

REARING MANAGEMENT OF RABBIT DOES : A REVIEW

ROMMERS J.M.¹, KEMP B.², MEIJERHOF R.³, NOORDHUIZEN J.P.T.M.⁴

¹ Centre for Applied Poultry Research, P.O. Box 31, 7360 AA BEEKBERGEN, The Netherlands

² Wageningen Institute of Animal Sciences, Wageningen Agriculture University, P.O.Box 338, 6700 AH, WAGENINGEN, The Netherlands

³ Hybro, P.O. Box 30, 5830 AA BOXMEER, The Netherlands

⁴ Division of Farm Animals'Health Care, Faculty of Veterinary Medicine University of UTRECHT, The Netherlands

ABSTRACT : Under the current management strategies, young does are not able to meet the high energy requirements for concurrent pregnancy and lactation during the first litters, resulting in nutritional deficits, decreased reproductive performance and a high replacement rate. Feed intake capacity seems to be the main limiting factor. According to literature it seems impossible to adequately solve this problem by taking management measures during the reproduction period. The rearing period seems to be the best time to influence body development and feed to optimize the reproductive performance of young does. This is because of the rapid development of organs and tissues at an early age.

The present review firstly summarises literature on body growth and development in rabbits. Management practises and factors which could be relevant during the rearing period to stimulate feed intake and influence body development are then reviewed. Finally, implications for rearing strategies are discussed.

The development and growth of the kits in life depends on the birth weight. Birth weight is influenced in the prenatal period by the parity, re-mating interval and nutrition of the doe. Optimal growth and development of the foetuses is provided when the doe is multiparous, kept under a semi-reproductive rhythm (42 days) and not restricted in feeding level. In the pre-weaning period, milk intake of the kits seems to be the most important factor affecting body growth and development so breeding does should not be reared in litters larger than 8 or 9 kits. After weaning, the energy intake and dietary fibre level of the diet seem to be important factors to regulate body growth and development and stimulate feed intake capacity. There are indications that reproductive performance can be optimized by using rearing strategies focussed on stimulating feed intake capacity. Further research is needed to improve our knowledge of the effect of rearing strategies on subsequent reproduction.

RESUME : Méthodes d'élevage des lapines reproductrices : une revue

Les pratiques courantes actuelles, ne fournissent pas à la jeune lapine, au cours de ses premières portées, la couverture des importants besoins en énergie nécessaires pour mener une lactation et une gestation simultanées. Il en résulte un déficit nutritionnel, des performances de reproduction diminuées et un taux de remplacement élevé. La capacité de consommation semble le principal facteur limitant. Compte tenu des connaissances actuelles, il ne semble pas possible de résoudre ce problème de manière satisfaisante en adoptant des techniques d'élevage appropriées pendant la période de reproduction. La phase d'élevage semble la plus favorable pour agir sur le développement corporel et la consommation en vue d'optimiser les futures performances de reproduction puisque le développement maximal des organes et des tissus a lieu dans le jeune âge.

Cette revue commence par faire le point sur les données de la littérature concernant la croissance corporelle et le développement du lapin. Sont ensuite résumés les pratiques d'élevage et les facteurs les

plus efficaces pour stimuler la consommation afin d'influencer le développement corporel durant la période d'élevage. Enfin les différentes stratégies d'élevages sont discutées.

Le développement et la croissance des lapereaux vivants dépendent de leur poids à la naissance ; ce poids est influencé par la parité, l'intervalle entre saillies et la nutrition de la mère. Le développement et la croissance optimale du foetus sont atteints quand la mère est pluripare, maintenue à un rythme de reproduction moyen (42 jours entre 2 fécondations) et nourrie sans restriction. Dans la période précédant le sevrage, la consommation de lait par les lapereaux est le plus important des facteurs influençant la croissance et le développement et les femelles reproductrices ne devraient pas élever de portées supérieures à 8-9 lapereaux. Après le sevrage ce sont la consommation d'énergie et le taux de fibres de l'aliment qui semblent être les plus importants facteurs de développement corporel et de capacité de consommation. Il semble que les performances de reproduction peuvent être améliorées par des stratégies d'élevage adaptées, orientées vers l'accroissement de la capacité d'ingestion. Des recherches complémentaires sont nécessaires pour en préciser les effets sur la reproduction.

1 - INTRODUCTION

In modern rabbit production, the limited reproductive lifespan of rabbit does is seen as a welfare (BLOKHUIS, 1995) and economic problem. The average replacement rate of does on commercial rabbitries in the Netherlands in 1997 was estimated at 160% (SNOEK *et al.*, 1998), which indicates that, on average, a doe produced 4.4 litters. This replacement is mainly attributed to a high replacement of young does, caused by early death, diseases and reproductive problems (FORTUN-LAMOTHE and BOLET, 1995; MAERTENS, 1987; Xiccato, 1996).

Data collected at our Centre (not published) indicated that approximately 50% of the replacements occurred before the third litter was weaned; approximately 50% caused by death and diseases and 35% by reproductive problems (not pregnant after two successive matings, abortion, and dystocia). Prolongation of the reproductive lifetime of does is desired from welfare and economic points of view because it will reduce rearing costs. When the reproductive lifespan of the does is prolonged by one litter on average, the income of a rabbitry will increase with approximately 5,50 Dutch guilders per doe (calculations based on KWIN (SNOEK *et al.*, 1997).

not able to meet the high energy requirements for pregnancy and lactation during the first litters. During the first lactation a reduction of the body fat content and body energy levels is observed (FORTUN *et al.*, 1993; MILISITS *et al.*, 1996; PARIGI-BINI *et al.*, 1990, 1991). Does that are lactating and pregnant at the same time also display significant losses of nitrogen and minerals (XICCATO, 1996). The nutritional deficit is considered to be responsible for the decreased reproductive efficiency of young does. Feed intake capacity is reported to be the main limiting factor (XICCATO *et al.*, 1995; XICCATO, 1996).

Research on improving the energy balance and

performances of young does by increasing the dietary energy concentration of the diet (FORTUN and LEBAS, 1994; MAERTENS and DE GROOTE, 1988b; PARTRIDGE *et al.*, 1986; XICCATO *et al.*, 1992, 1995) and adopting a more appropriate re-mating interval has been reported (CERVERA *et al.*, 1993; FRAGA *et al.*, 1989; PARIGI-BINI *et al.*, 1996). It was concluded that the problem of energy deficit in productive young does could not be solved adequately in this way and that other approaches to the problem should be taken. Solutions such as genetic selection towards a higher intake capacity (MAERTENS, 1992) or an adapted rearing program to stimulate feed intake capacity (PARIGI-BINI and XICCATO, 1993) were recommended. Implementation of genetic selection towards a higher intake capacity is difficult to accomplish at commercial rabbitries. An adapted rearing program seems more suitable as a management practice.

In commercial rabbit production, breeding does are reared in the same way as meat rabbits. In order to develop an adapted rearing program for breeding does to cope with the problems during the first lactations, proper knowledge about body growth and development (including feed intake) of the rabbit and related management factors is crucial.

This article reviews literature on body growth and development of the rabbit, summarizing management practises and factors (Figure 1) which could be relevant during the rearing period to stimulate feed intake and influence body development, with the perspective to optimize subsequent (re)productive performance and for identifying gaps in knowledge.

