently possess a main specificity that is the caecotrophy. For recall (see details in chapter 1), the caecotrophy is a complete behaviour involving an excretion and an immediate consumption of specific faeces, named soft faeces or "caecotrophes". Consequently, daily intake behaviour of the rabbit is constituted of two meals: feeds and caecotrophes. Although rabbit is not a rodent one of its main feeding behaviour features is to gnaw. The informations about the feeding behaviour have been mainly obtained on the domestic rabbit, either bred for meat or fur production, or as a laboratory animal. It basically involved rabbits receiving *ad libitum* a balanced complete pelleted feed, supplemented or not with dry forages or straw, but most generally without a real food free choice.
Regulation of the intake behaviour will be reviewed according to several factors: age, type of feed, etc. The last part will be devoted to feeding behaviour of the wild rabbit and of domestic rabbits in situation of free choice.

1 The behaviour of caecotrophy

The cæcotrophy plays an important role in rabbit nutrition, providing proteins and vitamins B from bacterial source (see chapter 1 for more details). Physiological mechanisms implicated in the caecotrophy are detailed in chapter 1. The starting of caecotrophy behaviour in young rabbit is not fully known but probably starts around 25 days of age, when a significant dry feed intake occurs that leads to a caecal and a colon filling (Gidenne *et al*, 2002; Orengo and Gidenne, 2007).
The hard pellets are expelled, but the soft pellets are recovered by the rabbit directly upon being expelled from the anus. To do this the rabbit twists itself round, sucks in the soft faeces as they emerge from the anus, and then swallows without chewing them. The rabbit can retrieve the soft pellets easily, even from a mesh floor. By the end of the morning there are large numbers of these pellets inside the stomach, where they may comprise three quarters of the total contents. The intriguing presence of these soft pellets in the stomach was at the origin of the first correct description of caecotrophy by Morot in 1882, *i.e.*, production of 2 types of faeces and systematic ingestion of one of the 2 types (the soft ones). This makes caecotrophy different from the coprophagy classically described for rats or pigs were only one

type of faeces is produced. The quantitative evaluation of the soft faeces intake is detailed in section 2.2.

2 Feeding behaviour in the domestic rabbit

2.1 Feeding behaviour of young rabbit: from milky way to solid food

The rabbit female give birth to nude and blind young in a nest after 31 days of gestation. Then, a period of rapid development begins for the young, ending in the weaning around 1 month later. During this period, the kits are going to evolve from a diet almost exclusively constituted by milk, scarcely available over the day, to several meals of solid food.

2.1.1 Milk intake

The initial nursing occurs during the parturition. The suckling is induced by the mother when the mother stands motionless over the kits in the nest. She gives no direct assistance to their offspring to suck (Hudson & Distel 1982; 1983). Therefore, the nipples location and milk ingestion depend on the kit individual abilities to behave efficiently under the female.

It was demonstrated a long time ago, that the rabbit female suckles her litter for 4–5 min once a day only, during the 2 weeks after birth (Zarrow *et al.*, 1965). However, more recently, data suggested that some does (either in wild or domestic rabbit) would nurse their young twice a day (Hoy and Selzer, 2002), In any case, suckling represents therefore less than 0.35% of the young spending time. In experimental conditions, if two females different are presented to the litter, the young are able to suckle twice a day or more (Gyarmati *et al.*, 2000). But double suckling of kits by their own mother represents few or no nutritional interest: kit's weight at 21 days increased by 4.6% according to Etchegaray-Torres *et al.* (2004), or clearly not influenced according to Tudela et Balmisse (2003) .On the contrary, in normal breeding conditions, it may happen relatively often that one or two kits from the same litter do not gain milk at one nursing (14% on day 1 according to Coureaud *et al.*, 2007). The first suckling bouts occurred during the parturition and within the first hour after the birth (colostrum), and are essential to the subsequent kits survival. Starvation is indeed one of the key-causes explaining the mortality that usually peaks during the first postnatal days (Coureaud and Schaal, 2000; Coureaud *et al.*, 2000), in addition to other factors as well as maternal inexperience and behaviour (Verga *et al.*, 1978, 1986). During suckling, competition for access to the nipples was very high. Indeed, in rabbit domestic breeds, there are frequently more kits in the litter than nipples on the mother’s abdomen : 7 to 10 kits per litter according to breed and selection and generally 4 pairs of nipples (Drummond, 2000; Hudson *et al.*, 2000; Bautista *et al.*, 2005) even if the number of nipples was increased up to 10-11 and even 12 for some does in breeds or lines selected for prolificacy (Fleischhauer *et al*., 1985; Rochambeau *et al*. 1988, Szendro *et al*., 1991;Coisne 2000). Without relation with the real number of nipples available, newborn rabbits do not appropriate a given nipple but change every 20 seconds, approximately, from one to another nipple within a same sucking bout. That is contrary to what occurs in other newborn mammals (e.g., kittens, piglets) in which a newborn keep the same nipple all along the lactation period. Bautista *et al.* (2005) have shown that the availability of milk across the eight nipples is equal during the first postnatal days, but that more milk is available on the two middle pairs by the end of the first postnatal week.

During the first week following birth, kits drink daily in one nursing session about 15% of their live-weight in milk and up to 25% for some individuals (around 15 to 25 g of milk ingested, Lebas, 1969). Their nipple searching behaviour is very stereotyped and controlled by a pheromonal signal (Schaal *et al.*, 2003). During the first post-natal week of life (between 4 and 6 days of age) the young also consumes some hard faeces deposited by the doe in the nest, thus stimulating the caecal flora maturation (Kovacs *et al.*, 2004). Thereafter, the individual milk intake increases gradually to reach a peak of 30 g/day between 17 and 25 days of age (figure 13.1). During this period, the milk intake is highly variable among kits due to individual ability, competition between littermates and milk availability (Fortun-Lamothe and Gidenne, 2000). After day 20-25, the maternal milk production decreases progressively. If food resources are sufficient, and if female is not fertilised again, milk production can continue up until 5th 6th weeks after birth, or even for a longer time. On the opposite, if the female is fertilised just after parturition and sustain concurrent pregnancy and lactation, the milk production decrease sharply at the end of pregnancy to be stopped 2-3 days before the following parturition (Lebas, 1972; Fortun-Lamothe *et al.*, 1999). This frequently occurs in wild conditions in spring, when female is mated again the day of parturition. In that case, young rabbits could be weaned from 3 weeks of age. But in breeding condition, weaning is generally carried out between 28 and 35 days of age, although milk production is not completely stopped.

2.1.2 Solid food intake and evolution of nutritional supply

The young rabbits begin to eat significant quantity of solid food around 16-18 days of age when there are able leave the nest and to move easily to access a feeder (with pelleted feed) and a drinker. Nevertheless, first contacts with solid elements occur during the first week of life when the young consumes some hard faeces deposited by the doe in the nest during suckling (Moncomble *et al.*, 2004; Kovacs *et al.*, 2004).

At the beginning, the young eat very small quantity of feed (<2g/day/rabbit before 20 days of age). The solid food intake increases really from 25 days of age to reach 40-50 g of feed per day at 35 days (Gidenne *et al.*, 2002) by it is highly variable among litters. Consequently, the feeding behaviour changes greatly in a few days, as the young switches from a single meal of milk per day to 25-30 solid and liquid (water) meals in 24 hours. The ingestion of solid food and water exceed that of milk during the fourth week of life.

It is interesting to note that when the sucking rabbits begin to eat solid food, they prefer to eat at the same feeder than their mother rather than to a young specific feeder (Fortun-Lamothe and Gidenne, 2003). Such a result suggests that initiation to solid food ingestion implicates initiation or imitation of the mother. In addition, for the early weaned rabbit, the watering system (nipple or "open air" drinker) did not affect the solid feed intake, while a too low diameter of the pellets causes a higher hardness and impairs the feed intake (Gidenne *et al.*, 2002, 2003).

