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Review article

Factors influencing does milk production and their implication for kit performance in rabbits

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ABSTRACT

Rabbit milk yield and chemical composition is determined by various factors. Growth rate and body weight gain are good indicators of kits doe's maternal behavior, especially in milk production. Generally, it is pronounced that growth and survival of kits towards weaning is the most important stage related to does milking potential. However, it is important to note that lactation curves vary with breed, notwithstanding milk production being influenced by various factors. Clearly, it has been observed that apart from genotype being a dominant factor in influencing milk production in rabbits, there are other factors such as nutrition, parity, stage of lactation, litter size etc. which have also been implicated. In this aspect, appropriate knowledge on factors that influence does milking capacity is essential for improved performance in rabbits. Provision of adequate nutritional requirements of nursed kits through dam's milk is essential for maximum growth, development and survival. In the early stage of growth until weaning, does milk is the exclusive source of nutrients to support the pertinent needs for maintenance and growth in rabbits. The accelerated growth preceding weaning can be ascribed to the doe's energy rich milk that is significant in both fat and protein and low lactose. An increase in milk intake, can improve kits growth traits and may also transcribe to heavier final market weight and financial gains. It is reasonable to suggest that to enhance kits nutritional intake, the mother should produce

adequate milk. On the other hand, milk production increases with increased litter size, while high total milk yield is registered in winter followed by autumn. Milk production increase firmly during the seven parity and decline from that time forward. Crossbreeding promote favorable and positive heterotic influence on milk yield and composition. There is a predictable positive correlation of does milking capacity and productive traits. The purpose of this review is to discuss the factors that influence milk production in does and their implication for rabbit performance.

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1. Introduction

A series of studies have been conducted and concluded that rabbit milk yield and composition are influenced by various factors which include: feeding (Maertens et al., 2006), breed (Jimoh and Ewuola, 2017; Fernandez-Carmona et al., 2004; Khalil et al., 2004), number of suckling kits (Taranto et al., 2003), physiological status (Xiccato et al., 2005; Pascual et al., 1996), (McNitt and Lukefahr, 1990) and lactation stage (Casado et al., 2006; Fortun-Lamothe and Bolet, 1988). Improved growth rate and body weight gain in rabbits are signs of good maternal instinct and behavior, especially milk production (Poornima et al., 2002). Individual kit milk share, body weight gain and survival rate are dependent on doestotal milk production. Apart from the mother and fetus genotypes exhibiting a major role in determination of weight at birth, the resultant litter weights normally depend on the suckled milk from the doe (Di Meo et al., 2004). It is also important to note that lactation curves are exclusive to each particular breed, in addition to milk yield and composition being influenced by various factors (McNitt and Lukefahr, 1990). Rabbit milk is characterized by high energy, lipid and protein and low lactose (Kolawole et al., 2013). In this respect, it explains the substantial growth potential of the rabbit kits preceding weaning. Effiong and Wogar (2007) reported that an improved intake in concentrate and forage impacted positively on nutrient availability resulting in an increase in milk production and hence adequate milk share to individual kits during pre-weaning phase. In growing rabbits before weaning, milk is exclusively the source of nutrients which promote kits growth, development and survival and depends on adequate doe milk production. Generally, it is pronounced that the does milking potential is directly proportional to the growth rate of rabbit kits (Khalil et al., 2004). Mehaia et al. (2002) has demonstrated that milk yield and composition are positively correlated with litter size and weight at weaning or mortality in lactation. The purpose of this review is to discuss the factors that influence milk yield and composition in does and their implication for rabbit performance.

