Strategies for rearing of rabbit does

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Abstract

This thesis describes strategies for rearing of young rabbit does with the objective to improve reproductive performance and prolong lifespan. Body development during rearing was considered the main factor to influence subsequent reproduction. Body development was manipulated by feeding level during rearing (ad libitum or restrictive) and age of first insemination (14.5 and 17.4 weeks) and was determined at the end of rearing by body weight and body composition. Does fed restrictively and inseminated at 14.5 weeks of age were too immature for reproduction. In these does, body weight was low (3.2 kg), protein development was not completed, and puberty characteristics were poor. An optimum body weight at first insemination was found (around 4 kg) to optimize litter size. At 14.5 wk of age and ad libitum feeding during rearing, over 70% of the does did not reach optimal body weight of 4 kg. Litter size of these does was reduced by 1.4 kit. At 17.5 week of age and ad libitum feeding during rearing, more than 75% of the does weighed at least 4 kg. However, heavy does were fatter, had a lower feed intake in the first gestation period, and the number of does with stillborn kits was increased. In restrictive fed does inseminated at 17.5 week of age, 60 to 80% of the does weighed around 4 kg, and the number of kits born alive was increased compared to does fed ad libitum during rearing and inseminated at 14.5 or 17.5 weeks of age. Milk production was influenced by the feeding strategy during rearing. Restrictive fed does inseminated at 17.5 week of age produced more milk than ad libitum fed does inseminated at the same age. This could be explained by the fact that restrictive fed does had not formed excessive fat depots at 17.5 week of age and had a higher feed intake as ad libitum fed does at the same age. Ad libitum fed does inseminated at 14.5 week of age, gained weight in the first gestation and first lactation period. Competition for nutrients between body growth and production must have occurred, and resulted in smaller litters and lower milk production than restrictive fed does inseminated at 17.5 week of age. Based on the results in this thesis it was concluded that young does should have a body weight around 4 kg at first insemination to optimize litter size. Feed restriction during rearing increased uniformity in body weight among does and stimulated feed intake in the first gestation period. The best reproductive performance in the first parity was obtained in does restrictively fed and inseminated at 17.5 week of age. Rearing strategies only affected body weight development, feed intake in the first parity. Long-term effects over three parities were absent and culling rate of does was not affected.

CONTENTS

GENERAL INTRODUCTION

INTRODUCTION

In the Netherlands, commercial rabbit production is a small branch of the livestock industry aiming at the production of rabbit meat. The numbers of rabbit breeders and rabbits have declined over 50% in the last decade. In 2001, 184 farms were registered, with a total population of 49.000 does and 334.000 meat rabbits (LEI and CBS, 2002). In 2003, the average total production per doe was estimated at 124 kg of market weight meat rabbits (Applied Research Animal Sciences Group of Wageningen UR, in press).

The breeding, reproduction, and meat production usually takes place within one rabbitry. On most farms, does and meat rabbits are housed in separate compartments. There is not a clear distinction made between does used for breeding and those for reproductive purposes. At weaning, female kits necessary for replacement of does are selected from the litters present. The number of kits selected depends on the average replacement rate of does at the farm. After weaning, these kits are reared until 11 to 12 weeks of age at the same housing and feeding conditions as meat rabbits. About three weeks before the first insemination, the young does are housed individually.

A farmer will strive for a maximum profit. This is reached by maximum meat production at minimum costs. As the keeping of does represents an important cost factor, the total number of meat rabbits produced per doe has a great influence on the profitability. The production is influenced by factors such as genetics, housing conditions, and management. Maximum profit can only be achieved when the animals are in good health. From economic and welfare point of view, low mortality rates are desired for meat rabbits as well as for does.

REPRODUCTIVE PROBLEMS OF YOUNG DOES

The average replacement rate of does on commercial rabbitries in the Netherlands was estimated at 170% in 2003 (Animal Sciences Group of Wageningen UR Applied Research, in press). This replacement is mainly attributed to a high replacement rate of young does, caused by early death, diseases, and reproductive problems (Fortun-Lamothe and Bolet, 1995; Maertens, 1987; Xicatto, 1996; own data collected at our

Centre, not published). This high replacement rate has been reported as a welfare problem in commercial Dutch rabbit production (Blokhuis, 1995).

During the last decade, research has focussed on the energy metabolism of young does, that are concurrently lactating and pregnant (Fortun et al., 1993; Parigi-Bini et al., 1990, 1992; Xicatto et al., 1992, 1995). The main conclusion was, that young does were unable to meet the high energy requirements for pregnancy and lactation during the first litters. A reduction of fat content and body energy levels is observed during first lactation (Fortun et al., 1993, Milisits et al., 1996; Parigi-Bini et al., 1990, 1991). Does, who are concurrently lactating and pregnant display significant losses in nitrogen and mineral levels (Xicatto, 1996). Feed intake is reported to be the main limiting factor (Xicatto et al., 1995, 1996). The nutritional deficit is considered to be responsible for the decreased reproductive efficiency of young does. Presumably, it deteriorates the animals' health. Finally, the lifespan of young does is decreased.

Research has focussed on improving the energy balance and performances of young does by increasing the digestible energy concentration of the diet (Fortun and Lebas, 1994; Maertens and de Grootte, 1988; Xicatto et al., 1992, 1995) and adopting a more appropriate reproductive rhythm (Cervera et al., 1993; Fraga et al., 1989; Parigi-Bini et al., 1996). Till now, this type of research has not been successful in compensating the energy deficit during the first lactation. A possible solution may come from the rearing period of young does. Rearing strategies should be adopted to stimulate body reserves and feed intake capacity before the first insemination takes place. The ultimate objective of this thesis was to study the effects of body weight and age at first insemination on body weight development, feed intake, production, and culling rate of does in the subsequent reproductive period.

THESIS

We studied the effects of different rearing strategies were on the development of young does, in terms of body weight, body composition, and feed intake capacity at first insemination, and their effects on body development, feed intake, reproductive performance and culling rate during the first two to three parities.

In Chapter 1, literature is reviewed, focussing on body growth and development of the rabbit and summarizing management practises and factors, that could be relevant during the rearing period for stimulating feed intake and influencing body development, with the perspective to optimize subsequent (re)productive performance. Feed intake during rearing and age at insemination seemed important factors to influence body development and composition at first insemination. Feeding levels were studied in two periods of rearing: 1) the pre-weaning period, in which kits highly depend on their mothers for nutrient intake and especially bone, heart and lung, intestine, and caecum have a high growth rate, and 2) the post-weaning period, in which feed intake is switched to solid food, and muscle, sexual organs, and fat tissue show a high growth rate.

In Chapter 2, the effects of milk intake on subsequent performances was investigated. The number of suckling kits within the litter modifies milk intake. Milk intake may influence body weight at first insemination and affect reproductive performance. Reproductive performance may also be affected by age at first insemination (14.5 and 17.5 weeks). This is reported in Chapter 2.

The consequences of body weight at 14.5 weeks of age on reproduction are further investigated in a retrospective study and described in Chapter 3. Results indicate that production is improved in heavier does. Delaying first insemination to older age seems preferable. Therefore, feeding level after weaning (ad libitum and restrictive) and age at first insemination (14.5 and 17.5 weeks) were investigated in the following two chapters.

In Chapter 4, effects on body development, body composition, and puberty characteristics at first insemination are described, whereas in Chapter 5 the effects on subsequent reproduction are presented.

Finally, an attempt was made to improve kindling performance of young does by modifying feed intake after the first insemination by feeding them restrictive during the first 10 days of the first gestation. The results of this study are given in Chapter 6.

In the General Discussion, the results of the different experiments are discussed. The consequences of the rearing strategies for reproduction are discussed and practical implications are given.

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CHAPTER 1

REARING MANAGEMENT OF RABBIT DOES: A REVIEW

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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 not possible 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 intake 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 rabbit. 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 pre-natal 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.

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 a welfare point as well as from an economic point 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)).

Under the current management strategies, young does are 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 Grootte, 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

Pre-natal period

(before birth)
- parity (1.1)
- physiological status (1.2)
- nutrition (1.3)
- number of embryos (1.4)

birth weight

↓

Rearing period

(before weaning) **individual milk intake**

↓

- milk production (2.1)
- milk composition (2.2)
- environmental conditions (2.3)

↓

(after weaning) **feed intake**

- feeding level (3.1)
- fibre (3.2)

age at first mating

BODY DEVELOPMENT (reserves) → **nulliparous does** ← **FEED INTAKE (capacity)**

Reproductive period
(first parity)

BODY COMPOSITION	PRODUCTIVITY	FERTILITY
energy protein fat	litter size (born alive + dead) milk production weaning weight + number mortality before weaning	ovulation rate kindling interval

(in next parities)

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).

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 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.

FEED INTAKE AND BODY GROWTH AND DEVELOPMENT OF ORGANS AND TISSUES FORM 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).

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).

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 at early age (before 12 weeks), especially those organs that are involved in energy 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).

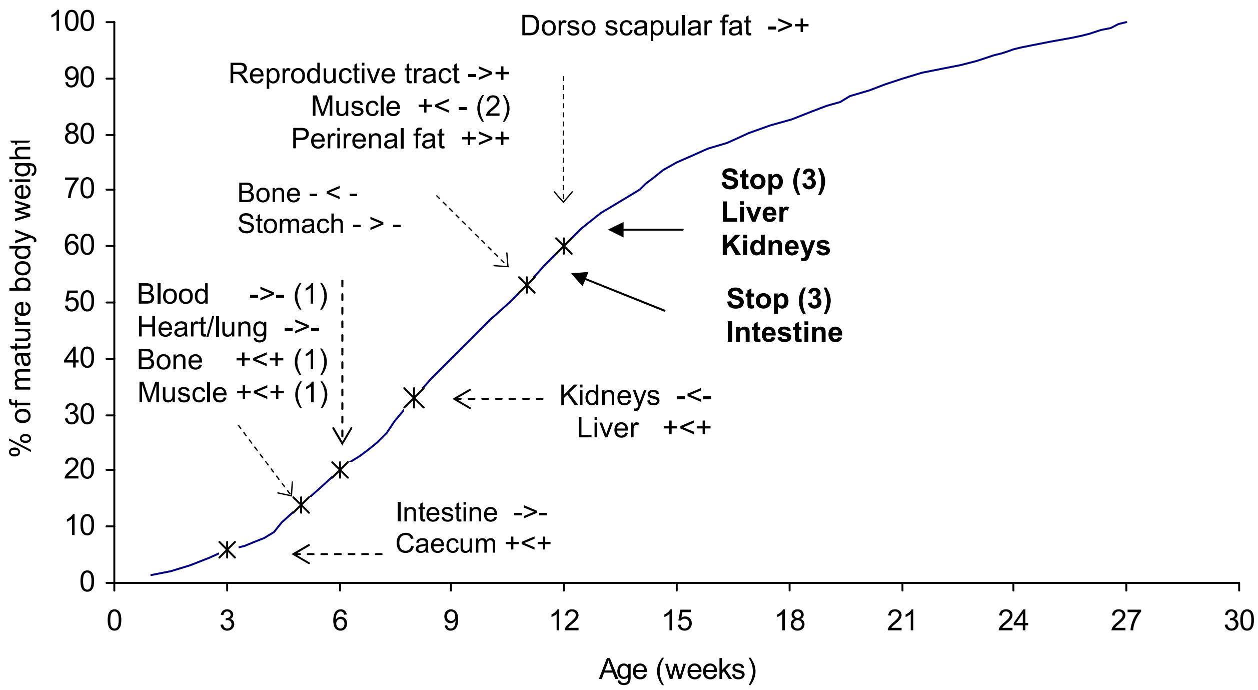
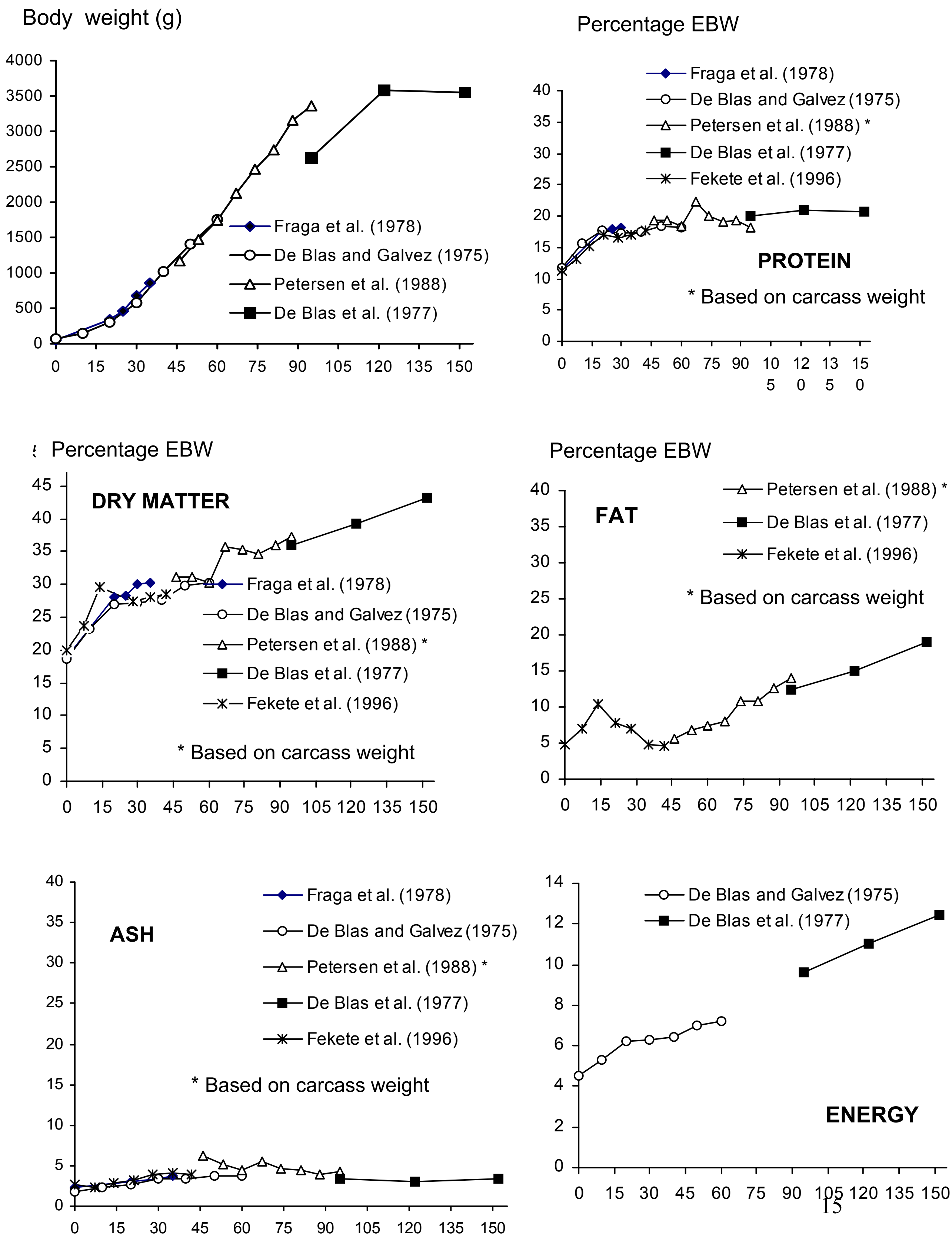


Figure 2. Body growth and development of organs and tissues in the rabbit, according to Cantier et al.[1] (1969) and (1985 points of the growth coefficient of several organs and tissues. At the different inflexion points the concerning organs and tissues are given. + or – indicates if the organ/tissue develops faster of slower than the whole body. < or > indicates if the development rate increases or decreased after the inflexion point). [3] Organ has reached maximum size.

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



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 (> 2,100 gram, Cantier et al., 1969; > 7 weeks of age, Deltoro and Lopez, 1985).

Voluntary Feed Intake

Voluntary feed intake is in general regulated by the level of 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-ruminents (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 ($BW^{0.75}$). In growing rabbits, the voluntary feed intake is about 950 to 1,000 KJ DE/day/kg $BW^{0.75}$. 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).

FACTORS AFFECTING BODY GROWTH AND DEVELOPMENT

The high early growth rate of most organs and tissues implicates 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).

In the pre-natal and pre-weaning stage 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.

1. Pre-natal Stage and Birth Weight

The pre-natal 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. Szendrö et al. (1996), Vasquez et al. (1997) and Ferguson et al. (1997) studied the effect of birth weight on performance of the kits until 12 weeks of age. Heavier weights at birth (45.2 vs 63.8 g (Szendrö 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 (2,436 vs 2,887 g and 3,003 vs 3,101 g, respectively) of age. Szendrö et al. (1996) found the mortality rate was significantly lower (-12.6%) at 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.

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.

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, which 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 relative 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.

1.3 Nutrition of the doe. Influences of feeding and/or energy level in the diet of does during gestation were studied by several authors (see Table 1). <u>Feeding level and energy content</u> of the diet seem to influence pre-natal 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 a medium and high feeding level. 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, 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 with respectively -12.5% and -11.7% compared to ad libitum fed pregnant primiparous does.

Hafez et al. (1967) reported that the 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 level). 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. 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).

<u>Energy source</u> does not seem to affect number of dead or live foetuses and 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 number of live or dead foetuses and foetal weight but influences 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 newborns 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 appear to be used by the foetal rabbit.

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 45.4, 40.7, 38.1 and 31.7 gram, 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. 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.

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 depending 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.

2.1 Milk Production of the Doe. The milk production of the doe is affected by factors, such as re-mating interval, parity, nutrition of the doe and litter size. The influence of these factors on milk production has 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 Grootte, 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 en De Grootte, 1991).

2.1.1 Re-mating Interval. Several authors (Barretto 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 Grootte, 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 different re-mating intervals such as 1, 9-10, 21, 25 or 28 days PP and non-pregnant does. The re-mating interval determines the physiological status of the doe and this mainly affects the decline in milk production after the maximum milk production and thus influences the total amount of milk produced.

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

Reference	Diet energy content (MJ DE/ kg DM)	Feeding level (g/day)	Parity	Litter size	Litter weight (g)	Kit weight Alive (g)	Mortality at birth (%)	Kits body com-position
Cervera et al., 1993	13.0 11.4 10.5 9.7	ad lib	N,P,M	NS	464^a 421^b 441^b 436^b	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 et al., 1994	9.7	75% maint ad lib	P		NS	44.4^a 55.5^b	NS	DM :12.5% protein:11.7% ash: NS fat: NS energy: NS
Hafez et al., 1967	not publ. (standard)	57 140 280	N	NS	not publ.	36 55 54	not publ.	fat: NS
Parigi-Bini et al., 1992	11.1	75% ad lib	P	NS	382^a 549^b	NS	16.2^a 3.3^b	NS
Partridge et al., 1986	12.9 14.8	maint. ad lib	M	NS	398^a 442^b	not publ.	9^a 28^b	not publ

Tabel 1. Continue.

Reference	Diet energy content (MJ DE/kg DM)	Feeding level (g/day)	Parity	Litter size	Litter weight (g)	Kit weight Alive (g)	Mortality at birth (%)	Kits body com-position
Viudes-de-Castro et al., 1991	9.7 13.0	ad lib	P	NS	NS	NS	9.3^{a} 22.0^{b}	not publ.
Parigi-Bini et al., 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 (strarch) 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 et al., 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 significantly different (AB; P <0.1; ab: P <0.05)

Parity: N= nulliparous; P= primipsarous; M= multiparous

In only two of the studies was an effect of re-mating interval found on milk production before the decline (first 21 days of lactation). However the results were not in agreement. Cervera et al. (1988) found a small effect of re-mating 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 with 8% ($P < 0.05$) for the 25 days PP re-mating 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 Grootte, 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 re-mating intervals, which makes it difficult to draw conclusions about the effect 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.

2.1.2 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 2197g, litter weight at 21 days) also negatively affected the growth of the litters during the fattening period. Maertens and De Grootte (1988b) stated that difference in weaning weight between primiparous and multiparous 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.

2.1.3 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 is seems that an increase in energy concentration of the feed increases milk production and/or weight at weaning. This effect seems related to the increase in dietary energy intake of the doe. This was found in most studies, except for Parigi-Bini et al. (1996) and 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 in 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 in priority 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).

Table 2. The effect of the energy content of the diet on milk production and litter weight at weaning. (percentage in increase is based on the diet with the lowest energy level)

Author	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 publ.	+ 15.6 %
Cervera et al. (1993)	9.7 – 13.0	animal fat	+ 13.1%	+ 19.2%
Fraga et al. (1989)	9.7 – 13.0	animal fat	+ 23.5%	not publ.
Lamb et al. (1984)	10.6 – 15.4	not publ.	not publ.	NS
Lebas and Fortun-Lamothe (1996)	9.8 – 12.1	starch starch and vegetable fat	- 8.1 NS	NS NS
Maertens and De Grootte (1988b)	9.7 – 11.9	not publ.	+ 6.8%	+ 9.5%
Parigi-Bini et al. (1996)	10.4 – 11.2	animal fat	+ 7.0%	+ 7.3%
Pascual et al. (1998)[2]	11.0 – 12.4 12.2	vegetable fat animal fat	+ 13.7% + 6.6%	+ 9.6% NS
Xiccato et al. (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 Effect on performance of multiparous does are given. A same effect of the diet was found during first lactations.

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

Author	DP to DE ratio (g/MJ)	Milk production*	Weight at weaning litter (kg) or kit (g)	Mortality (%)
Cervera et al. (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 et al. (1989)	12.4	2,30[(1)]	not published	19
	13.3	2,38		18
	13.9	2,35		24
Maertens and De Grootte (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 et al. (1986)	10.3	2,083[(1)]	4,846	7.4
	13.3	2,197	5,174	10.5
Sanchez et al. (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 et al. (1992)	11.2	167.8[(3)]	4,717	5.8
	12.5	174.9	4,997	3.4

[ab] means with a different letter are significantly different ($p<0.05$)

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

[4] first parturition; [5] does with four consecutive litters after first parturition

[6] based on crude protein instead of digestible protein

The amino acid requirements for reproducing does have not yet been clearly established (Xiccato, 1996). There is only limited information on the effect of amino acids on milk production. Maertens and De Grootte (1988a) investigated the effect of the lysine content of the diet on reproductive performance. No effect of lysine on the 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 decreased in the DE content 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 cecal volume and protein level. This cecal disequilibrium favourites the utilisation of protein as an energy source with deamination and increased ammonia production and increase the risk of digestive problems (Carabaño et al., 1988).

2.1.4 Litter Size. In rabbit, the number of suckling kits seems to influence the milk production. McNitt and Luckefahr (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 Szendrö (1992). Kustos reported only a slight effect on milk production of litters equalized 6, 8 and 10 kits, whereas Mohamed and Szendrö found a 5.5% increase between litters of 6 and 10 kits.

2.2 Milk composition. New-born rabbits have low body-energy reserves, low thermal isolation and high energy requirements. Therefore a positive relationships between kit viability and milk intake could be expected (Fraga et al., 1989). Rabbit milk contains approximately 30% dry matter. On dry matter basis the milk contains approximately 49% of protein, 39% of fat, 3.2% lactose and 8.5% of ash (Maertens, 1993).

The milk composition, with 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 usually 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.

2.3 Environmental Factors

2.3.1 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 Szendrö (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 phenomena 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.

2.3.2 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 doe and litters gave significant 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 gets only access to the nest box once a day.

2.3.3 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 kits have more chance to suck more teats or spend more time to switch 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 Szendrö, 1992; Rao et al., 1977; Szendrö, 1996; Vicente and Garcia-Ximénez, 1992; Zimmermann et al., 1988) and in some studies also the viability of the kits was decreased (Szendrö, 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.

2.3.4 The Number of Teats of the Doe. The number of teats might also influence milk production. Milk intake per kit increased with about 10% for does with ten nipples compared to those with eight (Mohamed and Szendrö, 1992).

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 only on feeding strategies to stimulate feed intake and body development.

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; Szendrö 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 inversed 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 later age (8 to 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, compensatory growth of other soft tissue will 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 parturition the restrictively reared does were even heavier than the non-restrictively does. A positive effect was found on the reproductive performance from the second litter onwards. The number of kits born in the second litter was increased with 1.4 kits and the litter weight at 21 days of lactation was increased in as 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 the 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.

3.2 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 $BW^{0.75}$) during the successive lactations, which resulted in a higher DE intake (1.26 vs 1.17 MJ/d/kg $BW^{0.75}$). Xicatto et al. (1999) found that does raised on a high fibre diet (19.9% vs 15.5%) ate 10 kcal/d/kg $BW^{0.75}$ 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 g).

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 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 pre-natal 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 focussing 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 and severe feed restriction in this period does not seem advisable from this point of view. Based on the body development as described, 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 (Perrrier and Ouhayoun, 1996) and negatively affects caecal development (Maertens and Peeters, 1988). Between 6-10 weeks of age, feed restriction will hinder the formation of 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, which 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 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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CHAPTER 2

THE EFFECT OF LITTER SIZE BEFORE WEANING ON SUBSEQUENT BODY DEVELOPMENT, FEED INTAKE, AND REPRODUCTIVE PERFORMANCE OF YOUNG RABBIT DOES

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ABSTRACT

An experiment was performed to study the effect of litter size before weaning on subsequent body development and composition, feed intake, and reproductive performance of young rabbit does with the objective to improve reproductive performance. Litter size (LS) before weaning (treatment) was 6, 9, or 12 kits. After weaning (30 d), 58 female kits per treatment (in two successive replicates) were reared and fed ad libitum to 14.5 wk of age (end of rearing). At 14.5 wk of age, receptive does were inseminated. Non-receptive and non-pregnant does were inseminated at 17.5 wk of age. The experiment ended when the second litter was weaned. Part of the animals was slaughtered to determine body composition at end of the experiment (replicate one) and at the end of rearing (replicate two). At weaning, BW differed among treatments (P < 0.05; 855, 773, and 664 ± 15 g for LS6, 9, and 12, respectively). Compensatory growth was observed. At the end of rearing LS12 does were smaller (P < 0.05) than LS9, and LS6 (3,524, 3,778, and 3,850 ± 48 g, respectively). After first lactation, no difference in BW among treatments was found. Compared with LS6, empty body weight (BW minus gut, bladder and uterus content) of LS12 contained more (P < 0.05) nitrogen (32.5 and 31.1± 0.3 g/kg), more (P < 0.05) ash (30.7 and 28.3 ± 0.6 g/kg), and less (P < 0.05) fat (168.6 and 200.2 ± 8.6 g/kg). No differences in body composition among treatments were found at the end of the experiment. During rearing, LS12 had the lowest (P < 0.05) daily feed intake (152, 164, and 169 ± 2 gram for LS12, 9, and 6, respectively). During the reproductive period, no differences in feed intake among treatments were found. Kindling rate (the number of kindlings per number of inseminations) was not influenced by treatment. In the first parity, total litter size (number of alive and stillborn kits) was lower (P < 0.10) for LS12 than for LS9 (6.4 and 8.6 ± 0.5, respectively). When first mating was delayed by 3 wk, an increased (P < 0.05) total litter size was found regardless of treatment (7.5 and 9.4 ± 0.3 for 14.5, and 17.5 wk, respectively). Decreasing litter size before weaning from nine to six kits did not alter future reproductive performance. Based on results of this study, it seems advisable to perform a limited standardization level (at nine kits) after kindling and postpone first mating to older age (17.5 wk) to improve reproductive performance.

INTRODUCTION

In modern rabbit production, the limited reproductive lifespan and reproductive problems of rabbit does are undesirable from both welfare and economic points of view. These problems seem to be related to insufficient energy intake during first lactation (Xicatto, 1996). The energy deficit in reproductive young does cannot be adequately met by increased energy level of the diet and (or) delayed mating interval during the reproductive period (Cervera et al., 1993; Xicatto et al., 1995; Parigi-Bini et al., 1996). The rearing period seems to be adequate to stimulate body development and feed intake with the aim of optimizing reproductive performance and lifespan of young does (Rommers et al., 1999).

The current rearing management of rabbit does focuses on maximal productivity and does not seem to prepare the animals well enough to cope with the high energy demand during first lactation. Studies on rearing management of rabbit does are scarce (Hartmann and Petersen, 1995, 1997; Xiccato et al., 1999).

Before weaning, kits are highly dependent on their mothers' milk output, and the number of suckling kits affects their individual milk intake and body growth (Lebas, 1969). However, information on the effect of litter size before weaning on subsequent reproduction is scarce and not consistent. Babile et al. (1982) reported that kits raised in small litters (5 compared with 11 kits) tended to produce larger litters with more kits born alive, and the number of kits weaned was significantly increased. However, Biró-Németh et al. (1999) did not find any effect of litter size (6, 8, or 10 kits) on future doe performance.

There is no information on the effect of litter size before weaning on subsequent body composition and feed intake in rabbits. Therefore, an experiment was performed to study the effect of litter size before weaning on subsequent body development and composition, feed intake, and reproductive performance.

MATERIALS AND METHODS

An experiment was performed in two successive replicates from April 1997 through November 1998. In the first replicate, 33 litters before weaning, and 48 female animals after weaning were used. The second replicate contained 55 litters before weaning, and 126 female animals after weaning. The Use and Care Committee of the Center for Applied Poultry Research approved all protocols.

Treatments (Pre-weaning Period)

The experiment was performed with a strain of New Zealand White rabbit kits, bred at the Center. On the first day after kindling (d 0), kits were selected from litters of multiparous does. Extremely small (< 45 g) and heavy (>100 g) kits were removed. Kits were randomly assigned to one of the following three treatments: six kits (LS6), nine kits (LS9), and 12 kits (LS12) per litter. The three treatments were assigned to similar does based on parity and previous litter weights at 21 d of age. The litters were put into nestboxes, and nestboxes were attached to the front of cages.