2 - FEED INTAKE AND BODY GROWTH AND DEVELOPMENT OF ORGANS AND TISSUES FROM BIRTH TO MATURITY

In rabbits the development of body weight, organs and tissues occurs at different growth rates, most of them showing a high growth rate at an early age (see Figure 2).

2.1 Body growth

Under ad libitum feeding conditions, the rabbit's body weight follows a characteristic sigmoid curve (CANTIER *et al.*, 1969; DELTORO and LOPEZ, 1985; OUHAYOUN, 1984), in which the maximum absolute growth rate (inflexion point) is obtained around 6-7 weeks of age (CANTIER *et al.*, 1969; VICENTE *et al.*, 1988; OUHAYOUN, 1984) and final body size is reached at approximately 25-30 weeks of age (CANTIER *et al.*, 1969; OUHAYOUN, 1984, VICENTE *et al.*, 1988).

2.2 Organ and tissue development

As shown in Figure 2 the total development of most organs is characterised by two or three phases with different growth rates. Most organs/tissues have a high growth rate (before 12 weeks), especially those organs who are involved in energy

Figure 1: Influence of management factors during different phases of rearing on body development and feed intake in subsequent reproduction. (Numbers in parentheses refer to sections where the factors are discussed.)

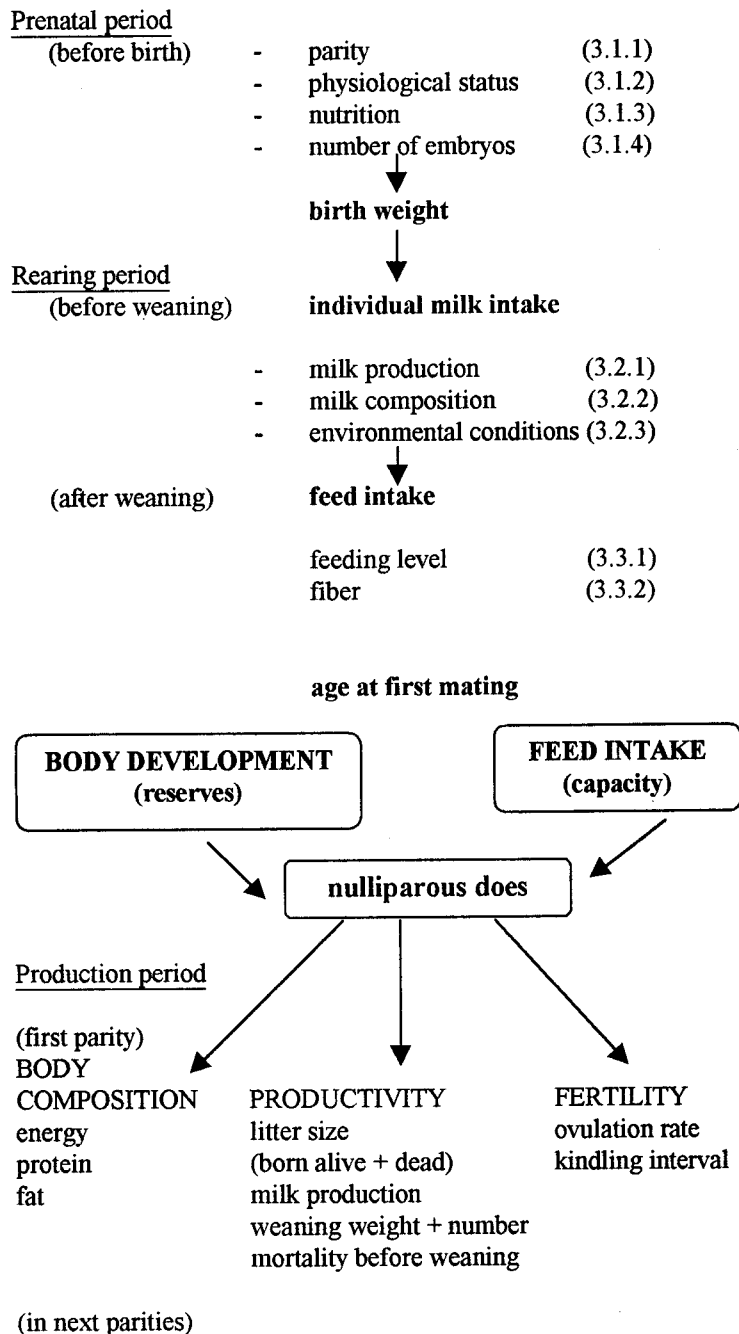
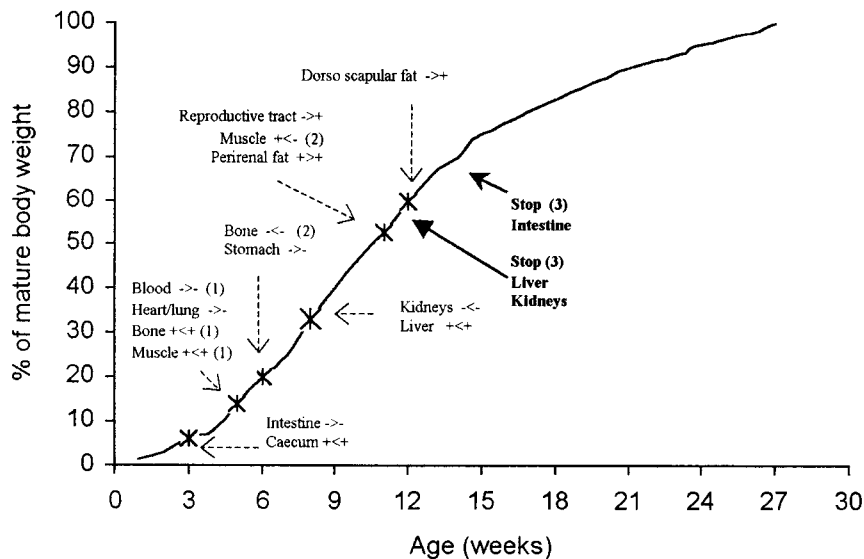


Figure 2 : Body growth and development of organs and tissues in the rabbit, according to CANTIER *et al*⁽¹⁾ (1969) and DELTORO and LOPEZ⁽²⁾ (1985).

✕ indicates the inflexion points of the growth coefficient of several organs and tissues. At the different inflexion points the concerning organs and tissues are given. + or - which indicates if the organ/tissue develops faster or slower than the whole body. < or > indicates if the development rate decreases or increases after the inflexion point, respectively.)⁽³⁾ Stop indicates when the organ has reached maximum size



metabolism for growth processes as the liver, kidneys and the digestive tract. The kidneys and the liver reach their maximum size around 12 weeks of age, long before final body weight is reached (DELTORO and LOPEZ, 1985).

The development of the chemical body composition (see Figure 3) reflects the development of the organs and tissues. Until approximately six weeks of age ash content shows a slight increase, corresponding the high growth rate of bones. Protein increases until approximately 10 weeks of age, when most of the muscle tissue has been formed. After 12 weeks of age perirenal and dorso-scapular fat depots are being formed, resulting in a rapid increase of fat and energy content of the body. The dry matter content increases with age, mainly through formation of protein and fat.

The growth rate of the reproductive organs starts to increase around 10 weeks of age. Sexual dimorphism in body composition does not appear before 15 weeks of age and is very small in rabbits (OUHAYOUN, 1984). Female rabbits show a greater level of fatness, due to a higher growth rate of fat depots in the second phase of growth (> 2100 gram, CANTIER *et al.*, 1969 ; >7 weeks of age, DELTORO and LOPEZ, 1985).