In parallel to modifications of the feeding behaviour, the nutrients ingested by young rabbits greatly change between birth and weaning (Figure 13.2). Indeed, the milk of rabbit doe is very rich in lipids (13g / 100g) and proteins (12g / 100g), but contains only traces of lactose (Maertens *et al.*, 2006). On the opposite, pelleted feed mainly contains glucids (80g / 100g; some are highly and some are weakly digestible, as starch or fibres, respectively), some proteins (15-18g / 100g) and only few lipids (2-5g / 100g) all of vegetable origin. Therefore, digestive capacities must rapidly evolve in the young during the development, in parallel with the evolution of its feeding pattern (Gidenne and Fortun-Lamothe, 2002). The ingestion of vegetable proteins becomes equal to that from the milk at around 25 days of age, and then exceeds it within a few days. On the other hand, lipids come mainly from milk until weaning. While the ingestion of glucids is almost nil until 17 days of age (< 0.3g / day), it becomes significant from day 21, in form of fibres and starch. However, proteins and fat in the milk constitute the main source of energy until weaning.

2.1.3 Regulation of the feeding behaviour in young rabbits

The individual feeding behaviour of the young before weaning and its regulation are not easy to study due to the interactions of each kit with its littermates and with the mother. Nevertheless, it is well known that the availability of milk is a key regulating factor of the solid food ingestion before weaning. Thus, if the size of the litter is reduced from 10 to 4 kits or if the milk production of the mother increases, the beginning of solid food ingestion is delayed of 2-4 days (Fortun-Lamothe and Gidenne, 2000) and the feed intake of the whole litter is lowered (Pascual *et al.*, 2001). Similarly, offering a second milking to the young (using a second doe) delayed the dry feed intake (Gyarmati *et al.*, 2000). On the opposite, early weaning (before 25 days of age) greatly stimulates and accelerates the dry feed intake (Xiccato *et al.*, 2005; Gallois *et al.*, 2005).
The influence of the feed nutritional composition on feeding behaviour is poorly known, although some authors use an original model of cage to measure the intake of the litter without separation from the mother (Fortun-Lamothe *et al.*, 2000). But, results obtained on young rabbits indicate contradictory that the variability among litter is very high (up to 45%), and the control of intake before weaning through the nutrient are not consistent. For instance, Pascual *et al.* (1998, 1999) suggest that suckling rabbits regulate their food consumption according to its digestible energy content, as weaned rabbits. On the opposite, a greater feed intake was found for a high compared to a moderate-energy diet (Debray *et al.*, 2002; Gidenne *et al.*, 2004). Finally, other factors, such the form of presentation of food, the pellet size and their quality (hardness, durability) play probably a key role in the starting of the solid feeding behaviour.
However, the individual feeding behaviour of the young remained largely unknown (regulation factors, number of meals, etc…), since no method is presently available to assess the intake level of young reared collectively (till weaning).

2.2 Feeding behaviour of the growing and adult rabbit.

From weaning (classically between 4 and 5 weeks) the daily feed intake of the domestic rabbit (fed a complete pelleted feed) increases correlatively to the metabolic live-weight (figure 13.3) and levelled up at about 5 months of age. Taking as a reference an adult animal fed *ad* libitum (140-150 g DM/day, for example, for a 4 kg New Zealand White): at 4 weeks a young rabbit eats a quarter of the amount an adult eats, but its live weight is only 14% of the adult's one. At 8 weeks the relative proportions are 62 and 42%; at 16 weeks they are 100 to 110 and 87%. Between the weaning (4-5 weeks) and 8 weeks of age, the weight gain reached its highest level (table 13.1) while the feed conversion is optimal. Then, the feed intake increases less quickly as well the growth speed, and the intake levelled up at around 12 weeks of age for current hybrid lines of domestic rabbit. A rabbit regulates its feed intake according to energy need, as for other mammals. Chemostatic mechanisms are involved, by means of the nervous system and blood levels of compounds used in energy metabolism. However, in monogastric animals the glycaemia plays a key role in food intake regulation, while in ruminants the levels of volatile fatty acids in blood have a major role. Since rabbit is a monogastric herbivore, it is not clear which is the main blood component regulating feed intake, but it is likely to be the blood glucose level. Voluntary intake, proportional to metabolic live-weight ($LW^{0.75}$), is about 900-1000 kJ DE/d/kg $LW^{0.75}$ (DE: digestible energy), and the chemostatic regulation appears only with a dietary DE concentration higher than 9-9.5 MJ/kg (see chapter 6). Below this level, a physical-type regulation is prevalent and linked to gut fill.

The intake of soft faeces increases only till 2 months of age and then remained steady (figure 13.3). Expressed as fresh matter, the soft faeces intake evolved from 10 g/day (1 month old) to 55 g/day (2 months), thus representing 15 to 35% of the feed intake (Gidenne and Lebas, 1987). However, the classical method to estimate caecotrophy probably underestimates it, since one adapts a collar around the neck of the rabbit to avoid intake of soft faeces from the anus that is stressful. Recently, Belenguer *et* al. (2008) developed methods based on microbial marker analysis that are more convenient for the animal.

The rabbit fractionates its voluntary solid intake in numerous meals: about 40 at 6 weeks of age, and a slightly lower number at adulthood (table 13.2). This meal fractionation is probably linked to the relatively weak storage capacity of the stomach (cf. chapter 1), particularly when compared to herbivorous animals or even carnivorous or omnivorous ones (such dog or pig).

For 6 weeks old rabbits, fed with a pelleted diet, the time spent on feeding every 24 hours a little bit more than 3 hours. Then, it drops rapidly to less than 2 hours. If a ground non pelleted diet is proposed to rabbits, the time spent to eat is doubled (Lebas, 1973).The number of liquid meals evolved in parallel to that of feed, and the time spent to drink is lower than that spent to eat. Furthermore, at any age, feed containing over 70% water, such as green forage, will provide rabbits with sufficient water at temperatures under 20°C and in this case rabbits may not drink at all. In growing rabbit fed with pellets, the normal ratio between water and dry matter is about 1.6-1.8. In the adult or the breeding doe it is increased up to 2.0-2.1.

The solid intake fluctuates over a 24 hour period, as shown in figure 13.4. Over 60% of the solid feed (excluding soft faeces meals) is consumed in the dark period for a domestic rabbit submitted to a 12L/12D light schedule. The nycthemeral changes of liquid meals is strictly parallel to that of solid meals for the domestic rabbit fed pellets (Prudh'on *et al*., 1975b), but no correlation can be established between time or intervals of solid and water meals. A peak of intake is observed at the end of the diurnal period, and about one hour before light stops Prud’hon *et al*. report a more intense feed consumption in the 6 weeks old rabbit. According to Horton *et al.* (1974) and Jolivet *et al.* (1983), the intake is usually spread into two periods: one at the end of the night (or early in the day) and another more important at the end of the day (or early night).

With ageing, the nocturnal feeding behaviour becomes more pronounced. The feeding habits of wild rabbits are even more nocturnal than those of domesticated rabbits. In fact, the domestic rabbit is no longer without eating, since it has more than 20 meals of dry feed a day, and it also has meals of caecotrophes (early morning). Moreover, Hirakawa (2001) pointed out that leporids (including rabbits) also consumed a part of their own hard faeces that are masticated contrary to soft faeces that are swallowed. Meals of soft faeces (and sometime hard) increase in proportion when food availability is insufficient for rabbits.