During the first 21 d of the pre-weaning period, the multiparous does had free access to the nestboxes for suckling. Nestboxes were checked for dead kits every other day during the first 2 wk, and twice a week from the 3rd wk until weaning (d 30). Dead kits were replaced by kits from other does on the farm with similar litter size in order to prevent a decrease in the number of kits and equalize individual milk intake. These kits were marked and excluded from subsequent measurements. On d 21, the kits were put into the cage of the doe and nestboxes were removed in order to stimulate intake of the solid feed of the kits. Kits were weaned at 30 d.

Post-weaning (Rearing) Period

At weaning (d 30), female kits, with bodyweight (BW) deviating less than 15% from the mean weight of the litter, were selected. From the selected females, a total of 58 animals per treatment were taken randomly and reared in individual cages, in which they were housed until the end of the experiment. The rearing period ended at 14.5 wk of age.

At the end of rearing, animals were checked for receptivity. Animals were considered receptive if the vulva was colored (red to purple) and swollen. Receptive animals were artificially inseminated. Fourteen days after insemination, pregnancy was checked by abdominal palpation. Non-receptive and non-pregnant animals were subjected to insemination once again at 17.5 wk of age. Animals that were not pregnant after two successive inseminations were removed.

Reproductive Period

During reproduction, animals were submitted to a semi-intensive breeding rhythm and inseminated 10 to 12 d post partum (PP). Artificial inseminations were performed with fresh mixed semen from 10 bucks, selected for growth performance. At every insemination date, one mixed and diluted semen dose was prepared. Dilution was performed using a commercial extender (Galap, IMV, France) according to the method developed by Zöldág et al. (1988). A GnRH analogue was applied i.m. (0.2 cc containing 0.0042 ml Buseriline-acataat/ml; Receptal, Hoechst Roussel Vet, Belgium) immediately after insemination to induce ovulation. Non-pregnant does were excluded from the experiment.

At the first day after kindling litter size was standardized. In the first parity, litter size was set at eight kits, and in the second parity at nine kits. Nestboxes were provided 4 to 5 d before parturition and removed at 21 d. Litters were weaned at 30 d. The experiment ended after weaning the second litter.

Husbandry

Animals were housed in cages (50 x 60 x 30 cm) made of galvanized wire net, and equipped with an automatic waterer and a manual feeder in the rabbitry of the Center. Nestboxes (30 x 25 x 30 cm) were attached to the front side of the cages. During rearing and reproductive periods, animals had free access to a standard commercial diet (ABC, Lochem, The Netherlands) containing 10.3 MJ/kg ME and 17 g/kg CP.

Animals were housed under controlled lighting. Before weaning, animals were kept at a 16 h photoperiod. During rearing, animals were submitted to a photoperiod of 12 h. The last 5 d before first insemination, the photoperiod was prolonged to 16 h to evoke receptivity. During the reproduction period, a photoperiod of 16 h was maintained. The minimum house temperature was set at 16 ^{o}C.

Measurements

Culling of Animals. The numbers of animals culled and the reasons were recorded throughout the experiment and dissections were performed on dead and diseased animals.

Body Weight. Kits were weighed individually on d 0, 21, and 30. After weaning, animals were weighed weekly until 14.5 wk of age (first insemination) and before second insemination at 17.5 wk of age. During the first and second parity, BW were recorded at kindling, at d 16, and 30 of lactation.

Feed Intake. Feed intake was determined for the following periods: weekly after weaning until 14.5 wk of age, the first gestation period, and during the first two parities, from kindling until d 16 of lactation, from d 16 until d 30 of lactation, and from weaning until kindling. The feeder was weighed at the beginning and the end of each period and all feed given was weighed and recorded. If feed wastage was observed, the entrance of the feeder was modified with wire to prevent animals from standing in front of the feeder, but still allowing them enough access to eat. If wastage occurred, period and cage were recorded, and the feed intake for this period was scored as missing value.

Reproductive Characteristics. Kindling rate was calculated as the number of does kindled/number of does inseminated. The number of alive and stillborn kits (total litter size), the number of kits at d 16 of lactation and at weaning, and the litter weight at d 16 and 30 were recorded. The average kit weight at d 16 was used as an estimate of milk production, because after 17 to 18 d kits start to consume solid feed (personal observation).

Body Composition. In the first replicate, body composition was determined at the end of the reproductive period (immediately after weaning of the second litter) for animals that had followed the semi-intensive breeding rhythm (five, eight, and four animals for LS6, 9, and 12, respectively). In the second replicate, 10 animals per treatment were randomly taken 5 d after the first insemination and used for determination of the body composition at the end of rearing.

Animals were weighed and slaughtered (COgas), and the contents of the digestive tract, bladder and uterus were eliminated to determine empty BW (EBW) (EBW= live weight minus gut, bladder and uterus content). The empty stomach was weighed separately. The empty bodies were frozen at –20 ^{o}C until they were ground and homogenized. Representative samples of the empty bodies were analyzed. Dry matter content was determined by freeze-drying. Nitrogen content was analyzed in fresh samples by Kjeldahl analysis. Protein was calculated by the nitrogen content multiplied by 6.25. Fat content was determined by extraction of freeze-dried samples with petroleum-ether and drying the extract at 80 ^{o}C in a vacuum oven (10 kPa) to a constant weight. Ash was determined in oven-dried samples in a furnace at 550 ^{o}C. Energy was measured in freeze-dried samples with bomb calorimetry (IKA C 7000, IKA Analysentechnik, Heitersheim, Germany).

Statistical Analyses

The experimental design was a randomized block. In the pre-weaning period, a block consisted out of three adjacent cages housing similar multiparous does based on parity and previous litter weights at 21 d of age. In the rearing and reproductive period, a block contained three adjacent cages. The three treatments were randomly assigned to the cages within a block. Variation among blocks also included variation due to replicate. Analyses of variance were carried out using the GLM procedure of SAS (SAS Inst. Inc., Cary, NC).

For the pre-weaning and rearing period, block and treatment were added to the model. Live weight during the 10 successive wk after weaning was analyzed with a split-plot model, using block, treatment, animals within block and treatment, week and the interaction between treatment and week as factors. Block was tested against animals (within block and treatment error term); treatment and week were tested against the residual error term. When block or interaction terms were not significant, they were excluded from the model.

During reproduction, blocks became unbalanced because of re-inseminations at 17.5 wk of age, and exclusion of non-pregnant does. Therefore, block was excluded from the model. Reproductive data were analyzed with treatment, age of first successful mating, and the interaction between treatment and age of first successful mating as factors. A Chi-square test was used to analyze treatment differences in kindling rate.

RESULTS

Animals

The number of animals per treatment during the different stages of the experiment and causes of withdrawal are given in Table 1. During the rearing period, one animal was removed due to severe skin mold (*Microsporum sp.*). Four does (in the first batch) were re-inseminated by mistake before 17.5 wk of age and were excluded from the experiment. Animals that aborted were removed from the experiment. In one animal (LS12), metritis was found at dissection. In the other animals, no pathological signs were found. Animals that showed no mothering ability after kindling were removed at d 2 after kindling and the number of kits at d 16 and 30 was scored zero. Does, which showed no mothering ability were excluded from the data set, the average number of kits at d 16 and 30 was similar. Culling after weaning of the first litter was caused either by metritis or mastitis. At end of the experiment, 47 animals remained from those that were successfully inseminated at 14.5 wk of age (16, 16, and 15 for LS6, 9, and 12, respectively). From the animals re-inseminated at 17.5 wk of age (see Table 2), 12 remained (seven, two, and three for LS6, 9, and 12, respectively).

Body Development

The mean BW during the suckling period is presented in Table 3. At 21 and 30 d of age, BW among treatments differed ($P < 0.05$). At weaning, 58 animals per treatment were selected for rearing. The average BW of the selected females was 852, 773, and 657 ± 12 g for LS6, 9, and 12, respectively.

The BW development during the subsequent rearing period is given in Figure 1. Until 4 wk after weaning, a difference ($P < 0.05$) was observed in BW among treatments with LS6 being the heaviest. From 5 wk after weaning, the differences in BW between LS9 and LS6 were not significant.

Table 1. Number of animals per treatment during rearing and reproduction and causes of withdrawal.

	Litter size, no.[a]		
Item, no.	6	9	12
	-------------------- Rearing period ------------		
Litters before weaning	37	25	26
Animals after weaning	58	58	58
Animals culled from weaning to 14.5 wk of age	0	0	1
Sacrificed for body composition at end of rearing	10	10	10
Does at start of reproductive period	48	48	47
	------------------ At 14.5 wk of age ----------		
Receptive does inseminated	45	47	44
Non-receptive does inseminated < 17.5 wk (excluded from experiment)	2	1	1
Does palpated negative	16	13	13
Does that aborted	0	1	3
Does that died during kindling (dystocia)	1	1	0
Kindlings from 14.5 wk inseminations	28	32	28
Does showing no mothering ability after kindling	1	0	1
Does culled after weaning of the 1st litter	2	0	1
	------------------- Second parity --------------		
Inseminations 10 to12 d postpartum (PP)	25	32	26
Kindlings	16	16	15
Non-pregnant does (excluded from experiment)	9	16	11
Does culled during gestation and lactation	0	0	0
Inseminations 10 to 12 PP in 2nd lactation	16	16	15
Pregnant does at end of experiment (sacrificed for body composition)	5	8	4

[a] Does raised in litters of 6, 9 or 12 kits in the pre-weaning period.

Table 2. Number of animals inseminated at 17.5 wk of age and causes of withdrawal during reproduction.

	Litter size, no.[a]		
Item, no.	6	9	12
Does inseminated at 17.5 wk of age[b]	18	13	14
	---------------- First parity ---- --------		
Kindlings from 17.5 wk inseminations	17	11	10
Non-pregnant does (excluded)	1	2	4
Does culled during lactation	0	0	0
Does culled after weaning 1st litter	4	2	1
	-------------Second parity ------------		
Inseminations	13	9	9
Kindlings	7	2	3
Non-pregnant does (excluded)	6	6	6
Does that died during kindling (dystocia)	0	1	0
Does culled during gestation and lactation period	0	0	0

[a] Does raised in litters of 6, 9 or 12 kits in the pre-weaning period.

[b] Non-receptive and non-pregnant does at 14.5 wk of age, minus animals re-inseminated before 17.5 wk of age.

Table 3. Pre-weaning weights (g) of kits raised in litters of 6, 9 or 12 kits.

	Litter size, no.[a]			
Item	6	9	12	Pooled SE
Litters, no.	37	25	26	
D 0[b]	68	68	67	1
D 21	459[c]	371[d]	327[e]	10
D 30	855[c]	733[d]	664[e]	15

[a] Kits raised in litters of 6, 9 or 12 kits in the pre-weaning period.

[b] Day 0 = kindling; day 30 = weaning.

[c,d,e] Row means with different superscripts differ (P <0.05).

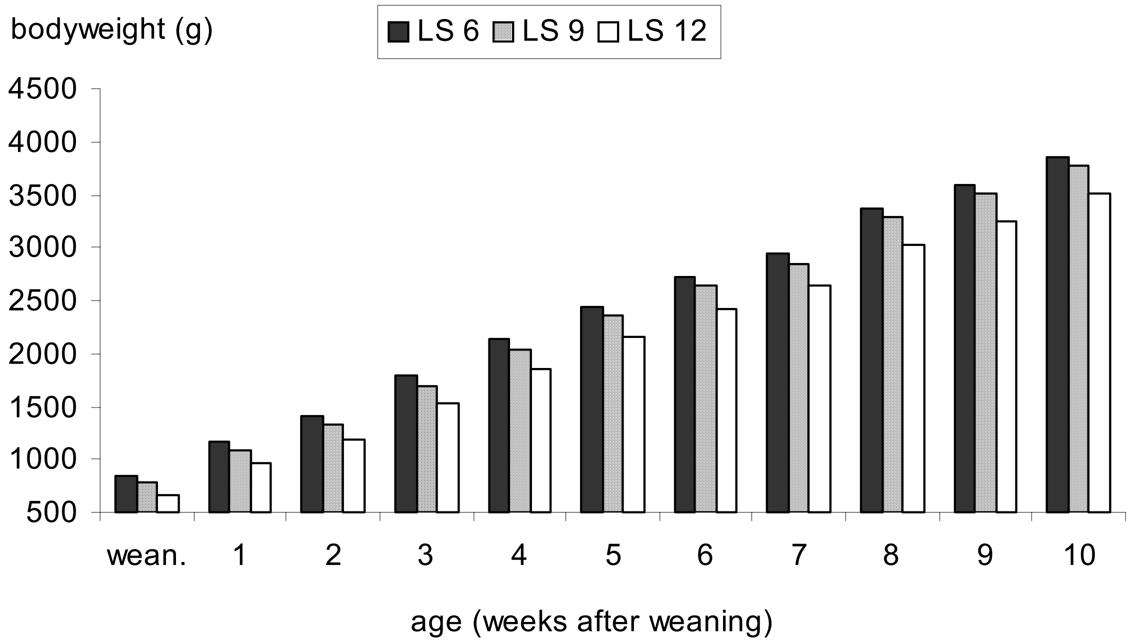

Figure 1. Body weight from weaning until first mating for does raised in litter size (LS) of 6, 9, or 12 kits in the pre-weaning period. From weaning to first mating, SE ranged from 12 to 48 g. From weaning to 4 wk after weaning, treatments differed ($P < 0.05$). From 5 wk after weaning onwards, no differences between LS6 and LS9 were found. At first mating, LS12 was smaller ($P < 0.05$) than LS6 or LS9.

At the first mating (14.5 wk of age), BW was 3,850, 3,778, and 3,524 ± 50 g for LS6, 9, and 12, respectively. At this age, animals of LS12 were smaller ($P < 0.05$) than animals of LS6 and LS9. Within treatments, there was no difference in BW between pregnant and non-pregnant animals. After the first kindling, there were no significant differences in BW among treatments (Figure 2).

Age of first successful mating (14.5 or 17.5 wk) influenced BW. Animals successfully inseminated at 17.5 wk of age were heavier ($P < 0.05$) than animals mated at 14.5 wk (see Figure 3). However, after the first parity, no significant differences in BW between ages of insemination were found. In the second parity, the number of animals at 17.5 wk of age was too small per treatment for proper statistical analysis (see Table 2).

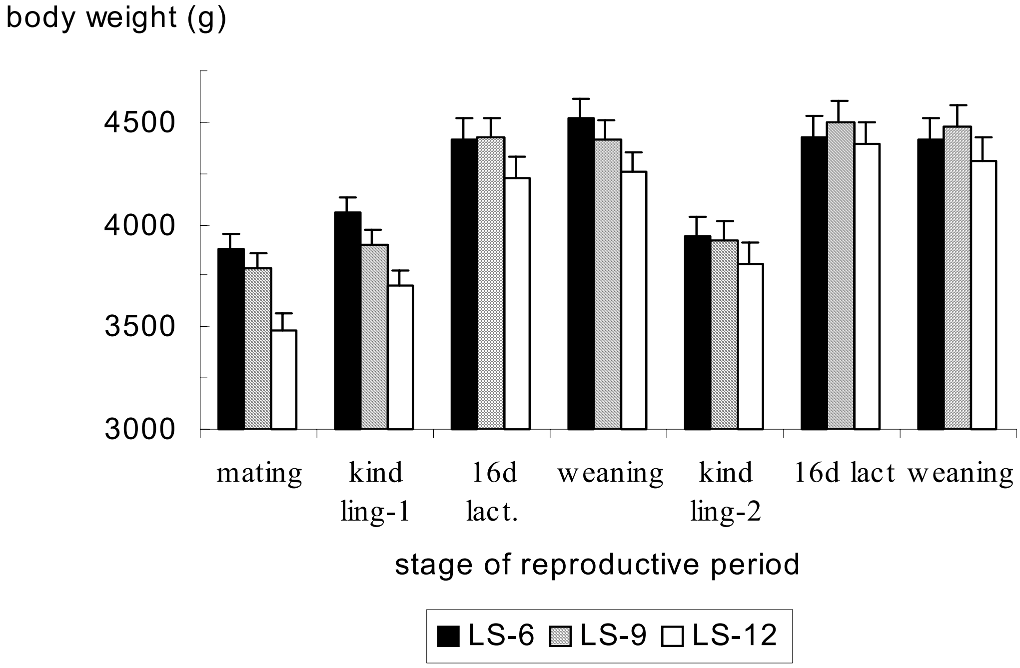

Figure 2. Effect of does raised in a litter size (LS) of 6, 9, or 12 kits in the pre-weaning period on subsequent body weight during reproduction, for animals successfully inseminated at 14.5 wk of age and 10 to 12 d postpartum. At 1st mating and 1st kindling, does raised in litters of 12 kits were smaller (P < 0.05) than does raised in litters of 6 or 9 kits.

Body Composition

Table 4 shows the chemical analyses of the EBW at the end of rearing and reproduction. At end of rearing, 10 animals per treatment were randomly selected for determination of body composition. No differences in BW among treatments were found. Empty body weight of LS12 tended to be lower (P < 0.10) than LS6. Dry matter, crude fat and energy content were lower (P < 0.05) for LS12 than for LS6, whereas the ash and nitrogen content were greater for LS12 than for LS6 (P < 0.05). At the end of reproduction, no significant differences in EBW and body composition among treatments were found. In all treatments, animals lost a substantial amount of their body fat (50 to 60% of the initial content) during reproduction.

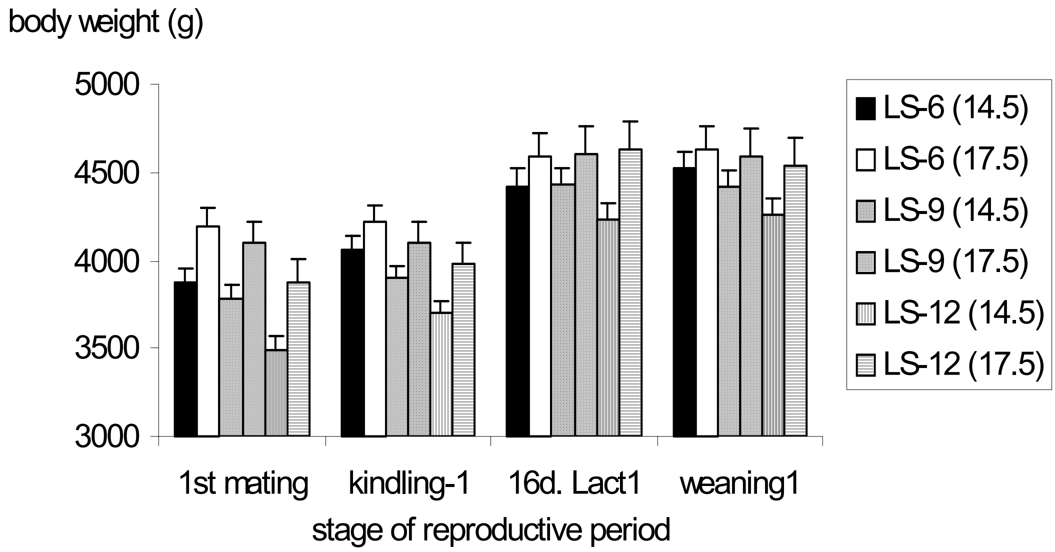

Figure 3. Effect of age of first successful mating (14.5 vs. 17.5 wk of age) and litter size (LS) in which does were raised (6, 9, or 12 kits) on subsequent body weight development during reproduction, for does pregnant 10-12 d post partum. At 1^{st} successful mating and 1^{st} kindling, treatments (age and litter size) differed ($P < 0.05$). At d 16 of lactation, differences (P <0. 05) among age of 1^{st} mating were found.

Feed Intake

During the rearing period, feed intake of LS12 was lower ($P < 0.05$) than that of LS6 and LS9 (169, 164, and 152 ± 2 g/d for LS6, 9, and 12 respectively). This could have accounted for the empty stomach weight that tended to be smaller ($P < 0.10$) in LS12 (see Table 4).

Animals raised in litters of 12 kits had the best ($P < 0.05$) feed conversion (4.0, 3.9, and 3.8 ± 0.03 for LS6, 9, and 6, respectively). During the first gestation period, feed intake did not differ among treatments for animals inseminated successfully at 14.5 wk of age (176, 171, and 168 ± 5 g/d for LS6, 9, and 12, respectively). Also, during the first and second parities, no differences in feed intake among treatments were found. During the first 16 d of the first lactation, feed consumption was 327 ± 5 g/d, whereas during second lactation this amount increased to 389 ± 6 g/d. There was no effect of age at first successful insemination (14.5 or 17.5 wk) on feed intake during the reproductive period.

Table 4. Effect of does raised in litter of 6, 9 or 12 kits in the pre-weaning period on subsequent body composition at end of rearing and reproduction.

	Litter size, no.[1]			
Item	6	9	12	SE
	--------------------- End of rearing ------------------			
Animals, no.	10	10	10	
Live weight, g	4,089	3,937	3,854	89
Empty BW, g	3,916[a]	3,748[ab]	3,631[b]	84
Empty stomach wt, g	26.9[a]	24.8[b]	24.9[b]	0.7
Empty body content, g/kg/EBW				
DM	428.8[c]	418.7[cd]	404.7[d]	6.5
Ash	28.3[c]	29.2[cd]	30.7[d]	0.6
Crude fat	200.2[c]	186.6[cd]	168.6[d]	8.6
Nitrogen	31.1[c]	31.6[cd]	32.5[d]	0.3
Energy, kJ/g EBW	12.5[c]	12.0[cd]	11.3[d]	0.3
	------------------- End of reproduction -------------			
Animals, no.	5	8	4	
Live weight, g	4,508	4,699	4,507	139
Empty BW, g	3,557	3,928	3,727	158
Empty stomach wt, g	31.0	31.9	32.1	1.5
Empty body content, g/kg/EBW				
DM	321.1	333.3	326.2	9.1
Ash	31.9	31.7	32.3	0.8
Crude fat	81.6	95.2	83.2	10.9
Nitrogen	32.0	32.0	32.9	0.3
Energy, kJ/g EBW	7.9	8.5	8.1	0.4

[1] Does raised in litters of 6, 9 or 12 kits in the pre-weaning period.

[ab] Row means with different superscripts differ (P < 0.05).

[cd] Row means with different superscripts tend to be different (*P* < 0.10).

Reproductive Performance

In Table 5, the reproductive performances are presented for animals pregnant after the first insemination at 14.5 wk of age and 10 to 12 d after first kindling.

Table 5. Effect of does raised in litters of 6, 9 or 12 kits in the pre-weaning period on subsequent reproductive performance, for animals inseminated successfully at 14.5 weeks of age and 10 to 12 days after 1st kindling.

Item	Litter size, no.[1] 6	9	12	SE
	---------- First parity ----------			
Animals, no.	28	32	28	
Kindling rate, %	62.2	68.1	63.6	
Kits, born, no.	7.5 [xy]	8.6[x]	6.4[y]	0.5
Kits, born alive, no.	7.1	7.6	6.0	0.6
Stillborn, %	9.2	13.8	12.4	
Kits, weaned, no.[a]	7.0	7.6	7.4	0.3
Kit wt at d 16, g	254	255	243	8
Kit wt at weaning, g	681	692	657	17
	---------- Second parity ----------			
Animals, no.	16	16	15	
Kindling rate, %	64.0	50.0	57.7	
Kits, born, no.	10.8	9.6	9.4	0.7
Kits, born alive, no.	9.7	6.7	7.7	1.0
Kits, weaned, no[a]	8.4	8.5	8.5	0.2
Kit wt at d 16, g	293	281	278	10
Kit wt at weaning, g	748	736	721	20

[1] Does raised in litters of 6, 9 or 12 kits in the pre-weaning period.

[a] Litter size standardized at 1st day after kindling; first parity at 8, and second parity at 9 kits.

[bc]Row means with different superscripts tend to be different ($P < 0.10$).

No difference in kindling percentage was found among treatments in the first and second parities. In the first parity, there was a tendency ($P < 0.10$) for a decreased total litter size of LS12 compared with LS9. No differences were found in the number of kits born alive or weaned on kit weight at d 16 of lactation and at weaning. No difference among treatments was found in the number of stillborn-free litters (22, 20, 22 litters for LS6, 9, and 12, respectively) and litters with all kits stillborn (one, one and three litters for LS6, 9, and 12, respectively). There was a tendency ($P < 0.10$) for number of litters with stillborn kits to be greater in LS9 compared with LS6 and LS12 (11, 5, and 2, respectively), but the average percentage of stillborn kits did not differ among treatments (10.5% ± 2.5). In the second parity, no difference in reproductive performance was found.

Table 6. Effect of does raised in litter sizes of 6, 9 or 12 kits in the pre-weaning period and age at first successful insemination (14.5 vs 17.5 wk) on reproductive performance in the first parity.

	Litter size, no.[1]								
	6		9		12		Overall		SE
Age 1st successful mating	14.5	17.5	14.5	17.5	14.5	17.5	14.5	17.5	
Animals, no.	28	17	32	11	28	10	88	38	
Kindling rate, %	62.2	94.4	68.1	84.6	63.6	71.4	64.7[d]	84.4[e]	
Kits, born, no.	7.5	9.0	8.6	9.9	6.4[b]	9.2[c]	7.5[d]	9.4[e]	0.3
Kits, born alive, no.	7.1	8.1	7.6	8.4	6.0[b]	8.1[c]	6.9[d]	8.2[e]	0.4
Kits, weaned, no.[a]	7.0	6.8	7.6	7.3	7.4	7.2	7.4	7.1	0.2
Kit wt at 16 d, g	254	266	255	245	246	271	250	261	5
Kit weight at 30 d, g	681	701	692	662	665	721	677	695	12

[1]Does raised in litters of 6, 9 or 12 kits in the pre-weaning period.

[a] Litter size standardized 1st d after kindling at 8 kits.

[bc]Row means with different superscripts within the litter size differ ($P < 0.05$).

[de]Row means with different superscripts differ ($P < 0.05$).

In Table 6, the effect of age at first successful mating on reproductive performance is presented. Delaying first mating for 3 wk improved overall kindling rate and reproductive performance. In LS12, an increased ($P < 0.05$) total litter size and number of kits born alive was found, when first successful mating occurred at 17.5 wk of age compared with 14.5 wk. In the second parity, the number of does inseminated at 17.5 wk of age was too small for proper statistical analysis of reproductive performance.

DISCUSSION

In our experiments, a significant effect of litter size before weaning on BW during the suckling period was found. At 21 d of age, a 28% difference in BW was found among LS6 and LS12. This is similar to data of Szendrö et al. (1996), who found a 31.9% difference in BW between LS6 and LS10, and Mohammed and Szendrö (1992), who reported a 33.4% difference in body weight gain between LS6 and LS10. From 21 d of age onwards, compensatory growth was observed in LS9 and LS12. From 21 to 30 d of age, the difference in BW between LS6 and LS9, and LS6 and LS12 was decreased from 18% to 14%, and from 28% to 22%, respectively. Compensatory growth could occur from this age onward, because solid feed was given ad libitum and it is known that kits start to consume solid feed around 21d of age. When BW at the end of rearing was corrected for initial BW at weaning, LS9 and LS12 would have reached a significantly ($P < 0.05$) heavier BW compared with LS6 (3,612 ± 45, 3,739 ± 36, and 3,788 ± 48 g for LS6, 9, and 12, respectively). This is in agreement with Ledin (1984), who stated that compensatory growth will take place when a less restrictive or ad libitum feeding level follows feed restriction. At 5 wk after weaning, LS9 had reached the same BW as LS6 (2,358, 2,444 and 2,155 ± 28 g for LS9, 6, and 12, respectively). The BW of LS12 was still reduced at the end of the rearing period (3,486 ± 80, 3,876 ± 80 and 3,782 ± 75 g for LS12, 6, and 9, respectively). During the first lactation period, LS12 reached the same BW as LS6 and LS9 (4,227 ± 105, 4,415 ± 106 and 4,429 ± 95 g for LS12, 6, and 9, respectively). If mating was delayed 3 wk, no differences in BW among treatments were found. So, if enough time is given, animals will compensate for the reduction in BW at weaning, which is in agreement with the findings of Ledin (1984).

After weaning, the feed efficiency was greater in LS6 than in LS12. The best feed conversion was found for LS12, which seems to be related to the development of the empty body composition and the lower BW. At the end of the rearing period, the carcasses of LS12 contained significantly more water and nitrogen, and less fat. Although empty body weight tended to be lighter, LS12 had relatively more protein, whereas LS6 was fatter. The formation of protein involves binding of water and leads to a higher BW gain than the formation of fat. The energy requirement for maintenance of the animals in large litters would have been lower due to the lower BW. Relatively more energy must have been available for body growth in LS12, resulting in better feed conversion.

At end of the rearing, LS12 carcasses contained more (P < 0.05) ash than LS6 carcasses. Bones are characterized by a high allometric coefficient before 3 wk of age (Deltoro and Lopez, 1985). Therefore, growth retardation during the suckling period can influence bone formation. However, it is not clear if the greater ash content is an indication of a better bone development caused by the lower growth rate before weaning or due to the smaller BW. At the end of the reproductive period, no differences in body composition were found among treatments for those animals which had the same physiological conditions during the reproductive period. These results are in agreement with Ledin (1984), who stated that during re-alimentation animals will correct for deviation from normal body composition if enough time is given.