2.3 Voluntary feed intake

Voluntary feed intake is, in general, regulated by the energy requirement and determined by body weight and physiological state of the rabbit. The appetite regulation in rabbits is assumed to be controlled primarily by the blood glucose level in the same way as in other non-ruminants (CHEEKE, 1987). However, feed intake and appetite are also

affected by other factors, such as particle size, palatability, dietary energy concentration of the diet, and environmental temperature (CHEEKE, 1987).

The voluntary feed intake is proportional to metabolic weight ($W^{0.75}$). In growing rabbits, the voluntary feed intake is about 950 to 1000 KJ DE/day/kg $W^{0.75}$. The chemiostatic regulation appears only with a DE concentration of the diet higher than 9 to 9.5 DE MJ/kg (PARTRIDGE, 1986; LEBAS, 1989; SANTOMA *et al.*, 1989). However, this regulation seems not fully developed in young rabbits (4-6 weeks of age) (MORISSE, 1986).

Although the development of the digestive tract is finished around 25-30 weeks of age, feed intake capacity is still increasing during the first litters and levels off after the fourth litter at approximately forty weeks of age (CASTELLINI and BATTAGLINI, 1991).

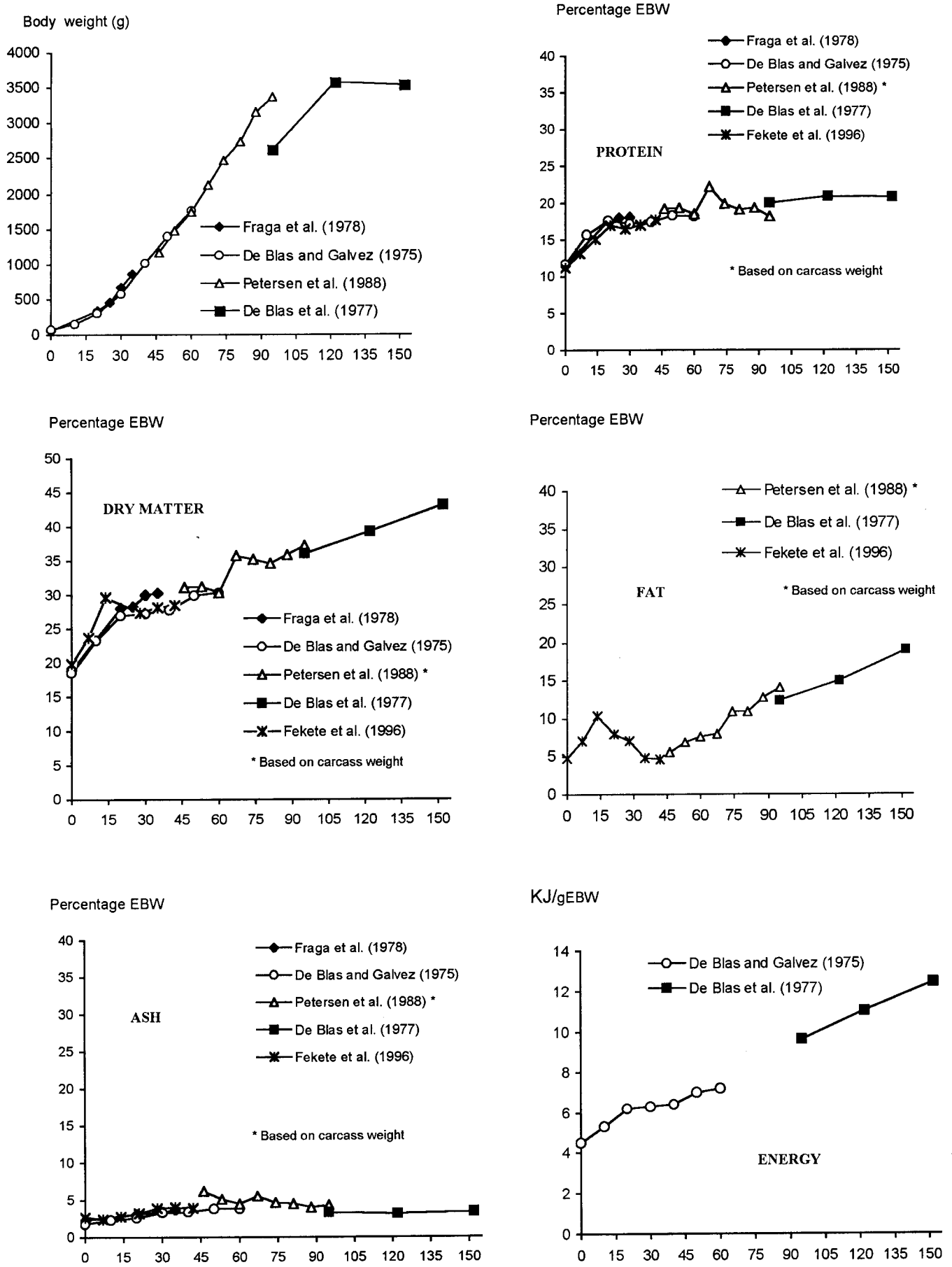
3 - FACTORS AFFECTING BODY GROWTH AND DEVELOPMENT

The high early growth rate of most organs and tissues indicates that the rearing period seems to be most adequate to influence body growth and development. In this section factors affecting body growth and development during the rearing period are reviewed.

The following stages are distinguished:

- 1) before birth (30-32 days)
- 2) from birth to weaning (28-35 days)
- 3) after weaning until first mating (from 28-35 days until approximately 15-17 weeks of age).

Figure 3 : The development of the chemical body composition in the rabbit : dry matter, ash, protein, fat and energy.



In the prenatal and pre-weaning stages maternal effects play an important role in survival and development of offspring. The embryos and suckling animals are highly dependent on their mothers for nutrient intake and environmental conditions; the gestation period is about one month (30-32 days) and, under commercial conditions, kits are weaned at 28 to 35 days.

A normal rearing period (from birth until first mating around 15 weeks of age) consists of approximately 30 % suckling and 70 % post-weaning period.

3.1 Prenatal stage and birth weight

The prenatal period is of importance because it will determine weight and body composition at birth. Both factors influence the development and survival during the pre-weaning period and therefore contribute to the development of the rabbit later in life. SZENDRÓ *et al.* (1996), VASQUEZ *et al.* (1997) and Ferguson *et al.* (1997) studied the effect of birth weight on performance of kits until 12 weeks of age. Heavier weights at birth (45.2 vs 63.8 g (SZENDRÓ *et al.*, 1996) and 57 vs 70 g (VASQUEZ *et al.*, 1997) resulted in heavier weights at 21 days (309 vs 389 g and 328 vs 368 g, respectively) and 12 weeks (2436 vs 2887 g and 3003 vs 3101 g, respectively) of age. SZENDRÓ *et al.* (1996) found the mortality rate was significantly lower (-12.6%) with birth weights ranging from 60-69 g compared to 40-49 g. Therefore birth weight seems to be an important factor explaining differences in growth performance.

Birth weight is influenced by several factors during the gestation period. Foetal growth is affected by the parity, physiological status, and nutrition of the doe, and the number and position of the young in the uterine horn.