Obviously, the feed intake level is modulated by the physiological status of the animal. For instance, a doe's voluntary intake varies greatly during the reproduction cycle (figure 13.5). The intake during the final days of pregnancy drops off markedly. Some does refuse solid food just before kindling. Water intake, however, never stops completely. After kindling, the feed intake increases very rapidly and can exceed 100 g dry matter/kg live weight a day. Water intake is also increased at that time: from 200 to 250 g a day per kg of live weight. When a doe is both pregnant and lactating, she eats amounts similar to that observed for a doe that is only lactating.

3 External factors modulating the feeding behaviour of the domestic rabbit

3.1 Feed composition and presentation form

One of the main dietary components implicated in feed intake regulation, after weaning, is the digestible energy (DE) concentration. The domestic rabbit (fed a pelleted balanced diet) is able to regulate its DE intake (and thus its growth) when the dietary DE concentration is between 9 and 11.5 MJ/kg, or when the dietary fibre level is between 10 and 25% ADF (Acid Detergent Fibre). The intake level is thus well correlated with the dietary fibre level, compared to the dietary DE content (figure 13.6). However, the incorporation of fat in the diets, while maintaining the dietary fibre level, increases the dietary DE level, but leads to a slight reduction of the intake. Other nutrients in the diets are able to modify the food intake, such protein and aminoacids (Tome, 2004). For example, an excess in methionin reduced by at least 10% the feed intake of the growing rabbit (Colin *et al.*, 1973; Gidenne *et al.*, 2002).

The diet presentation is an important factor modulating the feeding behaviour in the rabbit. Compared to meals, pelleted feeds are preferred at 97%, when offered in free choice (Harris *et al.*, 1983). Furthermore, meals seemed to modify the circadian cycle of feed intake (Lebas and Laplace, 1977). Pellet size and quality (hardness, durability) are also able to affect the feeding behaviour (see chapter 14). A reduction in pellet diameter, that also increases the hardness, reduces the feed intake of the young (Gidenne *et al.*, 2003) or of growing rabbit (Maertens, 1994) and although time budget for feeding was increased.

3.2 Environmental factors affecting the feeding behaviour of the rabbit (see also the chapter 15)

The rabbit's energy expenditure depends on ambient temperature. Feed intake to cope with energy needs is therefore linked to temperature. Studies on growing rabbits showed that at temperatures between 5°C and 30°C intake of pelleted feed dropped from 180 to 120 g/day and water intake rose from 330 to 390 g/day (table 13.3). A closer analysis of feeding behaviour shows that as temperature rises the number of solid meals eaten in 24 hours drops. From 37 solid feeds at 10°C the number drops to only 27 at 30°C (young New Zealand White rabbits). The amount eaten at each meal drops with high temperatures (5.7 g/meal from 10°C to 20°C down to 4.4 g at 30°C) but the water intake goes up, from 11.4 to 16.2 g/meal between 10°C and 30°C.
The negative effect of hot ambient temperatures (29-32°C) on daily feed intake could be partly counterbalanced by distribution of drinking water refreshed at 16-20°C . With "cold" water distribution, the average feed intake could be increased by 4-6% for fatteners as for breeding does with the corresponding improvement of performances (Duperray *et al.*, 1998). The feed intake was increased up to 11% for 7 weeks old fatteners in the experiment of Selim *et al*. (2004) with 6 hours of hot temperature (29-32°C) during each 24h cycle. The feeding and drinking behaviour of the doe and their litters according to the climatic conditions is detailed in chapter 15.
If drinking water is not provided and if the only feed available is dry with a moisture content of less than 14%, dry matter intake drops to nil within 24 hours. With no water at all, and depending on temperature and humidity, an adult rabbit can survive from 4 to 8 days without any irreversible damage, though its weight may drop 20-30% in less than a week (Cizek, 1961). Rabbits with access to drinking water but no solid feed can survive for 3 to 4 weeks. Within a few days they will drink 4-6 times as much water as normal. Sodium chloride in the water (0.45%) reduces this high water intake, but potassium chloride has no effect (sodium loss through urination). The rabbit is therefore very resistant to hunger and relatively resistant

to thirst; but any reduction in the water supply, in terms of water requirements, causes a proportional reduction in dry matter intake, with a consequent drop in most of the performance criteria. For example water availability for breeding does limited to 20 min. per day decreases their feed intake, milk production and kit's growth by about 17-18%, but has not effect on reproduction parameters or kit's mortality (Carles and Prud'hon, 1980)

Other environmental factors have also been studied in the domestic, such the light schedule or the housing systems. In absence of light (24h/24 dark), the feed intake of fattening rabbits is increased when compared to rabbits submitted to a sun light program (Lebas, 1977). In these conditions of absence of light, rabbits organised their feeding pattern in a regular 23.5-23.8 hours program, with about 5-6 hours devoted to soft faeces ingestion and the remaining part of the cycle to feed intake. In continuous lighting, the feeding pattern is organized in an about 25 hours program. (Jilge, 1982; Reyne and Goussopoulos, 1984). For breeding does, reduction of the lighting duration during a 24 hours cycle by introduction 2 folds a 4 hours period of dark during the normal 12h of lighting in a 12L/12D program (intermittent lighting) does modify the average daily feed intake despite an increase of the milk production leading to a better feed efficiency for milk production (Virag *et al.*, 2000).
As previously mentioned, type of caging also influences the daily feed intake and the feeding pattern of rabbits. For instance, the feed intake is affected by the density of rabbits in the cage. Increasing the density, which seems to lead to a higher competition for feeders among the animals, and leads to a reduction of feed intake (Aubret and Duperray, 1993). But this is not necessarily a result of a competition for feeders since it is also observed with rabbits in individual cages (Xiccato *et al.*, 1999). In comparisons of cage and pen housing of rabbits, enlarging the cage size for a group (with or without variation of the density) allows more movements to the rabbits and reduces the daily feed intake (Maertens and Van Herck, 2000). At the same density, rabbits caged by 2 or by 6 have the same daily feed intake, but in cages of 2, rabbits spent a lower proportion of their time budget for feed consumption: 5.8% vs 9.9% of the 10 hours of the lighting period during which they were observed (Mirabito *et al.* 1999). Finally according to the feeding pattern, the number of places at feeder (1 to 6) for a group of 10 rabbits did not influence the daily feed intake (Lebas, 1971).

4 Feeding behaviour in situation of choice

All studies at basis of the results above explained were conducted with domestic rabbits, generally fed with complete and more or less balanced diets. In the wild or in situation of free choice for caged rabbits, another dimension must be added to the feeding behaviour: how rabbits select the feeds?

4.1 Feeding behaviour of wild rabbits or rabbits in open situation (grazing rabbits)

First of all the feed resources available for wild rabbits are most generally constituted by a great range of plant material. Rabbit clearly prefer graminaceous plants (*Festuca* sp., *Brachypodium* sp. or *Digitaria* sp.) and graze only few dicotyledons if sufficient grasses are available (Williams *et al.*, 1974; Leslie et al., 2004). Within the dicotyledonous rabbits graze especially some leguminous plants and some compositae. But it could be underlined that grazing pressure on carrots (*Daucus carotta*) is very light, this plant being out of those preferred by rabbits (CTGREF, 1978).

Proportion of dicotyledonous species and even mousses may increase during some seasons depending on the availability of plants (Bhadresa, 1977). In winter time and early spring, grazing of cultivated cereals by rabbits may completely compromise the crop, especially up to a distance of 30-100 m of the warren (Biadi and Guenezan, 1992). When rabbits can choice between winter cereals cultivated with or without mineral fertilisation (phosphorus and/or nitrogen) they clearly prefer the cereals without artificial fertilisation (Spence and Smith, 1965).