Under normal conditions, sexual development in medium-sized rabbits begins around 10 to 12 wk of age (Cantier et al., 1969; Hulot et al., 1982; Deltoro and Lopez, 1985). Age and BW trigger the onset of sexual development. Growth retardation can delay the onset of puberty (Foster and Nagatani, 1999). Although BW of LS12 was lower and less fat was stored at first mating, no effect on kindling rate was found, suggesting animals had reached puberty at similar rates. After first pregnancy, a tendency (P < 0.10) for reduced litter sizes and number of kits born alive were found for LS12 compared with LS9. Animals of LS12 did not fully compensate in terms of growth rate compared with LS6 and LS9. This may have affected ovulation rate and (or) embryonic mortality, but this has not been studied in rabbits. Perhaps litter size would not have been reduced if animals were given more time to compensate by postponing the first mating until the same BW was reached. However, under practical conditions does are mated for the first time when 75 to 80% of final BW is reached (Lebas et al., 1986) and LS12 would have been mated based on its BW. Does re-inseminated successfully at 17.5 wk of age had an increased BW with an improved kindling rate and an increased total litter size and kits born alive compared with does inseminated successfully at 14.5 wk of age. However, animals mated at 17.5 wk of age were not randomly assigned to age of mating. Lebas and Coudert (1984) reported that the age of first mating had a major effect on the rate of pregnancy, but that additional study was needed to confirm their results. More research is necessary to more precisely determine the effect of age and BW at first mating on reproductive performance.

Milk production and BW at weaning in the first and second parity were not affected by the litter size in which the animals were raised or age at first successful mating. In the second parity, LS12 had the same BW and the same reproductive performance as LS6 and LS9. However, the reduced litter size during the first parity is not compensated for after two parities. No difference in reproductive performance was found between LS9 and LS6. The LS6 and LS9 animals had the same BW and composition at first mating, so it was not likely that differences would be found. Our results agree with Babile et al. (1982) who compared LS5 and LS11 and found better production results for LS5 than for LS11.

In our study, treatment did not affect feed intake during reproduction. In all treatments, animals lost a substantial amount of their initial body fat (50 to 60%) and body energy (30%) during the first two parities. Xiccato (1996) reported that in young does that are pregnant and lactating, a negative energy balance occurs, resulting in a 40% loss of body fat. In ruminants, negative energy balance during early lactation decreases fertility rate (Butler, 1999). In our study, the low kindling rate in the second parity might have been caused by the significant loss of body fat and energy. However, there is no information on the effect of negative energy balance on subsequent fertility in rabbits.

Based on our study, it does not seem likely that the litter size in which does are raised will decrease replacement rate of young does. There was no difference among treatments in the number of animals removed during the experiments, and feed intake during the first two parities was not affected.

IMPLICATIONS

Results obtained indicate that litter size before weaning affects BW at weaning and litter size after first pregnancy. Kits raised in litters of 12 kits tend to produce smaller litters in their first parity than kits raised in litters of nine kits, and this loss is not compensated for after two parities. Decreasing the litter size before weaning from nine to six kits does not alter future reproductive performance. Based on these results it is advisable to perform a limited standardization level (at nine kits) after kindling to increase weaning weight and improve reproductive performance. Delaying first mating by 3 wk positively affected kindling rate, total litter size, and kits born alive in the first parity. Although 75 to 80% of mature BW is reached at 14.5 wk of age, it seems advisable to delay first mating until 17.5 wk of age.

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CHAPTER 3

RELATIONSHIPS BETWEEN BODY WEIGHT AT FIRST MATING AND SUBSEQUENT BODY DEVELOPMENT, FEED INTAKE, AND REPRODUCTIVE PERFORMANCE OF RABBIT DOES

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ABSTRACT

In the second parity, no differences among groups were found, except for the percentage of stillborn kits at kindling. Small does had a higher percentage of stillborn kits than medium and heavy does, principally due to 2 does with 70 and 80% stillborn kits ($P < 0.05$).

A retrospective study was performed to evaluate the relationships between BW at first insemination and subsequent body development, feed intake, reproductive performance, and culling rate of rabbit does. Young rabbit does are vulnerable to body energy deficit in first lactation, resulting in decreased reproductive performance and high replacement rate. Heavy does at first insemination might be able to benefit from the extra amount of BW to cope with the energy deficit during first lactation. Data of three experiments were used in which does were fed ad libitum during rearing and inseminated at 14.5 wk of age. The first two parities of each doe were recorded. Does were categorized in three groups based on their BW at 14.5 wk of age (first insemination): heavy (BW $\geq$ 4,000 g), medium (BW 3,500 to 4,000 g), and small (BW < 3,500 g). Among does that kindled, differences in BW at first insemination were related to differences in voluntary feed intake and body growth rate during rearing. Heavy does consumed more feed per day (+ 45 g/d, $P < 0.001$)) and had a higher body weight gain (+ 12 g/d, $P < 0.001$) than small does from weaning (4.5 wk) to 14.5 wk of age. Body weight at first insemination did not affect BW, feed intake, and culling rate during the first two parities. Heavy does were heavier at first insemination and remained so throughout the reproductive period, but they followed a similar BW curve as medium and small does. A higher BW at first insemination (14.5 wk of age) improved litter size in the first parity (8.9, 7.7, and 6.4 for heavy, medium and small does, respectively, $P < 0.05$). Extra BW at start of reproduction improves litter size in the first parity but does not contribute to an improved feed intake or increased body weight development during reproduction.

INTRODUCTION

In commercial rabbit production, does suffer from a severe loss of body energy during first lactation, resulting in subsequent decreased reproductive performance and high replacement rate of young does (Xiccato, 1996). Rearing conditions may enhance the problem of negative energy balance during first lactation (Maertens, 1992; Xiccato, 1996).

Likewise does are often fed to appetite during rearing and first insemination is recommended at approximately 75 to 80% of mature BW (Lebas et al., 1986). In modern management, young does are not inseminated at a fixed BW but at a fixed age. Under ad libitum feeding conditions during rearing, does can develop according to their growth potential, and BW differences at first mating (at a fixed age) will be substantial. At the same age, heavy does can benefit from the extra amount of BW at the end of rearing to withstand the energy deficit during first lactation. The consequence of variation in BW at first mating (at a fixed age) on feed intake, body development, and prolificacy in subsequent reproductive life is unknown.

Therefore, the objective of this study was to evaluate relationships between BW at first mating and subsequent body development, feed intake, and reproductive performance in does fed ad libitum during rearing. To understand the causes of BW differences at first mating, BW, feed intake, and gain/feed ratio during rearing were also studied.

MATERIALS AND METHODS

Animals and Husbandry

Data from does fed to appetite during rearing were obtained from three subsequent experiments (Rommers et al., 2001a and a set of unpublished data). The experiments were performed from April 1997 to May 2001 with a strain of New Zealand White rabbits bred at the Institute of Animal Husbandry. The Use and Care Committee of the Research Institute of Animal Husbandry approved all protocols.

Rearing Period. Experiments varied in condition during the pre-weaning period. In Exp. 1 and 2, does were held in litter sizes of six, nine, or 12 kits, whereas in Exp. 3, does were held in litters of nine kits. After weaning (4.5 wk of age) does were reared similarly. In Exp. 1, 48 does, in Exp. 2, 42 does, and in Exp. 3, 52 does were put into individual cages (50 x 60 x 30 cm) of galvanized wire net, equipped with an automatic drinker, and a manual feeder in identical deep-pit compartments. Does had free access to a standard commercial diet, containing 10.3 MJ ME/kg, and 17% CP (ABCTA Lochem, The Netherlands). The first 2 wk after weaning, a minimum ambient temperature of 18 ^{o}C was maintained. From 2 wk after weaning onwards, the minimum ambient temperature was set to 16 ^{o}C. Does were submitted to a photoperiod of 12 h. Rearing period ended at 14.5 wk of age.

Reproductive Period. The reproductive period included the first two parities of each doe until weaning of the second litter. Does were housed in the same cages as during rearing. A minimum ambient temperature of 16 ^{o}C was maintained and does were submitted to a photoperiod of 16 h.

At 14.5 wk of age (end of rearing), receptive does were inseminated. Does were scored receptive if the vulva was red or purple colored and swollen. For the second parity, does were inseminated 10 to 12 d after kindling (semi-intensive breeding rhythm).

Inseminations were performed with fresh mixed sperm from 12 bucks, selected for growth performance. On each insemination date, one mixed and diluted semen dose was prepared. Dilution was performed using a commercial extender (Galap, IMV, L'Aigle Cedex, France) according to the method developed by Zöldágh et al. (1988). A GnRH analogue was administered i.m. (0.00084 ml Buseriline-acetate; Receptal, Intervet, Boxmeer, The Netherlands) immediately after insemination to induce ovulation.

Five days before kindling, each doe had free access to a nestbox that was put in front of the cage. The first day after kindling, litter size was standardized at eight kits in the first parity and nine kits in the second parity. Nestboxes were removed 3 wk after kindling and kits were put in the cage with the doe to stimulate solid-feed intake. Kits were weaned at 4.5 wk of age.

After first insemination, does were fed the same diet as during rearing. Experiments varied in feeding level during first gestation. In Exp. 1, and 2, does were fed to appetite, whereas in Exp. 3 does were fed, according to the recommendation of Maertens (1993) (first 21 d of gestation: 0.400 kJ ME/BW$^{0.75}$ + 0.38 MJ per day, from 21 d onward: 0.400 kJ ME/BW$^{0.75}$ + 1.13 MJ per day). After the first kindling all does were allowed to consume their feed on an ad libitum basis.

Measurements

The following separate phases were used for measurements: rearing period (from weaning at 4.5 wk until first insemination at 14.5 wk), first gestation period (from first insemination to first kindling), first lactation (from kindling to weaning [30d]), weaning to kindling interval (12 d), and second lactation (from second kindling to weaning of the second litter [30 d]).

Rearing Period

Body weight, Feed intake, and Gain/Feed Ratio. Does were weighed weekly from weaning (at 4. 5 wk of age) until first insemination at 14.5 wk of age. Feed intake was determined by weighing of the feeder at the beginning and end of each week and the weight of all feed supplies given within a week were recorded. If wastage occurred, period and cage were recorded, and the feed intake for this period was scored as missing value. Body weight and feed intake were used to calculate gain/feed ratio (g gain/g feed).

Reproductive Period

Body Weight and Feed Intake. In the first and second parity, BW was determined at the first day after kindling, at d 16, and at d 30 of lactation. Feed intake was determined for the first gestation period, from kindling until d 16 of lactation, from d 16 until d 30 of lactation for both the first and second parity, and from weaning to second kindling. Feed intake was determined by weighing of the feeder at the beginning and end of each reproductive stage and all feed given within each stage was recorded.

Reproductive Performance. Kindling rate was calculated as the number of does kindled divided by the number of does inseminated. The number of live and stillborn kits (total litter size), the number of kits at d 16 and d 30 of lactation, together with the litter weight at d16, and d 30 were recorded. The average kit weight at d 16 was used as an estimate for milk production, because in our system we observe that kits start eating solid feed from 17 d onwards (Rommers, personal communication).

Culling of Does. The number of does culled and the reason of culling was recorded. Dissections were performed on dead and diseased does.

Treatments

Body weight at first insemination at 14.5 wk of age was used to assign each doe to one of the following three groups: 1) heavy (H): BW $\geq$ 4,000 g, 2) medium (M): BW $\geq$ 3,500 and < 4,000 g, 3) small (S): BW < 3,500 g. The mature BW of medium-sized hybrid rabbits, as used in our study, varies between 4.5 to 5 kg. In rabbit production, first insemination is recommended at 75 to 80% of mature BW. In general, does smaller then 3,500 g are considered too small, whereas does heavier then 4,000 g are considered too fat for first insemination. Body weight ranges were based on this principle. The number of does in the second parity did not permit more then three groups for statistical analysis.

Statistical Analysis

Body weight, Feed Intake, and Gain/Feed Ratio During Rearing. Data of does that kindled after the first insemination at 14.5 wk of age were used for analysis. Body weight, feed intake, and efficiency were analyzed for the total rearing period. To understand the causes of BW differences at first mating, BW, feed intake, and gain/feed ratio were also calculated for each of the 10 successive weeks of rearing. For analysis of gain/feed ratio, individual gain/feed ratio deviating more then three times the standard deviation from the mean were scored as missing value (n= 4).

To test differences among groups during the total rearing period and the 10 successive weeks of rearing the following model was used: $Y_{ij} = \mu + E_i + G_j + (ExG)_{ij} + e_{ij}$ [model 1] where Y_{ij} is dependent variable; μ = overall mean; E_i = experiment 1, 2, and 3; G_j = group H, M, and S; and e_{ij} is the residual error. Experiment included variation due to differences in litter size before weaning. In all analysis, non-significant interactions were deleted from the model. All statistical analysis were performed with the GLM procedure of SAS (SAS Inst. Inc., Cary, NC).

Body weight, Weight Gain, and Feed Intake During the Reproductive Period. Data were used of does that kindled. To analyze the effect of treatment, model 1 was used.

Reproductive Performance. For the first parity, data were used of does that kindled after the first insemination at 14.5 wk of age. For the second parity, does were used that kindled after the first insemination 10 to 12 d postpartum. Differences in kindling rate and percentage of stillborn kits among groups were analyzed with a Chi-square test. To analyze the effect of treatment, model 1 was used.

Culling Rate of Does During the First Two Parities. Data of all does were used for analyses of culling rate. Differences in culling rate among groups were analyzed with a Chi-square test.

Experiment included variation due to differences in litter size in the pre-weaning period. The number of does that were raised in litters of 6, 9, and 12 kits before weaning for each group is included in Table 1. To test the effect of litter size in which kits were reared in the pre-weaning period on subsequent body development, feed intake, and reproductive performance, the above analysis (see model 1) was performed on data of kits raised in litters of 9 kits in the three experiments. At weaning, similar differences in BW among weight groups were found, and effects on body development and feed intake during rearing and reproduction were similar compared with analysis performed on all data. Therefore, we feel confident that the effect of litter size in the pre-weaning period did not affect subsequent results.

In Exp. 3, does were fed according to energy requirements. However, analysis performed on data of Exp. 1 and 2 revealed similar effects among groups for all characteristics compared with analysis based on all 3 experiments. Therefore, data of all three experiments were used in the analysis to increase the number of does per weight group.

RESULTS

Culling Rate

The change in number of does during the experiments for each group is given in Table 1. No culling occurred during rearing. During the reproductive period, no difference in culling of does among treatments was found. The total percentage of does culled was 11.9%, 12.5%, and 11.3% for heavy, medium, and small does, respectively.

No specific differences for culling reasons among groups were found. The percentage of does that succeeded the reproductive rhythm during the first 2 parities did not differ among groups. The percentage of does that kindled after the first insemination at 14.5 wk of age and after the first inseminations 10-12 d after kindling in the first and second parity was 38.1%, 38.6%, and 37.7% for heavy, medium, and small does, respectively.

Body Weight, Feed Intake, and Gain/Feed Ratio During Rearing

Body weight, weight gain, feed intake, and gain/feed ratio for the total rearing period (from weaning until first insemination) for does that kindled after the first insemination at 14.5 wk of age are presented in Table 2. Feed wastage was observed in 2 small does, and 1 heavy doe.

No interaction was found between experiment and group. For the total rearing period, groups differed ($P < 0.001$) in BW at weaning, BW at insemination, body growth, and feed intake. Heavy does at first insemination were does with the heaviest BW at weaning, the fastest weight gain, and the highest feed intake during rearing, whereas small does at first insemination were smallest at weaning, grew slowest, and ate the lowest amount of feed during rearing. Gain/feed ratio was similar for all treatment groups.

Table 1. Number of does during rearing and reproduction.

	Weight group								
Item BW at 14.5 wk of age, g:	≥ 4,000			≥ 3,500 and < 4,000			< 3,500		
	Pre-weaning period								
Litter size in pre-weaning period	6	9	12	6	9	12	6	9	12
Does, no.	8	22	5	22	58	12	18	19	29
	Rearing period								
At 4.5 wk of age (weaning)	45			92			56		
Culling during rearing	0			0			0		
Non-receptive at 14.5 wk of age[a]	3			4			3		
	First parity								
First insemination at 14.5 wk of age	42			88			53		
Non-pregnant[a]	10			22			17		
Abortion (culled)	1			0			3		
Kindling, 1st parity	31			66			33		
Dystocia	0			2			0		
Removed during 1st lactation[b]	4			8			3		
	Second parity								
Second insemination (10-12 d post partum)	31			64			33		
Non-pregnant[a]	11			22			10		
Kindling, 2nd parity	16			34			20		
Dystocia	0			0			1		
Removed during 2nd lactation[b]	0			1			1		
Total culled, no[c]	5			13			6		

[a] Non-receptive and non-pregnant does were excluded from the data set.

[b] Culling was caused by several reasons, such as does that did not nurse their kits, metritis, mastitis, diarrhea, and teeth disformation.

[c] Culled for other reasons then not pregnant

Table 2. Body weight, weight gain, feed intake and gain/feed ratio from weaning (4.5 wk of age) to first insemination (14.5 wk of age) for does that kindled after first insemination.

	Weight group			SEM	*P*-value
BW at 14.5 wk of age, g	≥ 4,000	≥ 3,500 and < 4,000	< 3,500		
Does, no.	32	66	36		
BW at weaning, g	828^{a}	752^{b}	636^{c}	14	0.001
BW at first insemination , g	4,222^{a}	3,750^{b}	3,180^{c}	27	0.001
Weight gain, g/d	47.6^{a}	42.0^{b}	35.7^{c}	0.4	0.001
Feed intake, g/d	179^{a}	160^{b}	134^{c}	2	0.001
Feed/gain ratio (g gain/g feed)	0.266	0.264	0.266	0.04	0.743

^{a,b,c} LSmeans with different letter in a row differ ($P < 0.001$).

Body weight at weaning was included as a covariate in the model to evaluate its effect on later performance. The covariate was significant ($P < 0.001$) for BW at 14.5 wk of age, feed intake, and gain/feed ratio, whereas the covariate was not significant for weight gain. However, after correction for BW at weaning differences in BW, body growth, and feed intake among groups maintained. Gain/feed ratio differed ($P < 0.05$) between heavy and small does, when BW at weaning was used as covariate in the analysis (3.66 and 3.87 for heavy and small does, respectively and intermediate for medium does, 3.77).

Analysis of BW, and feed intake per week revealed that differences among groups remained throughout the rearing period, and gain/feed ratio for the three groups followed the same curve until 14.5 wk of age.

Body Weight, Body Growth, and Feed Intake During Reproduction

The number of does that kindled to the second service was 20 for heavy, 34 for medium, and 16 for small does (see Table 1). Body weight during the successive periods of reproduction for these does is presented in Figure 1. Weight gain during reproduction is given in Table 3.

Table 3. Weight gain in different stages of reproduction for does, that kindled to the second service.

	Weight group			SEM	*P*-value
BW at 14.5 wk of age , g	≥ 4,000	≥ 3,500 and < 4,000	< 3,500		
Does, no.	16	34	20		
First gestation, g	-45[a]	167[b]	306[c]	41	0.001
	-------------------- First parity ---------------------				
Kindling to d 16 of lactation, g	614	462	516	58	0.17
Day 17 to d 30 of lactation, g	-34	8	-12	22	0.81
Weaning to kindling interval, g	-558	-487	-472	46	0.41
	-------------------- Second parity ----------------				
Kindling to d 16 of lactation, g	629	587	565	54	0.72
Day 17 to d 30 of lactation, g	-60	-4	-44	36	0.48

[a,b] LSmeans with a different letter in a row differ ($P < 0.05$).

Although does in Exp. 3 were feed restricted instead of ad libitum, no differences in BW, and weight gain during first gestation was found among experiments. Therefore, average BW of the three experiments is presented for each group. For one medium doe, weighing of the doe and feeder was missed at 16 d of first lactation. One small doe, failed to nurse the kits in the first lactation; the number of kits at d 16 and 30 of lactation was scored zero and feed intake was scored as missing value. The figure shows that heavy, medium, and small does had similar BW curves during reproduction. If BW during reproduction was corrected for difference in BW at first insemination, no differences in BW at the different stages of reproduction among experiments was found. This implies that groups followed the same BW curve independent of their BW at start of reproduction.

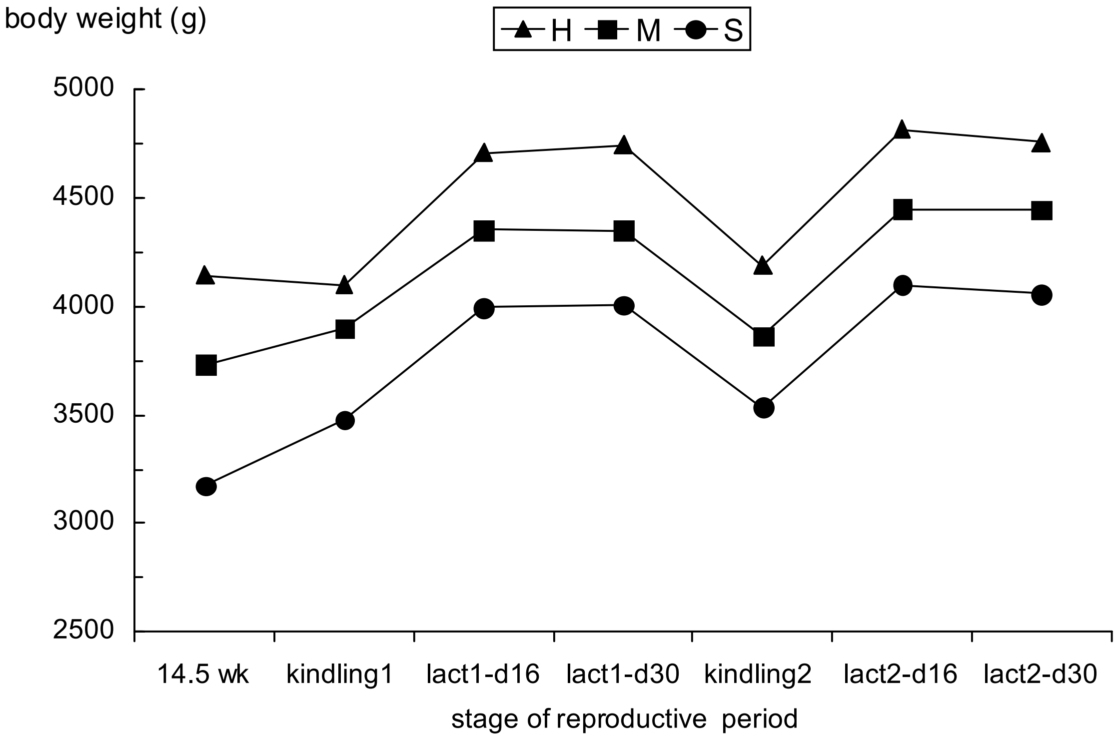

Figure 1. Body development during reproduction for heavy (H, n = 29), medium (M, n = 34), and small (S, n = 16) does based on BW at 14.5 wk of age (first insemination) that kindled to their second service. LSM are presented.

Small does were able to catch-up some of the difference in BW at 14.5 wk of age during first gestation (see Table 3). Small does grew 306 ± 52 g, medium does grew 167 ± 39 g, whereas H does lost - 45 ± 60 g during first gestation ($P < 0.001$). After two parities, small does remained smaller than medium and heavy does (4,057, 4,448, and 4,758 g respectively, $P < 0.001$).

Feed intake during the successive periods of reproduction for the heavy, medium, and small does is given in Table 4. Feed wastage was observed in the weaning to kindling interval (first to second parity) in one small doe and feed intake was scored as missing value. During first lactation, no difference in feed intake among experiments was found. Therefore, average feed intake of the 3 experiments for each group is presented from first kindling onwards. No differences in feed intake among groups were found during the first parity. In the first 16 d of the second lactation heavy does consumed more feed than small does, whereas feed intake of medium does was intermediate (402, 383, and 367 ± 11 g/d for heavy, medium, and small does, respectively).

Table 4. Daily feed intake (g) in different stages of reproduction for does, that kindled to the second service.

BW at 14.5 wk of age, g	≥ 4,000	≥ 3,500 and < 4,000	<3,500	SEM	*P* – value
Does, no.	16	34	20		
		First gestation			
Experiment 1 and 2	167	167	147	6	0.19
Experiment 3	146	150	142	7	0.33
		First parity			
Kindling to d 16 of lactation	327	324	314	11	0.32
Day 17 to d 30 of lactation[a]	464	478	480	13	0.88
Weaning to kindling interval	216	214	193	7	0.42
		Second parity			
Kindling to d 16 of lactation	402[a]	383[ab]	367[b]	9	0.019
Day 17 to d 30 of lactation[a]	567	568	532	14	0.06

[a] Feed intake of doe and kits.

[a,b] LSmeans with different letter in a row differ (*P* < 0.05).

Reproductive Performance

Reproductive performance in the first and second parity for each group is presented in Table 5. No interaction was found between experiment and group in either parity. No difference in kindling rate was found among groups after first insemination at 14.5 wk of age and after first insemination 10 to 12 d postpartum during first lactation.

In the first parity, small does produced smaller litters than heavy does, whereas total litter size of medium does was intermediate (8.9, 7.7, and 6.4 ± 0.5 for heavy, medium, and small does, respectively, *P* < 0.05). Heavy does had a higher percentage of still born kits at kindling than small, and medium does.

Table 5. Reproductive performance of the first and second parity.

	Weight group			SEM	*P*-value
BW at 14.5 wk of age , g	≥ 4000	≥ 3500 and < 4000	< 3500		
	---------------- First Parity ------------------				
Does, no	31	66	33		
Kindling rate, %	74.4	75.0	69.2		
Total litter size, no.	8.9[a]	7.7[ab]	6.4[b]	0.4	0.001
Kits born alive, no.	7.7	7.3	6.1	0.5	0.049
Kit mortality at birth, %	13.4[a]	5.5[a]	4.6[b]		
Kits at d 16 of lactation, no.[1]	7.3	7.7	7.4	0.2	0.29
Av. kit weight at d16 of lactation , g	262[a]	248[a]	235[b]	6	0.02
Kits weaned (d 30), no.[1]	6.9[y]	7.6[z]	7.3[yz]	0.2	0.08
Av. kit weight at 30 d of lactation , g	688	685	659	18	0.44
	--------------- Second Parity ---------------				
Does, no.	16	34	20		
Kindling rate, %	51.6	53.1	60.6		
Total litter size, no.	10.8	10.2	10.0	0.6	0.67
Kits born alive, no.	9.4	9.0	8.3	0.8	0.63
Kit mortality at birth, %	13.0[a]	11.8[a]	17.0[b]		
Kits at 16 d of lactation, no.[1]	8.5	8.4	8.2	0.2	0.52
Av. kit weight at 16 d of lactation , g	295[y]	294[y]	276[z]	7	0.09
Kits weaned (30 d), no.[1]	8.4	8.4	8.1	0.2	0.37
Av. kit weight at 30 d of lactation , g	767	766	726	16	0.12

[1] Litter size was standardized after kindling; in the first parity at eight kits, in the second parity at nine kits.

[ab] LSmeans with a different letter in a row differ ($P < 0.05$).

[yz] LSmeans with a different letter in a row tend to be different ($P < 0.1$).

Five does that lost most or all of their kits (60 up to 100% stillborn) principally caused this mortality. There was a tendency ($P < 0.10$) for a higher number of kits weaned for medium than for small and heavy does. Although heavy does had a higher litter weight at d 16 of lactation ($P < 0.05$), no differences were found among groups in mean kit weight at weaning.

In the second parity, no differences among groups were found, except for the percentage of stillborn kits at kindling. Small does had a higher percentage of stillborn kits than medium and heavy does, principally due to 2 does with 70 and 80% stillborn kits ($P < 0.05$).

DISCUSSION

Rabbit does are vulnerable to a severe energy deficit during first lactation (Xiccato, 1996), resulting in decreased reproductive performance and high replacement rate. Our hypothesis was that, at the same age at first insemination, heavier does might be able to benefit from the extra amount of BW to overcome the energy deficit during first lactation.

Firstly, the causes of weight differences at first mating, BW, body development, feed intake, and gain/feed ratio during rearing for does that were fed to appetite were evaluated. Data of the rearing period showed, that heavy does can be characterized as does with a high growth rate, and a high voluntary feed intake, whereas small does showed a 25% lower growth rate, and consumed 25% less food per day. Gain/feed ratio among groups was equal. This indicates that in heavy does no additional fat deposits could have been formed. At the same level of feed intake, gain/feed ratio decreases when fat is being formed. This was not the case. Even when feed conversion was corrected for BW at weaning, gain/feed ratio of heavy does was higher instead of a lower than small does. Therefore, it can be assumed that heavy does had not formed relatively more fat tissue compared with medium and small does at 14.5 wk of age and body composition among groups must have been similar. Heavy does were heavier as a consequence of a higher feed intake or a higher growth potential, but that overfattening had not occurred.

Secondly, the effect of BW at first insemination on subsequent bodyweight gain, feed intake, and reproductive performance was studied. If heavy does are able to benefit from the extra amount of BW, it should be expressed in either a decreased culling rate or improved reproductive performance. However, no difference was found among groups in the percentage of does culled during reproduction or percentage of does kindling to the second insemination.

Body weight at 14.5 wk did affect productive performance in the first parity. Heavy does produced 2.5 kits more than small does in the first parity. Rommers et al. (2001b) showed that at the same age, heavier does had larger uterine horns, and more corpora lutea on the ovaries compared with small does. In that study, lower BW was caused by restricted feed intake during rearing and resulted in an average BW of 3,590 g for small does. BW at 14.5 wk of age for small does in this study was even 400 g lower.