3.1.1 Parity

PARIGI-BINI and XICCATO (1993) reported a 10% higher birth weight of kits born alive from multiparous does compared to primiparous does. VASQUEZ *et al.* (1997) reported that the kits of multiparous does were heavier at birth as compared to those of primiparous does. In their study the difference in birth weight between multiparous and primiparous does amounted +3.8 g (+6%). The lower birth weight of rabbits born at the first parturition is due to the fact that during the first pregnancy the does haven't finished their own body growth, and because the feed intake of the does is lower than thereafter (PARIGI-BINI *et al.*, 1992). In the second parturition, rabbits born from lactating does are lighter than rabbits born from non-lactating does as discussed below.

3.1.2. Physiological status

In rabbits, foetal-placental units and mammary glands use the same substrates such as glucose, long-chain fatty acids and free fatty acids (FRAGA *et al.* 1989, GILBERT *et al.*, 1984). Therefore in does that are concurrently pregnant and lactating, a competition between the uterus and mammary gland for nutrient supply will occur and this will influence foetal development and survival.

FORTUN *et al.* (1993) reported that in does mated immediately after parturition, foetal growth is reduced

(-19.6%) and late foetal mortality (>15d of gestation) is increased (+10%) in lactating compared to non-lactating primiparous does. GONDRET and FORTUN-LAMOTHE (1996) showed that the birth weight of the kits of does concurrently pregnant and lactating was lower (-9%) than the weight of kits of does who were only pregnant but this difference was not significant, which could be due to the small group size that was used (14 and 15 animals per treatment) and the relatively small difference between treatments.

Concurrent gestation and lactation also seems to affect muscular characteristics of the kits until 70 days of age (slaughter weight) (GONDRET and FORTUN-LAMOTHE, 1996). In their study with post-partum mated (PP) primiparous does, concurrent gestation and lactation seemed to cause a delayed myofibre maturation rate. However, at 70 days of age GONDRET and FORTUN-LAMOTHE (1996) did not find differences in myosin maturation.

3.1.3 Nutrition of the doe

The influence of feeding and/or energy level in the diet of does during gestation were studied by several authors (see Table 1).

Feeding level and energy content of the diet seem to influence prenatal conditions. In five studies, the level of feed intake was investigated. HAFEZ *et al.* (1967) investigated a low, medium and high level of a standardized balanced diet during gestation in nulliparous does and found a higher birth weight at medium and high feeding levels. However, COUDERT and LEBAS (1985) and PARIGI-BINI *et al.* (1992) found no effect of feeding level on average birth weight. PARIGI-BINI *et al.* (1992) reported that the number of kits born alive was improved (lower mortality rate at birth) at the higher feeding level.

FORTUN *et al.* (1994) demonstrated that a restricted maternal feed intake (75% of ad libitum) in non-lactating primiparous does significantly decreased foetal weights (-24.1%) and resulted in lower litter and kit weights after birth compared to ad libitum feeding.

In most studies, increasing the energy level of the diet did not affect total litter size, but resulted in an increased litter weight or average weight of the kits born alive. However, a higher energy level increased mortality at birth. No significant effect was found by XICCATO *et al.* (1995) possibly due to the limited number of does having a second parturition (7, 6 and 7 does, respectively).

Nutritional deficit also seems to affect the chemical composition of the foetuses. FORTUN *et al.* (1994) reported that in feed restricted primiparous pregnant does the foetal dry matter and protein percentage were decreased by -12.5% and -11.7%, respectively compared to ad libitum fed pregnant primiparous does.

HAFEZ *et al.* (1967) reported that restricted feed intake of the doe during gestation caused a reduction in hepatic glycogen of the kits (3.0, 3.1 and 4.5 mg/g of liver for respectively the low, medium and high feeding levels). It was suggested that hepatic glycogen provides a major source of energy to the neonates. It was stated that further studies were needed to evaluate the physiological significance of decreased hepatic glycogen values on neonatal survival.

Table 1 : Effect of feeding level and energy content in the diet during gestation on performances at parturition.

Reference	Diet energy content (MJ DE/kg DM)	Feeding level (g/day)	Parity	Litter size	Litter weight (g)	Kit alive average weight (g)	Mortality at birth (%)	Kits body composition
CERVERA <i>et al.</i> , 1993	13.0 11.4 10.5 9.7	Ad lib	N,P,M	NS	464a 421b 441b 436b	Not publ.	Not publ.	not publ.
COUDERT and LEBAS, 1985	not publ. (standard)	150 200	N,P,M	NS	Not publ.	NS	NS	not publ.
FORTUN <i>et al.</i> , 1994	9.7	75% Maint. ad lib	P		NS	44.4 ^a 55.5 ^b	NS	dry matter : 12,5% protein : 11.7% ash: NS fat: NS energy: NS
HAFEZ <i>et al.</i> , 1967	not publ. (standard)	57 140 280	N	NS	not publ.	36 55 54	Not publ.	fat: NS
PARIGI-BINI <i>et al.</i> 1992	11.1	75% ad lib	P	NS	382 ^a 549 ^b	NS	16.2 ^a 3.3 ^b	NS
PARTRIDGE <i>et al.</i> , 1986	12.9 14.8	Maint. Ad lib	M	NS	398 ^a 442 ^b	Not publ.	9 ^a 28 ^b	not publ.
VIUDES-de-CASTRO <i>et al.</i> , 1991	9.7 13.0	Ad lib	P	NS	NS	NS	9.3 ^a 22.0 ^b	not publ.
PARIGI-BINI <i>et al.</i> , 1996	10.4 11.2 (anim. fat)	Ad lib	P	9.1 ^A 7.7 ^B	NS	NS	3.2 ^a 9.1 ^b	NS
LEBAS and FORTUN-LAMOTHE, 1996	9.9 12.2 (starch) 12.2 (starch and fat)	Ad lib	N,P,M	NS	Not publ.	59.4 ^a 53.8 ^b 58.3 ^a	4.9 ^a 12.0 ^c 8.4 ^b	not publ.
XICCATO <i>et al.</i> , 1995	11.3 12.2 (starch) 11.9 (fat)	Ad lib	P	9.3 8.5 9.6	NS	58.8 65.2 64.6	32.2 44.7 55.2	fat + 7 g/kg energy + 0.3 MJ

means with different letters are significant different (AB: $p < 0.1$, ab: $p < 0.05$)
parity: N= nulliparous, P= primiparous and M= multiparous does

Body moisture and fat percentages of the kits was not influenced by the maternal feed intake (HAFEZ *et al.*, 1967), which is in agreement with PARIGI-BINI *et al.* (1992) and FORTUN *et al.* (1994).

Energy source does not seem to affect number of dead or live foetuses or foetal weight but does influence milk production. FORTUN-LAMOTHE and LEBAS (1996) and XICCATO *et al.* (1995) studied the effect of the source of energy addition, starch (maize of barley) and/or fat (sunflower oil and animal fat) on foetal growth and mobilisation of body reserves in concurrently pregnant and lactating rabbit does. Energy origin does not seem to affect the number of live or dead foetuses or foetal weight but does influence milk production of the doe.

HEIRD *et al.* (1987) studied the effect of a diet containing 6% fructose on litter size and weight, and kit liver weight.

Fructose is a major foetal blood sugar in many species of animals and, according to HEIRD, positive effects of fructose on the weight of new-borns were found in cows and sows. However, HEIRD *et al.* (1987) did not find any effect of fructose on litter size, litter weight or liver weight in rabbits. The authors suggested that fructose might not be used by the foetal rabbit.