2. Stage of lactation and milk production in rabbit does

Rabbits does experience peak lactation at approximately 20 days after giving birth (McNitt and Lukefahr, 1990). Litter weight at 21 through 28 days old is a reflection of adequate milking capacity of the doe (Tawfeek, 1996). This coincides with the milk production peak at 21 days after giving birth in most rabbit breeds. Weight preceding 21st day when kits exclusively rely on their doe's milk, their growth performance is tantamount to reflect the milking potential and the amount of milk share kits consumed (Cifre et al., 1998; Bignon et al., 2013). Peaker and Taylor (1975) working with a Dutch rabbit breed observed that 20 days of lactation coincided with milk yield peak production and depressed thereafter, however, by 30 to 32 days' milk yield was still appreciably high. In addition, milk fat and protein progressively increased in the final stage of lactation, while sodium and potassium was depressed from early to around 11 to 14 days of lactation and then increased. The composition of milk is considerably richer in protein and fat in the fourth week, while total milk production declines sharply bin third week (Lebas et al., 1997). The decrease in daily milk yield in the fourth week improved the concentration of other milk components (Kamar et al., 1985). At this stage, there is a negative correlation of milk yield and its chemical components of fat, protein and total solids. Hall (1971) observed that the composition of C₈:0 and C₁₀:0 increased considerably in milk fat as lactation progressed to the detriment of C₁₆:0, C₁₈:1 and C₁₈:2. Throughout the lactation stages potassium and lactose registered a converse trend to that presented by sodium and chlorine. During the

early stage of lactation, the doe produces enough milk to meet the nutrients requirement of growing kits. Milk production tend to improve with increased weeks of lactation (Kolawalo et al., 2013). However, the major minerals composition was elevated at the final stage of lactation while minor mineral level remaining constant. On the other hand, noticeable changes occurred in milk fat, protein and lactose in New Zealand White and Dutch rabbits after the third week of lactation, but in the 4 to 6th week only fat and protein increased while lactose was depressed (Cowie, 1969). In the third week of lactation due to decline in milk production kits are unable to meet their nutritional requirement from suckling alone (Kacsala et al., 2015). Milk production trend start declining at the start of third week of lactation, which result in nutritional deficit for suckling kits (Gyarmati et al., 1999). Due to inadequate milk production by the mother it would be necessary at this stage to introduce kits to solid feed (Xiccato et al., 1999). Towards the end of lactation when does are also pregnant, energy and protein demand are very high and despite an elevated feed intake, there is a negative energy balance and enormous body reserve mobilization (Parigi-Bini et al., 1992). The negative energy balance has an adverse effect on milk production. Concurrent pregnancy and lactation in primiparous rabbit does offset nutritional requirements for both fetal growth and milk production. This can be exacerbated by depressed feed intake. Theilgaard et al. (2009) in a milk production comparative analysis study of Spanish maternal lines (V, A, LP), observed that LP had high milk yield as compared with the V line does during the first week of lactation.

3. Litter size and milk production in rabbit does

There is an inverse relationship between litter size and weight at weaning, which can be ascribed to decline of milk production as lactation progresses and consequently reducing the milk portion of each suckling kit hence reducing their growth (Tawfeek, 1995). An increase in litter size is associated with a decline in quantity of milk share for each kit (Zerrouki et al., 2012; Yuan et al., 2015). In this respect, large sized litters could compromise the nursing ability of does (Vidjannagni et al., 2017). Kowalska (2008) reported that milk yield was influenced by litter size and the major driver of low mortality of kits was high fat content rather than milk yield. Milk yield attained a maximum as the number of kits increased to a litter size of 12 kits (McNitt and Lukefahr, 1990). Milk production increased with increased litter size (Kolawalo et al., 2013). The correlation between milk production and litter weaning weight was high ($r=0.86$) (McNitt and Lukerhar, 1990). Registered milk yield of does had a quadratic typical feature on rabbit growth, this was well pronounced in higher milk production order. Kits from large sized litter raised by poor lactational does registered low growth. Growth was considerably depressed as litter size at weaning increased from one to four kits. And thereafter depicted a constant negative linear tendency to a litter size of 11 kits. Kolawole et al. (2013) determined milk yield using the weigh-suckling method and reported an inversely proportional relationship between milk yield and intake as the number of kits increased. Mohamed and Szendro (1992) reported an increased in milk yield with large litter size of 10 kits. This was ascribable to kits stimulative effect on the mammary gland that promote milk let down or the maternal behavior. In other multiparous species, it was observed that mothers milk production efficiency, represented as milk production per unit mammary gland size, increased with increasing total milk yield (Sheffield and Anderson, 1985). Hardman et al. (1970) observed that littermates adjusted to an increase in milk production by suckling twice. However, Lukefahr et al. (1990) suggested nine kits as an optimum size to promote growth, that the extra kits can be given to foster does.