Body weight at first insemination seems to affect milk production; heavy does had heavier kits at d 16 of lactation in the first parity. In the second parity medium and heavy does tended to have heavier kits at 16 d of lactation. However, in both parities the higher milk production did not result in a heavier weight of the kits at weaning. Kits of small does may have compensated for the lower amount of milk available to them by consuming more pelleted feed as found by Parigi-Bini et al. (1992) and Xiccato et al. (1995). In our study feed intake of the kits was not recorded separately from the feed intake of the doe.

In the second parity, no difference among groups in reproductive performance was found anymore. The decreased kindling rate (average of 53%) might have been related to the body energy loss, that occurs in the first parity (Parigi-Bini and Xiccato, 1993). Parigi-Bini and Xiccato (1993) found a lower litter size in the second parity, which was not the case in our study. A more intensive breeding rhythm was used in their study (does were re-mated between 1 to 4 days after kindling), that could have resulted in a more negative energy balance during lactation. This might have affected litter size in the second parity in their study. Taking into account the limited number of small does, the higher rate of stillborn kits in this group seems to be caused by two does with a high kit mortality and this fact should induce prudence to draw conclusions.

The fact that no difference was found in percentage of does that could follow the reproductive rhythm or percentage of does that was culled during reproduction can be explained by the feed intake and BW curve during reproduction. Although heavy does had a higher voluntary feed intake during rearing, no difference in feed intake during the first parity was found compared with small and medium does. Our data reveal that correlation between feed intake during rearing and feed intake during first lactation is low (r = 0.14). In the weaning to kindling interval and in the first 16 d of second lactation, heavy does had a higher feed intake than small does. Except for maintenance requirement, the extra feed intake seems to have been used for milk production. In several studies, an increased energy intake resulted in an increased milk production, whereas the weight gain of the doe was not affected (Fortun-Lamothe, 1997). Although heavy does were heavier at first insemination and remained heavier throughout the reproductive period, they followed a similar BW curve after weaning of the first litter as small and medium does. This BW loss from weaning of the first litter to kindling of the second litter is related to the high energy demand for fetal growth (Parigi-Bini et al., 1990) and drop in feed intake during the last 10 days of gestation (Partridge et al., 1986; Maertens, 1993). Our findings indicate that heavy does do not seem to benefit from the extra feed intake capacity or the extra BW at start to an increase BW development, improve feed intake, or decrease culling during reproduction.

IMPLICATIONS

It can be concluded that differences in body weight at 14.5 wk of age in ad libitum fed does during rearing is related to difference in voluntary feed intake and growth potential during rearing. A higher BW at end of rearing results in a better productive performance in the first parity in terms of litter size, probably due to a higher degree of maturity. However, feed intake during reproduction is not improved and no differences in BW development during reproduction was observed.

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CHAPTER 4

EFFECT OF DIFFERENT FEEDING LEVELS DURING REARING AND AGE AT FIRST INSEMINATION ON BODY DEVELOPMENT, BODY COMPOSITION, AND PUBERTY CHARACTERISTICS OF RABBIT DOES

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ABSTRACT

An experiment was performed to study the effect of feeding level during rearing and age at first mating on body growth, body development and puberty of rabbit does. The experiment started at six wk of age, using 64 animals of a strain of New-Zealand White rabbits. Feeding level was either ad libitum (AL) or restrictive (R) and animals were inseminated at 14.5 or 17.5 wk of age. In R-animals, feed restriction was up to 58% of AL from six to 12 wk of age. From 12 wk of age onwards, feeding level was steadily increased to stimulate body growth and sexual development. Average feeding level of R-animals during rearing was 79% of AL. Five days after insemination, 10 animals per treatment were slaughtered to determine body composition, corpora lutea (CL) and embryos. At 14.5 wk of age, R-animals were lighter ($P < 0.001$; 3,621 ± 232 and 4,121 ± 343 g for R-14.5 and AL-14.5, respectively) and their empty bodies (EB) contained 12% less ash, 11% less protein and 41% less fat than EB of AL-14.5 animals. When rearing period was extended to 17.5 wk of age, R-17.5 animals reached a similar BW as AL-14.5 animals (4,139 ± 256g). From 14.5 to 17.5 wk R-animals were able to compensate for differences in ash and protein content, but fat content of the EB was 14% lower compared with EB composition of AL-14.5 animals. When rearing period was extended with three wk under AL feeding conditions, animals gained 9% in BW (4,489 ± 309 g), mainly caused by deposition of fat tissue (+ 34%). First insemination at older age improved receptivity and embryo recovery. Best performance was found for AL-17.5 animals (receptivity 81.3% and embryo recovery rate of 84.7%). No differences were found in puberty characteristics between AL-14.5 and R-17.5 animals. From R-14.5 animals only 12.5 % was receptive at insemination. According to the number of animals with CL, only 50% of this group had reached puberty, indicating that these animals were too immature to start reproduction. Based on this experiment, it can be concluded that restrictive feed intake during rearing resulted in retardation of puberty. Delayed first mating to older age in restrictive fed animals resulted in similar protein and ash development and similar puberty characteristics compared with ad libitum fed animals, but preventing excessive fat deposition. Delaying first mating to older age under ad libitum feeding conditions resulted in the heaviest animals with the highest fat content, but also the best puberty characteristics. Therefore, more research is needed to study the effect of feeding level and extended rearing period on future reproduction and culling of does.

INTRODUCTION

The current rearing management of rabbit does does not appear to prepare animals well enough for subsequent reproduction, in which concurrent lactation and pregnancy demand a high nutritional intake. Nutritional energy deficit during first lactation is considered to be responsible for the decreased reproductive efficiency and the high replacement rate of young does (Xiccato et al., 1995; Xiccato, 1996). The energy deficit in reproductive young does can not be solved sufficiently by management measures during reproduction (Cervera et al., 1993; Xiccato et al., 1995; Parigi-Bini et al., 1996). Solutions such as an adapted rearing program (Parigi-Bini and Xiccato, 1993) were recommended, but information on this is scarce. Feed intake during rearing seems an important factor influencing body development (Rommers et al., 1999). Under practical conditions, rabbit does are often fed ad libitum until first mating. First mating is recommended in rabbit production when 75 to 80% of final body weight is reached (Lebas et al., 1986), which commonly occurs between 14 to 16 wk of age. Delaying first mating to older age might increase the risk of overconditioning, which might cause health problems during lactation or decrease reproductive performance. However, Rommers et al. (submitted) showed that does mated at 17.5 wk of age and fed ad libitum during rearing showed better reproductive performance in their first parity as compared with does mated at 14.5 wk of age. In this study of Rommers et al. (submitted) body weight and age at first mating were correlated. Therefore, an experiment was performed to study the effect of feeding level during rearing and age of first mating on body growth, body development and puberty features of rabbit does, with the objective to delay first mating to older age without excessive fat deposition.

MATERIAL AND METHODS

The experiment was performed from February to August 1999. The Use and Care Committee of the Research Institute of Animal Husbandry approved all protocols.

Animals and Husbandry

The experiment was performed with a strain of New Zealand White rabbits, bred at the Research Institute of Animal Husbandry. Before weaning, kits were raised in litters of nine kits. At weaning (30 d of age), from each of 16 litters, four female kits, with live weight deviating by less than 15% of the average litter weight, were selected. Each group of four sisters was taken and put into four adjacent individual cages (50 x 60 x 30 cm) of galvanized wire net, equipped with an automatic drinker, and a manual feeder. After weaning, animals were fed a standard commercial diet, containing 10.3 MJ/kg ME and 170 g/kg crude protein (ABCTA, Lochem, The Netherlands). Animals were fed according to treatment until five d prior to first insemination. From five days prior to insemination onwards all treatment groups were fed the standard diet ad libitum to stimulate receptivity. The experiment ended five days after first insemination when 10 animals per treatment were slaughtered.

Animals were housed in a deep-pit compartment with controlled lighting. Before weaning, animals were kept at a 16-h photoperiod. During rearing, animals were submitted to a photoperiod of 12 h. The first two wk after weaning, a minimum ambient temperature of 18 ^{o}C was maintained. From two wk after weaning onwards, the minimum ambient temperature was set at 16 ^{o}C.

Treatments

Treatments started at six wk of age, using a 2 x 2 factorial design with feeding level and age of first insemination as factors. Feeding level was either ad libitum feeding (AL) or restrictive feeding (R) until first insemination; first insemination was performed at either 14.5 or 17.5 wk of age. Sisters were randomly assigned to one of the four treatments (AL-14.5, AL-17.5, R-14.5 and R-17.5).

From data of a previous experiment (Rommers et al., submitted), body weight (BW) curve for AL-animals was fitted (see Figure 1). The BW curve for the R treatments was derived from this curve. From 6 to 10 wk of age, body growth was purposively reduced to hinder protein development (Ledin, 1984) by gradually reducing feed intake. From 10 wk of age onwards, body growth was increased by gradually increasing feed intake to stimulate sexual development and puberty, following the slope of the AL-curve. Taking into account the fact that animals first compensate for the loss in protein (Ledin, 19984), the purpose of the feeding plan was to prevent excessive fat deposition (which commonly occurs after 10 to 12 wk of age; De Blas et al., 1977; Deltoro and Lopez, 1985) by obtaining the same BW at 17.5 wk of age as AL-animals had at 14.5 wk of age.

The R-animals were fed daily a restricted amount of feed, aiming to follow the fixed BW curve as drawn in Figure 1. Therefore, BW was determined twice weekly from weaning until first insemination and based on BW feed intake was corrected in order to follow the fixed BW curve. If the daily supply was not eaten completely, remaining feed was removed.

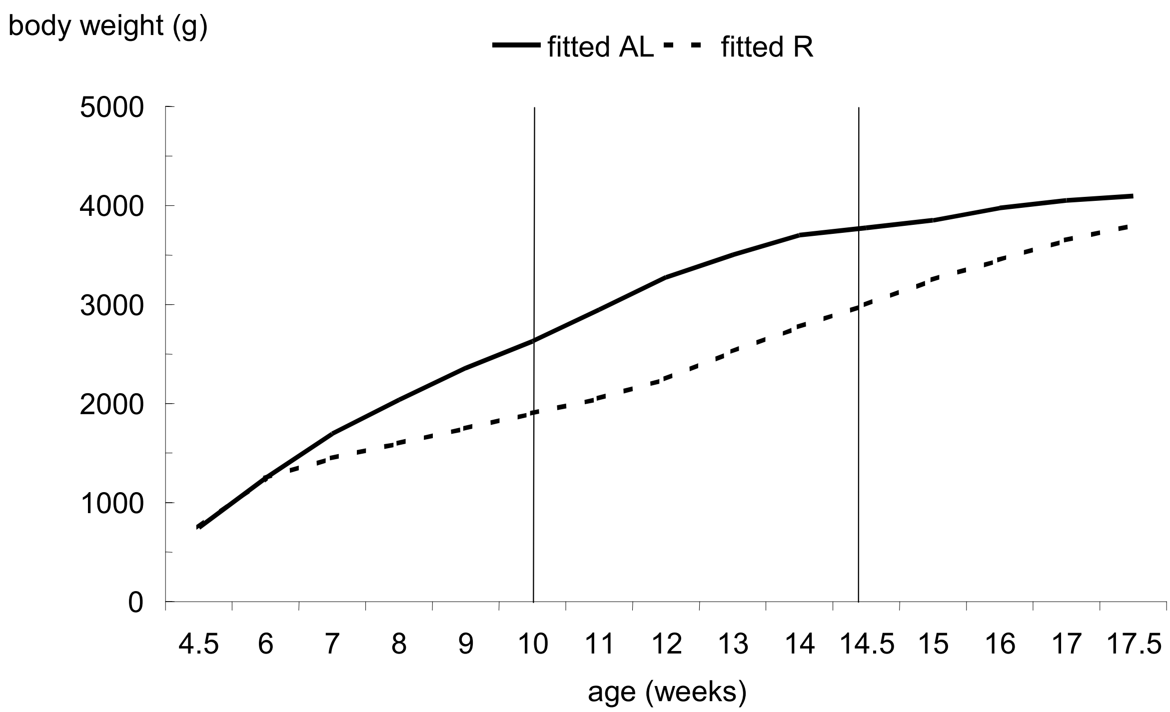

Figure 1. Fixed body weight curve for the ad libitum (AL) and restrictive (R) feeding during rearing from weaning (4.5 wk) to first insemination at 14.5 or 17.5 wk of age.

Inseminations

Artificial insemination was performed with fresh mixed semen of 10 bucks, selected for growth performance. At the day of insemination, one mixed and diluted semen dose was prepared. Dilution was performed using a commercial extender (Galap, IMV, France) according to the method developed by Zöldág et al. (1988). A GnRH analogue was injected i.m. (0.2 ml Receptal, Hoechst Roussel Vet, Brussels) immediately after insemination to induce ovulation.

Measurements

Body Weight and Feed Intake. Animals were weighed individually twice weekly from weaning to first insemination. For AL-animals, feed intake was determined twice weekly by weighing of the feeder at beginning and end of each period and the weight of all feed supplies given in between were recorded. For R-animals the amount of feed not eaten per day was weighed wkly to determine actual feed intake. If wastage occurred, period and cage were recorded, and feed intake for this period was scored as missing value.

Body Composition. Body composition was determined for 10 animals per treatment (sisters). Animals were weighed and killed (CO-gas) five days after insemination, and the contents of the digestive tract and bladder were removed. Empty body weight (EBW) is defined as live weight minus gut and bladder content. Also empty stomach and uterine horns were weighed separately. Empty bodies (EB) were frozen at –20 ^{o}C until grinding and homogenization. Representative samples of the empty bodies were analyzed. Dry matter content was determined by freeze-drying. Nitrogen content was analyzed in fresh samples by Kjeldahl analysis. Protein was calculated by the nitrogen content multiplied by 6.25. Fat content was determined by extraction of freeze-dried samples with petroleum-ether and drying the extract at 80 ^{o}C in a vacuum oven (10 kPa) to constant weight. Ash was determined in oven-dried samples in a furnace at 550 ^{o}C.

Puberty Characteristics. Receptivity, number of corpora lutea (CL), number of embryos and embryo recovery rate. Five days before insemination and at insemination, animals were checked for receptivity by the color and turgidity of the vulva. Animals were scored receptive, if the vulva was swollen and colored (red or red to purple). From the 10 animals per treatment group slaughtered five days after insemination, reproductive tract was removed and uterine horns were flushed with saline (twice 5 ml per uterine horn) and embryos were collected in a petridish. Number of embryos were counted under a light microscope (magnification x 10). Corpora lutea (CL) were counted on the ovaries. Recovery rate was calculated as number of embryos divided by number of CL.

Statistical Analyses

The experiment was a randomized block. A block consisted out of four adjacent cages with sisters. The four treatments were randomized within a block. Analyses of variance were carried out using the GLM procedure of SAS (SAS Inst. Inc., Cary, NC, USA). Differences between LSM were analyzed by the PDIFF option of the GLM procedure of SAS. Body weight, feed intake and body composition data were analyzed with block, feeding level, age of first insemination, and the interaction between feeding level and age of first insemination as factors. A Chi-square test was used to analyze treatment differences in receptivity and embryo recovery rate. Data are presented as means and standard deviations.

RESULTS

Animals

During the experiment one animal of R-17.5 died four d after insemination. Liver necrosis and haemorrhagic fluid in the abdomen and cervix were observed at dissection. No other animals were culled during the experiment.

Body Weight, Feed Intake and Feed Conversion

The actual BW curves for the treatments and fixed BW curves are in Figure 2. Between six and eight wk of age, BW of R-animals was not reduced as planned. At six wk of age, feed intake of R-animals was fixed at the average daily feed intake of the previous four days (7 to 10 d after weaning). This level ranged for individual animals between 99 and 152 gram/d. In high feed intake levels, body growth was not reduced as expected, resulting in a higher average BW as planned. Therefore, feed intake was reduced to 115 gram/d for all R-animals with a higher feed intake than 115 gram/d at 7.5 wk of age (see Figure 3). This feeding level was maintained until 10 wk of age.

From 10 wk of age onwards, daily feed intake was steadily increased by 5 to 15 gram/d weekly. From 12 wk of age onwards BW curve of R-animals run parallel to the BW-curve of AL-animals.

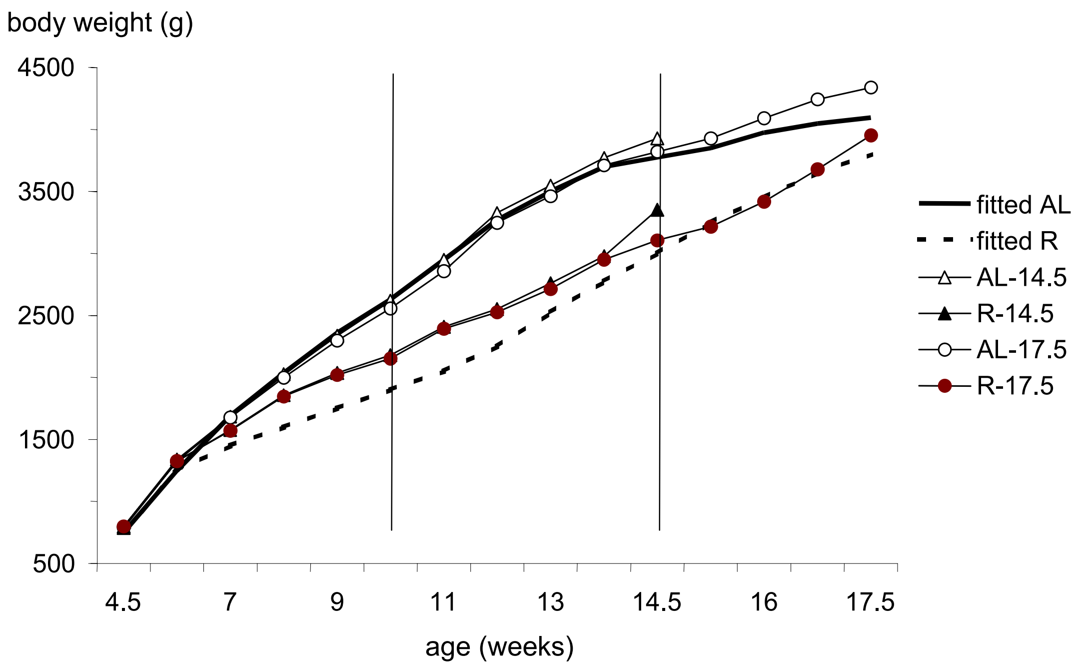

Figure 2. Realized and fixed BW curves during rearing (from weaning to first insemination) for animals, fed ad libitum (AL) or restrictive (R) and inseminated at 14.5 or 17.5 wk of age. The standard deviation ranged from 65 to 384 g.

The AL-animals reached a higher BW as expected at first insemination at 14.5 as well as at 17.5 wk of age. Because the same angle of the BW curve of AL-animals was followed for R-animals from 10 wk of age, we succeeded in reaching similar BW for R-17.5 animals and AL-14.5 animals at first insemination (see Table 1).

Feed intake during rearing for AL and R-groups is in Figure 3. Average feeding level of R-animals during rearing was 79% of AL-animals. However, from six to 10 wk of age, feed restriction was more severe (up to 58% of AL). From 10 wk of age onwards, feeding level was steadily increased to stimulate body growth and sexual development (from 115±5 g to 238±8 g from 10 until 17 wk of age, respectively).

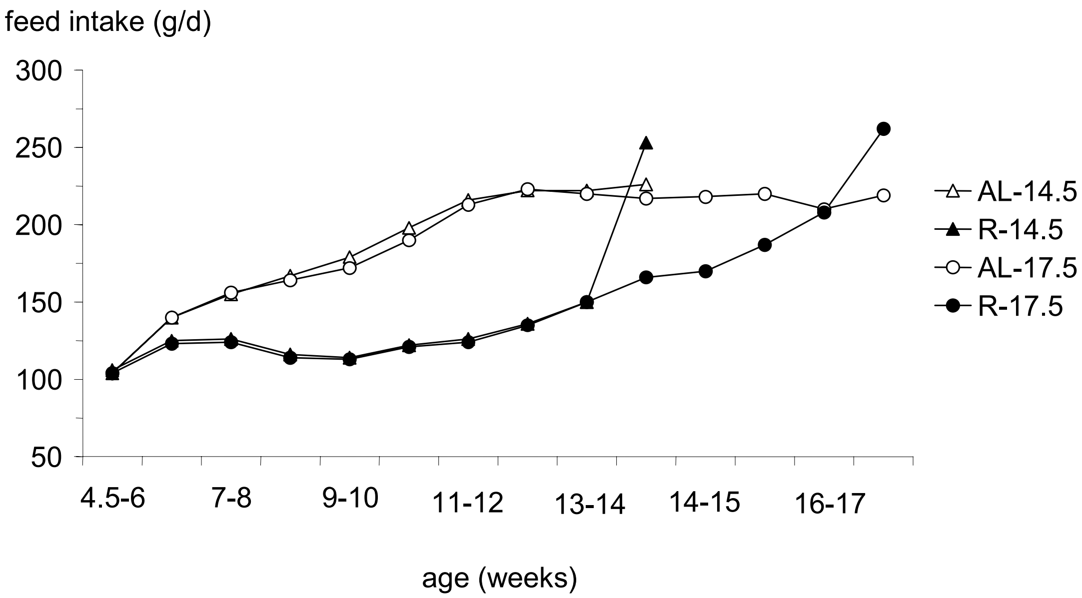

Figure 3. Mean daily feed intake (g) during rearing for animals fed ad libitum (AL) or restrictive (R) and inseminated at 14.5 or 17.5 wk of age. The R-groups were flushed five d prior to insemination. The standard deviation of the AL-groups ranged from 10 to 56 g. The standard deviation of the R-groups ranged from 4 to 38 g.

Around 12 wk of age, feed intake of AL-animals had reached its maximum. From 15 wk onwards, no difference in feed intake between R and AL group was found. During flushing, daily feed intake of R-animals (14.5 and 17.5) increased. R-14.5 animals consumed 27 g/d more food than AL-14.5 animals (253 ± 16 for R-14.5 and 226 ± 28 g for AL-14.5), whereas R-17.5 animals consumed 262±53 g/d during flushing and exceeded the feed intake of the AL-group with 43 g/d.

Feed conversion during rearing was affected by feeding level and age of insemination (see Table 1). Ad libitum feeding as well as extended first insemination to 17.5 wk of age resulted in a higher ($P < 0.001$) feed conversion compared to restrictive feeding or first insemination at 14.5 wk of age (see Table 1). However, feed conversion of R-17.5 animals did not differ from AL-14.5 animals over the total rearing period.

Body Development and Body Composition

At start of the experiment (six wk of age), AL and R-animals had similar BW (see Table 1 and Figure 2). From seven wk of age onwards, AL-animals were heavier ($P < 0.05$) than R-animals. No interactions between feeding level and age of first insemination were found until 14.5 wk of age.

Table 1. Body weight, body growth, feed intake, and feed conversion from weaning to first insemination for animals fed ad libitum (AL) or restrictive (R) and inseminated at 14.5 or 17.5 wk of age. Means and standard deviations are presented in the table.

	Treatment					
Feeding level	Ad Libitum		Restrictive		P^1	
Age of insemination (wk)	14.5	17.5	14.5	17.5	Feeding	Age
Number of animals	16	16	16	16		
BW at weaning (= 30 d) (g)	796±75	792±56	785±64	799±74	NS	NS
BW at six wk (g)	1,339±113	1,323±74	1,324±114	1,325±107	NS	NS
BW at A.I. (g)	4,121±343	4,489±309	3,621±232	4,139±256	***	***
Average body growth (g/d)	43.2±4.1	37.7±3.0	36.8±2.8	34.1±2.3	***	***
Average feed intake (g/d)	180±22	185±21	139±8	149±8	***	*
Feed conversion	4.17±0.29	4.91±0.29	3.77±0.25	4.40±0.27	***	***

[1] No interactions were found between feeding level and age of insemination.
NS: not significant; * indicates $P < 0.05$, *** indicates $P < 0.001$.

At 14.5 wk of age, no differences were found in BW and body gain between AL-14.5 and AL-17.5 animals. At 14.5 wk of age, R-14.5 animals were heavier and had a higher ($P < 0.001$) growth rate as compared with R-17.5 animals, due to flushing prior to insemination. During the last three wk of rearing (from 14.5 to 17.5 wk), body gain of

R-animals was higher (P < 0.001) than AL-animals. At first insemination, R-17.5 animals had reached the same BW as AL-14.5 animals (see Table 1).

The body composition of the animals slaughtered five d after insemination is in Table 2. No interaction was found between feeding level and age of insemination.

Table 2. Body composition of ad libitum (AL) and restrictive (R) fed animals, inseminated at 14.5 and 17.5 wk of age. Animals were slaughtered five d after insemination. Means and standard deviations are presented.

	Treatment					
Feeding level	Ad Libitum		Restrictive		P	
Age of insemination (wk)	14.5	17.5	14.5	17.5	Feeding	Age
Number of animals	10	10	10	9		
BW at slaughter (g)	4,080±281	4,548±228	3,590±179	4,152±304	***	***
EBW (g)	3,719±298	4,189±252	3,217±155	3,779±300	***	***
Av. wgt full digestive tract (g)	576±83	595±57	553±49	588±52	NS	NS
Av. wgt empty stomach (g)	28±3	29±5	31±3	30±3	*	NS
Av. wgt uterine horns full (g)	34±5	45±7	18±5	32±8	***	***
Av. wgt uterine horns after removal of embryos (g)	11±4	12±3	6±5	11±2	*	**
Empty body composition:						
Water (g)	2,115±156	2,270±109	2,002±103	2,251±187	NS	***
Ash (g)	111±8	116±9	98±7	109±12	***	**
Protein (g)	726±53	794±34	645±27	752±49	***	***
Fat (g)	754±180	1013±219	443±84	651±103	***	***

[1] No interactions between feeding level and age of insemination were found.
NS: not significant; * indicates P < 0.05; ** indicates P < 0.01; *** indicates P < 0.001.

Feeding level and age of first insemination both affected body composition. Both AL-feeding and insemination at 17.5 wk of age resulted in heavier animals, with more ash, fat, and protein content. At 17.5 wk of age, AL-animals showed the highest weight and fat content; at the same age R-animals recuperated ash and protein, reaching the same levels as AL-14.5 animals, whereas fat deposition was lower than in AL-14.5 animals.

The weight of the uterine horn was affected by feeding level and age of insemination. In AL-17.5 animals the full uterine horns were heaviest. After removal of embryos, no differences among AL-17.5, AL-14.5 and R-17.5 were found. R-14.5 animals had the smallest uterine horns.

Puberty Characteristics

Puberty characteristics for the different treatments are in Table 3. Age and feeding level affected receptivity before flushing and at insemination. Both AL-feeding and insemination at 17.5 wk of age resulted in more ($P < 0.01$) receptive animals. At 17.5 wk of age, AL-animals showed the highest receptivity. The number of receptive animals was similar for R-17.5 and AL-14.5. The R-14.5 animals showed the poorest receptivity; only 2 of the 16 animals were receptive at insemination.

An interaction between feeding level and age of first insemination was found for the number of animals with CL. In the R-feeding group the number of animals with CL increased significantly ($P < 0.05$) when first mating was delayed, whereas in the ad libitum feeding group no significant increase was found with age. Age and feeding level did not affect the average number of CL (see Table 3), although numerically mean number of CL was lowest in R-14.5 group. An interaction was found between feeding level and age of first insemination for number of animals with embryos. At 14.5 wk of age feeding level did not affect number of animals with embryos, whereas at 17.5 wk of age significantly ($P < 0.05$) more animals with embryos were observed in the ad libitum feeding group compared to restrictive fed animals (10 for AL-17.5 and 5 for R-17.5). Feeding level and age of first insemination did not influence the mean number of embryos. An interaction was found between feeding level and age of first insemination for embryo recovery rate. Embryo recovery rate was significantly ($P < 0.01$) improved at 17.5 wk of age under ad libitum feeding, whereas at 14.5 wk of age feeding level did not influence embryo recovery rate. AL-17.5 animals had the highest recovery rate. The worst puberty characteristics were found for R-14.5 animals. In five of the 10 slaughtered animals CL was observed, indicating that five animals had reached puberty. In only one of these five animals embryos were found.

Table 3. Effect of feeding level (ad libitum (AL) or restrictive (R)) and age of first insemination (14.5 or 17.5) on puberty characteristics.
Numbers, means and standard deviations are presented.

	Treatment				*P*		
Feeding level	Ad Libitum		Restrictive		Feeding	Age	Feeding * Age
Age of first insemination (wk)	14.5	17.5	14.5	17.5			
Item							
Animals, no.	16	16	16	15			
Animals receptive before flushing, no.	5	7	0	7	NS	**	NS
Animals receptive at insemination, no.	7	13	2	9	*	***	NS
Animals killed, no.	10	10	10	9			
Animals with CL, no.	9^{a}	10^{a}	5^{b}	9^{a}	T	**	*
Mean CL[1]	8.6±3.6	9.8±2.2	5.8±2.4	8.1±3.6	T	NS	NS
Animals with embryos, no.	4^{bc}	10^{a}	1^{b}	5^{c}	*	***	*
Mean embryos[2]	9±2.4	8.3±1.7	9	9.5±1.5	NS	NS	NS
Embryo recovery (%)	46.8^{a}	84.7^{b}	31.0^{a}	65.8^{c}	*	***	**

[1]Based on the number of animals with CL.

[2] Based on the number of animals with embryos.

[abc] Row means with different superscripts differ. NS: not significant; T: $P < 0.1$;

* indicates $P < 0.05$; ** indicates $P < 0.01$; *** indicates $P < 0.001$.