3.1.4. Number of embryos and the position of the embryo in the uterine horn

The number of embryos and the position of the embryo in the uterine horns seem to affect the weight of the embryo at 30 days of pregnancy (BRUCE and ABDUL-KARIM, 1973; PALOS *et al.*, 1996). PALOS *et al.* (1996) reported that with an increase of the number of embryos the average weight declined (in the case of 1, 3, 6 or 9 embryos in one uterine horn; the average body weight at 30 days of pregnancy was

Table 2 : The effect of the energy content of the diet on milk production and litter weight at weaning. (Percentage increase is compared to the diet with the lowest energy level)

Authors	Energy content (MJ DE/kg DM)	Energy source	Milk production	Weight at weaning
BARRETO and De BLAS (1993) ¹	8.9 - 11.9	animal fat	not published	+ 15.6 %
CERVERA <i>et al.</i> (1993)	9.7 - 13.0	animal fat	+ 13.1 %	+ 19.2 %
FRAGA <i>et al.</i> (1989)	9.7 - 13.0	animal fat	+ 23.5 %	not published
LAMB <i>et al.</i> (1984)	10.6 - 15.4	not published	not published	NS
LEBAS and FORTUN-LAMOTHE, (1996)	9.8 - 12.1	starch starch and vegetable fat	- 8.1 % NS	NS NS
MAERTENS and De GROOTE, (1988b)	9.7 - 11.9	not published	+ 6.8 %	+ 9.5 %
PARIGI-BINI <i>et al.</i> (1996)	10.4 - 11.2	animal fat	+ 7.0 %	+ 7.3 %
PASCUAL <i>et al.</i> (1998) ²	11.0 - 12.4 12.2	vegetable fat animal fat	+ 13.7 % + 6.6 %	+ 9.6 % NS
XICCATO <i>et al.</i> (1995)	11.3 - 12.2 11.9	Starch starch and animal fat	NS + 11.7 %	NS NS

1 Difference in weaning weight was only found when the fat added diet was compared to the low energy diet with the highest crude fibre level (169 g CF/kg DM).

2 Effects on performance of multiparous does are presented. Similar effects of the diet were found during first lactations.

45.4, 40.7, 38.1 and 31.7 g, respectively). Independent of the number of embryos, the largest embryo was to be found at the ovarian end of the uterine horn. The smallest embryo was found near the cervical end of the uterus. Bruce and ABDUL-KARIM (1973) reported that the placental blood flow appeared to be greater in the conceptus adjacent to the ovary. Furthermore, Duncan (1969) showed that in 27-29 day pregnant rabbits, foetal weight, placental weight and placental blood flow were greater in the conceptus at the ovarian end of each uterine horn than in conceptus at intermediate or vaginal end positions.

3.2 The pre-weaning period

The nutrient intake of rabbit kits during the first three weeks of their life comes from the doe's milk. The individual milk intake therefore contributes to their growth and development as well as their survival before weaning. Milk intake of the kits is strongly dependent on the size of the suckling litter and the milk production of the doe. Milk production is affected by a great number of factors, such as: breed (MCNITT and LUKEFAHR, 1990) or strain (VICENTE and GARCIA-XIMÉNEZ, 1992), and individual doe differences (MCNITT and LUKEFAHR, 1990). Other important factors are parity, the physiological state of the doe influenced by the re-mating interval (concurrently pregnant or not), the chemical composition of the diet and the feed intake level of the doe (MAERTENS, 1992). Milk composition could also be relevant for the development of the kits during the pre-weaning period. Environmental conditions such as pre-weaning management can influence milk intake and therefore affect body growth and development of the kits.

3.2.1 Milk production of the doe

The milk production of the doe is affected by factors, such as remating interval, parity, nutrition of the doe and litter size. The influence of these factors on milk production have been described by several authors.

To determine milk production, different methods can be used, such as weighing of the doe before and after suckling (FRAGA *et al.*, 1989; MAERTENS and DE GROOTE, 1988b; XICCATO *et al.*, 1995), weighing of the litter before and after suckling (PARIGI-BINI *et al.*, 1996) and litter weight or growth at 21 days (LEBAS and FORTUN-LAMOTHE, 1996; CERVERA *et al.*, 1993). In general the 21-day litter weight is considered an adequate expression of lactation performance (LEBAS, 1969; LEBAS *et al.*, 1986; MAERTENS, 1993).

The milk production of the doe depends on the day of lactation and increases until the end of the third week of lactation (KUSTOS *et al.*, 1996; LEBAS *et al.*, 1986; MCNITT and LUKEFAHR, 1990). The maximum milk yield reaches nearly 300 gram milk per day (MAERTENS and DE GROOTE, 1991).

- Remating interval:

Several authors (BARRETO and DE BLAS, 1993; CERVERA *et al.*, 1988 and 1993; FRAGA *et al.*, 1989; KUSTOS *et al.*, 1996; LAMB *et al.*, 1984; LEBAS, 1972; MAERTENS and DE GROOTE, 1991; MENDEZ *et al.*, 1986; PARIGI-BINI *et al.*, 1996) studied the effect of re-mating interval on doe performances including milk production, litter weight at weaning and kit survival using re-mating intervals such as 1, 9-10, 21, 25 or 28 days PP and non-pregnant does.

The remating interval determines the physiological status of the doe and this mainly affects the decline in milk

Table 3 : Effect of DP/DE ratios in the diet on milk production, weight at weaning and mortality before weaning.

Authors	DP to DE ratio (g/MJ)	Milk production*	Weight at weaning: litter (kg) or kit (g)	Mortality (%)
CERVERA <i>et al.</i> (1988)	10.1	1.832 ^{b(1)}	3.668	36.3 ^a
	10.9	1.942 ^{ab}	3.412	18.5 ^b
	12.7	2.021 ^{ab}	3.905	27.2 ^{ab}
	13.0	2.083 ^a	4.158	24.8 ^{ab}
FRAGA <i>et al.</i> (1989)	12.4	2.30 ⁽¹⁾	not published	19
	13.3	2.38		18
	13.9	2.35		24
MAERTENS and De GROOTE (1988a)	11.4 ⁴	301 ^{a(2)}	606 ^a	19.4
	13.7	325 ^b	671 ^b	10.3
	11.4 ⁵	399 ^a	717 ^a	3.4
	13.7	423 ^b	744 ^b	2.2
MENDEZ <i>et al.</i> (1986)	10.3	2.083 ⁽¹⁾	4.846	7.4
	13.3	2.197	5.174	10.5
SANCHEZ <i>et al.</i> (1985)	17.1 ⁶	2.55 ⁽¹⁾	3.99	11.7
	18.4	2.78	4.38	8.0
	20.2	2.69	4.12	11.9
XICCATO <i>et al.</i> (1992)	11.2	167.8 ⁽³⁾	4.717	5.8
	12.5	174.9	4.997	3.4

* Milk production determined by ⁽¹⁾ weight of litter (kg) or ⁽²⁾ kit (g) at 21 days or ⁽³⁾ weighing of does before and after suckling (g)

a,b Means with a different letter are significantly different ($p < 0.05$)

⁽⁴⁾ First parturition; ⁽⁵⁾ Does with four consecutive litters after first parturition; ⁽⁶⁾ Based on crude protein instead of digestible protein

production after the maximum milk production and thus influences the total amount of milk produced.