Grazing rabbits may be very selective and for example choice one part of the plant or the type of plant with the highest nitrogen concentration (Steidenstrücker, 2000). Similarly, wild rabbits have grazed more intensively one variety of spring barley than 4 others in a test performed in Ireland, probably in relation with plant's composition. But differences in sugar content of varieties did not fully explain this varietal selection by grazing rabbits (Bell and Watson, 1993).
The great winter appetence of rabbits for buds and young stems of some woody plants must be underlined. Grazing of very young trees or of shoots may completely compromise regeneration of some forests (CTGREF, 1980), or more specifically the regeneration of different shrubs like juniper (RSPB, 2004) or common broom (Sabourdy, 1971). In winter time rabbits like to eat bark of some cultivated trees (not only young stems), specially that of apple trees and in some extent that of cherry and peach trees. Barks of pear, plum or apricot trees are generally less attacked (CTGREF, 1980). In forests, rabbits clearly prefer broad-leaved trees but may also attack bark of conifers (mainly spruce and some types of pines), but on the contrary when very young trees are available rabbits prefer to eat apical or lateral sprouts of spruces or firs instead of that of oaks (CTGREF, 1978).

So basic reasons of the choices remain unclear, even if they are constant. It could only be said that it is under regulation of hypothalamus since hypothalamic lesions modify clearly the choice pattern of rabbits (Balinska, 1966).

Many experiments were conducted specially in Australia and New Zealand to study the wild rabbits comportment when different more or less manufactured baits are proposed (the final objective being the eradication of imported wild rabbits). Many variations were observed depending on the type of bait, but also of season. For example pollard+bran pellets (5/1 in weight) are well consumed throughout the year. In contrast, the acceptability of carrots or oats varies seasonally. Addition of salt (1% or 5% NaCl) or of lucerne meal (15%) the pollard+bran pellets significantly reduces the baits consumption (Ross and Bell, 1979).

4.2 Free choice for domestic caged rabbit

When a choice is proposed between a control diet and the same diet + an appetiser, rabbits generally prefer the diet with the appetiser. But when the same 2 diets are offered alone to rabbits the daily feed intake is exactly the same and the growth performance too (Fekete and Lebas, 1983). It means that the pleasant smell of the proposed food is not essential for the feed intake regulation. This was also proved with a repellent diet (addition of formalin) clearly rejected in the free choice test but consumed in the same quantity in the long term single food test (Lebas, 1992).
In the same way Cheeke *et al.* (1977) have demonstrated that rabbits prefer alfalfa with saponin, a bitter component, up to 3 mg/g of the diet whereas rats always prefer the control diet without saponin in the range of 0.4 to 5 mg/g (figure 13.7). But when single feeds with different levels of saponin are offered to rabbits (saponin from 1.8 to 6.4 mg/g of complete

diet), the feed intake and growth rate are independent of the saponin level (Auxilia *et al.*, 1983)
On the contrary, when a toxic is present such as aflatoxins, rabbits refuse completely to consume the diet or consume it in very low quantities (Fehr *et al.*, 1968; Morisse *et al.*, 1981; Saubois and Nepote, 1994). This regulation may be considered as pertinent to protect the animal against food injuries.
When a concentrate (low fibre diet compound diet) and a fibrous material are proposed as free choice to rabbits, they prefer the concentrate. The fibrous material is consumed in only small quantities and the growth rate may be reduced (Lebas *et al*, 1997). The consequence is also an immediate increase of the sanitary risk for rabbits with digestive disorders by lack of fibre (Gidenne, 2003). This is the consequence of the specific search of rabbit for energetic sources (scarce in the wild), the dominant regulation system of feed intake in rabbits.
Effectively when 2 energetic concentrates are proposed with free choice as it was done by Gidenne (1985) with a complete diet and fresh green bananas, the growth rate is equivalent to that of the control and the digestible energy daily intake identical. Nevertheless it must be underlined that in this study the proportion of bananas in the dry matter intake decreased from 40% at weaning (5 weeks) to 28% at the end of the experiment 7 weeks later.
In another way, rabbits receiving a diet deficient in one essential amino acid (lysine or sulphur amino acids) and drinking water with or without the missing amino acid in solution, prefer clearly the solution with the missing amino acid (Lebas and Greppi, 1980)
To add a last constituent to this chapter on free choice, it could be reminded that in free choice situation a simple variation of humidity of one component may change the equilibrium in the rabbit's choice. For example when dehydrated lucerne and normally dried maize grains (11% humidity are offered *ad libitum* to rabbit the result of the choice is 65% lucerne/35% maize. But if the water content of the maize grains is increased up to 14-15%, the proportion of maize becomes 45-50% (Lebas, 2002). In this case the choice reason of rabbits seems motivated more by the immediate palatability of the feeds than by their nutritive value.
As it was described above regulation of intake in free choice situation is delicate to predict. Thus in most practical situations of rabbit production the utilisation of a complete balanced diet is advisable.

5 Feeding behaviour in situation of feed restriction

5.2 Quantitative limitation

When a limited quantity of pelleted food is distributed to rabbit, the animal consumes its daily allocation within few hours. For example for rabbits caged individually or by two, a quantity representing 85% of the *ad libitum* intake is ingested in a maximum of 16 hours, but if the quantity is reduced to 70%, the time used to ingest this quantity is reduced to 10 hours (Bergaoui *et al.*, 2008).

When restricted rabbits are caged in groups, the time spent for feed intake is shorter and depends of the number of rabbits able to eat pellets at the same time. For example according to Tudela and Lebas (2006) for fattening rabbits caged by 8, with a restriction at 85%, all the daily allocation is consumed in 8 hours if only one rabbit has access to the feeder; but if 2 rabbits can accede simultaneously to the feeder only 89% of the daily allocation are consumed in the same 8 hours. According to the same authors, if the daily allocation is distributed one half at 8:00 and the other half at 18:00, to groups of 8 fattening rabbits with only one place at feeder, all the quantity distributed is consumed within the 2 hours following the distribution

(93% during the first hour), but if 2 rabbit can consume simultaneously 3 hours are necessary for the ingestion of all the allocation (76% during the first hour).

The restriction at 85% does not induced a real competition for feed intake between the 8 rabbits of the cage as is can be assumed from the identity of live weight, whatever the number of places at feeder (1 or 2) or the number of distribution per day (1 or 2). More, the within cage standard deviation of live weight is also independent of these factors and identical to that of the *ad libitum* control group. On the contrary, if the feed restriction is more stronger (60%) the average live weight is not affected by the number of feed distributions, but the standard deviation of live weight is significantly increased by 20% when compared to that obtained with groups restricted at 85% or fed *ad libitum*, a situation which can be interpreted as the result of a real competition between rabbits for the access to the feeder with a 60% restriction (Tudela and Lebas, 2006).

5.2 Limitation of the daily access to feeder or drinker

5.2.1. Restricted access to the feeder

If rabbits can accede to the feeder during less than 14-16 hours / 24h, the feed intake is reduced as demonstrated by the different studies conducted in Hungary (Szendrö *et al*., 1988; Tal El Den *et al*, 1988) and summarized by Lebas (2007) on figure 13.8. For example a time limited to 8 hours per day induced on average a 80% reduction of feed intake. Nevertheless it must be underlined that reduction of the duration of the access to feeders induces a stronger reduction in young rabbits feed intakes than in older fattening rabbits : *e.g.* reduction to 64%, 73% and finally 81% during each of the 3 weeks following weaning at 32 days of rabbits with 8 hours of access to feeders (Foubert et al., 2007) or 73% reduction with 9 hours per day for 4-5 weeks old rabbits (Matics et al., 2008) and consumption quite identical to *ad libitum* control at 12 weeks with continuous 8 hours per days limitation of access (Szendrö *et al.*, 1988). If a breeder hopes, by reduction of the feeding time, to induce a known quantitative restriction for a group of fattening rabbits (*e.g.* 85%, or adjustment to a theoretical curve of intake), it would be necessary to determine regularly the real feed intake in some cages in order to adjust once or twice per week the duration of the access to feeders for the whole group.