DISCUSSION

The results of this experiment show that it is possible to delay first mating to older age without affecting body development for ash and protein, but preventing excessive fat deposition. For this purpose different feeding strategies during rearing can be used. Feed restriction before weaning is not preferable (Rommers et al., 1999) and an early restriction after weaning can affect (at four wk of age) caecal traits (increase pH and reversed ratio of propionic and butric acid proportion), that favor conditions for pathogenic agents (Maertens and Peeters, 1988). Therefore, in our experiment feed restriction was started at six wk of age. The restrictive feeding plan was set to delay body growth from six to 12 wk of age in order to be able to stimulate body growth, when sexual development starts (around 12 wk of age) without having the problems of excessive fat deposition.

The body weight curves in Figure 2 show, that in our experiment ad libitum fed animals reached over 80% of mature BW at 14.5 wk of age and were fit to start reproduction, according to the definition of Lebas et al. (1986). The AL-14.5 group was used as control. Under the restrictive feeding regime (presented in Figure 3), animals were 500 g lighter at 14.5 wk of age than ad libitum fed animals. The EB of restrictive fed animals contained 12% less ash, 11% less protein and 41% less fat than ad libitum fed animals.

The restrictive fed animals reached similar BW compared with AL-14.5 animals when rearing period was extended with three wk. So, with the adapted feeding regime, we were able to control BW as planned. The EB composition for ash and protein of restrictive fed animals at 17.5 wk of age was similar to ad libitum fed animals at 14.5 wk of age, only fat content was lower (-14%). Based on our results, it seems that from 14.5 to 17.5 wk of age animals were able to compensate for differences in ash and protein content. This is in agreement with findings of Ledin (1984), who reported that animals will try to correct for the deviation from normal body composition caused by restrictions during re-alimentation. From metabolic point of view, it can be suggested that R-animals were still using most of the nutrient intake for protein development instead of fat formation. In ruminant it is shown (Rukkwamsuk et al., 1999) that overconditioning causes health problems due to fatty liver during lactation. There are indications (Hartmann and Petersen, 1997), that feed restriction during rearing increases body weight gain during the first three parities, resulting in heavier animals, but data on feed intake during lactation are not available.

When rearing period was extended with three wk under ad libitum feeding conditions, mainly fat content of EB increased (+34%). Most of the ash and protein seemed to have been formed before 14.5 wk of age. This is in agreement with findings of Deltoro and Lopez (1985), who reported that under ad libitum feeding conditions, medium-sized rabbits bone and muscle tissue have a high growth rate before sexual development occurs around 12 wk of age. Also De Blas et al. (1977) found mainly an increase in fat content in rabbit does between three to five month of age, whereas ash and protein were unchanged. So, the results of our study show that with controlled feed intake during rearing, first mating can be delayed to older age without affecting protein and ash content of the EB, but preventing overconditioning.

The rearing method influences fertility performance of young does. Restrictive feed intake during rearing seems to delay puberty. From R-14.5 animals, only five of the ten slaughtered animals had CL and thus had reached puberty, whereas in nine of the 10 ad libitum fed animals CL were found. At slaughtering at 14.5 wk of age, smaller (less developed) uterine horns were observed in restrictive fed animals. Based on these results, restrictive fed animals at 14.5 wk of age seemed too immature for reproduction, although BW had reached 75 to 80% of mature BW. Even flushing during the last five d prior to insemination did not evoke receptivity as would be expected according to Van den Broeck and Lampoo (1979). This implicates that BW on itself is not a good indicator to determine time of first insemination of young does, but rearing conditions should also be taken into account, according to the statement of Maertens (1987).

The puberty characteristics of restrictive fed animals at 17.5 wk of age was similar to ad libitum fed animals at 14.5 wk of age. This implicates that restrictive feeding can be used to prevent overconditiong at first insemination without negatively affecting puberty characteristics. There are some indications (Hartmann and Petersen, 1995) that feed restriction during rearing has a positive effect on litter size after the first parity. Therefore, more research is needed to study the effect of restrictive feeding during rearing with delayed first insemination on subsequent reproductive performance.

Although delayed first insemination with three wk under AL-feeding conditions resulted in heavier animals, which EB contained more fat, the level of fatness did not seem to have negative effects on puberty characteristics. A high receptivity rate at insemination (81.3%) and a high recovery rate (84.7%) were found for AL-17.5. In a previous experiment (Rommers et al., submitted), in which ad libitum fed non-pregnant does were re-inseminated at 17.5 wk of age, kindling rate and number of kits born alive were increased compared to animals inseminated successfully at 14.5 wk of age. Also Lebas and Coudert (1984) reported, that first mating at older age had a positive effect on the rate of pregnancy, but after 16 to 18 wk of age no further improvement was found (depending on breed). Hulot et al. (1982) reported that in ad libitum fed does, the percentage of does mated and ovulating reached one-third at 14 wk and two-thirds at 17 and 20 wk of age. However, Lebas and Coudert (1984) did not find an effect of early mating (at 15 wk of age) on prolificacy, death during suckling, mortality and withdrawal of does, what is not corresponding with our results. Therefore, the effect of mating at older age under ad libitum feeding conditions on reproductive performance and culling rate of young is not clear and needs further research.

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CHAPTER 5

EFFECT OF BODY WEIGHT AND AGE AT FIRST INSEMINATION ON PERFORMANCES DURING SUBSEQUENT REPRODUCTION IN RABBIT DOES

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ABSTRACT

An experiment was performed to study the effect of BW and age at first mating on body growth, feed intake, reproductive performance, and culling of rabbit does over three parities. Treatment started at five wk of age, using 155 does of a strain of New-Zealand White rabbits and ended at first insemination. Three treatments were applied. Ad libitum feeding until mating at 14.5 wk (AL-14.5) or 17.5 wk of age (AL-17.5), and restrictive feeding until mating at 17.5 wk of age (R-17.5). Feed restriction during rearing was used to obtain similar BW at 17.5 wk of age as compared to ad libitum feeding at 14.5 wk of age in order to discriminate between age and BW at first mating. In R does, feed restriction was up to 54% of AL from six to 10 wk of age. From 10 wk of age onwards, feeding level was steadily increased to stimulate body growth and sexual development. Average feeding level of R does during rearing was 80% of AL-17.5. When rearing period was extended to 17.5 wk of age, R-17.5 does reached similar BW as AL-14.5 does at first mating (3,907 vs. 3,791 ± 46 g, respectively), whereas under ad libitum feeding regime does were heavier at 17.5 wk of age (4,390 ± 46 g).

During the reproductive period, AL-17.5 does did not benefit from either the extra amount of BW or the older age at first mating. Heavier BW at the same age (AL vs. R-17.5) of first mating negatively affected feed intake during first gestation (- 25%) and first parity (- 10%), resulting in weight loss (- 6%) during first gestation and decreased litter weight (- 19%) and litter growth (- 14%) in the first parity. Postponed first mating with three wk (17.5 vs. 14.5 wk) and similar BW at first mating as AL-14.5 does did not affect feed intake and BW development during the first three parities. However, number of live born kits and weight at first kindling (+ 23% and + 18%, respectively), and litter growth in the first parity (+14%) were improved in R-17.5. Neither age nor BW at first mating influenced culling rate of does during the first three parities of reproduction.

INTRODUCTION

In commercial rabbit production, does suffer from a severe loss of body energy during first lactation, leading to decreased reproductive performance and high replacement rate of young does (Xiccato, 1996). Rearing conditions may affect the problem of negative energy balance during first lactation (Maertens, 1992; Xiccato, 1996).

Under practical conditions, rabbit does are often fed to appetite during rearing until first mating. First mating is recommended when 75 to 80% of mature BW is reached (Lebas et al., 1986). However, BW might not be a good indicator, and does may be immature at first mating although desired BW is reached, resulting in poor pregnancy rates or decreased reproductive performance (Lebas and Coudert, 1984; Rommers et al., 2001a). Delaying first mating to older age could be favorable. However, does will be heavier with the risk of excessive fat deposition (Deltoro and Lopez, 1985) that might cause health problems or decrease reproductive performance. Restrictive feeding during rearing can be used to control BW and prevent overfattening.

The relation between BW and age at first mating on subsequent performances has never been studied in detail. Rommers et al. (2001b) studied the effect of BW and age at first mating on body growth, body composition and puberty characteristics at the end of rearing. With a restrictive feeding regime, it was possible to obtain does, which differed three wk in age at first insemination (14.5 vs. 17.5 wk), but which had similar BW, body composition, and puberty characteristics. Under ad libitum feeding conditions, older does were heavier, contained more fat, but had the best puberty characteristics compared to younger does. However, information on subsequent reproduction is not known. Therefore, an experiment was performed to study the relation between BW and age at first insemination on body weight development, feed intake, reproductive performance and culling in the first three parities.

MATERIALS AND METHODS

The experiment was performed from October 2001 to September 2002. The Use and Care Committee of the Research Institute of Animal Husbandry approved all protocols.

Animals and Husbandry

The experiment was performed with 155 does of a strain of New Zealand White rabbit does, bred at the Research Institute of Animal Husbandry. Does were housed in deep-pit compartments in individual cages (50 x 60 x 30 cm) of galvanized wire net, equipped with an automatic drinker, and a manual feeder. The experiment started when does were 4.5 wk of age and ended at weaning of the third litter of each doe.

Rearing Period

Before weaning, kits were raised in litters of nine kits. At weaning (30 d of age), from each litter three female kits, with live weight deviating by less than 15% of the average litter weight, were selected. Each group of three sisters was taken and put into three adjacent cages and assigned to one of the three treatments. Does were submitted to a photoperiod of 12 h. The first two wk after weaning, a minimum ambient temperature of 18 ^{o}C was maintained. From two wk after weaning onwards, the minimum ambient temperature was set at 16 ^{o}C. Does were fed a standard commercial diet, containing 10.3 MJ/kg ME and 170 g/kg crude protein (ABCTA, Lochem, The Netherlands) and were fed according to treatment regime until five d prior to first insemination. From five days prior to insemination onwards all treatment groups were fed the standard diet to appetite to stimulate receptivity (flushing).

Treatments

Treatments started at five wk of age. Three treatments were applied. Ad libitum feeding until mating at 14.5 wk (AL-14.5) or 17.5 wk of age (AL-17.5), and restrictive feeding until mating at 17.5 wk of age (R-17.5). Restricted feeding and first insemination at 14.5 wk of age was not tested because results of a previous experiment (Rommers et al., 2001b) showed that restrictedly fed does were immature for reproduction at 14.5 wk of age.

The purpose of the restrictive feeding regime was to postpone age of first mating from 14.5 to 17.5 wk of age, reaching the same BW at 17.5 wk of age as AL-does had at 14.5 wk of age. This makes it possible to discriminate between age and BW at first mating. To prevent overfattening and to be able to stimulate sexual development and puberty that starts around 10 to 12 wk of age (Ouhayoun, 1984), the following feeding regime was chosen: body growth was delayed from five to 10 wk of age by gradually increasing feed restriction, whereas from 10 wk of age onwards daily feed supply was gradually increased. From five to 10 wk of age mainly protein development is hindered. From 10 wk of age onwards, does will first compensate for the loss in protein (Ledin, 1984) and thereby excessive fat deposition will be postponed. At 17.5 wk of age, the restrictive fed animals reach the same BW as AL-14.5.

The R-does were fed a restricted amount of feed daily, aiming to follow the BW curve as shown in Figure 1. The BW curve of the AL-treatments was derived from data of previous experiments. Therefore, BW was determined weekly from weaning until 10 wk of age and twice weekly from 10 wk of age to first insemination. Feed intake was corrected after each time does were weighed in order to follow the fixed BW curve. If the daily supply was not eaten completely, remaining feed was removed.

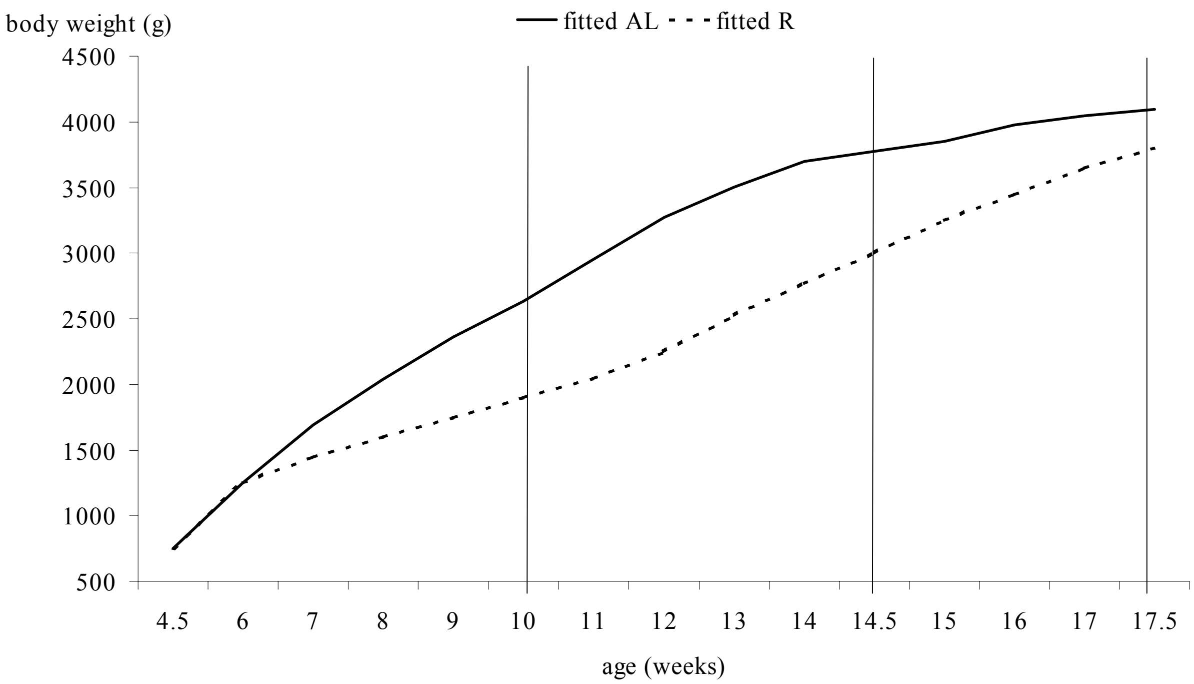

Figure 1. Fixed body weight curve for ad libitum (AL) and restrictive (R) feeding during rearing from weaning (4.5 wk) to first insemination at 14.5 or 17.5 wk of age.

Reproductive Period

From 17.5 wk of age onwards, the photoperiod was set at 16 h. Does were fed to appetite the same commercial standard diet as during rearing. Does were submitted to a semi-intensive breeding rhythm and inseminated 10 to12 d postpartum. Artificial insemination was performed with fresh mixed semen of 10 bucks, selected for growth performance. At the day of insemination, one mixed and diluted semen dose was prepared. Dilution was performed using a commercial extender (Galap, IMV, France) according to the method developed by Zöldág et al. (1988). A GnRH analogue was injected i.m. (0.2 ml Receptal, Hoechst Roussel Vet, Brussels) immediately after insemination to induce ovulation. Non-pregnant does were inseminated three wk after the first insemination. Does not pregnant after two successive inseminations were excluded from the experiment.

Nestboxes (30 x 25 x 30 cm) were attached to the front sides of the cages five d prior to kindling and removed at 21 d of lactation. At the first day after kindling litter size was standardized. Litters were standardized by cross fostering of kits within a treatment. In the first parity, litter size was standardized at eight kits, in the second and third parity it was set at nine kits. Kits were weaned at 30 d of lactation.

Measurements

Body Weight. Does were weighed individually once every week from weaning to 10 wk of age and twice weekly until first insemination. During first gestation, does were weighed weekly. After kindling, does were weighed at 16 d, and 30 d of lactation in the first three parities.

Feed Intake. During rearing, feed intake was determined weekly from weaning to 10 wk of age and twice weekly until first insemination by weighing of the feeder at beginning and end of each week and the weight of all feed supplies given in between were recorded. For R-does the amount of feed not eaten per day was weighed weekly to determine actual feed intake. If wastage occurred, week number and cage were recorded, and feed intake for was scored as missing value. During first gestation, feed intake was determined weekly. After first kindling feed intake was determined for the following periods in the first three parities: from kindling to d 16 of lactation, from d 16 to d 30 of lactation, and from d 30 of lactation to subsequent kindling.

Reproductive Performance. Kindling rate was calculated as the number of does that kindled after the first insemination divided by the number of first inseminations. The number of live and stillborn kits (total litter size), the number of kits at d 16 and d 30 of lactation, together with the litter weight at d 16, and d 30 were recorded. The average kit weight at d 16 was used as an estimate for milk production, because in our system we observe that kits start eating solid feed from 17 d onwards (Rommers, personal communication).

Culling. The number of does culled and the reason for culling was recorded. Dissections were performed on dead and euthanized diseased does.

Statistical Analyses

The experiment was a randomized block. A block consisted out of three adjacent cages housing sisters. The three treatments were randomly assigned to the cages within a block. Analyses of variance were carried out using the GLM procedure of SAS (SAS Inst. Inc., Cary, NC, USA). Differences between LSmeans were analyzed by the PDIFF option of the GLM procedure of SAS. Data are presented as LSmeans and standard errors.

Rearing Period. Data of all does were used for analyses. Body weight, feed intake, and feed efficiency were analyzed for the total rearing period. Differences among treatments were tested using the following model : $Y_{ij} = \mu + B_i + T_j + (BxT)_{ij} + e_{ij}$ [model 1] where Y_{ij} is dependent variable; μ = overall mean; B_i = block, three adjacent cages with sisters; T_j = treatment AL-14.5, AL-17.5, and R-17.5; BxT_{ij}= interaction between block and treatment; and e_{ij} is the residual error. In all analyses, non-significant interactions were deleted from the model.

Reproductive Period. In the first parity, data were used of does that kindled after the first insemination. In the second and third parity, does were used that kindled after the first insemination 10 to 12 d postpartum. Blocks became unbalanced because of exclusion of culling and non-pregnant does. Therefore, block was excluded from model 1. Differences in kindling rate and percentage of stillborn kits among treatments were analyzed with a Chi-squared test.

Culling Rate of Does During the First Three Parities. Data of all does in the experiment were used for analyses of culling rate. Differences in culling rate among treatments were analyzed with a Chi-squared test.

RESULTS

Animals and Culling

Experiment started with 52, 51, 52 does for AL-14.5, AL-17.5, and R-17.5, respectively. During the rearing period four does with diarrhea were removed. At dissection no further abnormalities were found.

In Table 1 the number of does and culling during the reproductive period are presented. Does non-pregnant after the first insemination, does with small litters ($\leq$ 3 kits), and does with 100% stillbirth were not used for analyses of the reproduction period. These animals were not included in the culling, because under practical conditions they would have been re-inseminated. During the reproductive period, there was no difference in culling rate among treatments (27.5, 25.0, and 23.1% for AL-14.5, AL-17.5, and R-17.5, respectively). Eighty percent of the culling occurred in the first two parities. Culling was caused by several reasons, such as reproductive failure, dystocia, digestive disorder, *Pasteurella multocida*, fatty liver. Culling after weaning was due to feet injuries, metritis, and mastitis.

Body Weight, Feed Intake, and Gain/Feed Ratio During Rearing

At weaning, there was no difference in BW among treatments (741, 743, and 740 $\pm$ 5 g for AL-14.5, AL-17.5, and R-17.5, respectively). From five wk onwards, feed intake of R-17.5 was progressively reduced from 85% at 6 wk of age to 54% of AL at 10 wk of age. From 10 wk onwards, feed intake was gradually increased to 120% of AL during the last five d before insemination (see Figure 2).

Table 1. Number of does and cullings during the first three parities of reproduction

Feeding strategy during rearing	Ad libitum				Restrictive	
Age at first insemination, wk	14.5		17.5		17.5	
Item, no.		Culled		culled		Culled
			First parity			
At first insemination	51		48		52	
Non-pregnant of 1st insemination[1], from which	8		6		7	
- Non-pregnant after two inseminations[3]		*5*		-		*3*
- Culled during first parity[3]		*1*		*1*		-
Culled during gestation		-		1		-
Dystocia		-		-		1
At kindling	43		40		44	
Excluded at standardization[2]	6		10		2	
Culled during lactation		-		2		1
At second insemination (10-12 d postpartum)	37		28		41	
Culled after weaning		1		-		1
			Second parity			
Non-pregnant of 1st insemination[1], from which	9		3		7	
- non-pregnant after two insemination[3]		*2*		*1*		*1*
- culled during second parity[3]		-		*1*		*1*
Culled dystocia		1		1		1
At kindling	26		25		32	
Excluded at standardization[2]	1		2		4	
Culled during lactation		-		2		1
At third insemination (10-12 d postpartum)	25		21		27	
Culled after weaning		1		1		-
			Third parity			
Non-pregnant of 1st insemination[1], from which	8		3		6	
- culled during third parity[3]		*1*		*1*		*1*
Culled dystocia				1		
At kindling	16		16		20	
Withdrawn at standardization[2]	1		-		2	
Culled during lactation		2		-		-
Total culled		14		12		12

[1] Does non-pregnant after two successive inseminations were culled.
[2] Does with ≤ 3 live kits or 100% stillbirth were excluded due to lack of kits for standardization.
[3] Does were excluded for further measurements except for culling.

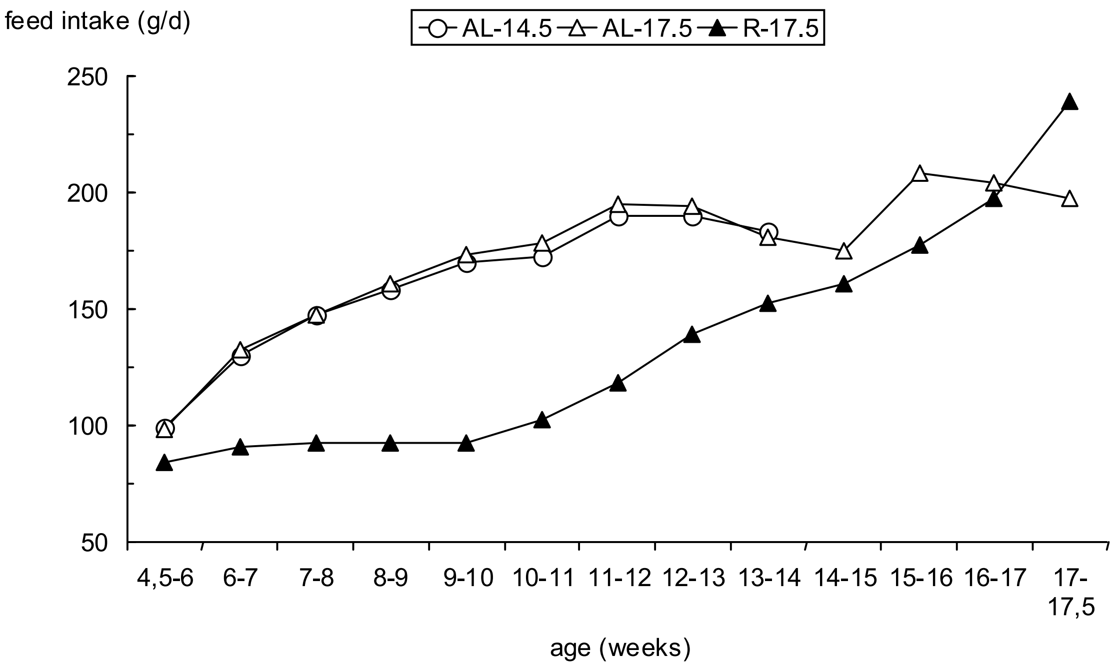

Figure 2. Average feed intake for ad libitum (AL) and restrictive (R) fed does during rearing from weaning (4.5 wk) to first insemination at 14.5 or 17.5 wk of age.

In Figure 3 body growth during rearing is presented. From 10 wk of age onwards, growth rate of AL-does gradually decreased. The growth rate of R-does increased after 10 wk of age, with a growth spurt during the last five d before insemination, in which does were flushed. At the end of rearing BW of AL-14.5, AL-17.5, and R-17.5 were 3,791 ± 35, 4,390 ± 37, and 3,910 ± 34 g, respectively. AL-17.5 was heavier than AL-14.5 and R-17.5 (P < 0.001). BW of AL-14.5 and R-17.5 was comparable. Feed to gain ratio over the total rearing period was equal for AL-14.5 and R-17.5 (0.27 ± 0.003, respectively), whereas feed to gain ratio of AL-17.5 was lower (0.23 ± 0.003; P< 0.001

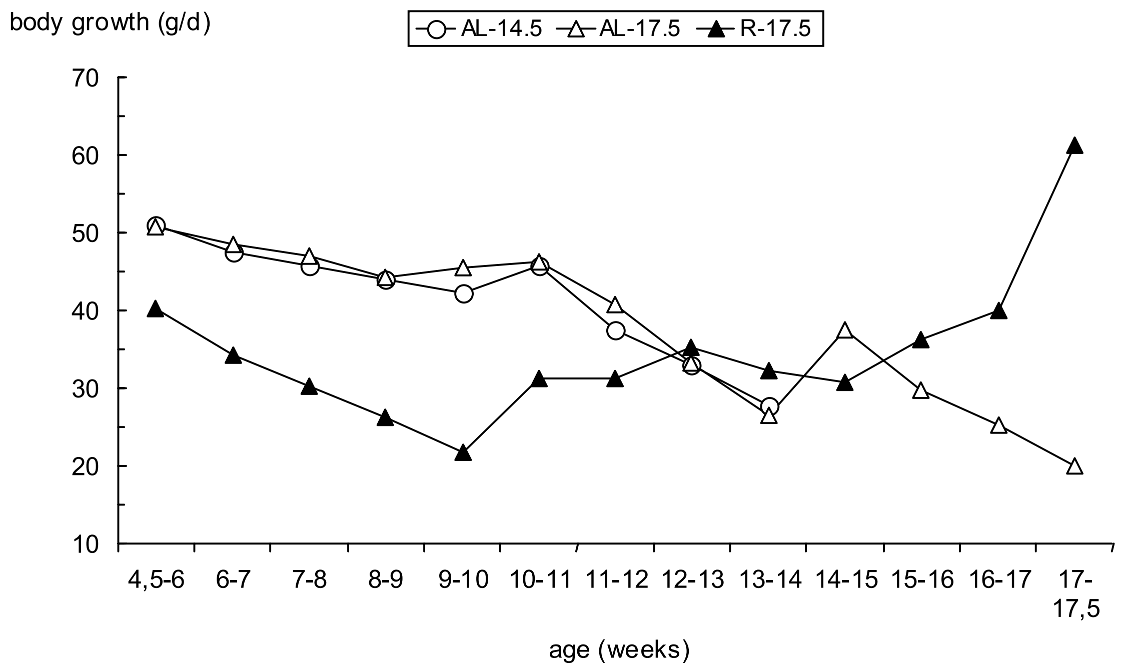

Figure 3. Average body growth for ad libitum (AL) and restrictive (R) fed does during rearing from weaning (4.5 wk) to first insemination at 14.5 or 17.5 wk of age.

Body Weight, Body Growth and Feed Intake during Reproduction

Body weight for the successive reproductive periods is presented in Figure 4. AL-17.5 does were heavier at first insemination (4,356 ± 48; *P* < 0.001) and remained so during the reproductive period. AL-14.5 and R-17.5 does were smaller at first insemination (3,991 ± 46 and 3,933 ± 45, respectively) than AL-17.5 does, but part of the difference was compensated for during the first gestation period. Body weight gain during first gestation (excluding fetus) was 106, -260, and 41 ± 40 g for AL-14.5, AL-17.5, and R-17.5, respectively (*P* < 0.001). After the first kindling, body growth among treatment was comparable. Based on does that kindled after every first insemination until the third parity, body weight gain over the three parities of AL-14.5 and R-17.5 does was comparable (498 and 333 ± 83 g, respectively), whereas AL-17.5 does had a lower body weight gain (174 ± 83, *P* < 0.05). Does, that were able to follow the semi-intensive reproductive rhythm until the third parity showed similar BW development in the first two parities as does that became non-pregnant during the experiment.

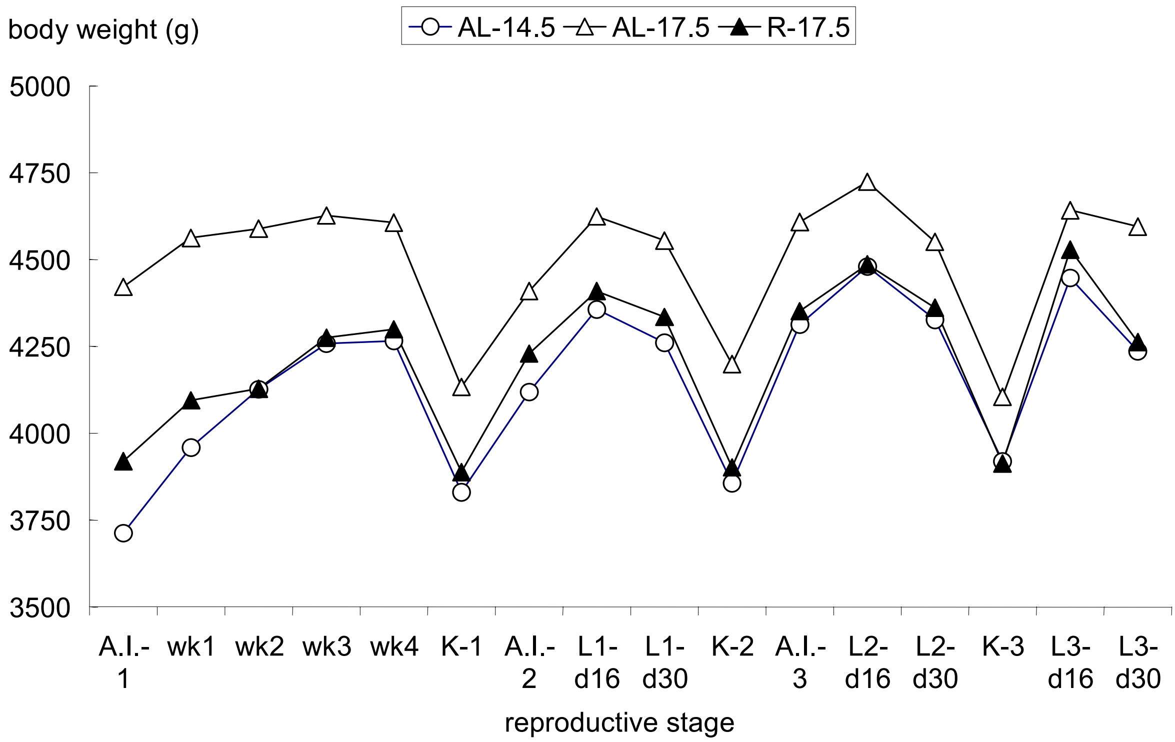

Figure 4. Average BW for ad libitum (AL) and restrictive (R) fed does during the reproductive period for does pregnant after first insemination (14.5 or 17.5 wk of age, 10 to 12 d postpartum). K= kindling 1, 2, and 3. L= lactation 1, 2, and 3.