4. Nutrition and milk production in rabbit does

Nutrition is one of the important factors influencing milk yield and composition of rabbit does (Sabrout et al., 2017; Mahmoud et al., 2013) and constitutes a major part of the production cost in a rabbit enterprise. This implies rabbit milk yield and chemical composition is greatly determined by the plane of nutrition. Rabbit milk is characterized by high energy, lipid and protein, and low lactose (Kolawole et al., 2013) which are derived from dietary source and partly nutrient mobilization from body reserves. This may explain the absolute pre-weaning growth trend of young rabbits. Jimoh and Ewuola (2007) assessing milk yield in four breeds of rabbits provided with a comparable plane of nutrition observed that the British Spotted rabbit, despite its high milking capacity had pronounced weight loss. Generally, it is pronounced that different genotypes vary in their capacity to adjust voluntary feed intake to suit their lactation energy requirements (Pascual et al., 2000). This is mainly due to variation of nutritional requirement of maternal lines or breed at different physiological state. Improved weaning

weights have been observed in intensive rabbit production systems because of effective utilization of nutrients to increase the quality and quantity of does milk in the system (Ndor et al., 2010). Optimal feeding due to its influence on high milk production has a positive impact on litter size likewise the litter weight at kindling and weaning.

Seasonal effect influenced the mineral composition (Na, Ca and Mg) of milk in does. This explains the significance of year and month contribution to total chemical and mineral composition of rabbit milk (Iraq et al., 2007). Nasr (1994) assessing milk yield and some associated characters concluded that these factors were influenced by season of kindling. The nutritional effect was confounded in year and/or season of production, where highest total milk yield was registered in winter followed by autumn (Iraq et al., 2007). A similar trend was reported by Ramadan (2005). However, this disagreed with Hassan et al. (1992) who reported that season had no influence on total milk yield in New Zealand rabbit. The other seasonal effect on milk production is through seasonal variation in temperature. Barreto and De Blas (1993) observed that due to high seasonal temperatures the voluntary feed intake of does is depressed creating a nutritional deficit for milk production. Fernandez et al. (2003) working with New Zealand White and California rabbit breeds with standardized litter size of 8 kits observed that dry matter intake during lactation was lower, but digestible energy intake and milk yield were higher for a control diet having 12MJ DE and 122g DP per kg DM. The low dry matter intake was influenced by high seasonal temperature.