In only two of the studies was an effect of remating interval on milk production found before the decline (first 21 days of lactation). However the results were not in agreement. CERVERA *et al.* (1988) found a small effect of remating interval on average litter weight at 21 days of age only for larger litters (8-9 kits). Litter weight of eight or nine kits was reduced by 8% ($p < 0.05$) for the 25 days PP remating interval compared to 1 and 9 days PP. MENDEZ *et al.* (1986) found a positive effect of a re-mating interval of 25 days PP compared to 1 day PP. Litter weight at 21 days was increased with 12.5%, whereas no differences in milk production were found between 1 and 9 days PP.

The decline in milk production is faster in PP pregnant does than in non PP pregnant (MAERTENS and DE GROOTE, 1991) or non pregnant does (KUSTOS *et al.*, 1996; LEBAS, 1972). LEBAS (1972) and MAERTENS *et al.* (1988) observed a large difference in daily milk production after 18 days of lactation between kits whose mother was PP pregnant or not. MAERTENS *et al.* (1988) reported that, although the kits compensated for the lower milk production by increasing their solid feed intake, a 4% lower weight at weaning was

found compared with kits from non PP pregnant does. In the same way, FRAGA *et al.* (1989) stated that during late lactation (21-28 days PP) the milk yield of PP pregnant does was significantly lower than in non-pregnant does and in does mated 9 days PP (0.70 vs 1.14 kg on average, respectively).

In most studies different weaning ages were used for the different remating intervals, which makes it difficult to draw conclusions about the effects of re-mating interval on weaning weight or mortality rate. Only LAMB *et al.* (1984) and PARIGI-Bini *et al.* (1996) used the same weaning age (28 days) for the different re-mating intervals (PP vs 21 days PP (LAMB *et al.*, 1984); 10 days PP vs 28 days PP (PARIGI-BINI *et al.*, 1996)). No effect of re-mating interval on weaning weight and the number of kits weaned was found in their studies.

-Parity:

The total milk production is affected by the lactation number. VICENTE and GARCIA-XIMÉNEZ (1992) observed significant differences during all lactating weeks between primiparous and multiparous does, which could not be explained by different litter sizes. In their study, the lower

lactation performance of the primiparous does (1931 vs. 2197 g, litter weight at 21 days) also negatively affected the growth of the litters during the fattening period. Maertens and DE GROOTE (1988b) stated that difference in weaning weight between primiparous and multiparous does might be caused by the limited feed intake capacity during first lactation. According to MCNITT and LUKEFAHR (1990) parity tended ($p < 0.1$) to influence lactation yield, increasing steadily through the seventh parity and declining thereafter.

- Nutrients in the does ration:

The effect of energy content on milk production and weight at weaning is reported in several studies (see Table 2). The source of feed stuff used to increase energy level varied in these studies (animal or vegetable fat, starch).

In general it seems that an increase in energy concentration of the feed increases milk production and/or weight at weaning. This effect seems to be related to the increase in dietary energy intake of the doe. This was found in most studies, except for PARIGI-BINI *et al.* (1996), LEBAS and FORTUN-LAMOTHE (1996), and XICCATO *et al.* (1995) when additional energy came from starch only. According to FORTUN-LAMOTHE (1997) addition of fat to the diet increases the digestible energy intake of the rabbit does (231 kJ per day /1% increase in ether extract). The additional energy intake is used for milk production and leads to heavier weights at weaning (+2.1% for each 1% increase in ether extract).

XICCATO *et al.* (1995) reported that, although statistically not significant, the new-born kits from does fed high-energy diets (starch and fat) seem to have higher birth weights (+6.1 g) but lower body energy (- 0.3 MJ/kg) and lipid contents (- 7 g/kg).

The DP to DE ratio also affects milk production. A ratio of 11.5 to 12.5 g DP/MJ DE is recommended (XICCATO, 1996). In general, lower DP to DE ratios lead to a decrease in milk production as shown in Table 3. Protein excess, however, is not favourable because it increases the risk of digestive problems of the doe (MAERTENS, 1993; XICCATO, 1996).

The amino acid requirements for reproducing does have not been clearly established (XICCATO, 1996). There is only limited information on the effect of amino acids on milk production. Maertens and DE GROOTE (1988a) investigated the effect of the lysine content of the diet on reproductive performance. No effect of lysine on milk production was found. However, in primiparous does an increased mortality rate before weaning was found (28.6% vs 19.4%) in does fed a diet with a high lysine (0.91%) and high P/E ratio (13.9) compared to a low lysine (0.69%) and low P/E ratio (11.4) diet. In the second and following litters no effect of the lysine content on the mortality before weaning was found but mortality was still increased in the high P/E ratio diet.

Fibre is needed in the diet to prevent digestive problems. A crude fibre concentration > 11.5% is recommended in the diet of reproductive does (MAERTENS, 1993). Altering the

fibre level in the diet often results in a change of the energy level and protein/energy ratio in the diet and therefore can affect milk production as demonstrated by BARETTO and DE BLAS (1993). An increased dietary fibre content (23.8 vs 18.0% ADF) of the diet given during reproduction decreased energy digestibility and thus digestible energy content. Although feed intake was increased and DE intake was not affected, kits' weight at weaning was significantly decreased (453 vs 507 g). A similar effect, although not significant, was reported by MENDEZ *et al.* (1986).

However, an excess of dietary fibre is not desirable because increasing fibre results in a decrease in the DE content and a high protein/energy ratio commonly results. Such a situation is favourable for the proteolytic micro-flora in the caecum to produce ammonia with an increasing risk of digestive disorders (DE BLAS *et al.*, 1981; Lebas, 1989). A lower level of fibre as recommended will increase the DE intake, but will also negatively influence the retention time of the digesta in the caecum inducing an increased caecal volume and protein level. This caecal disequilibrium favours the utilisation of protein as an energy source with deamination and increased ammonia production and increases the risk of digestive problems (CARABAÑO *et al.*, 1988).

- Litter size:

In rabbits, the number of suckling kits seems to influence the milk production. MCNITT and LUKEFAHR (1990) reported that milk production increased as the number of kits increased with a plateau at 12 kits, depending on breed. Also CERVERA *et al.* (1988) found a higher milk production (+57.4% at 21 days PP) when litter size increased from 1-4 to 8-9 kits per litter. However, this effect was much smaller (+13.8%) when litter sizes of 5-7 kits were compared with 8-9 kits, which is in agreement with KUSTOS *et al.* (1996) and MOHAMED and SZENDRŐ (1992). KUSTOS reported only a slight effect on milk production of litters equalized at 6, 8 or 10 kits, whereas MOHAMED and SZENDRŐ (1992) found a 5.5% increase between litters of 6 and 10 kits.

3.2.2 Milk composition

New-born rabbits have low body-energy reserves, low thermal isolation and high energy requirements. Therefore a positive relationship between kit viability and milk intake could be expected (FRAGA *et al.*, 1989).

Rabbit milk contains approx. 30% dry matter. On a dry matter basis the milk contains approximately 49% protein, 39% fat, 3.2% lactose and 8.5% ash (MAERTENS, 1993).