The same Hungarian group has also observed the time spent by rabbits to consume their food in conditions of restricted access to feeders. The total number of meals per day is not affected by limitation of time (30-35 on average at 12 weeks), but meals are concentrated in the smaller number of hours "available", without significant increase of the duration of each meal. Nevertheless, with 9h/24h available for feed intake, the total duration spent for feed consumption is 1 hour 20 min. per day to be compared to the 1 hour 45 min. per day used by rabbits of the same age fed *ad libitum* (Szendrö *et al*., 1988).

5.2.2. Restricted access to drinking water

Limitation of the time of access to drinkers is also a method to reduce the rabbit feed intake. A lot of year ago, Prud'hon *et al* (1975) have demonstrated that after one week of adaptation rabbit receiving free access to drinking water during only 10 minutes per 24 hours have a feed intake reduced by 86 to 76% of that of the *ad libitum* drinking rabbits, depending of the age: 86% for 6-9 weeks old rabbits, 84% for 11-14 weeks old ones and 76% for adults. The adaptation period was introduced because of the drastic reduction of water and feed intake (-

63 and -53% respectively) the 1-2 days following the application of the restriction, followed by a 6-8 days of adaptation to the new situation (Lebas and Delaveau, 1975).

In practical conditions with fattening rabbits, an access to drinking water limited to 1h30 min. to 4 hours induces a reduction of water intake stronger than that of pelleted food mainly for short durations of watering, as demonstrated on figure 13.9. As a consequence, the water to feed ratio is reduced from 1,74 for rabbits fed *ad libitum* down to 1.54 for those receiving water during only 2 hours or 1h30 per day.

It must be pointed out that with a restriction of access to drinkers, the water to feed ratio is always reduced as consequence of the drastic reduction of water intake compared to the *ad libitum* control. But when feed intake is reduced even stronger that after water access restriction (Boisot *et al*., 2005) the water intake is enhanced clearly above the *ad libitum* intake (Table 13.4) and the water to feed ratio is largely increased above that of the control.

Conclusion

The rabbit feeding behaviour is very particular compared to other mammals, with special features, such the caecotrophy, associated to a particular digestive physiology, intermediate between the monogastric and the herbivore. As herbivorous, the feeding strategy of the rabbit is almost opposite to ruminants. The feeding strategy of the latter consists to retain the food particles in the rumen till they reach a sufficiently low size. The rabbit has adopted a reverse strategy characterised by a preferential retention of fine digesta particles in the fermentative segment (caecum and proximal colon), with a quick removal of the coarse particles (such low digested fibres) in hard faeces. This is associated to numerous meals, thus favouring a quick digesta rate of passage and the digestion of the most digestible fibre fractions.
Therefore, the rabbit is adapted to various feeding environments, from desert to temperate or even cold climates, and is able to consume a very wide variety of feeds, from seeds to herbaceous plants.

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Table 13.1 : Feeding behaviour of the domestic rabbit after weaning . Mean values from rabbits (current commercial lines), fed *ad-libitum* a pelleted diet (89% DM), and having a free access to drinkable water.

	Periods of age (weeks)	
	5-7 weeks	7-10 weeks
Solid feed intake (g/d)	100-120	140-170
Weight gain (g/d)	45-50	35-45
Food conversion	2.2-2.4	3.4-3.8

Table 13.2: Feeding and drinking behaviour of the domestic rabbit from 6 to 18 weeks old. Mean values from 9 New Zealand White rabbits, fed *ad libitum* a pelleted diet (89% DM), and having a free access to drinkable water (Prud'hon *et al.*, 1975).

	Age in weeks		
	6	12	18
Solid feed (pellets, 89% DM)			
Solid feed intake (g/d)	98	194	160
No. of meals per day	39	40	34
Average quantity per meal (g)	2.6	4.9	4.9
Drinking water			
Water intake (g/d)	153	320	297
No. of drinks per day	31	28.5	36
Average weight of 1 drink (g)	5.1	11.5	9.1

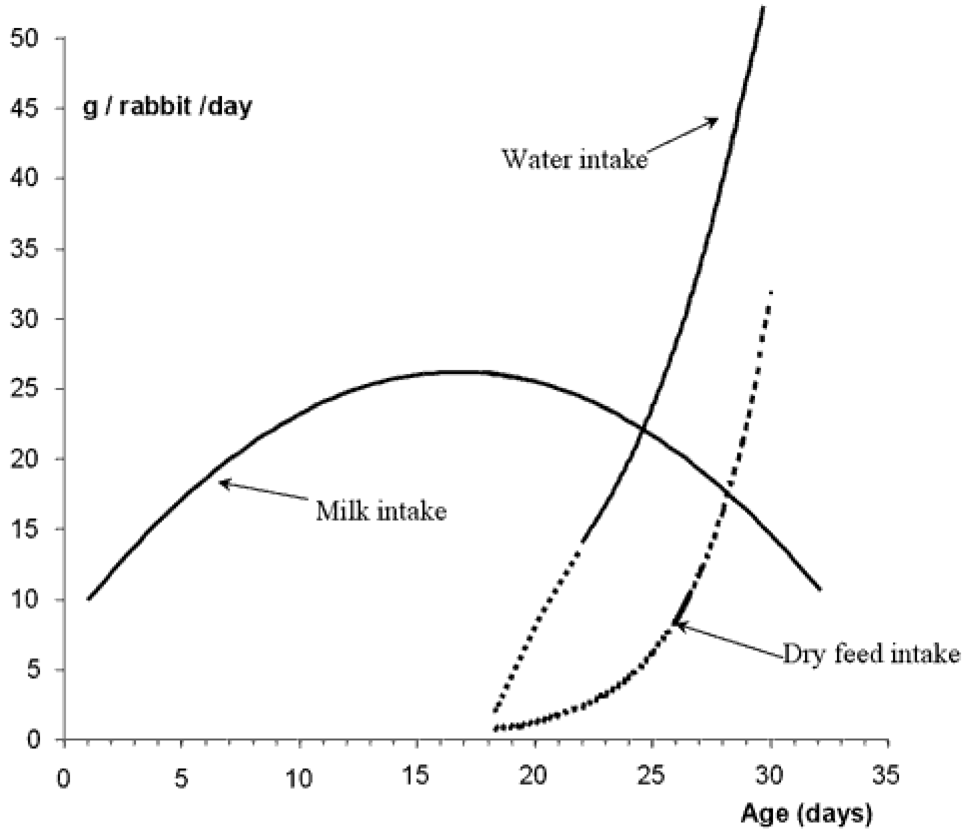
Table 13.3: Feeding behaviour of the growing rabbit according to ambient temperatures

Ambient temperature	**5°C**	**18°C**	**30°C**
Relative humidity	80%	70%	60%
Pelleted feed eaten [1] (g/day)	182	158	123
Water drunk (g/day)	328	271	386
Water/feed ratio	1.80	1.71	3.14
Average weight gain (g/day)	35. 1	37.4	25.4

Data from Eberhart (1980)

Table 13.4 : Effect of a limitation of daily drinking duration or of a reduction of the quantity of pellets distributed, on relative water and feed intakes (Boisot *et al.*, 2005) Observation during the 3 weeks following weaning at 31 days

Feeding and watering conditions	*Ad libitum* control	Water available 1 hour per day	Quantitative feed restriction (theoretical 65%)
Feed intake	136 g/d = 100%	78%	66%
Water intake	228 g/d = 100%	56%	136%
Water / feed ratio	1.7	1.2	3.5



(adapted from Szendrö *et al.*, 1999; and Fortun-Lamothe and Gidenne, 2000)
Mean values, for litters of 7-9 kits, with pelleted dry feed, nipple drinker, and weaned at 30d (doe remated 11d after kindling).