Volek et al. (2014) reported that white lupin seed was a suitable dietary crude protein source for lactating does without an adverse effect on feed intake and milk yield. White lupin seed had a potential to improve milk fatty acid profile. The use of alternative feed resources which do not compromise on total digestible nutrients have been identified as a pathway of curtailing on exorbitant feed costs. The nutritional composition of milk of does supplemented with fish oil reduced the level of short chain fatty acids (C8:0-C10) while increasing the level of long chain fatty acids (C16:1-C0000202:6) (Kowalska, 2008). A diet constituting 74% Alfalfa as a forage improved feed intake and milk production as compared to a commercial diet (Lukefahr et al., 1983). A higher proportion of PUFA in the milk was observed in does supplemented with lard and sunflower oil by Fraga et al. (1989) and Lebas et al. (1996) respectively. The proportion of mono-unsaturated fatty acids was unusually high in milk of does supplemented with a basal diet plus 5% extruded flaxseed diet (Castelli et al., 2004). Generally, it is pronounced that alternative feed resources such as forages may supply nutrients below the requirement for optimum milk production (Butterworth, 1967). Effiong and Wogar (2007) reported that an improved intake in concentrate and forage impacted positively on nutrient availability resulting in an increase in milk provision to kits during pre-weaning phase. In this aspect verification on tradeoff between use of conventional and alternative feed resources need to be done. The inclusion of dietary fat increased milk yield in does, in turn improving litter weight and curtailing on numbers of kits replaced during lactation (Pascual et al., 1996). On the other hand, addition of dietary fat also improved energy content of milk, promoting a higher litter weight gain and reduced mortality. Fraga et al. (1989) observed that inclusion of dietary fat improved milk yield, while the amount of short and medium chain fat acids profiles was not influenced by diet. However, the long chain fatty acid profiles in milk responded to dietary fat inclusion and improved milk intake and weaning weights. Villalobos et al. (2010) acknowledged that the phase of growth and development of kits towards weaning is the most important stage related to does milking capacity. Milk intake at this stage is dependent on size of suckling litter. Therefore, it is reasonable to suggest that provision of adequate plane of nutrition to does at this stage may enhance milk production which in turn will reflect on performance. It has been noted that sometimes high environmental temperatures can depress feed intake in does at this stage adversely affecting milk production.

5. Dam parity order and milk production in rabbit does

There was a linear relationship between milk production and parity order (El-Maghawry et al., 1993). McNitt and Lukefahr (1990) observed that parity affected lactation milk in a curvilinear manner, which increased firmly during the seventh parity and decline from that time forward. An increase in milk yield with increase in parity order has been observed in rabbits by Hassan et al. (1992) which was ascribed to mammary gland development. Parity order influence mineral (fat, total solid and ash) content of milk (Khalil, 1994). This was supported by Pascual et al. (1999) who reported that fat, total solid and ash registered lowest amounts during first parity and highest during sixth parity. The tendency was compatible with mammary gland advancement and the physiological state of the does (El-Sayiad et al., 1994). In multiparous does parity order did not influence either milk yield or composition

except ash (El-Nagar et al., 2014). The significant peak level of potassium in milk was observed in fifth parity (Iraq et al., 2007). Nulliparous and multiparous does registered lower milk yield at 21st day of lactation as compared with primiparous does. The low milk production in nulliparous and multiparous was ascribed to low feed intake which resulted in failure to meet nutritional requirements for lactation (Fortun-Lamothe, 2006). Low milk production increased mortality rate in growing rabbits among primiparous does, while milk yield increased with parity order (Kowalska, 2008). It is also important to consider the effects of suckling litter size, which might have impacted negatively on multiparous body reserves resulting in weight loss. Different genotypes vary in their capacity to adjust voluntary feed intake to suit their lactation energy requirements (Pascual et al., 2000). On the same note, Xiccato et al. (2004) observed that there was an increase in milk production with increase in parity and litter size.

There was a positive correlation of 0.34 between milk production and body weight (McNitt and Lukefahr, 1990). Does in poor body condition due to inadequate feeding have complications in mobilization of their body reserves to sustain the increasing demand for lactation. This implies that does in good body condition due to adequate feeding are likely to produce more milk for the suckling kits. Due to nutrient mobilization during lactation the doe body composition changes considerably to a large extent to loss of fat and protein. This has negative effect on the does' body weight. Growth, development and survival of growing rabbits up to 18 to 19 days of age mainly depend on their doe's milk quantity and quality (Piles et al., 2012). This implies that milk production capacity of does will influence pre and post weaning growth performance, survival rate and correspondingly total meat yield and financial gains.