Feed intake during reproduction is given in Table 2. In the first gestation and lactation period AL-17.5 does consumed less feed than AL-14.5 and R-17.5 ($P < 0.05$). In the weaning to kindling interval of the second parity, AL-17.5 consumed more feed than AL-14.5 ($P < 0.05$), whereas R-17.5 was intermediate. In the third lactation, there were no differences in feed intake among treatments. Does, that were able to follow the semi-intensive reproductive rhythm until the third parity showed similar feed intake in the first two parities as does that were non-pregnant during the experiment.

Table 2. Feed intake (g/d) during different stages of reproduction for does that kindled after first inseminations (14.5 or 17.5 wk of age, 10 to 12 d postpartum).

Feeding strategy during rearing	Ad libitum		Restrictive		
Age at first insemination, wk	14.5	17.5	17.5	SEM	P-value
Item, g/d					
	----------------- First gestation -------------				
Week 1	215[a]	206[a]	236[b]	5	0.001
Week 2	207[a]	159[b]	189[a]	6	0.001
Week 3	184[a]	135[b]	189[a]	6	0.001
Week 4	112[a]	85[b]	114[a]	5	0.001
d 28 until d 32	79[ab]	69[a]	99[b]	9	0.01
Avg in gestation period (32 d)	167[a]	137[b]	172[a]	3	0.001
	------------------ First parity -----------------				
First lactation:					
From kindling to d 16	302[a]	237[b]	274[c]	8	0.001
From d 17 to d 30	460[a]	454[a]	491[b]	9	0.05
Avg first lactation (30 d)	376[a]	338[b]	375[a]	8	0.01
From weaning to kindling (12 d)	160[a]	181[b]	176[ab]	6	0.05
	----------------- Second parity -------------				
Second lactation:					
From kindling to d 16	385	369	397	9	0.1
From d 17 to d 30	537	541	536	14	0.96
Avg in second lactation (30 d)	456	448	461	10	0.69
From weaning to kindling (12 d)	183	199	197	7	0.23
	---------------- Third parity ----------------				
Third lactation:					
From kindling to d 16	374	380	397	9	0.16
From d 16 to d 30	527	561	544	18	0.43
Avg in third lactation (30 d)	445	464	466	11	0.38

[ab] Means with different letter in a row differ significantly.

Table 3. Reproductive performance for does that kindled after first insemination (14.5 or 17.5 wk of age, 10 to 12 d postpartum).

Feeding strategy during rearing	Ad libitum		Restrictive	Pooled	
Age at first insemination, wk	14.5	17.5	17.5	s.e.	P-value
Item	------------------- First parity --------------				
Kindling rate, %	84.3	83.3	84.6		0.95[2]
Total born, no.	7.0	6.5	7.7	0.4	0.1
Born alive, no.	6.1[a]	6.1[a]	7.5[b]	0.4	0.02
Stillborn, %	13.5	6.5	2.3		0.15[2]
Kits weaned, no.[1]	7.2[a]	7.5[ab]	7.8[b]	0.2	0.03
Avg kit wt at d 16, g	251[ab]	242[a]	271[b]	7	0.01
Avg kit wt at weaning (d 30), g	713[ab]	683[a]	741[b]	14	0.02
	------------------ Second parity -----------				
Kindling rate, %	72.2	89.3	78.0		0.21[2]
Total born, no.	9.4	9.4	9.8	0.5	0.84
Born alive, no.	8.8	8.8	9	0.6	0.96
Stillborn, %	6.8	6.4	8.1		0.11[2]
Kits weaned, no.[1]	8.6	8.6	7.8	0.3	0.08
Avg kit wt at d 16, g	303[a]	300[a]	346[b]	7	0.001
Avg kit wt at weaning (d 30), g	793[a]	793[a]	856[b]	16	0.01
	----------------- Third parity ---------------				
Kindling rate, %	66.7	76.2	74.1		0.75[2]
Total born, no.	9.8	9.0	10	0.6	0.44
Born alive, no.	8.9	8.8	8.9	0.8	0.99
Stillborn, %	9.0	2.1	11.5		0.09[2]
Kits weaned, no.[1]	8.8	8.7	8.9	0.1	0.61
Kit wt at d 16, g	306[a]	306[a]	331[b]	7	0.02
Kit wt at weaning (d 30), g	775	756	785	24	0.68

[1] Litter size standardized at first day after kindling; first parity at eight kits, second and third parity at nine kits.

[2] Chi-square test.

[ab] Means with a different letter in a row differ significantly.

Reproductive Performances

Reproductive performance is presented in Table 3. Due to small numbers of live born kits, kits of litters with three or less kits were removed and used for cross fostering (see Table 1).

Does that did not nurse kits, were excluded from the experiment. During the reproductive period, there was no difference in kindling rate among treatments. In the first parity, R-17.5 does produced more live kits than AL-14.5 and AL-17.5. In the second and third parity, there was no difference in litter size among treatments. Kits of does of R-17.5 were heavier at d 16 of lactation in all parities, which indicates that does produced more milk and resulted in heavier kits at weaning in the first two parities.

DISCUSSION

Rabbit does are susceptible to a severe energy deficit during first lactation (Xiccato, 1996), resulting in decreased reproductive performance and high replacement rate. Our hypothesis was that does fed to appetite and inseminated at 17.5 wk of age are more matured and have more body reserves (protein and fat tissue) which enable them to better resist the energy deficit during first lactation, resulting in better performance and/or decreased culling. In a previous study ad libitum fed does at 17.5 wk of age had indeed more fat and the best puberty characteristics compared to ad libitum fed does mated at 14.5 wk of age (Rommers et al., 2001b). However, ad libitum feeding and first mating at older age may lead to overfattening, that might cause health problems or decreased reproductive performance. Restrictive feeding can be used to prevent excessive fat deposit, but it also affects BW at first mating. Therefore, the objective of this study was to discriminate between BW and age at first insemination and investigate their effects on subsequent reproduction. Does were inseminated either at 14.5 or 17.5 wk of age and feeding was either ad libitum or restrictive. Restrictive feeding regime was applied to obtain an older doe, which had similar BW as ad libitum fed does at 14.5 wk of age. In a previous study (Rommers 2001b) restrictive fed does were found too immature for reproduction at 14.5 wk of age. Therefore this treatment was not included in this experiment.

Table 4. Effect of feeding strategy during rearing and age of first insemination on performance in the first three parities of reproduction.

Feeding strategy	Ad libitum		Restrictive	s.e.	*P*-value
Age at 1st insemination	14.5	17.5	17.5		
Parameter (g)	--------------- First gestation (32 d) -----------				
BW at 1st insemination	3,791[a]	4,356[b]	3,933[a]	46	0.001
Total feed intake	5,348[a]	4,378[b]	5,504[a]	109	0.001
Body growth	106[a]	-260[b]	41[a]	40	0.001
Litter weight at 1st kindling[1]	417[a]	397[a]	490[b]	20	0.003
	---------------- First parity (42 d) ---------------				
BW at kindling	3,872[a]	4,107[b]	3,927[ab]	51	0.006
Total feed intake	11,722[ab]	10,846[a]	1,.006[b]	258	0.007
Body growth	17	27	-36	42	0.52
Litter growth[2]	4,692[a]	4,628[a]	5,360[b]	171	0.004
Litter weight at 2nd kindling[1]	637	672	817	81	0.24
	----------------- Second parity (42 d) ----------				
BW at 2nd kindling	3,856[a]	4,199[b]	3,902[a]	71	0.003
Total feed intake	14,156	14,364	14,469	389	0.84
Body growth	63	-94	7	44	0.09
Litter growth[2]	6,056	6,156	5,937	290	0.86
Litter weight at 3rd kindling[1]	683	653	696	131	0.63
	-------------- Third lactation (30 d) ------------				
BW at 3nd kindling	3,952	4,105	3,914	76	0.18
Total feed intake	13,353	13,935	13,971	339	0.38
Body growth	279	491	348	66	0.08
Litter growth[2]	6,160	5,978	6,318	264	0.65
BW at weaning	4,236[a]	4,595[b]	4,262[a]	82	0.006

[1] Average kit weight at kindling multiplied by the total number of kits born (including stillborn).

[2] Total litter weight at weaning minus total weight of live born kits at kindling.

[ab] Means with a different letter in a row differ significantly.

Table 4 outlines the effect of the treatments on body growth, feed intake, and productivity during the first three parities. The effect of BW is demonstrated by comparing ad libitum and restrictive fed does mated at 17.5 wk of age. Ad libitum fed does are heavier. In a previous study, it was shown that the empty body of these does contained more protein and fat tissue and that the best puberty characteristics were obtained compared to restrictive fed does at the same age (Rommers, 2001b). The better puberty characteristics that were found at end of rearing (Rommers et al., 2001b) might be counteracted by the lower feed intake and weight loss during first gestation. During first gestation of AL-17.5 does, feed intake was 25% lower, does lost 6% of their initial BW at first mating and litter weight at kindling was 19% lower compared to R-17.5 does. Feed intake was still lower in the first parity in Al-17.5 compared with R-17.5 does and litter growth was decreased, probably due to a lower milk production. The lower feed intake could be explained by the higher fat content of these does at first insemination. When the mass of adipose tissue increases, insulin insensitivity could develop. In pigs, it is shown that fat animals at the end of pregnancy and early lactation are insulin resistant, resulting in higher glucose concentration in blood plasma, which may explain the observed reduction in voluntary feed intake (Revell and Williams, 1993). The reduced feed intake in does, which have more fat could also be explained by the secretion of leptin by the fat cells. Recent studies in pigs and bovine have demonstrated that leptin is an important regulator of feed intake (Barb et al., 2001; Delavaud et al., 2002). In rabbit does this phenomenon have not been studied, to the knowledge of the authors. Based on these results, it can be concluded that AL-17.5 does did not benefit from either the extra amount of BW or the older age at first mating.

Restrictive feeding can be used to control body growth and prevent excessive fat deposition. Restrictive fed does mated at 17.5 wk of age had similar BW (see Table 4) and similar body composition (Rommers, 2001b) as ad libitum fed does mated at 14.5 wk of age. Older age at first mating (with similar BW) improved litter weight and litter growth in the first parity. The better reproductive performance of R-17.5 does can not be explained by differences in feed intake or body growth compared to AL-14.5. However, it could be that priority is shifted towards reproduction when first insemination is postponed to older age. In other words, the improved productivity in older does with similar BW at first mating could be related to a higher degree of maturity.

Age nor BW at first mating affected culling rate of does during reproduction. On average 25% of does were culled during the first three parities. Although, AL-14.5 and R-17.5 does had a higher feed intake during first gestation and first parity compared to AL-17.5 does, BW development during reproduction was similar for all treatments. Therefore, it can be assumed that body energy loss was not affected and thereby culling rate was not affected.

IMPLICATIONS

Our findings indicate that ad libitum vs. restrictive feeding at the same age of first insemination (17.5 wk) negatively affected feed intake during first gestation and first parity, resulting in weight loss during first gestation and decreased litter weight and litter growth in the first parity. However, postponed first mating to older age (17.5 vs. 14.5 wk) under restrictive feeding resulted in similar BW as ad libitum fed does at 14.5 wk of age, but improved reproductive performance, probably due to a higher degree of maturity. Neither age nor BW at first mating influenced culling rate of does during the first three parities of reproduction.

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CHAPTER 6

THE EFFECT OF LEVEL OF FEEDING IN EARLY GESTATION ON REPRODUCTIVE SUCCESS IN YOUNG RABBIT DOES

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ABSTRACT

An experiment was performed to study the effect of restricted feeding during early gestation on feed intake during different phases of gestation and kindling performance in young rabbit does. Nulliparous rabbit does (n = 94) were inseminated at 14.5 weeks of age. During the first 10 days of gestation, does were fed individually either to appetite (AL) or 1.35 times maintenance requirement (R). After 10 days of gestation, all animals were fed to appetite. Does were weighed at insemination and after kindling. Feed intake was recorded during the first 10 days of gestation and weekly thereafter. The number of does that kindled, number of live and stillborn kits and litter weight was recorded. The experiment ended after kindling. During feed restriction, AL does consumed 70 g per day more on average than R does (209 and 139 ± 4 g for Al and R respectively; *P* < 0.001). In the first and second week after feed restriction, compensatory feed intake occurred. Restrictive fed does ate more than AL does (+ 34 ± 5 g per day from day 11 to 17 of gestation; *P* < 0.001; + 17 ± 6 g per day from day 18 to 24 of gestation; *P* < 0.05). The last week of gestation, feed intake of AL and R was comparable (89 and 100 ± 5 g, respectively). At kindling, AL does had consumed 8 ± 3 g per day more feed over the total gestation period than R does (*P* < 0.04). Feeding level during early gestation did not affect kindling rate (83%), total litter size (7.9 ± 0.4) nor number of does with stillborn kits (10 vs. 9 for Al and R, respectively). Regardless of treatment, in the last week of gestation (day 25 to 32) the number of does with stillbirth was lower and average birth weight was higher (*P* < 0.01) in does eating more than the average daily feed intake compared to does eating below average. Based on the results of this study it was concluded that feed restriction for 10 days during early gestation does not affect kindling performance of young does. Feed intake in the last week of gestation affects kit survival and birth weight.

INTRODUCTION

It is common practice in commercial rabbit production to feed rabbit does to appetite directly after mating and during gestation. However, in gilts (Jindal et al., 1996) and ewes (Cumming et al., 1975; Parr et al., 1982) it has been demonstrated that high-feeding levels during early gestation can decrease embryonic survival which affect litter size. Therefore, it is of interest to determine whether ad libitum feeding should be recommended for young does during early gestation. In late gestation no feed restriction should be applied since restricted feed intake in the second part of gestation results in increased kit mortality (Coudert and Lebas, 1985) or reduced fetal growth (Fortun et al., 1994).

To our knowledge, information on the effect of feeding level during early gestation on the number of live born kits in rabbit does is not available. Therefore, an experiment was performed to study the effect of restricted feed intake during early gestation on feed intake during different phases of gestation and kindling performance in young rabbit does.

MATERIAL AND METHODS

Animals and Husbandry

The experiment was performed from May to July 2001. The Use and Care Committee of the Research Institute of Animal Husbandry approved all protocols.

The experiment was performed with 94 nulliparous does of a strain of New Zealand White rabbits, bred at the Research Institute of Animal Husbandry. Does were housed in individual cages (50 x 60 x 30 cm) of galvanized wire net, equipped with an automatic drinker, and a manual feeder in two similar deep-pit compartments (containing 64 and 32 cages, respectively) with controlled lighting. Does were submitted to the 16-h photoperiod and the minimum ambient temperature was set at 16 ^{o}C.

Does were reared under similar conditions and were fed to appetite with a standard commercial diet, containing 10.3 MJ/kg metabolizable energy and 170 g/kg crude protein (ABCTA Lochem, The Netherlands) until the beginning of the experiment. The experiment started at 14.5 weeks of age when all does were artificially inseminated with fresh mixed semen from 10 bucks, selected for growth performance. At the day of insemination, one diluted and mixed semen dose was prepared. Dilution was performed using a commercial extender (Galap, IMV, France) according to the method developed by Zöldág et al. (1988). Does were inseminated between 10.00 and 12.00 h in the morning. A GnRH analogue was injected i.m. (0.2 mL containing 0.0042 mL Buseriline-acataat/mL; Receptal, Hoechst Russel Vet, Brussels) immediately after insemination to induce ovulation. Twelve days after insemination does were palpated to check pregnancy. Non-pregnant does were excluded from the experiment. Five days before kindling, does were provided access to a nestbox that was placed in front of each cage. At day 32 after insemination, does that had not kindled were treated with oxytocin i.m. (0.5 cc; syntheticoxytocin 10 I.E./mL, Intervet, Boxmeer, The Netherlands) in the morning to induce parturition. The experiment ended after kindling.

Treatments

Nutritional treatment started on the day after insemination (day 1) and was applied during the first 10 day after insemination. Does were randomly assigned to one of the following two feeding treatments: 1) feeding to appetite during the first 10 days of gestation (AL), and 2) restrictive feeding during the first 10 days of gestation (R). Does fed restrictively were fed daily. The daily amount of feed during restriction was based on the recommendations of Maertens (1993; 400 kJ ME/ kg $BW^{0.75}$ for maintenance and a fixed amount for growth 0.38 MJ ME/d). All does were fed to appetite from day 11 of gestation onwards and were fed the same diet as during rearing.

The experiment was performed in three batches (n= 42, 22, 32 for batch 1, 2, and 3, respectively) with batches being three weeks apart. Sisters within a batch were randomly assigned to one of the two treatments.

Measurements

Body weight of each doe was determined at the day of insemination and after kindling in the morning between 10.00 and 12.00 h. For both treatments, feed intake of each animal was determined for the first 10 days of gestation and weekly thereafter until kindling. For R-does the amount of feed not eaten per day was weighed at the end of the restrictive period to determine the actual feed intake. If feed wastage occurred, feed intake for that doe was scored as a missing value.

Kindling rate was calculated as the number of does, which kindled, divided by the number of does inseminated. After parturition, nestboxes were checked for live and stillborn kits. For each doe, live born kits were weighed and the average birth weight was calculated by dividing the litter weight by the number of kits. A number of does were culled during the experiment and dead or diseased animals were necropsied.

Statistical Analysis

To test differences between treatments, all data were analysed with the GLM procedure of SAS (1990; SAS Inst. Inc., Cary, NC, USA) using the following model: $Y_{ij} = \mu + B_i + T_j + (BxT)_{ij} + e_{ij}$ [model 1] where Y_{ij} = dependent variable; μ = overall mean; B_i = batch 1, 2, and 3; T_j = treatment (j = AL, R); $(BxT)_{ij}$ = interaction between batch and treatment, and e_{ij} is the residual error. Difference in kindling rate and percentage stillborn kits between treatments were analysed with a Chi-square test.

Differences between does treated or not treated with oxytocin were tested with model 1, in which oxytocin was included. Batch was omitted from the model, because none of the does were treated with oxytocin in batch two. In all analyses, non-significant interactions were deleted from the model.

Additional analyses were done to study the effect of feed intake during the successive weeks of gestation on kit mortality. Does were classified on basis of their actual feed intake in two classes: 1) higher or 2) lower than average feed intake within each treatment. Birth weight differences between groups were analysed by ANOVA using treatment and feed intake class as explaining factors. Extension of this model with maternal body weight (at the day of insemination) as covariate resulted in similar contrasts between treatment groups. For each week of gestation, differences in mortality (expressed as number of does with kit mortality) were analysed with a Chi-square test per treatment.

RESULTS

Animals

Ninety-four does were inseminated at 14.5 weeks of age per treatment. Eight does of each treatment were not pregnant after insemination. One doe of treatment R died during parturition (dystocia) and all 12 kits were born dead. These does were excluded from the data. On day 32, 11 does (seven AL, and four R, respectively) were treated with oxytocin to provoke parturition. There was no interaction between oxytocin treatment and feeding level and in both treatments (AL and R), does treated with oxytocin produced smaller litters than non-treated does (6.5 ± 2.3 and 8.2 ± 2.8, respectively; $P < 0.05$), but kit mortality was not significantly affected by oxytocin (10.2% and 6.2% for treated and non-treated does, respectively).

Level of feed intake

Body weight was similar for both groups at insemination (3730 and 3768 ± 57 g for AL and R, respectively) and at kindling (3,810 and 3,918 ± 50 g, respectively). During feed restriction, AL does consumed 70 g/d more on average than R does (209 and 139 ± 4 g for AL and R respectively; $P < 0.001$). In the first and second week after feed restriction, compensatory feed intake occurred as presented in Table 1.

Does fed restrictively during the first 10 days of gestation ate more than AL does (+ 34 ± 5 g/d from day 11 to 17 of gestation; $P < 0.001$; + 20 ± 6 g/d from day 18 to 24 of gestation; $P < 0.05$) while in the last week of gestation, feed intake of AL and R was similar (91 and 102 ± 5 g, respectively). At kindling, AL does had consumed 8 ± 3 g/d more feed over the total gestation period than R does ($P < 0.04$).

Table 1. Number of does with and without stillborn kits according to their voluntary feed intake in different periods of gestation. Feed intake is presented as LSmean ± SE.

Treatment	Ad libitum		Restrictive		*P*-value AL	*P*-value R
Period of gestation	d 11 to d 17					
Average feed intake (g/d)	162		196			
	< mean[1]	> mean[1]	< mean[2]	> mean[2]		
Actual feed intake (g/d)	138 ± 20	184 ± 16	176 ± 19	224 ± 19		
Does with no stillborn kits (no.)	14	15	17	12		
Does with stillborn kits (no.)	5	5	5	4	0.925	0.871
Period of gestation	d 18 to d 24					
Average feed intake, g/d	157		177			
	< mean[1]	> mean[1]	< mean[2]	> mean[2]		
Actual feed intake, g/d	134 ± 17	176 ± 17	147 ± 25	213 ± 19		
Does with no stillborn kits, no.	15	14	16	13		
Does with stillborn kits, no.	3	7	5	4	0.235	0.984
Period of gestation	d 25 to d 32					
Average feed intake, g/d	91		102			
	< mean[1]	> mean[1]	< mean[2]	> mean[2]		
Actual feed intake, g/d	67 ± 17	119 ± 14	76 ± 221	126 ± 20		
Does with no stillborn kits, no.	13	16	10	19		
Does with stillborn kits, no.	8	2	8	1	0.054	0.004

[1] Does, whose voluntary feed intake is below (<) or above (>) the average feed intake of does fed to appetite in the first 10 d of gestation.

[2] Does, whose voluntary feed intake is below (<) or above (>) the average feed intake of does fed restrictive in the first 10 d of gestation.

Kindling performance of the first parity is presented in Table 2. Feeding level during early gestation did not significantly affect kindling rate, total litter size and the number of does with stillborn kits. Average kit mortality was higher in AL than in R-does. However, four does with a high mortality (44% up to 100%) in the AL-group were the principal contributors to this difference in mortality between the treatments. Exclusion of these four does resulted in mortality rate of 2.7 ± 0.7 and 3.8 ± 7.6 for AL and R-does, respectively.

Table 2. Kindling performance for does fed ad libitum or restrictively during the first 10 days of gestation. LSmeans and SEM are presented.

Item	Feeding level Ad libitum	Restrictive	SEM	P value
Animals inseminated, no.	47	46		
Kindling rate, %	83.0	82.6		0.96
Length pregnancy, days	31.6	31.6	0.07	0.95
Litters, no.	39	38		
Total litter size, no.	7.9	7.9	0.4	0.94
Litters with mortality, no.	10	9		0.76
Stillborn, %	9.7	3.8		0.01
Birth weight, g	63	66	3	0.33

Effect of feed intake on kit mortality and birth weight

Does, classified on basis of their actual feed intake showed differences in mortality (expressed as number of does with kit mortality) (see Table 1). In the first two weeks after feed restriction, no effect of feed intake on number of does with kit mortality nor on average birth weight of the kits was found. In the last week of gestation, the number of does with stillbirth was higher in does eating less than the average feed intake in both treatments (P < 0.01). Average kit mortality in does with stillbirths, was 18.0 ± 8% and 29.3 ± 29% for does consuming more or less than the average feed intake, respectively. Does, which ate more than average during the last week of gestation had heavier kits than does eating less than average feed intake (71 and 60 ± 2.7 g, respectively; $P < 0.01$).

DISCUSSION

The objective of this study was to examine whether young does should be fed to appetite or restrictively fed during early gestation so as to improve kindling rate, litter size, live born kits and birth weight. However, no effect of feeding level during early gestation on kindling rate or litter size was found. This is unexpected for several reasons.

In gilts and ewes, some feed restriction during early gestation decreases embryo mortality and the critical period for the nutritional effects on embryonic survival in gilts seems to be limited to the period immediately after mating, starting the first day after mating and lasting for approximately 10 days (Jindal et al., 1996). In rabbits, implantation starts between the seventh and eighth post-ovulatory day (Hilliard and Eaton, 1971). In our study, a restriction period of 10 days was chosen to cover the implantation period. In gilts and ewes, the level of feed restriction during early gestation seems to be important for embryo survival around implantation. Low feeding levels ranged from one to 1.5 in gilts and 0.25 to one times maintenance in ewes. High feeding levels ranged from two to 2.6 times maintenance requirement in gilts (Jindal et al., 1996 and 1997; Dyck and Strain, 1983) and two times maintenance in ewes (Cumming et al, 1975; Parr et al., 1982). The largest effects on embryo survival were obtained in gilts fed one to 1.5 times maintenance and in ewes fed maintenance requirement. In our study, does were fed 1.35 versus two times maintenance requirement. So, feeding levels during early gestation were comparable to that used for pigs and sheep studies.

In rabbits, a previous study investigated the effect of feeding level before and during first gestation in young rabbit does on reproductive performance (Coudert and Lebas, 1985). Low feeding level during early gestation (75% of ad lib. until day 13) succeeded by ad libitum feeding until kindling resulted in a reduced number of live born kits. However, in their study low feeding level was started at 11 weeks of age (around the onset of puberty) and could have altered ovarian development as demonstrated by Hulot et al. (1982).

One potential explanation for the absence of an effect of feeding level on litter size in the present study is that feeding level does not affect embryo survival in rabbit as it does in other species.

In ewes and pigs, it has been demonstrated that a high feeding level during early gestation declines embryo survival. Feeding level alters the metabolic clearance rate of the blood flow through the liver (Parr et al., 1993a; Symonds and Prime, 1989) and affects plasma progesterone levels (Cumming et al., 1971; Parr et al., 1993b). Extra progesterone supply in gilts fed high feeding levels seem to prevent the negative effects of high feeding levels on embryo survival (Jindal et al., 1997). Plasma progesterone concentrations during early gestation are important for embryo survival in rabbits as in other species (Hilliard, 1973). Fortun et al. (1994) reported increased plasma progesterone levels at day 17 of gestation in rabbit does fed to maintenance requirement compared with does fed to appetite during gestation. In that study progesterone levels were similar between these treatment groups at day 28 of gestation and no effects were found on the number of fetuses at day 28 of gestation. This may indicate that in rabbits the effects of progesterone on embryo survival are limited or that other mechanisms prevail.

Another potential explanation for the fact that no effect of feed restriction on litter size was found in this study is that potential effects on embryo survival in early gestation are compensated by a decreased fetal survival in later gestation. In gilts, it has been demonstrated that uterine capacity is important in regulation of prenatal survival. Père et al. (1997) found a relationship between early (< d 35) and late fetal mortality. In gilts with a high early fetal mortality, late fetal mortality was low, and vice versa. Uterine space seems to be involved in these effects. In rabbits, uterine competition also occurs in the number of implanted embryos when selecting for uterine capacity (Argente et al., 1997). In our study, potential positive effects of feed restriction on embryo survival could have been diminished by high fetal survival, resulting in no effect on litter size.

In this study, the level of feed intake in the last week of gestation seems to affect kit survival and birth weight regardless of treatment. Difference in feed intake among does seems related to individual feed intake capacity of does. Individual feed intake is dependent of maternal body size. However, analysis included maternal body weight as covariate and resulted in similar contrasts. Does with a low voluntary feed intake capacity show increased kit mortality at kindling. Our findings are supported by de study of Coudert and Lebas (1985) who indicated that low feeding levels in the second half of gestation (from day 13 onwards) resulted in higher fetal mortality. Our study indicated that the effects of feed intake on kit mortality are restricted to the last week of gestation. Feeding level in early gestation did not affect feeding level in the last week of gestation, which may explain the absence of an effect of treatment on kit mortality. Stimulating voluntary feed intake during the last week of gestation might improve litter size and birth weight. However more research is needed to study factors to stimulate voluntary feed intake of young does to improve future reproduction.

CONCLUSIONS

It can be concluded that feed restriction for 10 days during early gestation does not affect kindling performance of young does, which had been fed to appetite during rearing. Voluntary feed intake capacity in the last week of gestation varies among does. Does with a high voluntary feed intake show improved kit survival and increased birth weight.

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GENERAL DISCUSSION

INTRODUCTION

In modern Dutch rabbit production the limited reproductive lifespan of rabbit does (approximately 4.2 litters per doe; Animal Sciences Group of Wageningen UR, Applied Research, in press) and the decreased reproductive performance of young does compared to multiparous does are seen as a welfare (Blokhuis, 1995) as well as an economic problem. During first lactation does loose substantial part of their initial fat (-40%) and energy reserves (-25% to -30%) (Xiccato, 1996). Moreover, concurrent pregnancy and lactation will display losses in nitrogen and mineral levels (Xiccato, 1996). The negative energy balance during first lactation seems to be related to the high replacement rate and reproductive problems of young does. Earlier research showed that improving energy balance and reproductive performance by increasing dietary energy concentration or adopting a more appropriate re-insemination interval were only marginally successful.