Figure 13.1: Milk, water and dry feed intake of the young rabbit

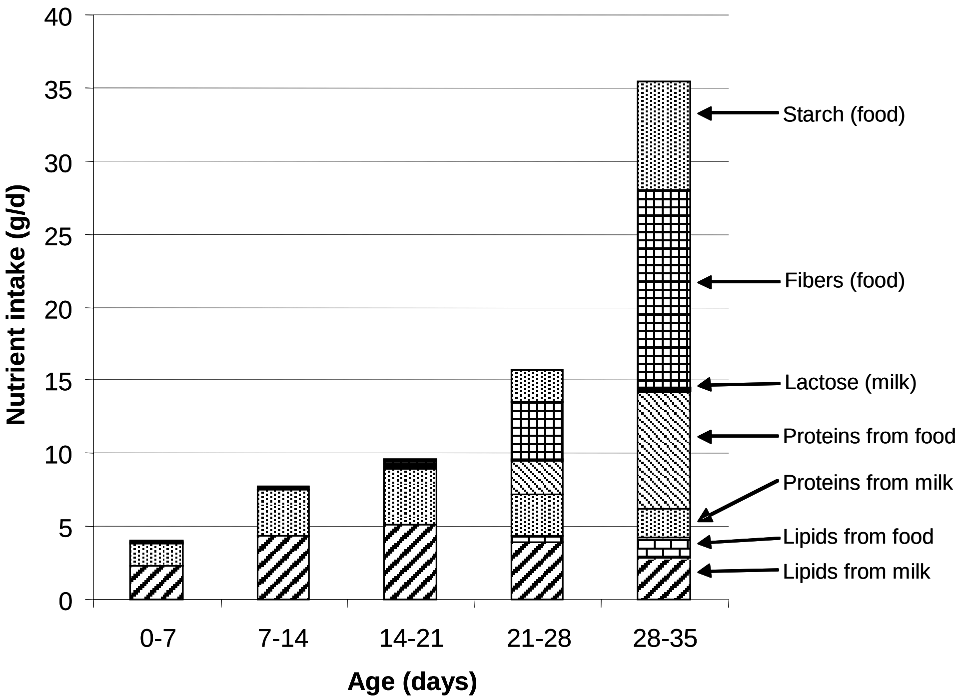
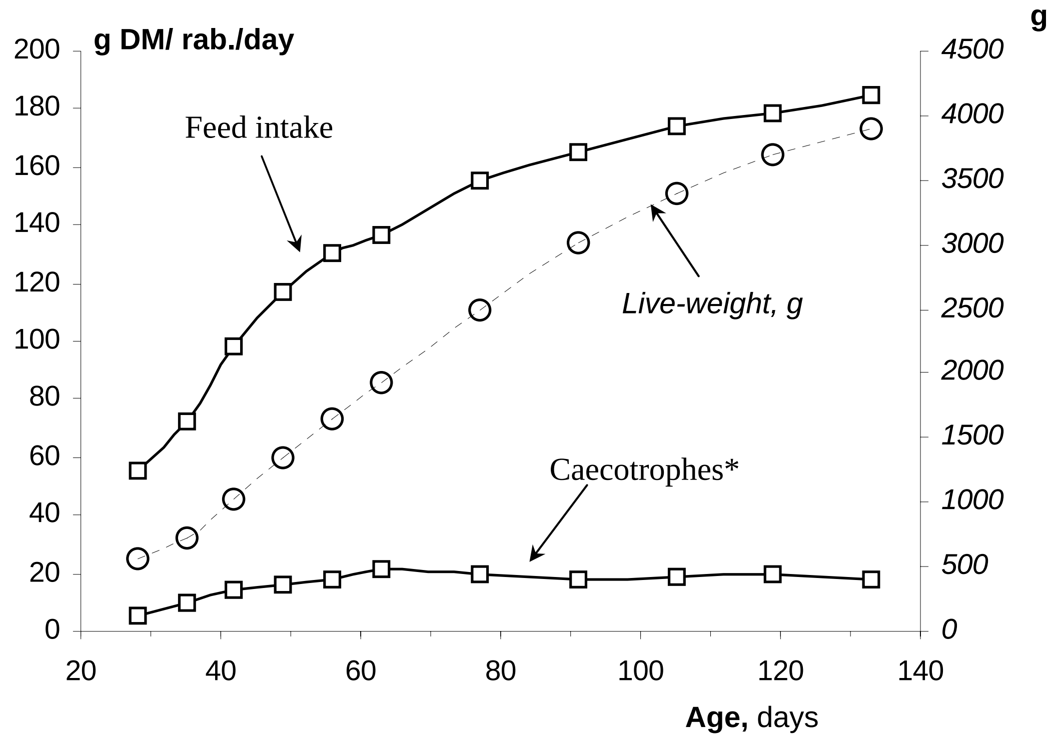
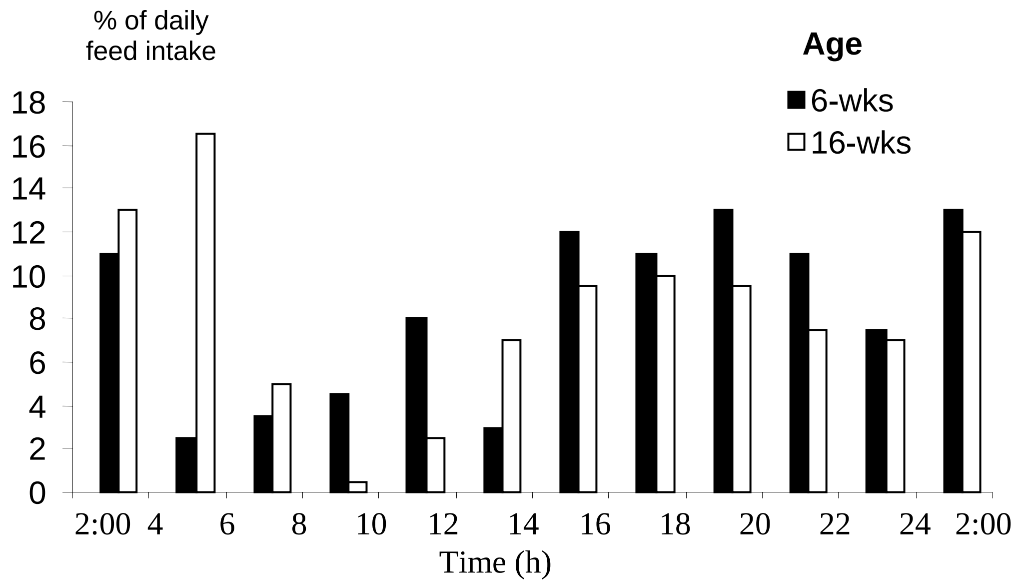


Figure 13.2: Evolution of the nutrient composition of food ingested by young rabbits between birth (day 0) and weaning (day 35) in breeding conditions.



Data from domestic rabbit, fed *ad-lib.* a pelleted feed (Gidenne and Lebas, 1987)
*: data of caecotrophes excretion obtained on rabbits wearing a collar.

Figure 13.3: Dry matter intake from pelleted feed, caecotrophes, and live-weight from weaning (28d) till adulthood.



Mean values for domestic rabbits (n=6) fed *ad-lib*. a pelleted feed (daily feed intake= 80 and 189 g/d resp. for 6 and 16 wks old) and bred under a 7:00-19:00 light schedule (Bellier *et al.*, 1995).

