ABSTRACT: This paper reviews the relationships between reproductive performance and welfare of the rabbit does. In the last 10 years the profitability of rabbit farms has increased mainly due to improvements in management and genetic selection but several problems mainly related to animal welfare have also occurred. The mortality and rates of female replacement per year are very high and the replaced females often show poor body condition and low performance. The effect of kindling order, litter size, genetic strain, weaning age and reproduction rhythm on the reproductive performance and welfare of females and some mechanisms implicated in these effects are discussed. Modern rabbit does produce a lot of milk which have a high energetic value which leads to a mobilization of body fat which results in an energy deficit. In the current reproductive rhythms, there is an extensive overlap between lactation and gestation. The resulting energetic and hormonal antagonism reduces the fertility rate and lifespan of the doe. Strategies to improve the fertility, lifespan and welfare of does are discussed. An approach which combines various strategies seems to be required to meet these objectives. Since the factors involved in this productive system are fixed (genetic strain, environment) the most powerful way to improve doe welfare is to choose a reproductive rhythm that is adapted to the physiology of the does.

Key words: Rabbit doe, Welfare, Reproductive performance.

INTRODUCTION – Reproductive performance is the main factor which assures high productivity on rabbit farms. This requires that the management practices take into account the physiology and behaviour of the animals. Reproductive activity is under the control of the neuro-endocrine axis; the genetics, feeding and management factors strongly modify hormonal release and consequent effects.

In the last 10 years, the mean productivity of rabbit farms has increased and become more homogeneous though the use of artificial insemination (AI), cycled production and the use of very prolific strains. During the same time several problems related to animal welfare have also appeared e.g. excessive replacement, high mortality and culling rates of does and hypo-fertility (Facchin et al., 1999).

In the light of this the main factors affecting reproductive performance and animal welfare are discussed.

ENERGY BALANCE AND BODY COMPOSITION DURING LACTATION – The body condition and energy balance (EB) in female rabbits appears to be correlated to a short- and long-term reproductive efficiency. A notable effort has therefore been made to estimate in vivo body composition by using simple, non-destructive methods (Fortun-Lamothe et al., 2002).

The golden standard for estimating body composition has been a comparative slaughter, but this technique does not allow the animals to be monitored over several reproductive cycles.

Recently, ultrasound equipment has been used to measure the perirenal fat thickness, which is the main reserve tissue of rabbit (Pascual et al., 2004; Dal Bosco et al., 2003).

Body Condition Scoring (BCS) has also been proposed (Bonanno et al., 2005; Cardinali et al., 2007) as the way for assess the nutritional status of rabbit does. BCS is widely used for livestock, such as ewes, cows and sows, because it is more accurate than body weighing or a simple visual appraisal (Maes et al., 2004).

During lactation, the high energy output associated with milk production is not entirely compensated by feed intake and rabbit does meet this energy deficit by increasing the mobilisation of body reserves and loose body ener-
A certain amount of fat mobilisation is physiological but it has short- and long-term consequences when it differs from an optimum rate. During the reproductive career does that are not able to mobilise body fat have little chance of having a long reproductive career (Quevedo et al., 2005); at the same time, a low fat level and high fat mobilisation increases the risk of being eliminated (Theilgaard et al., 2006).

Body fatness and fat mobilisation also affect the fertility rate (Castellini et al., 2006). These two components are not independent since thin does will have less fat mobilisation during the subsequent lactation period. This metabolic unbalance is affected by several factors and is particularly relevant in primiparous does because the energy requirement must sustain lactation, pregnancy as well as body growth (Parigi Bini and Xiccato, 1998). Management errors at this early stage compromise the entire reproductive career of the does. Many authors agree on the importance of specific feeding plans for young does (Rommers et al., 2004) that increase their intake capacity (Xiccato et al., 1999); they also recommend delaying the first AI.

Further, primiparous does should be reinseminated after weaning because AI during lactation has particularly negative effect on rabbit does (Castellini et al., 2006). Efforts have been made to increase the energy intake during lactation by increasing the digestible energy of the diets (Parigi-Bini and Xiccato, 1998; Fortun-Lamothe, 1998). The high energy of these diets however, failed to improve the EB of the does because there was a simultaneous increase in milk production.

**GENETIC SELECTION** – The theory of resource allocation (Beilharz et al., 1993) suggests that natural selection acts to make the best use of feed resources and to adapt to local environmental stress. The resources consumed are partitioned among the different demands (maintenance, reproduction, movement, reaction to environmental stress) to ensure the survival of the species.

Genetic programs have different objectives and consequently, the resources are mainly distributed towards the physiological processes related to the selected traits (Rauw et al., 1999). This selection could be detrimental to other processes, physiological, behavioural or immune (Rauw et al., 1998).