Another approach to overcome the problems of a negative energy balance is to focus on the rearing conditions of young does. The rearing period can be used to stimulate deposition of body reserves and may increase feed intake capacity before the reproductive period starts. We hypothesized that the reproductive ability in terms of fertility, productivity and reproductive lifespan is influenced by body development during rearing. Body development can be influenced by management measures, in particular feed intake and age at first insemination. We hypothesized that those does, which are “well developed” and have an improved feed intake and/or efficient energy utilization may be in favor to overcome the negative energy balance during first lactation. This should be expressed in either an improved reproductive performance or a decreased culling rate.

The following sections will focus on conditions for rearing, relationships between rearing strategies studied in this thesis and body development in terms of organ and tissue growth. The successive consequences for productivity, feed intake, body weight development, and culling in subsequent reproduction will be discussed. Finally practical implications will be given.

CONDITIONS FOR REARING

In current rearing, does are often fed ad libitum from weaning to first insemination. Before weaning, milk intake varies and is influenced by the litter size, in which the doe is raised. First insemination is applied when 75% to 80% of mature body weight (BW) is reached (Lebas et al., 1986), usually around 14 to 16 weeks of age. At first insemination BW is around 3.5 kg. At this time most of the bone and muscle tissue have been formed, and protein and ash content level off at approximately 20% and 3%, respectively (De Blas et al., 1977). The reproductive organs show a rapidly increasing development around 10 weeks of age (Ouhayoun, 1984) and they are supposed to be sufficiently developed at first insemination. Feed intake capacity is not fully developed at first insemination, but increases during subsequent lactations until it reaches a plateau level after the fourth lactation (Castellini and Battaglini, 1991).

We stated that does, which are "well developed", should be more capable to cope with the forenamed problems during first lactation. In this context, "well developed" refers to several factors, such as:

1. Enhanced skeleton growth (to create more volume for feed intake and/or fetes);
2. Higher degree of maturity (by delaying first insemination in order to obtain a heavier animal with more body reserves in terms of protein and fat).

However, postponing first insemination to older age will enable the animals to form excessive fat depots, which could cause problems. In ruminants, it is shown that excessive fat depots cause health problems due to fatty liver in lactation (Rukkwamsuk et al., 1999). In rabbits, an increased kit mortality at kindling has been reported in does with a higher body fat content at kindling (Partridge et al., 1986). To prevent excessive fattening, a form of feed restriction during rearing could be applied. Feed restriction during rearing could also be a tool to improve feed intake during reproduction. When rabbits are fed less restrictive or fed to appetite after a period of feed restriction, compensatory feed intake will take place and feed efficiency is improved (Ledin, 1984). These mechanisms could be useful to increase energy availability during first gestation and early lactation.

REARING STRATEGIES

Rearing strategies were focussed on body development during rearing by changing the level of feed intake during different phases of development, with or without postponing the age of first insemination. The rearing period was divided into two periods and the effect of feeding level was studied in each period. The following periods were distinguished:

1. Before weaning (4.5 wk of age). The period before weaning is characterized by a high growth rate of bone, heart and lung, intestines, and caecum. Milk is the major source of feed. The number of kits within a litter affects individual milk intake. We assumed that stimulating milk intake would stimulate skeleton growth and this would result in larger /heavier does.
2. From weaning until first insemination. The period after weaning is characterized by a rapid development of the caecum until 5 to 6 weeks of age as a consequence of the transition from milk to solid food. Feed restriction should not be applied in this phase, because the caecum plays a major role in the digestion of the rabbit and feed restriction can even favor conditions for pathogenic agents (Maertens and Peeters, 1988).

   Muscle (protein) tissue shows a high development rate until 10 to 12 weeks of age (Cantier et al., 1969; Deltoro and Lopez, 1985). By restricting feed intake from 5 to 6 weeks of age onwards, protein and fat deposition will be hindered. After 10 weeks of age, feed intake was gradually increased to stimulate sexual development that starts around 10 to 12 weeks of age and to enable does to compensate for the loss in protein development. In this way, it can be prevented that young does will have developed excessive fat depots at first insemination, whereas sexual development in these does is stimulated.

The results of the experiments described in this thesis showed that BW and body composition at first insemination could be manipulated by rearing strategies. Body weight at first insemination depended on feeding level (both in the pre- and post-weaning period) and age at first insemination. Depending on the rearing strategy applied, BW at first insemination varied between 3.2 kg and 4.2 kg (for restrictively fed does inseminated at 14.5 wk of age (R-14.5) and ad libitum fed does inseminated at 17.5 wk of age (AL-17.5), respectively).

In the experiments, in which body composition was determined at the end of rearing (see Chapter 2 and 4), mainly body fat content was affected and varied between 14% and 24% of the empty body weight (for R-14.5 and AL-17.5 does, respectively). Body protein and ash content were hardly influenced and ranged around 20%, and 3% of the empty body weight, respectively, independent of rearing strategy. This is in agreement with the study of Ledin (1984), who stated that in case of feed restriction priority is given to organ development. In our studies, protein and ash contents at first insemination were comparable to levels reported by De Blas et al. (1977) for five months old does. In the study of De Blas et al. (1977), it was stated that at five months of age growth rate had slowed down with the tendency to put on fat and that protein and ash development was completed.

We supposed that milk intake before weaning would enhance skeleton growth, but this was not supported by the results in Chapter 2. Does raised in different litter sizes had similar ash content (111 g, 109 g, 111 g for kits raised in litters of 6, 9, and 12 kits, respectively). The reason for this is not clear, but there are several possible explanations. It could be that milk intake was not sufficiently reduced in does raised in litter of 12 kits to impose an effect. Skeleton growth might have a high priority at this age, so nutrients will first of all be used for this purpose, and/or does might have been able to catch up for the loss in ash content after weaning, because feed was given to appetite from weaning onwards.

The impact of the rearing strategies on the reproductive performance and lifespan of young does will be discussed next.

CONSEQUENCES OF REARING STRATEGIES FOR PRODUCTION

The main objectives for application of rearing strategies are to improve reproductive performance of young does and to prolong their reproductive lifespan. Improved reproductive performance implicates improvement of several reproductive factors, such as: kindling rate, litter size, kit survival at kindling and during lactation, and milk production. To prolong the lifespan of the does, a low culling rate during reproduction should be achieved.

Kindling rate

Based on the results of the experiments described in this thesis, kindling rate varied between experiments (range 62% - 85%), but was not affected by rearing strategies.

Litter size

Rearing strategy seems to affect litter size. In Chapter 2, heavier does, raised in litters of six or nine kits, produced more kits (+ 1.1 and + 2.2, respectively) in the first parity than small does raised in litters of 12 kits. Chapter 3 shows that in does fed ad libitum and inseminated at 14.5 wk of age a positive relation exists between BW at 14.5 wk of age and litter size in the first parity. Litter size improved from 6.4 to 8.9 kits for does weighing less than 3.5 kg to more than 4 kg at first insemination. In Chapter 5, restrictive fed does inseminated at 17.5 wk of age produced more alive born kits (+ 1.4) and weaned more kits (+ 0.6) in the first parity than does fed ad libitum and inseminated at 14.5 or 17.5 wk of age. Therefore, we choose to study the relationship between BW at first insemination and litter size in the first parity in more detail in this discussion. For this analyses, all available data sets from this thesis will be used, namely: data of Chapter 2, an unpublished data set used in Chapter 3, and data of Chapter 5. The relationship will be studied for the following three rearing strategies: ad libitum feeding and first insemination at 14.5 wk of age (AL-14.5), or 17.5 wk of age (AL-17.5), and restrictive feeding and first insemination at 17.5 wk of age (R-17.5).

The relationships between BW at first insemination, and litter size in the first parity was studied by dividing BW at first insemination into 6 BW-classes: 1) < 3.5 kg, 2) 3.5 – 3.75 kg, 3) 3.75 – 4 kg, 4) 4 – 4.25 kg, 5) 4.25 – 4.5 kg, 6) > 4.5 kg. For BW-classes containing less than five does the average was not calculated. The percentage of does and the average litter size in each BW-class were calculated. The outcome is presented in Figure 1 for AL-14.5 does, in Figure 2 for AL-17.5 does, and in Figure 3 for R-17.5 does.

Figure 1 shows that litter size increases when does are heavier at 14.5 wk of age. However, litter size seems to level off: between eight and nine kits at 4 to 4.25 kg BW for data of Chapter 2, and at 3.75 to 4 kg BW for unpublished results. In Chapter 5, there were not enough data of does heavier than 4 kg. These results indicate that at 14.5 wk of age, does need a certain BW (around approximately 4 kg) at first insemination to improve litter size in the first parity. In Chapter 3, it was reported that heavy (> 4 kg) does at 14.5 wk of age had similar feed efficiency during rearing than small (< 3.5 kg) does and that heavy does could not have deposited additional fat tissue towards the end of rearing.

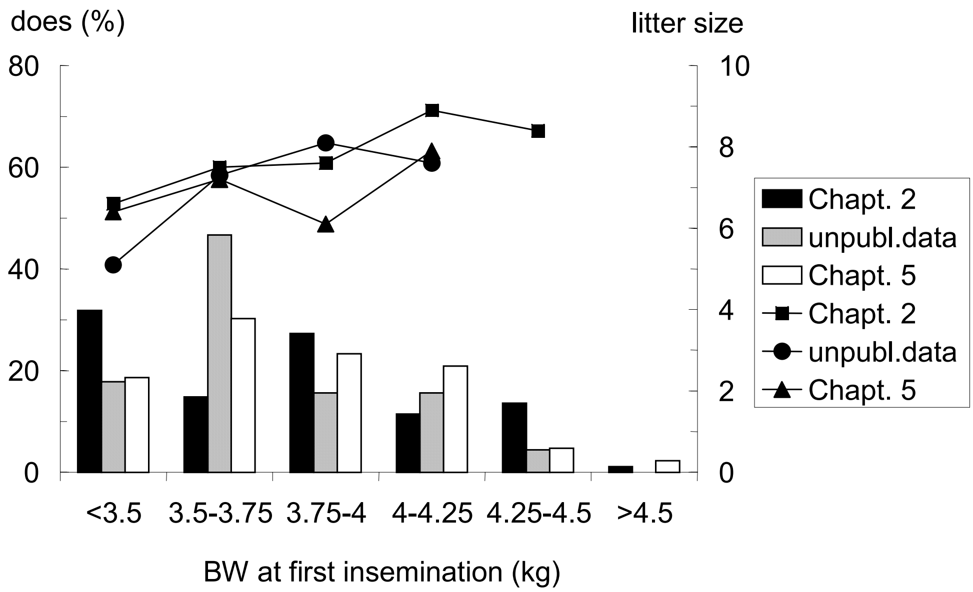

Figure 1. Relationship between BW at first insemination at 14.5 wk of age and litter size in the first parity for does fed ad libitum during rearing based on three experiments. The distribution of does in different BW-classes is presented in bars. Average litter size is represented by lines.

Heavy does must still have been deposited protein and fat tissue as small and medium does did. Therefore, heavy does contained more protein and fat, because they are heavier and this might indicate that they were more mature than medium and small does. This is supported by the fact that in Chapter 4, does fed restrictively during rearing and inseminated at 14.5 wk of age were small (3.2 kg) and showed poor fertility and embryo recovery. It seems that body development of small does is not optimal at 14.5 weeks of age and results in a lower maturity and decreased litter size in the first parity. The fact that under ad libitum feeding conditions over 70% of the does did not reach BW of 4 kg at 14.5 wk of age (see Figure 1) can explain the decreased litter size. The improved litter size that was found in does raised in litters of six (LS6) and nine kits (LS9) in the pre-weaning period (see Chapter 2) can be explained by the fact that more does (60, and 38.9% for LS6, and LS9, respectively) weighed around 4 kg at 14.5 wk of age, whereas only 22.9% of does raised in litters of 12 kits did so. Body development of does raised in litters of 12 kits does not seem optimal at 14.5 wk of age. In Chapter 3, small (< 3.5 kg), medium (3.5 to 4 kg) and heavy (> 4 kg) does were compared for subsequent performance. Litter size in small does was reduced compared to medium and heavy does (-1.3 and – 2.5 kits, respectively). Small does had a 25% lower growth rate during rearing. From these findings it can be stated that does need a certain BW (around 4 kg) to optimize litter size and under current rearing conditions first insemination should be delayed to older age.

To increase BW at first insemination under ad libitum feeding conditions, the rearing period was prolonged until 17.5 wk of age. The relationship between BW at first insemination at 17.5 wk of age and litter size is presented in Figure 2. Data of Chapter 2 were excluded from this analysis, because does inseminated at 17.5 wk of age were selected. These does had not become pregnant from the first insemination at 14.5 wk of age and were treated with a GnRH analogue (Receptal®; Intervet, Boxmeer, The Netherlands) to provoke ovulation. This treatment might have affected litter size. In the BW-classes < 3.5 kg (Chapter 5) and < 3.75 (unpublished data), no average litter size was calculated, because of the small number of does.

Figure 2 shows that litter size in the first parity is not strongly related with BW at first insemination (at 17.5 wk of age). No additional increase is achieved in litter size when does get heavier than approximately 4 – 4.25 kg for does in Chapter 5, and around 4.25 – 4.5 kg for does in unpublished results. Litter size seems to level off at approximately 4 kg BW, which is in accordance with does inseminated at 14.5 wk of age. First insemination at older age (17.5 wk) improved receptivity and embryo recovery (see Chapter 4), but it did not result in increased litter size (see Chapter 5) as compared to does inseminated at 14.5 wk of age.

When postponing first insemination to 17.5 wk of age under ad libitum feeding conditions more than 75% of the does reached BW of at least 4 kg. However, heavy BW at 17.5 wk of age gives does with a high fat content. Under this rearing strategy, does were heavier at first insemination, but weight gain was mainly caused by deposition of fat tissue (see Chapter 4). Based on these results, it can be concluded that the number of does that reach a BW of at least 4 kg is increased if first insemination is applied at 17.5 wk of age. However, part of the does that reached over 4 kg BW, will be fatter. A higher fat content can have negative effects during gestation and lactation as will be discussed later in this Chapter.

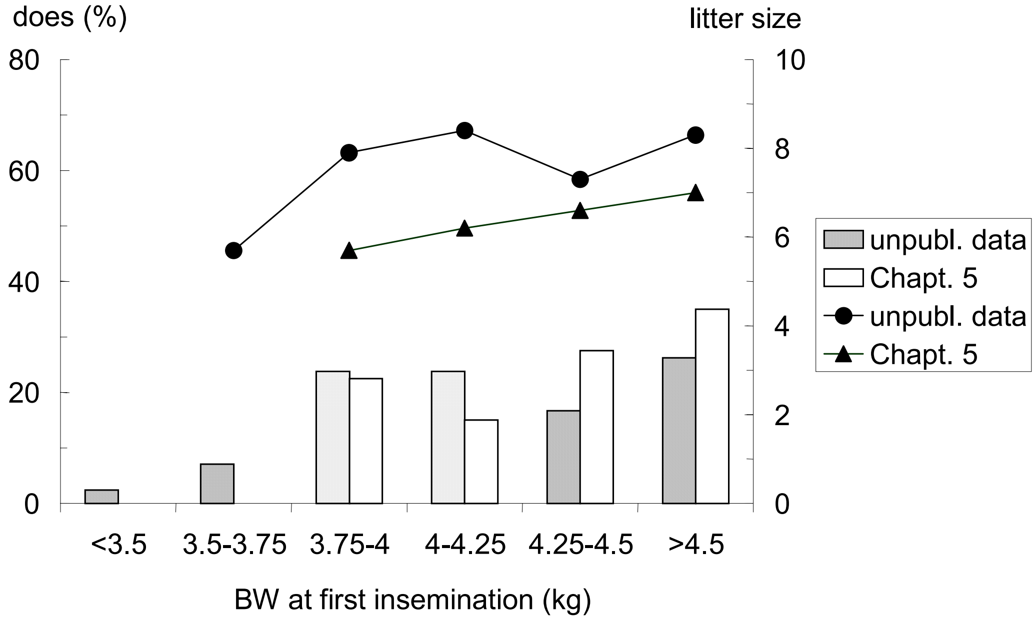

Figure 2. Relationship between BW at first insemination at 17.5 wk of age and litter size in the first parity for does fed ad libitum during rearing based on three experiments.
The distribution of does in different BW-classes is presented in bars. Average litter size is represented by lines.

To prevent overfattening at first insemination, feed intake was restricted during rearing. Rearing period was prolonged with three weeks to enable does to restore protein and part of the fat development. At the end of rearing, R-17.5 does had similar BW, ash, protein, and fat content as AL-14.5. Fat content was lower than AL-17.5 does (see chapter 4). Puberty characteristics of R-17.5 were similar to those of AL-14.5.

Average litter size and percentage of does in the BW-classes were calculated. The outcome is presented in Figure 3. Restrictive feeding during rearing increased uniformity in BW at first insemination. The number of does weighed more than 4.25 kg was too low to calculate average litter size. The percentage of does that reached BW around 4 kg at first insemination was 60 and 80% for unpublished data and data presented in Chapter 5, respectively. There was no strong relationship between BW at first insemination and litter size. Litter size seems to plateau around approximately eight kits from 3.75 to 4 kg for does in unpublished results. Does in Chapter 5 showed a small increase until 4 to 4.25 kg was reached. From 4.25 kg onwards, the number of does was too small and no more data were available.

It can be stated that restrictive feeding reduces variation in BW at first insemination. This means a considerable decrease in the number of too small does at 14.5 wk of age and number of too heavy does at 17.5 wk of age, as was seen under ad libitum feeding conditions.

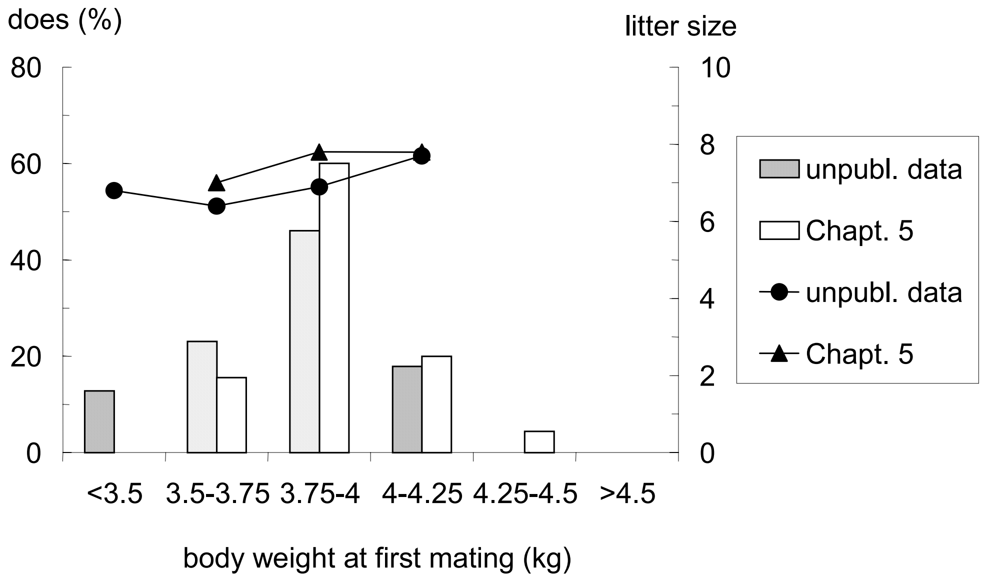

Figure 3. Relationship between BW at first insemination at 17.5 wk of age and litter size in the first parity for does fed restrictively during rearing based on three experiments.
The distribution of does in different BW-classes is presented in bars. Average litter size is represented by lines.

Stillbirth

In our experiments, there was no clear relationship between BW at mating and stillbirth within one rearing strategy. The percentage of stillbirth varies greatly among does within treatments. Only in Chapter 3, a significant ($P < 0.05$) higher percentage of stillbirth was found for heavy does (BW > 4 kg) inseminated at 14.5 wk of age compared to small does (BW < 3.5) (13.4% vs. 4.6%, respectively). No difference in stillbirth was found between AL-14.5 and AL-17.5 (see Chapter 5).

The percentage of stillbirth seemed decreased for R-17.5 compared to AL-14.5 and AL-17.5 (2.3, 6.5, 13.5%, respectively), but the difference was not significant. We also determined the number/percentage of litters, which had one or more stillborn kits. Fifty percent (20 litters with still born kits/40 litters) of the does in AL-14.5 had stillborn kits, 22.5% (9/40) in AL-17.5, and 9.1% (4/44) in R-17.5. Restrictive feeding seems to reduce the incidence of stillbirth. Data in Chapter 6 reveal that the percentage of does with stillbirth seems related to the voluntary feed intake of the does in the last week before kindling. In does with a low feed intake an increased number of litters with stillbirth were found. Fetes growth in rabbits is characterized by a high growth rate during the last 10 days of gestation (Xiccato, 1996). Parigi-Bini et al. (1992) showed that feeding level during gestation can affect mortality at birth. They reported a lower mortality rate at birth at higher feeding levels during gestation. The lower number of does with stillbirth of R-17.5 compared to AL-17.5 could be explained by the higher feed intake during the last week of gestation that was found in R-17.5 does (137 g/d vs. 172 g/d for AL-17.5 and R-17.5, respectively). The lower feed intake in AL-17.5 does could be explained by the higher fat content of these animals at first insemination compared to R-17.5 does (24 vs. 17%, respectively) and this is in agreement with the findings of Partridge et al. (1986), who found higher kit mortality at birth in animals, which have substantial quantities of fat.

In order to minimize stillbirth, restrictive feeding during rearing is preferred, because does will eat more throughout gestation resulting in decreased stillbirth at kindling.

Milk Production

Litter weight at 16 days of lactation was used as an estimate for milk production in all experiments, because kits start to consume solid food from 17 days onwards (personal observation). The relationship between litter weight at 16 days and BW at first insemination for the different rearing strategies is presented in Figure 4. In AL-14.5 does, milk production is independent of BW at first insemination and varies between 1.8 and 2 kg. At 17.5 wk of age in does fed ad libitum, milk production slightly increases when does are heavier at first insemination, but the level of milk production is similar to AL-14.5 does. At 14.5 wk of age, there were no does with BW > 4.5 kg.

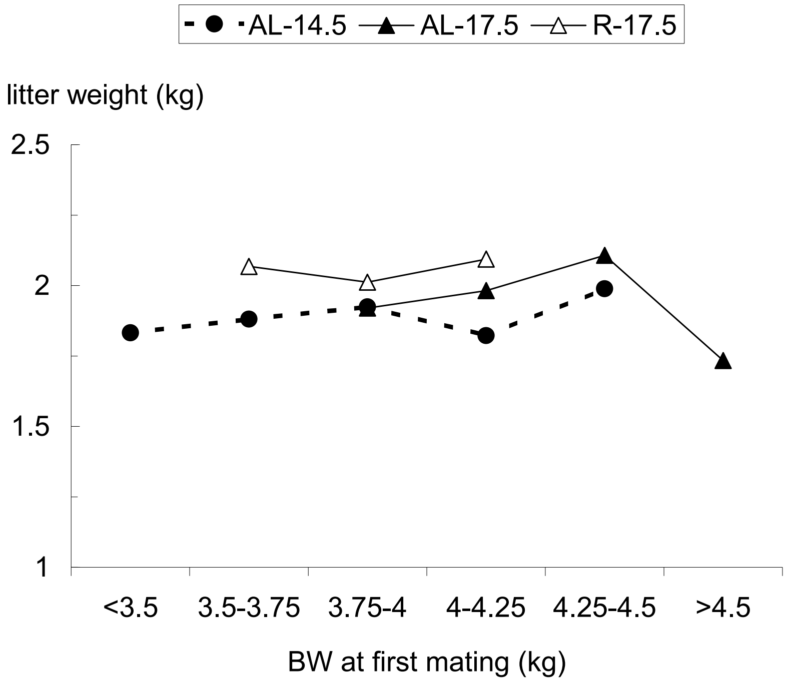

Figure 4. Relationship between BW at first insemination and litter weight at 16 d in the first lactation for does fed ad libitum (AL) during rearing and inseminated at 14.5 or 17.5 wk of age, and does fed restrictively during rearing (R) and inseminated at 17.5 wk of age.

In AL-17.5 does heavier than 4.5 kg at first insemination milk production drops (to approximately 1.7 kg; $P < 0.01$). This could be related with the decreased feed intake during first lactation. Average feed intake during the first 16 d of lactation was decreased by 10% in does weighing more than 4.5 kg compared with does weighing 4.25 to 4.5 kg (data not published).

Does inseminated at 17.5 wk of age and fed restrictively during rearing had an increased litter weight at 16 d of lactation compared to AL-14.5 and AL-17.5 (approximately +200 g), independent of BW at insemination. Restrictively fed does inseminated at 17.5 wk of age had an increased feed intake during first gestation (+20%) and first lactation (+10%) compared to AL-17.5 does. The extra available energy is most likely used for milk production.

In lactating does, R-17.5 does ate approximately 10% less food than AL-14.5 does during the first 16 d of lactation. However, AL-14.5 gained in weight, in the first gestation as well as in the first lactation period. This suggests that AL-14.5 does still have a “drive for growth”, because of their physiological immaturity at first insemination. Competition for nutrients between body growth and production must have occurred, and has resulted in smaller litters and lower milk production. This was not the case in R-17.5 does and this explains the increased milk production found in R-17.5 compared to AL-14.5 does as shown in Figure 4.

A higher milk production will result in an increased kit growth and/or decreased kit mortality before weaning. The best productive performances were found in R-17.5 does as described in Chapter 5.

As we have seen, under ad libitum feeding conditions during rearing, milk production during first lactation increases slightly with BW at first insemination until does are very heavy (> 4.5 kg). Milk production is not influenced by age of first insemination, but depends on the feeding strategy during rearing. In does fed restrictively during rearing the best performances were found probably because they eat well during lactation (as compared to AL-17.5 does) and give less priority to body growth (compared to AL-14.5 does).

Culling Rate of Does

We hypothesized that rearing strategies could prolong the reproductive lifespan of does, as result of an improved body development or an improved feed intake and/or efficient energy utilization. However, culling rate of does in the first three parities was not affected by rearing strategies. Based on data in Chapter 1, 5, and unpublished results, the overall culling rate for the different rearing strategies was 30.4%, 24.4%, and 26.7% for AL-14.5, AL-17.5, and R-17.5, respectively.

Data collected at our institute (not published) indicates that approximately 50% of the replacements occurs before the third litter is weaned. In our experiments, culling of does was recorded during the first two or three parities (depending on experiment), which covers most of the period of high incidence of replacement. Therefore effects could have been expected, if the rearing strategies would have had any influence on culling.

One explanation for the absence of an effect of rearing strategy on culling rate in this thesis might be that the number of does per treatment may have been too low. Because of practical limitations, larger numbers of animals per treatment were not possible in our experiments.

Another explanation for the fact that no effect of rearing strategy on culling rate was found might be that the applied rearing strategies had no long term effects on body weight development and feed intake in the first two or three parities. In all experiments, effects of rearing strategy were limited to the first parity. In the second and third parities no substantial effects of rearing strategies on body growth, feed intake, and reproductive performance were found.

Although rearing strategies affected body weight and body composition at first insemination, it gave no substantial profit in terms of body weight development, body composition and feed intake over two or three parities. Heavy does at first insemination (AL-17.5) lost substantial BW during first gestation. Ad libitum fed does inseminated at 14.5 wk of age showed substantial growth during first gestation that resulted in decreased reproductive performance in the first parity. Feed intake of R-17.5 does was improved in the first gestation and lactation period. However, the extra energy seems to have been used to improve reproductive performance in the first parity instead of improving energy balance, which has also been reported by Xiccato (1996). This preference for reproduction makes it difficult to improve energy balance during first lactations and reproductive lifespan of rabbit does.

CONCLUSIONS

Based on the findings presented in this discussion, it can be concluded that:

1. In order to optimize litter size, young does should have a body weight of around 4 kg at first insemination.
2. Restrictive feeding during rearing and first insemination at 17.5 wk of age improves uniformity in BW at first insemination. Under ad libitum feeding conditions, more than 70% of the does will not have reached optimal BW (around 4 kg) for litter size at 14.5 wk of age. Litter size in these does is reduced by approximately 1.5 kits. At 17.5 wk of age, the majority of the does (75%) is heavy (>4 kg). With restrictive feeding during rearing, between 60% to 80% of the does have a BW of around 4 kg.
3. Extending first insemination with three weeks of age under ad libitum feeding conditions results in fatter animals. With restrictive feeding and first insemination at 17.5 wk of age excessive fat deposition can be prevented, without reducing body protein and ash content.
4. Litter size and stillbirth were predominantly related to BW at first insemination. Litter size increased with increased BW at first insemination until 4 kg, when a plateau is reached. Small does (< 3.5 kg) are physiologically immature for reproduction.

Stillbirth is increased in heavy does, due to a decreased feed intake during first gestation. Effects were restricted to the first parity.

5. Litter weight at 16 d of lactation (estimate for milk production) is influenced by the feeding strategy during rearing. Restrictive fed does mated at 17.5 wk of age had the highest milk production, mainly caused by an improved feed intake compared to AL-17.5 does, and a lower weight gain during first gestation compared to AL-14.5 does.
6. Rearing strategies did only affect body weight development and feed intake in the first parity. Long term effects on subsequent parities were absent and culling rate of does was not influenced.