6. Genotype and milk production in rabbit does

Lactation curves are characteristic of each particular breed, regardless of milk production being influenced by various factors (McNitt and Lukefahr, 1990). Purebreds of New Zealand White does were more efficient in converting feed into milk translating into high milk yield than purebred California rabbit (Lukefahr et al., 1983). Cowie (1969) in a comparative analysis study of milk yield at the end of third week of lactation in New Zealand White and Dutch rabbits registered daily milk yields of 270g and 140g in New Zealand White and Dutch rabbits respectively. However, there were no differences in milk yields when compared based on body weight. Milk yield and composition of crossbred was determined by the degree of the characters in the maternal genotype, in addition to heterotic effect for the character (El-Nagar et al., 2014). Paternal breed did not affect lactational ability of does (Lukefahr et al., 1983). However, El-Sabroun et al. (2017) observed that milk protein and fat milk varied in V-Line and Alexandria line, while lactose and ash content were comparable.

There were no differences in milk components such as fat, protein, lactose and ash between New Zealand White and Californian rabbits (El-Sayiad et al., 1994). This was in agreement with El-Sabroun et al. (2017) who observed a non-significant difference in milk yield for an exotic and a local synthetic rabbit line. However, the genetic groups registered differences in milk protein and fat composition. In a similar study, Maertens et al. (2006) observed that there were no differences in milk composition characters between commercial hybrids. Pure and crossed does carrying V-Line genes expressed favorable and positive heterotic influence on milk yield and composition (Al-Sobayil et al., 2005). Khalil et al. (2004) reported a significant and positive heterotic effect ranging from 9.7 to 22.7% for milk yield and 3.2 to 15.8% for total chemical milk composition. This was partly in agreement with Irag et al. (2007) while working with crosses of local Gabali with V Line rabbits observed a pronounced heterotic effects on milk yield and composition. However, on contrary, Abd El-Azizi et al. (2002) observed a non-significant direct heterotic influence on milk production parameters.

7. Implication

Observations from various studies provide apparent evidence that genetic and non-genetic factors influence milk production in rabbits. In this respect, can safely conclude that milk production in rabbits vary with genotype, nutrition, litter size, parity order and stage of lactation. The quantity and quality of feeding has been the major driver of the milk nutritional value and consequently improving growing kits' performance. Therefore, meeting the acceptable does nutritional requirements during lactation in order to produce enough milk is essential for maximum growth and survival of kits. Lactation is a crucial phase of development during which is vulnerable to suboptimal nutrition as a result having a profound adverse effects on overall kits performance both pre and post weaning. Productivity of rabbit kits as a function of potential growth rate as influenced by milking capacity of their

mothers and knowledge of factors which drive milk production is crucial in improving production. Suggestions are that the detrimental effects of suboptimal maternal nutrition during lactation on milking capacity and the indirect kits performance can be easily corrected through appropriate nutritional modification and intervention enforced during the lactation window. This implies that performance of growing rabbits is dependent on maternal behavior, especially in provision of sufficient milk, which also sometimes is influenced by parity order. Young does produce less milk than older does and also milk production is influenced by the doe's body condition during lactation which is underpinned by level of nutrition. The differentiated milk production capacity for first kindlers and older does can be explained by variation in maternal ability, where older does have better maternal instinct than first kindlers. Energy mobilization from body reserves constitutes a significant portion to the energetic cost of milk production in initial stages of lactation through distinct metabolic transformation. It has been acknowledged that nutrient mobilization for milk production causes a discord between does nutritional needs and its kits, mainly over the proportion of milk each kit consume. However, it is important to note that energy requirement for milk production can be met by both dietary intake and body reserve mobilization. Suboptimal nutrition during early lactation induces a negative energy balance because the maintenance and milk production energy demands surpass the amount of energy a doe can consume. On the other hand, milk production of does can vary substantially depending on breed, and a strong relationship between milk yield and litter size has been observed. Litter size promote the number of functional mammary glands through their suckling stimulative effects. The number of littermates contributes to the determination of milk production in the sense that milk yield increase as litter size increases.

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