Selection programs of rabbit does are mainly based on litter size (De Rochambeau, 1998). This selection was very efficient and was accompanied by an increase in the milk production with a consequent increase in the nutritional requirements.

In other species, selection programs for increasing milk production have led to a reduction in the female fertility (Grimard et al., 2005). In rabbit, a comparison of performance and longevity between selected vs. old rabbit strains showed different results (De Rochambeau, 1998; Quevedo et al., 2005; Costa et al., 2004) but generally the effect of selection on the does fertility is low. Nevertheless, the low fertility of primiparous females is often attributed to poor body condition and indirect experiment on the effect of litter size showed that does nursing small litters (4-6 pups) have greater sexual receptivity, higher fertility rate (Fortun-Lamothe and Gidenne 2000, Castellini et al., 2003) and the lowest relative risk of dying or culling (Theilgaard et al., 2006).

In selected rabbits lactation takes a priority as a physiological function and the rabbit mobilises a large part of its body reserves to satisfy its requirements (Fortun-Lamothe et al., 1999). Consequently, when pregnancy and lactation are overlapped, this competition seems to be between the mammary glands and the gravid uterus to the detriment of foetal growth. It has been suggested that the increased energy demand of selected strains is met by higher feed efficiency and by an increased mobilisation of body reserves during lactation (Quevedo et al., 2005; Costa et al., 2004). If the latter condition is associated with a reproductive rhythm which does not allow a suitable body fat level to be restored the fertility rate decreases (Castellini et al., 2006) as does the chance for survival (Theilgaard et al., 2006).

Therefore, the effects of selection programs on feed intake capacity and energy balance must be studied mainly in field experiments. Similarly, the effects of selection on long-term prolificacy and length of reproductive career are not well known.

**HEALTH STATUS** – The health status of rabbit does (more than 120% per year replacement; high mortality and culling rate, Guerder, 2002) is critical among the domestic species and has repercussion on the viability of young rabbits. It is known that stress caused by excessive production programs reduces immune response and the animals are more subject to diseases.

Genital tract infections, often caused by incorrect AI practices, are the major cause of hypo-fertility (Gram et al., 2002). It has been demonstrated that uterine infection negatively affects fertility (Facchin et al., 1999) and prolongs the life span of corpora lutea (Boiti et al., 1999) due to an infiltration of uterine leukocytes, reduced prostaglandins synthesis and increased reabsorption of spermatozoa. The female genital tract is particularly prone to infection because seminal plasma has immunosuppressive properties. Seminal plasma is designed to prevent a reaction against sperm antigens in the female reproductive tract and may play...
a critical role in genital infection, not only because semen could be a vector of germ but also because of the presence of immunosuppressive factors. Prostaglandins (PGE₂) are the main substances which modulate immune response in the uterus; they modify the release of cytokines (increases IL-10, decreases IL-12; Rozeboom et al., 2000). However, during the course of an infection, the immune suppression induced by seminal plasma may not be sufficient to protect spermatozoa from the attack of uterine leukocytes, thus the transit toward the oviduct becomes impossible.

This hypothesis was recently validated in rabbit does (Dal Bosco et al., 2005). Genital inflammation induced by lipopolysaccarides, stimulators of prostaglandins synthesis widely used to induce inflammation, reduces the number of spermatozoa capable of reaching the oviduct by activating and increasing the number of uterine leukocytes and stimulating spermatozoa reabsorption.

**LITTER SIZE AND REPRODUCTIVE RHYTHM** – In female rabbit, milk production and feed intake increase with litter size (Lebas, 1987). However, an increased feed intake is not enough to compensate for the higher needs for milk production; consequently the EB and level of body fat decrease as the litter size increases (Figure 1; Fortun-Lamothe et al., 1999; Fortun and Gidenne, 2000; Castellini et al., 2003, 2006).

Rabbit does can sustain lactation and gestation simultaneously but this overlapping depresses several aspects of reproductive activity (sexual receptivity, ovulation, fertilization, implantation, embryo survival) due to hormonal antagonism (prolactin, Kermabon et al., 1994; Theau–Clement and Fortun-Lamothe, 2005) and energy deficit.

Changing the weaning age and reproductive rhythm appears to be an effective way to reduce the energy deficit in rabbit does (Xiccato et al., 2004). Early weaning reduces the energy deficit and the mobilization of body stores by limiting the duration of lactation (8, 14 and 19% for weaning at 21, 26 or 32 days, respectively).

In contrast, the estimated energy deficit and body mobilization of the rabbit doe increased when the reproductive rhythm became intensive (Castellini et al., 2006).