The milk composition, with the exception of lactose, is influenced by the lactation stage (CHRIST *et al.*, 1996, EL-SAYIAD *et al.*, 1994; KUSTOS *et al.*, 1996; PARTRIDGE *et al.*, 1983), parity (CHRIST *et al.*, 1996) and the physiological status of the doe. In general, dry matter, protein and fat increase at the end of the lactation (>21 days PP) through a decline of the total milk yield, which is faster in PP-pregnant than in non PP-pregnant lactating does. The levels of lactose are nearly constant during lactation, probably because lactose is one of the main constituents concerned in maintaining constancy of the osmotic properties of milk

(EL-SAYIAD *et al.*, 1994). According to EL-SAYIAD *et al.* (1994) milk composition is not influenced by breed (New Zealand White vs Californian).

Milk composition can be influenced by the diet of the doe. Studies were performed (FRAGA *et al.*, 1989, Lebas *et al.*, 1996, CHRIST *et al.*, 1996) to investigate the effect of increasing dietary fat on fat content and fatty acid composition of the does' milk. When fat was added to the diet, the level of unsaturated fatty acids in the milk fat increased, whereas the fat content of the milk was not significantly affected. FORTUN-LAMOTHE (1997) reported that although a positive effect of fatty acid composition of does milk on the survival of the kits was hypothesized, no effect was found in the experiments reviewed.

In contradiction with others, LEBAS *et al.* (1996) reported that the diets with increased energy levels induced a significantly lower protein content of the milk. The dietary energy source influenced the lipid content as well as the milk fatty acid proportions. In the milk of does in which the dietary energy level was increased by addition of vegetable oil instead of starch the lipid content of the milk tended to be higher and there was an increase in the proportion of long-chain fatty acids in the milk. The diet containing oil led to the highest kit weights, whereas the diet containing starch led to the lowest kit weights. According to the authors, the main explanation for the growth difference of the kits was probably an increase in the milk production instead of the modification of the milk composition.

3.2.3 Environmental factors

- Maternal behaviour:

The maternal behaviour of the doe affects nest building (thermo-isolation) and suckling of the kits. Does nurse their young only once daily (HUDSON *et al.*, 1996) and teat order specificity does not exist in rabbits (HUDSON and DISTEL, 1983). Although it is generally assumed that does suckle their kits only once a day, behavioural studies (WASSERZIER *et al.*, 1997) indicated that does enter their nest more than once a day.

According to MOHAMED and SZENDRŐ (1992) nursing behaviour of the doe is also influenced by litter size. They reported that does with smaller litters (6 kits) spend a longer time (+15%) in the nest box than those nursing larger litters (10 kits). Although this phenomenon was not explained by the authors, it could be related to the eagerness of the doe to be released of the milk pressure, which could be increased because of the reduced number of suckling kits.

- Pre-weaning management:

In general, there are two main rearing strategies during the suckling period: does are given free access to the nest box or they are only allowed to enter the nest box (and suckle their kits) once a day. MAERTENS *et al.* (1988) reported that a separate housing of the does and litters gave significantly lighter weights at 21 days. At weaning this difference reached more than 10% in comparison with does housed together with their litters. Post weaning mortality was also much higher in litters which were separately housed before weaning (8.4% and 14.9% for "free access of doe" and "separately" reared litters, respectively). Because

does enter their nest more than once a day (WASSERZIER *et al.*, 1997), it is possible that the kits can consume more milk than when the doe only gets access to the nest box once a day.

- Litter size:

The number of suckling kits affects the individual milk intake of the kits and influences body growth (LEBAS, 1969). In smaller litters (<9 -10 kits) there are more teats than kits available. Because rabbit kits do not have their own teat but switch between teats, in smaller litters have more chance to suck more teats or spend more time switching teats searching for the most productive one (HUDSON *et al.*, 1996) and therefore consume more milk. In several studies a decreased daily weight gain was found with increasing litter size (MOHAMED and SZENDRŐ, 1992; RAO *et al.*, 1977; SZENDRŐ, 1996; VICENTE and GARCIA-XIMÉNEZ, 1992; ZIMMERMANN *et al.*, 1988) and in some studies the viability of the kits was also decreased (SZENDRŐ, 1996; VICENTE and GARCIA-XIMÉNEZ, 1992).

BABILE *et al.* (1982) observed that litter size in the pre-weaning period not only affected body growth but also influenced subsequent reproduction performance. Kits reared in litters of five were significantly heavier at 120 days of age than kits raised in litters of 11 kits (3442 vs 3097 g, respectively). Although the weight at 120 days did not affect receptivity, there was a tendency for an improved total litter size and number of kits born alive and a significantly increased number of kits weaned for does raised in the small litters.

- The number of teats of the doe:

The number of teats might also influence milk production. Milk intake per kit increased by about 10% for does with ten nipples compared to those with eight (MOHAMED and SZENDRŐ, 1992).

3.3 After weaning

After weaning, body growth and development are influenced by several factors, such as environmental conditions (temperature, housing density) and nutrition (feed intake level and composition of the food). This section will focus on feeding strategies to stimulate feed intake and body development.

3.3.1 Feeding level

In general rabbits are fed ad libitum until slaughter weight (approximately 2,5 kg live weight) is reached. Studies on the effect of feed restriction of fattening rabbits were initiated to decrease the high losses of weaning rabbits caused by diarrhoea (Maertens and PEETERS, 1988) and to improve the performances during fattening (McNITT and MOODY, 1991; SCHOLAUT and LANGE, 1990; SZENDRŐ *et al.*, 1988). In general, restricted feeding during the fattening period leads to a decreased daily weight gain and a better feed efficiency. However, the better feed conversion is partly false, because the comparison with ad libitum feeding is often made until the same finishing age instead of the same finishing weight is reached and therefore measured in a more favourable weight range.

There is only limited information on the effect of feed restriction and re-alimentation on the development of organs and tissues (FERREIRA and CARREGAL, 1996; LEBAS and LAPLACE, 1982; LEDIN, 1984; Maertens and PEETERS, 1988; PERRIER and OUHAYOUN, 1996). In all these experiments body growth was decreased during feed restriction. Feed restriction mainly affected the weight of the liver (decrease). An early restriction (at 4 weeks of age) affected caecal traits (increased pH and inverted ratio of propionic and butyric acid proportion) which favour conditions for pathogenic agents (MAERTENS and PEETERS, 1988).

Feed restriction at early age (5-8 weeks) seemed to delay skeletal development, whereas at a later age (8-11 weeks) the effect was to hinder the formation of fat deposits (PERRIER and OUHAYOUN, 1996).

During feed restriction, feed digestibility was increased and, according to LEDIN (1984), this effect remained after the feed restriction was ended. When feed restriction was followed by a less restrictive or ad libitum feeding level, feed intake and body growth were increased and compensatory growth took place. LEDIN (1984) suggested that if a restriction is followed by a higher (but still restricted) feeding level, priority is given to the development of the internal organs, especially the liver. Only if there is an excess of nutrients during the first part of the re-alimentation period, will compensatory growth of other soft tissue take place. LEDIN (1984) stated that in his experiments the animals were trying during re-alimentation to correct for the deviation from normal body composition caused by the restrictions and that this would have occurred, if the experiments were prolonged.

HARTMANN and PETERSEN (1995, 1997) showed that feed restriction during the rearing period had a positive influence on body weight gain as well as production performance in the reproduction period. Although feed restriction during the rearing period resulted in a lower body weight and delayed first matings, after the first parturition the restrictively reared does had reached the same body weight as the non restrictively reared group. At the second and third parturitions the restrictively reared does were even heavier than the non restrictively reared does. A positive effect was found on reproductive performance from the second litter onwards. The number of kits born in the second litter was increased by 1.4 kits and the litter weight at 21 days of lactation was increased in the second (+0.8 %) and the third (+ 6.4 %) litters.