Figure 13.4: Circadian pattern of feed intake in growing or adult rabbit.

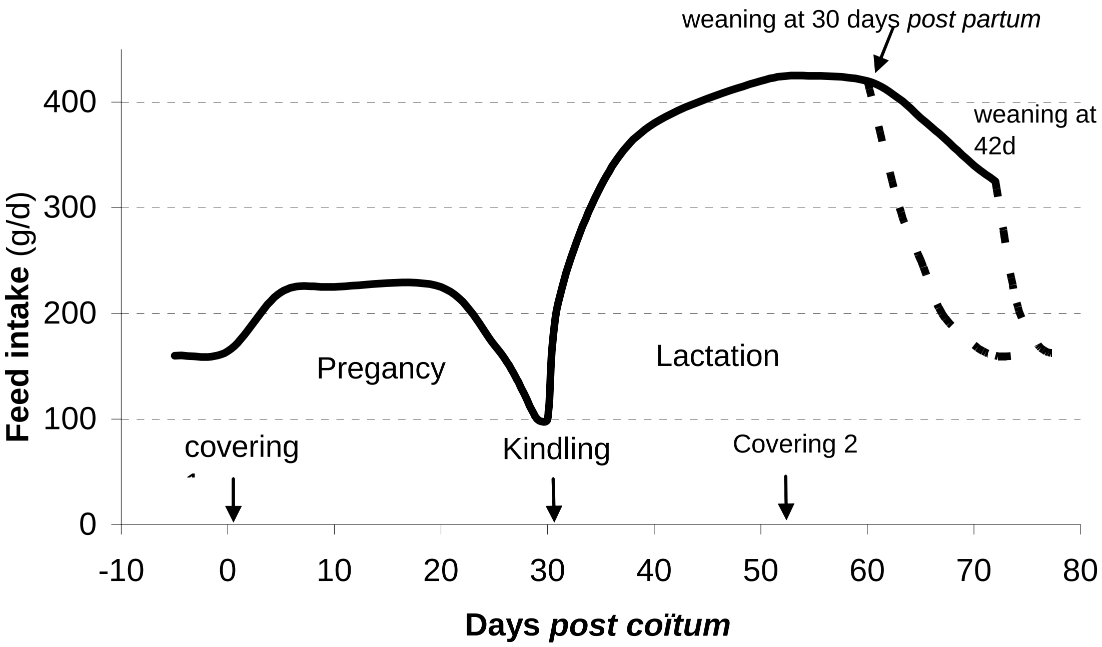
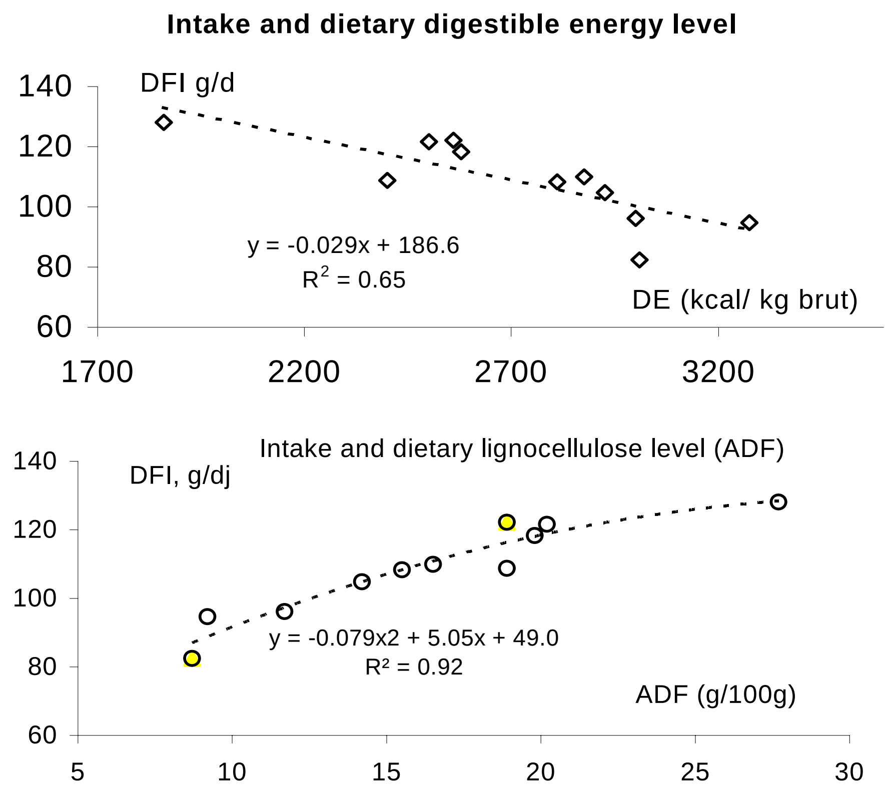


Figure 13.5: Intake behaviour of a doe* during gestation and lactation
* data from Lebas (1975), domestic rabbit fed a balanced pelleted feed (89% DM)



DFI: daily feed intake measured between weaning (4 wks) and 11 weeks of age.

Figure 13.6: Feed intake prediction in the domestic rabbit, after weaning

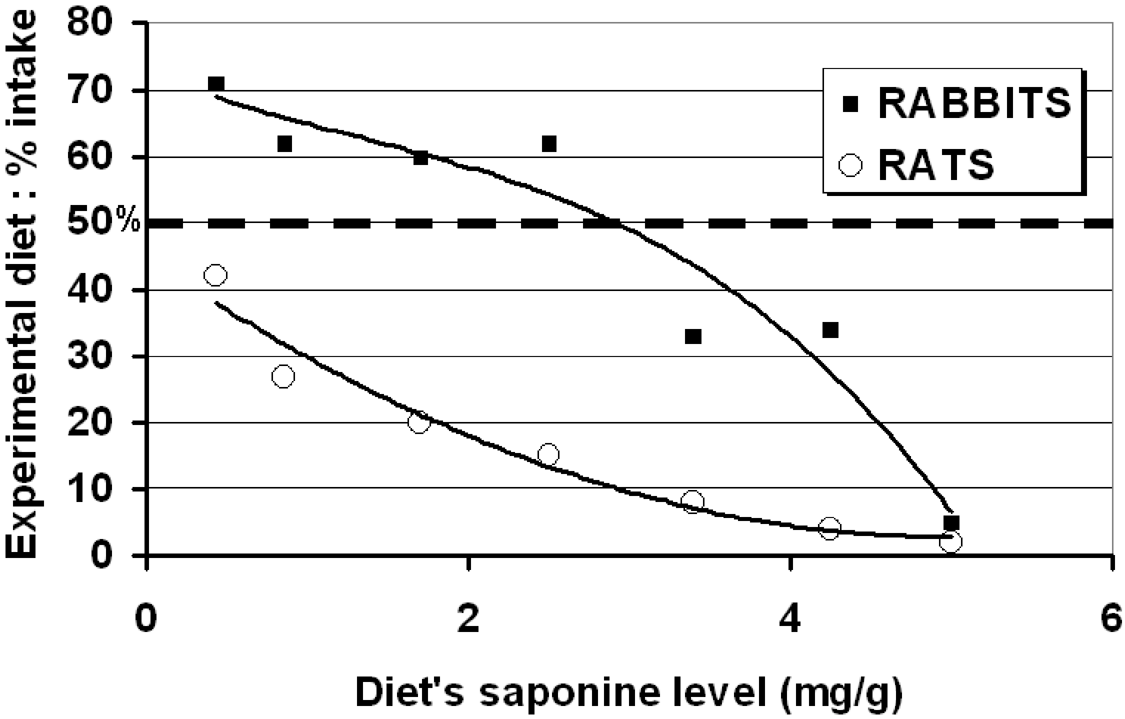


Figure 13.7 : Relative feed intake of a lucerne based diet with various levels of saponin in rats and rabbits in situation of free choice between this diet and a control diet without saponin
(Cheeke *et al.*, 1977)