The reproductive rhythms can be categorized as intensive (AI post partum or within 4 days from partum), extensive (AI after 3 wks. of lactation or after weaning) or intermediate (AI at 11 d). In addition, AI can be done on the same day (fixed) or conditioned to the level of some parameter (body condition score, sexual receptivity).

Rabbit does can mate immediately after kindling (Ubilla and Rebollar 1995) but, several studies have shown that a continuous intensive rhythm reduces litter size, fertility rate and the length of reproductive activity (Maertens and Okerman, 1988, Cervera et al., 1993) particularly in highly productive strains.

Considering the reproductive career of females, this situation becomes problematic because the animals have only a few days to reconstitute their body reserves. In commercial rabbit farms the most widely used reproductive rhythm is based on AI at 11 d post partum and on the weaning of young rabbits at 28-30 days of age. This rhythm is perfectly associated with the cycled production system, in which groups of animals are inseminated on fixed days of the week. This system does not take into consideration the reproductive physiology of rabbit does (Castellini et al., 2003) and often requires treatment for oestrus synchronization (Theau and Roustan, 1992).

Castellini et al. (2003) showed that a reproductive rhythm alternating AI at 1 day post partum with AI post-weaning reduces the energy deficit of the females by 6.7% when compared to AI at 11 day post partum. It improved both receptivity and fertility and therefore seems to be more respectful of the doe physiology. The replacement rate of the females was also lower (80% versus 90%).

Extensive rhythms virtually eliminate the hormonal and energetic antagonisms between lactation and pregnancy and the does partially compensate the lower production intensity (remating interval 63 vs 42 days) with a higher fertility rate (79.0% vs 60.2%; Castellini et al., 2003). However, does inseminated post-weaning showed a lower than expected productivity: one critical point was an excessive deposition of fat (in about 18% of the does). Does that do not become pregnant after one or more AI are too fat and this reduces fertility. It seems that the relationship between body composition and reproductive performance is not linear: when
the physiological conditions are the best (non-lactating does, sexually receptive and optimal body fat), almost all the does are pregnant (93%) whereas the results are poor if the does are too lean or too fat.

The lifespan of the doe is also correlated with the body fat: Theilgaard et al. (2006) have shown that the risk of eliminating doe is correlated with the fat deposits. The animal needs a certain amount of fat during lactation to ensure sufficient resources to maintain the offspring without losses in other body functions. This result suggests that body fatness is an important factor that mediates the exchange between longevity and current and future reproduction performance. Regarding performance the relationship between body fatness and survival shows that the two extremes, too fat and too thin, have higher relative risk ratios than an optimum fat level.

**ANIMAL WELFARE** – No studies have been reported that specifically deal with the welfare status of mature does and only a limited amount of information on cage dimensions and enrichment is available (Hansen and Berthelsen, 2000). Some experiments, even if not focused specifically on animal welfare, give indications about some general tendencies. Once the minimum requirement of space (cage height and area) is defined, the factor that plays the major role is the reproductive management of does (synchronization of oestrus, reproductive rhythm, and weaning age). The general assumption implies that the reproduction management should respect the peculiar sexual behaviour of does, allowing adequate body reserves to be reconstituted and to determine sustainable fat mobilization. If all these points are considered, then the productive performance generally improves.

With regard to this, the most widely used reproductive rhythm (AI at 11 days post partum) has many limitations: many does at AI have poor BCS values (Figure 2; 71.2%), low sexual receptivity (37.2%) and low fertility rates (50.9%) (Cardinali et al., 2007).

Extensive rhythms, compared to AI at 11 days, seems to be better suited to the reproductive physiology of rabbit, maintains a more sustainable equilibrium of body weight, fat deposits (Feugier et al., 2005) and fat mobilisation which simultaneously reduces production losses (44.2 vs 32.2%; Castellini et al., 2006). As previously affirmed a critical point is an excessive fat deposition in that do not become pregnant for one or more AI. Thus, reproductive rhythms that are attentive to the body condition of the doe are more appropriate. An optimal body condition positively modulates the pituitary activity (FSH levels: 34.5 vs 20.0 ng/mL and preovulatory LH surge 20.3 vs 16.9 ng/mL) and consequently, sexual receptivity and the fertility rate (figure 2: 80.0% and 86.6%, respectively; Cardinali et al., 2007). Based on these results, the perspective of applying an in vivo method for scoring the body condition of rabbit doe appears to be promising, in light of defining a reproductive management program that is adapted to rabbit behaviour and welfare.

**CONCLUSIONS** – Some strategies permit better management of energy balance and improvement of the body status, performance and welfare of rabbit does. A multifactorial approach which combines various strategies seems to be required to meet these objectives. Since at short-term most of the factors involved in rabbit production system are predetermined, the choice of a reproductive rhythm that is better suited to the physiology of the does is the best way to provide a suitable welfare for the rabbits.

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