In young female rabbits and non-lactating does restricted feeding is used to reduce feed costs and prevent obesity. Several authors studied the effect of a feed restriction in the late rearing period (10-12 weeks to 16-18 weeks of age) on the fertility of young does and the production performance during their first litter (COUDERT and LEBAS, 1985; VAN DEN BROECK and LAMPO, 1977 and 1979; MAERTENS, 1984). Feed restriction mainly influenced the age of the first fertile mating. However, this negative effect was diminished, when does were flushed for 5 to 7 days before the first mating. COUDERT and LEBAS (1985) and MAERTENS (1984) found a negative effect of feed restriction on the number of

kits born alive in the first litter. However, COUDERT and LEBAS (1985) did not find any effect on later production performance.

3.3.2. Dietary fibre level

Dietary fibre plays an important role in the diet of the rabbit because it influences the caecal microbial activity. An inadequate nutrient supply (especially fibre) can cause caeco-colic digestive disturbances, resulting in diarrhoea and mortality (GIDENNE, 1997). However, the dietary fibre level also affects the digestibility of the other nutrients in the diet (DE BLAS *et al.*, 1986; GIDENNE, 1987, 1997; Hoover and HEITMANN, 1972; NIZZA *et al.*, 1997; MAITRE *et al.*, 1988; ORTIZ *et al.*, 1989; PARIGI-BINI *et al.*, 1994; SPREADBURY and DAVIDSON, 1978) and can influence growth rate (HOOVER and HEITMANN, 1972; GIDENNE, 1987, 1997; MAITRE *et al.*, 1988) and chemical body composition (especially fat content) in the growing period (PARIGI-BINI *et al.*, 1994; SPREADBURY and DAVIDSON, 1978). Growth rate is not influenced, if the composition of the diet is adjusted to supply an adequate amount of energy, protein and other essential nutrients (ORTIZ *et al.*, 1989; PARIGI-BINI *et al.*, 1994; SPREADBURY and DAVIDSON, 1978).

The dietary fibre level can be used during the rearing period to stimulate stomach development (DE BLAS *et al.*, 1986; PARIGI-BINI *et al.*, 1994) and therefore increase feed intake capacity in the reproduction period. In the growing period, increased dietary fibre levels resulted in a higher passage rate of digesta through the digestive tract (DE BLAS *et al.*, 1986; GIDENNE, 1987) and increased feed intake because of the rabbit's ability to compensate for the digestible energy intake (PARIGI-BINI *et al.*, 1994). In several studies increased empty stomach weights were found at increased fibre levels (DE BLAS *et al.*, 1986; PARIGI-BINI *et al.*, 1994), which could be explained by an adaptation to a greater weight of feed and/or the greater weight of soft faeces in the stomach of rabbits fed fibrous diets (DE BLAS *et al.*, 1986).

NIZZA *et al.* (1997) and XICCATO *et al.* (1999) found a positive effect of an increased fibre level in the diet during the rearing period on feed consumption during reproduction. They also reported a tendency for an increased feed intake of the does raised on the fibrous diet (119.1 vs 110.3 g/d/kg LW^{0.75}) during the successive lactations, resulted in a higher DE intake (1.26 vs 1.17 MJ/d/kg LW^{0.75}). XICCATO *et al.* (1999) found that does raised on a high fibre diet (19.9% vs 15.5%) ate 10 kcal.d⁻¹. kg LW^{0.75} more and lost less body fat (-405 vs 504 g) and body energy (-3,628 vs -4,294 kcal).

NIZZA *et al.* (1997) reported that the increased feed intake did not affect fertility rate and number of kits born alive, but tended to improve the litter weight at 21 days (2685 vs 2584 g), the number of kits weaned (8.04 vs 7.69) and the weight of the kits at weaning on day 35 (923.7 vs 898.1 gram).

4 - IMPLICATIONS FOR REARING STRATEGIES

The current rearing strategies for does do not necessarily

prepare the animals well enough for the reproductive period, considering the nutritional deficits, decreased reproductive performance and high replacement rates. There are many factors during the rearing period that influence body growth and development, but not all of these factors seem equally suitable. From the literature reviewed, it seems that in all stages of the rearing period nutrition is an effective factor to regulate and control body growth and development.

Birth weight influences later body growth and development in life. Birth weight can be manipulated by affecting the nutrient supply of the foetuses in the prenatal period. Nutrient supply of the foetuses is influenced by the parity, re-mating interval and nutrition of the doe. There are indications (XICCATO *et al.*, 1995) that feeding an increased energy level to the doe during gestation might increase mortality rate at birth. Therefore, parity and re-mating interval of the doe seem to be the main factors to influence birth weight. Optimal growth and development of the foetuses can be provided when the doe is multiparous, kept under a semi-intensive reproductive rhythm (42 days), and not restricted in feed/energy intake.

In the pre-weaning period, the first three weeks of life, the nutrient intake of the kits mainly consists of the doe's milk. Total milk production of the doe can be stimulated by increasing the energy level of the diet. Research is focusing on the effect of fat addition in the diet on energy intake and milk production of lactating does. Individual milk intake can be stimulated by reducing the number of suckling kits. According to BABILE *et al.* (1982) reproductivity is positively influenced, when the reproducing doe is reared in a small litter. However, to our knowledge there is no information on the effect of litter size (milk intake) during the pre-weaning period on further body development and feed intake capacity.

After weaning, dietary feed/energy level seems to be an important factor to regulate body growth and development. In modern rabbit production, does are given free access to a concentrated diet and body growth and development are stimulated to a maximum. If feed restriction is applied, it is often started at 10 to 12 weeks of age to prevent excessive formation of fat depots. According to the literature reviewed, the development of the reproductive organs is characterised by a high growth rate after 10 weeks of age so severe feed restriction in this period does not seem advisable from this point of view. Based on the pattern of body development, it seems more logical to start feed restriction at an earlier phase. However, restriction before six weeks of age seems inadvisable because it will delay skeletal development (PERRIER and OUHAYOUN, 1996) and negatively affects caecal development (MAERTENS and PEETERS, 1988). Between 6-10 weeks of age, feed restriction will hinder fat deposition (PERRIER and OUHAYOUN, 1996) and will delay muscle development. By increasing the feeding level from 10 weeks onwards compensatory growth will take place, mainly in terms of muscle development, with an increased feed efficiency. According to LEDIN (1984) the animals will try to correct for the deviation from normal body composition during re-alimentation. By prolonging the rearing period, it should be possible to create a mature animal with a low fat content that might be better adapted to

meet the high demands during the subsequent reproduction period. There are indications (HARTMANN and PETERSEN, 1995 and 1997) that restricting the feeding level from six weeks onwards has a positive effect on body growth and productivity during the reproductive period, but information on the effect on body composition is missing. Except for the effect on the feeding/energy level the addition of fibre in the diet during the rearing period also seems to be a method to optimize subsequent (re)productive performance (NIZZA *et al.* 1997; XICCATO *et al.*, 1999).

More research is needed to improve our knowledge of the effect of rearing strategies on body development, feed intake capacity in subsequent reproduction.

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