PRACTICAL IMPLICATIONS

Results obtained in this thesis indicate that young does should have reached a BW around 4 kg to improve litter size. With the current rearing strategy, this BW is often not reached. By establishing a threshold for BW before does can be inseminated for the first time, litter size can be improved. In a cycled reproduction system, restrictive feeding can be used to increase the number of does with optimal BW, which have to be inseminated at the same day. Restrictive feeding during rearing implicates postponing first insemination with approximately three weeks. Besides an increase in uniformity of BW and thereby improving litter size, restrictive feeding during rearing results in an improved milk production and weaning weight of the kits at the end of the first lactation.

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SUMMARY

This thesis describes the effects of different rearing strategies for young rabbit does on body development and reproduction performance. In current rearing, does are often fed to appetite from weaning to first insemination. First insemination is applied when 75 to 80% of mature body weight (BW) is reached, that occurs around 14 to 16 weeks of age. Under current rearing, young does loose significant part of their fat and energy reserves during first lactation. This seems related to the decreased reproductive performance and high replacement rate of young does, that are undesired from both economic and welfare point of view. Feed intake during lactation seems to be the limited factor. The objectives of this thesis were to optimize body development and feed intake capacity of young does to improve their reproductive performance and to prolong their lifespan.

In Chapter 1, literature on body growth and body development of rabbits is summarized and management practices and factors that could be relevant during the rearing period to stimulate feed intake and body development are reviewed. Body development in rabbits is characterized by a high growth rate of organs and tissues at early age (before 12 weeks). After 12 weeks of age, mainly fat depots are being formed. Feeding level seemed an important factor to regulate body growth and development together with age of first insemination.

Therefore, several experiments were performed, in which the level of feed intake and the age of first insemination on body development and composition, feed intake, reproductive performance, and culling rate of does were studied. Feeding level was manipulated in two successive periods during rearing; 1) the period before weaning (30 days of age) in which kits depend on their mother's milk for nutrient intake, and 2) the period after weaning in which kits eat solid food. Rearing period ended at first insemination, that was applied at 14.5 or 17.5 weeks of age.

In Chapter 2, nutrient intake in the pre-weaning period was investigated. Milk intake was manipulated by varying the number of suckling kits in a litter. Kits were raised in litters of 6, 9 or 12 kits (LS6, 9, 12). Milk intake in the pre-weaning period affected body

growth during rearing and BW at first mating (at 14.5 wk of age). Kits raised in small litters (LS6) were heavier at first mating than kits raised in large litters (LS12). Kits raised in litters of nine were able to compensate for the differences in BW at weaning and reached similar BW as LS6 at end of rearing. The amount of milk intake in the pre-weaning period affected body composition at first mating. Ash content (bone formation) was not improved in heavy does (LS6), but they had more fat tissue and energy than small does (LS12). Heavier does (LS6, and 9) produced more kits (+ 1.1 and + 2.2, respectively) than small does (LS12) in the first parity. Feed intake during first lactation was not affected. In the second parity, no differences in BW, feed intake or reproductive performance were found among treatments. Treatment did not affect culling rate. Does which had not become pregnant of the first insemination at 14.5 wk of age were re-inseminated at 17.5 wk of age. Reproductive performance of these does was significantly improved in the first parity.

In Chapter 3, data of Chapter 2 and a set of unpublished data were used to investigate the effect of BW at 14.5 week of age on subsequent reproduction. Does were divided in three classes based on their BW at first insemination (14.5 week of age) (< 3.5, 3.5 – 4, $\geq$ 4 kg, respectively). Differences in BW at 14.5 week of age were caused by difference in growth potential and feed intake during rearing. Heavy does (> 4 kg) were does with high voluntary feed intake, but according to their gain to feed ratio at end of rearing, no excessive fat deposition could have occurred. However, the fact that they were heavier implicates that they will have more body reserves in terms of protein and fat. Extra BW at start of reproduction improved litter size in the first parity. Heavy does at first insemination (BW $\geq$ 4 kg) produced more kits (+ 2.5) compared to small does (BW < 3.5 kg). Extra BW at start did not contribute to an improved feed intake or increased BW development during reproduction and had no effect on culling.

In Chapter 4, the effect of BW and age of first insemination on body development, body composition, and puberty characteristics at the end of rearing were studied. Does were fed ad libitum (AL) or restrictive (R) and were inseminated at 14.5 or 17.5 week of age. Feed restriction was used to manipulate body development by preventing excessive fat deposition and stimulating sexual development. With the feed restriction we succeeded in “creating” does, which had similar body composition and body weight, but differed three weeks in physiological age (14.5 vs. 17.5), whereas puberty characteristics were comparable. Does fed to ad libitum and mated at 17.5 week of age were heaviest, contained more fat and had the best puberty characteristics. Does fed restrictively and mated at 14.5 weeks of age were physiologically too immature for reproduction. Only two of the 16 does (12.5%) fed restrictively were receptive at first insemination. In five of the 10 does that were killed to determine body composition corpera lutea were found, and only one doe had embryos.

In Chapter 5, the effect of the treatments tested in Chapter 4 were investigated on performance in the reproductive period. Based on the results in Chapter 4, restrictive feeding and mating at 14.5 wk of age was not applied. Does fed ad libitum and mated at 17.5 week of age (AL-17.5) were heaviest at first insemination. Although these does were older and had more body reserves, reproductive performance was not improved. Heavier BW at the same age (AL-17.5 and R-17.5) resulted in a reduced feed intake during first gestation (-25%) and first lactation (-10%), probably due to the high amount of body fat. This resulted in weight loss during first gestation (-6%) and decreased litter weights (-19%) and litter growth (-14%) in the first parity. Although AL-14.5 and R-17.5 does had similar BW and body composition at first insemination, R-17.5 does produced more alive born kits (+ 1.4) and weaned more kits (+ 0.6) in the first parity. Feed intake in the first parity was similar. The ad libitum fed does inseminated at 14.5 week of age gained weight in the first gestation period as well as in the first lactation. Competition for nutrients between body growth and production must have occurred, and resulted in smaller litters and lower milk production. This could indicate that AL-14.5 does were physiological not mature enough for reproduction. Effect of rearing strategies was limited to the first parity. Culling rate of does during the first three parities was not affected by rearing strategy.

In Chapter 6, an attempt was made to improve litter size after first insemination by restricting feed intake during the first 10 days of gestation. Feed intake in first 10 days of gestation did not affect kindling performance of young does. However, further analysis on ad libitum fed does revealed an effect of feed intake in the last week of gestation on kit survival and birth weight. In does with the highest feed intake during the last week of gestation, the lowest number of litters with stillborn kits with the highest birth weight was found. Feed intake in the last week of gestation was not influenced by feed restriction in early gestation.

In the General Discussion, the consequences of rearing strategies for production were further analyzed and discussed based on BW at first insemination. Body weight at first insemination was divided into six BW-classes from very small (< 3.5 kg) to very heavy (> 4.5 kg). The effect of BW on reproductive parameters was analyzed for the following rearing strategies: AL-14.5, AL-17.5, and R-17.5, using the data of Chapter 2, a set of unpublished data also used in Chapter 3, and data of Chapter 5. Kindling rate was not affected by rearing strategy.

In all rearing strategies, litter size increased when does were heavier, although this relationship was most profound in AL-14.5. Litter size was optimized between eight and nine kits in does weighing approximately 4 kg at first insemination. Feeding strategy during rearing influenced the uniformity in BW of does at first insemination. In AL-14.5 does, more than 70% of the does were smaller than 4 kg at first insemination. In does smaller than 4 kg litter size was reduced by approximately 1.5 kit. In AL-17.5 does, 75% of the does were heavier than 4 kg. Body composition determined in Chapter 4, revealed that heavy does have more fat. Based on results in Chapter 5, in does with excessive fat depots, the percentage of does with stillborn kits in their litter will be increased, because feed intake during first gestation is decreased.

In R-17.5 does, the percentage of does that weighed around 4 kg at first insemination was 60 to 80%. In these does litter size was improved, because the percentage of small animals (with low litter size) as well as the percentage of very heavy animals (with high stillbirth) is reduced.

There was not a clear relationship between milk production and BW at first insemination. However, in R-17.5 does milk production was higher than in AL-14.5 and 17.5 does, independent of BW-class. The difference in milk production between R-17.5 and Al-17.5 could be explained by the higher feed intake of R-17.5 in the first gestation and lactation period. The difference in milk production between R-17.5 and AL-14.5

could be explained by the fact that AL-14.5 gained weight during first gestation as well as during first lactation. Competition for nutrients between body growth and production must have occurred, and resulted in smaller litters and lower milk production. The higher milk production of R-17.5 does resulted in higher kit weight at weaning. The best reproductive performance in the first parity was found in R-17.5 does. Rearing strategies only affected body weight development, feed intake and reproductive performance in the first parity. Long-term effects over three parities were absent and rearing strategy did not influence culling rate of does.

SAMENVATTING

Deze samenvatting is met name bedoeld als samenvatting voor niet-ingewijden op dit onderzoeksgebied.

De commerciële konijnenhouderij is een kleine sector binnen de Nederlandse veehouderij, waarin konijnen worden gehouden voor de productie van konijnenvlees. In 2001 waren er 183 geregistreerde konijnenbedrijven (LEI en CBS, 2002). Deze bedrijven liggen met name in het zuiden van het land (Noord-Brabant en Limburg). In 2001 werden op deze bedrijven circa 49.000 voedsters (vrouwelijke konijnen) gehouden. Een voedster produceert gemiddeld 47 vleeskonijnen in circa zeven worpen per jaar. De vleeskonijnen worden bij een gewicht van ongeveer 2.6 kg aan de slachterij afgeleverd (Animal Sciences Group van Wageningen UR, Praktijkonderzoek, in druk). De Nederlandse productie bedraagt nog geen 0,5% van de wereldproductie van konijnenvlees. In 2000 werd de wereldproductie van konijnenvlees geschat op 1,8 miljoen ton (Lebas en Colin, 2000). Produceerden Italië, Frankrijk en Spanje in 1996 nog de helft van de wereldproductie aan konijnenvlees, in 2000 was hun aandeel gedaald naar 35% door een sterke stijging in de productie van konijnenvlees in het Verre Oosten (met name China). De consumptie van konijnenvlees in Nederland is beperkt (ongeveer 800 gram per persoon per jaar); het merendeel van de vleeskonijnen wordt dan ook geëxporteerd naar landen zoals België, Frankrijk en Duitsland.

Een konijnenhouder streeft naar maximale vleesproductie bij zo laag mogelijke kosten. De huisvesting en de verzorging van voedsters vormen een belangrijke kostenpost voor een bedrijf en het totaal aantal vleeskonijnen dat per voedster kan worden afgeleverd heeft grote invloed op de totale opbrengsten. Een optimaal rendement is alleen mogelijk wanneer er met gezonde dieren wordt gewerkt. Een lage sterfte onder zowel de vleeskonijnen als de voedsters is uit welzijns- en economisch oogpunt gewenst.

Het gemiddelde vervangingspercentage van voedsters wordt geschat op 170% (Animal Sciences Group of Wageningen UR, Praktijkonderzoek, in druk). Dit betekent dat een voedster gemiddeld 4,2 worpen voortbrengt in haar leven. Uit gegevens verzameld op de proefaccommodatie voor konijnen bij het Praktijkonderzoek, bleek dat meer dan de helft van de vervanging toe te schrijven is aan gezondheids- en reproductieproblemen van jonge voedsters (dieren die minder dan drie worpen hebben geproduceerd). Jonge voedsters komen met name in de eerste lactatie in de problemen, doordat hun voeropname niet toereikend is om de energie nodig voor melk productie en groei van foeten (volgende worp) te dekken. Hierdoor teren jonge voedsters in op hun vetten (- 40%) en energie (- 20%) en neemt onder andere hun weerstand af. De verlaagde productieresultaten (ten opzichte van oudere voedsters) en de korte levensduur van jonge voedsters worden hieraan toegeschreven.

Onderzoekers in Frankrijk, Italië en Spanje hebben gezocht naar oplossingen door tijdens de eerste worp een aantal maatregelen toe te passen waarmee het energietekort zou kunnen worden teruggedrongen, zoals: het verstrekken van energierijk voer en het uitstellen van het dekken/insemineren van jonge voedsters na het werpen. Deze maatregelen boden onvoldoende resultaat. Daarom is in dit proefschrift gezocht naar een andere oplossing, gericht op het optimaliseren van de lichaamsontwikkeling en voeropname in de periode voordat de voedster in productie wordt genomen, de opfokperiode.

Met de huidige opfokmethode worden opfokvoedsters vanaf spenen (het scheiden van moeder en jongen op circa 28 tot 35 dagen leeftijd, waardoor de jongen van melk op vast voer overgaan) tot aan de eerste dekking of inseminatie onbeperkt gevoerd. Wanneer de dieren ongeveer 75 tot 80% van hun volwassen gewicht hebben bereikt, worden ze voor de eerste keer gedekt /geïnsemineerd. De opfokvoedsters zijn dan circa 14 tot 16 weken oud en wegen rond 3,5 kg. Met deze opfokmethode wordt de groei van de dieren bepaald door onder andere hun groeiaanleg en deze wordt maximaal gestimuleerd. Met deze opfokmethode komen de voedsters in de eerste lactatie in de problemen, zoals in het voorgaande is beschreven. Daarom is gezocht naar andere opfokmogelijkheden.

Dit proefschrift beschrijft van verschillende opfokstrategieën de effecten op lichaamsontwikkeling en reproductie van voedsters. Het doel hiervan is de productieresultaten van jonge voedsters te optimaliseren en de vervanging te verlagen. De gedachte daarbij is dat een voedster “beter toegerust” aan de reproductie periode begint dan met de huidige opfokmethode het geval is. Met “beter toegerust” bedoelen we onder andere dat een voedster goed ontwikkeld is (skelet), waardoor ze voldoende volume heeft voor voer en foeten en voldoende is uitgegroeid (meer volwassen) en over meer reserves (vlees en vet) beschikt.

Om lichaamsontwikkeling in de opfokperiode te kunnen optimaliseren, is als eerste een literatuurstudie uitgevoerd, waarin de lichaamsontwikkeling van konijnen in kaart is gebracht en is nagegaan welke managementmaatregelen in de opfok effectief gebruikt kunnen worden om lichaamsontwikkeling te sturen. Het resultaat van deze literatuurstudie is beschreven in Hoofdstuk 1. Lichaamsontwikkeling van konijnen wordt gekenmerkt door een hoge groei van organen en weefsels op jonge leeftijd (voor 12 weken). Vanaf zes tot circa 12 weken vindt met name vlees (eiwit) aanzet plaats, vanaf 12 weken wordt voornamelijk vet aangezet. Rond 10 - 12 weken leeftijd komen voedsters in de puberteit. Voerniveau in de opfokperiode en leeftijd van eerste inseminatie zijn de belangrijkste factoren waarmee groei en ontwikkeling van konijnen kunnen worden beïnvloed.

Vervolgens is een serie proeven uitgevoerd, waarin effecten van voerniveau in de opfok en leeftijd van eerste inseminatie op groei, voeropname, productie, en uitval van voedsters is onderzocht. Het effect van voerniveau is bestudeerd in twee verschillende perioden van de opfok, te weten: 1) de periode voor spenen, waarin de dieren vrijwel geheel afhankelijk zijn van de melkgift van de moeder; 2) de periode na spenen, waarin de dieren uitsluitend vast voer krijgen gevoerd.

In Hoofdstuk 2 is het effect van het voerniveau vóór spenen op lichaams-samenstelling, gewichtsontwikkeling, voeropname, productie en uitval in de eerste twee pariteiten beschreven. De periode vóór spenen wordt gekenmerkt door een hoge groeisnelheid van het skelet. De gedachte was dat dieren, die veel voeding krijgen in deze periode een goed skelet kunnen ontwikkelen. Melkopname van de jongen wordt beïnvloed door het aantal jongen in een nest. Het aantal tepels van een voedsters ligt rond de acht á tien. In een kleine worp (6 jongen) kunnen de jongen een overmaat aan melk drinken. In een grote worp (12 jongen) kunnen de jongen onvoldoende melk op nemen, waardoor een groeiachterstand zal ontstaan. In een worp van 9 zullen de jongen net voldoende melk kunnen opnemen.

De grootte van de worp waarin de voedster geboren was bleek het gewicht en lichaamsamenstelling op 14,5 week leeftijd (eerste inseminatie) te beïnvloeden. Voedsters uit een worp van 6, waren zwaarder en vetter dan dieren uit een worp van 12. De voedsters uit een worp van 9 wisten het verschil in gewicht bij spenen in te halen en waren bij eerste inseminatie op 14,5 week leeftijd even zwaar als voedsters uit een worp van 6. Het anorganisch stof gehalte (skelet) bleek niet beïnvloed. De zwaardere voedsters produceerden beter in de eerste worp (+ 1,1 en + 2,2 jongen, in vergelijking met een worp van respectievelijk 6 en 9 jongen). Voeropname, gewichtsontwikkeling, en uitval van voedsters werden niet beïnvloed door de worpgrootte, waarin de voedster was opgefokt. Uit het onderzoek werd geconcludeerd, dat het opfokken van voedsters in een worp van 12 nadelige effecten heeft op de productie, terwijl het opfokken in een worp van 6 geen verdere voordelen heeft ten opzicht van opfok in een worp van 9. Toekomstige fokvoedsters kunnen daarom het beste worden opgefokt in een worp van ongeveer 9 jongen voor het spenen. Dit kan worden bereikt door jongen uit een grote worp over te leggen naar kleinere worpen. Dit kan na werpen en na circa de eerste levensweek, wanneer de grootste uitval van jongen heeft plaatsgevonden.

In Hoofdstuk 3 is het effect van het gewicht op 14,5 week leeftijd (eerste inseminatie) op de reproductie bestudeerd. Hiervoor zijn de gegevens beschreven in Hoofdstuk 2 en data, die niet zijn gepubliceerd, gebruikt. Voedsters werden op basis van hun gewicht op 14,5 week leeftijd onderverdeeld in drie gewichtsklassen, te weten: zwaar (> 4 kg), middel (3,5 tot 4 kg), en licht (< 3,5 kg). Verschillen in gewicht op 14,5 week leeftijd worden veroorzaakt door verschillende groeisnelheden en voeropnames in de opfokperiode. Zware dieren groeien snel en hebben een hoge voeropname. Echter de voerconversie (de hoeveelheid voer die een dier nodig heeft om 1 kg in gewicht te groeien) was gelijk voor de drie gewichtsklassen. Dit betekent dat de zware dieren nog geen extra vet aan het aanzetten waren bij eerste inseminatie. Maar door een zwaarder gewicht beschikken deze dieren over meer eiwit en vet. Zware voedsters produceerden grotere eerste worpen (+ 2,5 jongen) dan lichte voedsters, maar de voeropname en uitval in de reproductieperiode waren niet verbeterd.

In Hoofdstuk 4 is het effect van gewicht en leeftijd bij eerste inseminatie op lichaamsontwikkeling, lichaamssamenstelling en de puberteit onderzocht. De puberteit werd gemeten aan de hand van de willigheid (kleur vulva), bevruchtingspercentage, aantal *Corpera lutea (*restanten van eicelblaasjes, die op de eierstokken achterblijven na de eisprong) en het aantal embryo's. Voedsters werden in de opfok beperkt (R) of onbeperkt (AL) gevoerd en op 14,5 of 17,5 week voor de eerste keer geïnsemineerd. De voerbeperking was zodanig dat de voedsters met name in de eiwitaanzet (6 tot 10 weken leeftijd) werden beperkt. Vanaf 10 weken leeftijd kregen de voedsters geleidelijk meer voer per dag om het eiwittekort in te kunnen halen en de seksuele ontwikkeling niet te verstoren. Met de voerbeperking bleek het mogelijk om voedsters te "creëren" met dezelfde lichaamssamenstelling en puberteit, maar met drie weken leeftijdsverschil (AL-14,5 en R-17,5). Onbeperkt gevoerde dieren op 17,5 week leeftijd waren het zwaarste, het meest vervet en scoorden het hoogste in puberteit. Beperkt gevoerde dieren op 14,5 week leeftijd waren nog niet toe aan reproductie. De dieren waren licht (3,2 kg), nog niet klaar met eiwitaanzet en scoorden slecht op puberteit; slechts twee van de 16 voedsters waren willig bij eerste inseminatie en bij slechts de helft van de dieren werden corpera lutea gevonden op de eierstokken en slechts bij één dier werden embryo's aangetroffen.

In Hoofdstuk 5 is vervolgens het effect van de opfokstrategieën, die in Hoofdstuk 4 zijn beschreven, onderzocht op de gewichtsontwikkeling, productie, voeropname, en uitval in de eerste drie worpen. Gebaseerd op de bevindingen in Hoofdstuk 4, werd beperkte voedering in de opfok en inseminatie op 14,5 week leeftijd niet opgenomen in de proef. Onbeperkte voedering in de opfok, en inseminatie op 14,5 of 17,5 week leeftijd en beperkte voedering en inseminatie op 17,5 week leeftijd werden in deze proef met elkaar vergeleken.

Onbeperkt gevoerde voedsters, die op 17,5 week leeftijd waren geïnsemineerd waren het zwaarste. Echter deze voedsters produceerden niet beter dan AL-14,5 voedsters, ondanks het feit dat ze zwaarder (meer reserves) en ouder waren. Zwaardere dieren op dezelfde leeftijd geïnsemineerd (AL-17,5 vs. R-17,5) bleken minder voer op te nemen tijdens de eerste dracht (- 25%) en eerste lactatie (- 10%), waarschijnlijk doordat ze vetter waren. Dit leidde tot gewichtsverlies in de eerste dracht (- 6%) en lagere geboortegewichten (- 19%) en een lagere groei van de jongen voor spenen (- 14%).

Alhoewel de beperkt gevoerde dieren op 17,5 week leeftijd hetzelfde gewicht en lichaamssamenstelling hadden als de onbeperkt gevoerde dieren op 14,5 week leeftijd, produceerden ze in de eerste worp meer levend geboren jongen (+ 1,4) en leverden meer gespeende jongen (+ 0,6). Voeropname in de eerste pariteit was gelijk voor beide opfokstrategieën. De onbeperkt gevoerde dieren op 14,5 week leeftijd geïnsemineerd groeiden in de eerste dracht en eerste lactatie meer dan de R-17,5 voedsters. Dit betekent dat de opgenomen hoeveelheid voer over zowel eigen lichaamsgroei als productie moet worden verdeeld, wat leidde tot minder jongen en een lagere melkproductie in de eerste worp in. Dit zou er op kunnen wijzen dat de voedsters op 14,5 week leeftijd onvoldoende volwassen zijn. Deze effecten werden alleen gevonden in de eerste worp. In de tweede en derde worp waren er geen verschillen meer in productie, voeropname en gewichtsontwikkeling tussen de opfokstrategieën. De uitval van voedsters over drie pariteiten was gelijk voor de opfokstrategieën.

In Hoofdstuk 6 is onderzocht of het mogelijk is om de productie (aantal jongen) nog verder te verbeteren door te variëren in voerniveau na inseminatie. De voeropname van de voedsters in de eerste 10 dagen van de dracht was onbeperkt of beperkt. De achterliggende gedachte was dat tijdens het bevruchtings- en implantatieproces het hormoon progesteron een belangrijke invloed geeft op de overleving van embryo’s. Progesteron wordt door de eierstokken geproduceerd, aan het bloed afgegeven en zorgt onder andere voor groei van het baarmoederslijmvlies. Het hormoon wordt in de lever afgebroken. Bij een voerbeperking wordt de afbraak van progesteron in de lever vertraagd. Hierdoor blijft het progesterongehalte in het bloed verhoogd en dit zou een positief effect kunnen hebben op de vroege sterfte van embryo’s zoals bij onder andere schapen en varkens is aangetoond. Progesteron werd in deze proef niet gemeten, maar het aantal jongen (levend en dood) bij werpen werd geteld. De voeropname in de eerste 10 dagen van de dracht bleek geen invloed te hebben op de worpgrootte en percentage doodgeboren jongen. Er was echter een verband tussen de voeropname in de laatste week van de dracht en het aantal voedsters met doodgeboren jongen. Het aantal voedsters met doodgeboren jongen was het laagste voor de groep voedsters, die de hoogste voeropname in de laatste week van de dracht hadden. Er was echter geen relatie tussen de voerniveau in de eerste 10 dagen en de laatste week van de dracht.

In de Algemene Discussie zijn de consequenties van de opfokstrategieën voor de productie verder geanalyseerd en bediscussieerd. Hiervoor werden voedsters werden onderverdeeld in zes gewichtsklassen van licht (< 3,5 kg) tot zeer zwaar (> 4,5 kg) op basis van hun gewicht bij eerste inseminatie. Het effect van gewicht op de productie werd geanalyseerd voor de volgende opfokstrategieën: onbeperkte voedering en inseminatie op 14,5 week (AL-14,5) of 17.5 week leeftijd (AL-17,5), beperkte voedering en inseminatie op 17,5 week leeftijd (R-17,5). De data beschreven in Hoofdstuk 2 en 5, en de ongepubliceerde data beschreven in Hoofdstuk 3 werden gebruikt voor de analyse.

Het bevruchtingspercentage werd niet beïnvloed door de opfokstrategie. In alle opfokstrategieën nam de worpgrootte toe naarmate de dieren zwaarder werden, deze relatie was het duidelijkste aanwezig in de AL-14,5 voedsters. Het optimum voor worpgrootte lag tussen de acht en negen jongen en werd bereikt bij een gewicht van ongeveer 4 kg. De opfokstrategie beïnvloedde met name de uniformiteit van het gewicht van de voedsters bij eerste inseminatie. Op 14,5 week leeftijd en onbeperkte voedering was meer dan 70% van de dieren lichter dan 4 kg. Lichtere voedsters produceerden kleinere worpen (gemiddeld -1,5 jong). Wanneer de voedsters later worden gedekt (op 17,5 week leeftijd) blijkt 75% van de dieren zwaarder dan 4 kg te zijn. Maar deze dieren zijn ook vetter (Hoofdstuk 4) en de resultaten van Hoofdstuk 5 hebben laten zien dat de voeropname in de eerste dracht is verlaagd, waardoor het percentage doodgeboren jongen hoger wordt. Bij de beperkt gevoerde voedsters had 60 tot 80% van de dieren een gewicht rond de 4 kg op 17,5 week leeftijd. De worpgrootte van deze voedsters was verbeterd doordat het aandeel lichte dieren (met kleinere worpen) en het aandeel zware dieren (met meer doodgeboren jongen) kleiner was.

Er was geen duidelijke relatie tussen gewicht bij eerste inseminatie en melkproductie in de eerste worp. Beperkt gevoerde voedsters (R-17,5) produceerden meer melk dan AL-14,5 en AL-17,5 voedsters. Het verschil in melkproductie tussen R-17,5 en AL-14,5 kon worden verklaard door het feit dat AL-14,5 voedsters nog groeiden tijdens de eerste dracht en lactatie. De hogere melkproductie voor R-17,5 voedsters ten opzichte van AL-17,5 voedsters lijkt samen te hangen met de hogere voeropname van R-17,5 voedsters in de eerste worp. De hogere melkproductie van R-17,5 voedsters gaf zwaardere jongen bij spenen. De beste productieresultaten werden dan ook gevonden voor R-17,5 voedsters. Opfokstrategieën blijken alleen effecten te hebben op gewichtsontwikkeling, voeropname en productie in de eerste pariteit. Lange termijn effecten over drie pariteiten werden niet aangetoond. De opfokstrategieën hadden geen invloed op het uitvalspercentage van voedsters.

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CURRICULUM VITAE

Johanna Maria (Jorine) Rommers werd geboren op 18 oktober 1960 te Zwolle. Na de lagere schoolperiode in Westenholte bezocht zij de Thomas à Kempisscholen-gemeenschap in Zwolle. In 1979 behaalde zij het VWO-B diploma, waarna zij een jaar als uitwisselingsstudente doorbracht in Carver, Massachussets (USA). Daar behaalde zij het highschool diploma aan de Plymouth-Carver Highschool te Plymouth. Na terugkeer in Nederland werkte zij als dierenartsassistente in een praktijk voor gezelschapsdieren te Zwolle. In het najaar 1981 begon zij met de studie aan de Bijzondere Hogere Landbouwschool te Leeuwarden en studeerde in 1985 af in de richting Veehouderij en Onderzoek.

Na het beëindigen van haar studie werkte zij enkele maanden als bedrijfshulp op een gemengd landbouwbedrijf in Zwitserland. Op 1 december 1985 begon zij haar werkzaamheden bij het toenmalig Centrum voor Onderzoek en Voorlichting voor de Pluimveehouderij (COVP) “Het Spelderholt” als Technisch Medewerkster Ethologie. In eerste instantie betrof het een contract voor vier jaar, gericht op de ontwikkeling van een alternatief huisvestingssysteem (volièresysteem) voor leghennen. Na afloop van dit contract kreeg zij een vaste aanstelling en deed gedragsonderzoek naar het optreden van stereoptyp gedrag bij leghennen in batterijkooien. Eind 1991 werd de overstap gemaakt naar het toenmalig Praktijkonderzoek voor de Pluimveehouderij, waar zij als junior-onderzoeker Konijnenhouderij werd aangesteld. Deze naam werd later gewijzigd in Senior Technisch Onderzoeker. In deze functie heeft zij zich onder andere bezig gehouden met het onderzoek dat heeft geresulteerd in dit proefschrift.

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Cover: Thea Fiks- van Niekerk, free after Walt Disney's "Bambi"

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