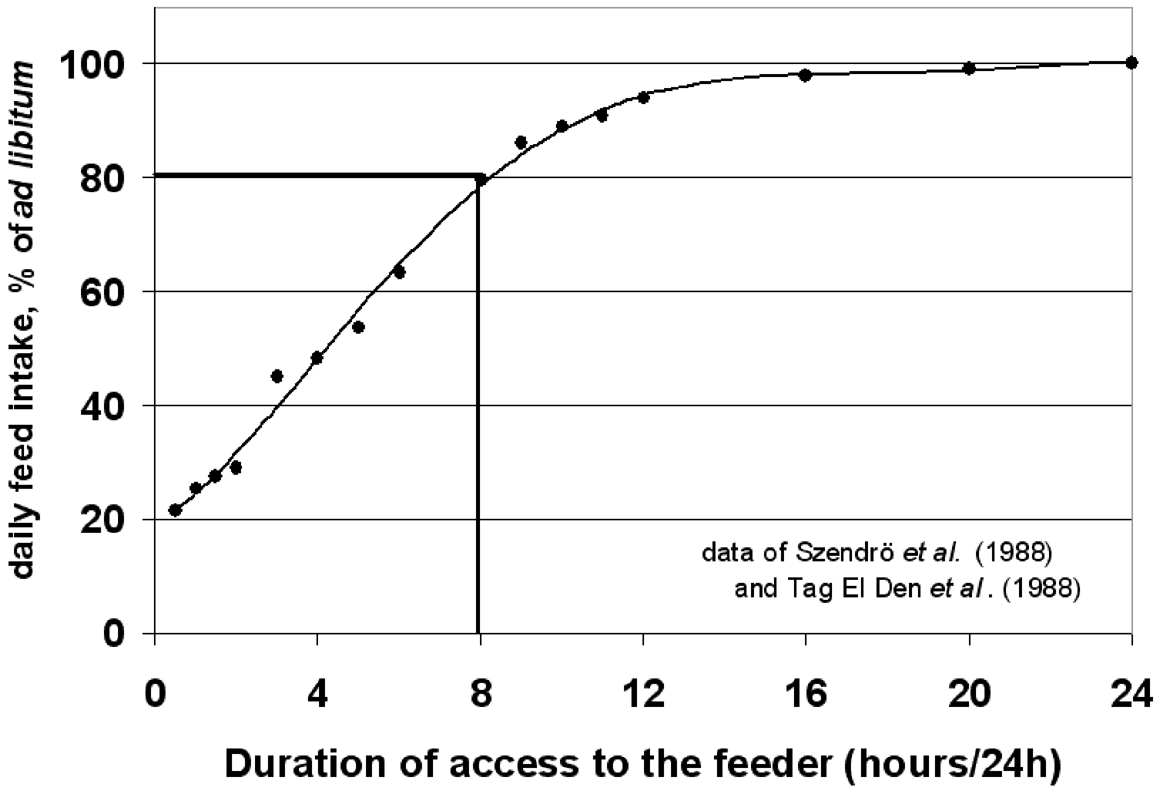


Figure 13.8. Pelleted feed intake of rabbit with a limited time of access to the feeder (synthesis by Lebas, 2007)

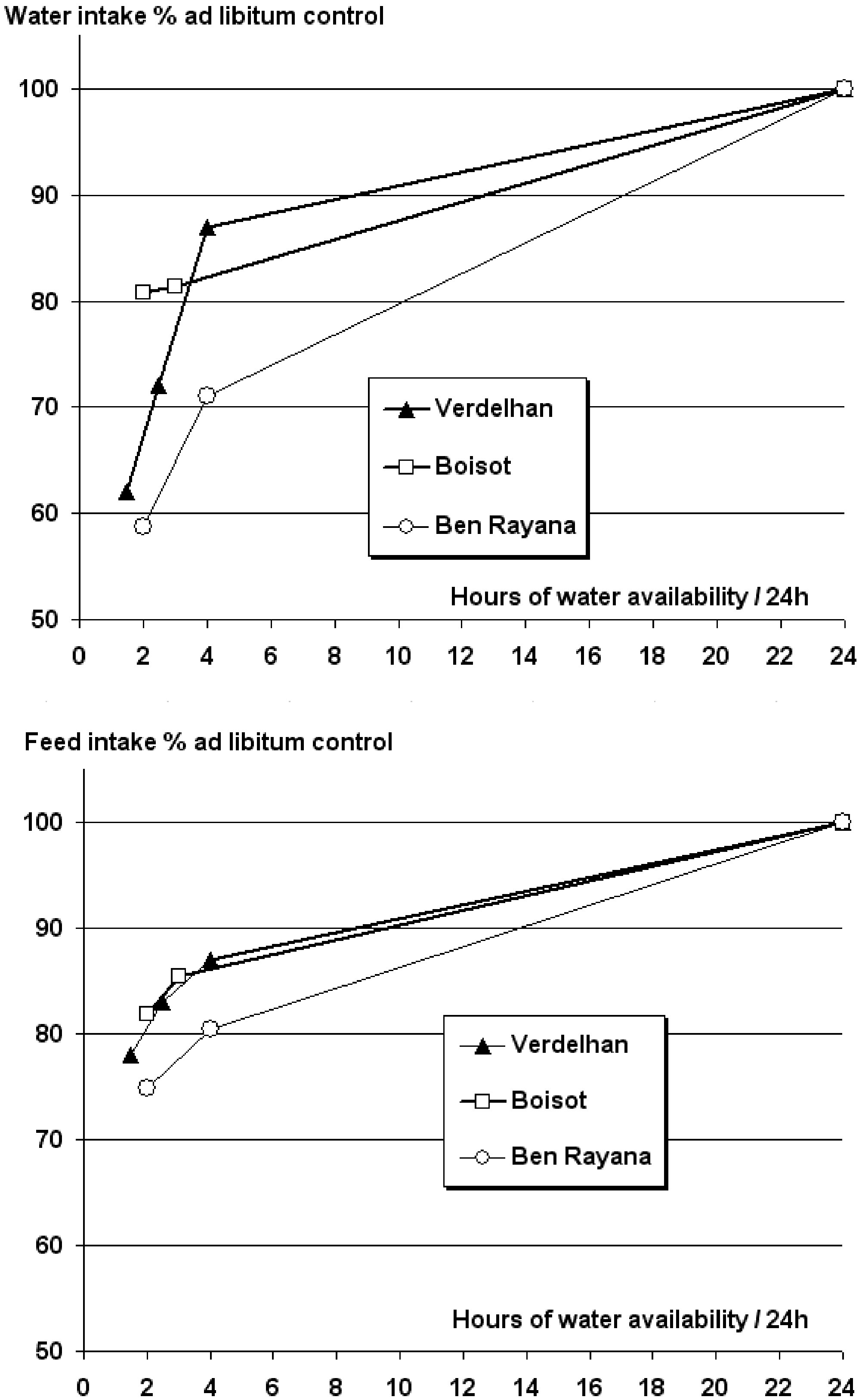


Figure 13.9 : Average water and feed intakes of fattening rabbits able to drink water during a limited duration every day (1.5 to 4 hours/24h) but fed *ad libitum*, according to Verdelhan *et*

al. (2004), Boisot *et al.* (2004) and Ben Rayana e*t al*. (2008). Results expressed as percentage of the control watered and fed *ad libitum*.