EFFECTS OF PROVINDING SUPPLEMENTAL ENERGY AND PROTEIN ON GROWTH AND CARCASS CHARACTERISTICS OF WEANED RED DEER STAGS *(Cervus elaphus)* RAISED IN CONFINEMENT.

by

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ABSTRACT

EFFECTS OF PROVINDING SUPPLEMENTAL ENERGY AND PROTEIN ON GROWTH AND CARCASS CHARACTERISTICS OF WEANED RED DEER STAGS (*Cervus elaphus*) RAISED IN CONFINEMENT.

M.Sc. **Josée Chicoine** **Animal Science**

The objectives of this study were to determine the impact of feeding supplemental energy and protein on the growth performance and on the carcass characteristics of weaned red deer stags. Forty-eight weaned stags were divided into 8 groups and randomly allocated to four dietary treatments. Two levels of energy (E) and protein (P), low (L) or high (H) were obtained by the addition of various amounts of oats and soybean meal (SBM). This trial was divided into 2 phases: For the first 32 weeks (Phase I), diets LE/LP and HE/LP contained 0.5 and 1.0 kg/deer respectively of oats; diet LE/HP consisted of 0.15 kg of oats and 0.30 kg of SBM, and diet HE/HP, of 0.5 kg of oats and 0.35 kg of SBM. In Phase II, the level of supplementation was increased while keeping a constant relationship with the body weight of the deer. The animals were group fed, and offered mixed hay *ad libitum*. The animals were weighed every two weeks, over 48 weeks and slaughtered at 90.5 to 100.6 kg body weight. Increasing the energy level in the supplement resulted in a substitution effect of grain for forage. As a result, there was no difference in total energy consumption. For this reason, no difference was

observed (P>0.05) between treatments for values of ADG or final weight. Feeding supplemental protein over 368 g/deer/d didn't improve ADG or liveweight (P>0.05). There were no treatment differences (P>0.05) in estimates of carcass yield, kidney fat, or tissue depth (GR). Results indicate that concentrate feeding does not stimulate overall growth rate.

RESUME

LES EFFETS D'UNE SUPPLEMENTATION ALIMENTAIRE D'ENERGIE ET DE PROTEINE SUR LA CROISSANCE ET SUR LES CARACTERISTIQUES DE LA CARCASSE CHEZ LE CERF ROUGE MALE (*Cervus elaphus*) ELEVE EN CAPTIVITE.

M.Sc. **Josée Chicoine** **Science Animale**

Les objectifs de cette étude étaient de déterminer l'impact d'un supplément alimentaire d'énergie et de protéine sur la performance et sur les caractéristiques de la carcasse chez le jeune cerf rouge mâle. Quarante-huit cerfs rouges sevrés ont étés divisés en 8 groupes et assignés de façon aléatoire à l'un des quatre traitements alimentaires. Deux niveaux d'énergie (E) et de protéine (P), bas (L) ou élevé (H), ont étés obtenus par l'addition d'avoine et de tourteau de soya (SBM). Cette étude était divisée en deux phases : Pour les 32 premières semaines (Phase I), les diètes LE/LP et HE/LP consistaient respectivement en 0.5 et 1.0 kg/cerf d'avoine ; la diète LE/HP consistait en 0.15 kg d'avoine et de 0.30 kg de SBM, et la diète HE/HP, de 0.5 kg d'avoine et de 0.35 kg de SBM. Pendant la Phase II, le niveau de supplementation a été augmenté tout en maintenant une relation constante avec le poids des cerfs. Les animaux étaient nourris en groupe et du foin était offert à volonté. Les animaux étaient pesés toutes les 2 semaines jusqu'à la fin des 48 semaines que dura l'expérience, à la fin de laquelle les animaux furent abattus avec un poids vivant de 90.5 à 100.6 kg. L'augmentation du niveau d'énergie dans le supplément a causé un effet de substitution du grain

pour le foin. Par conséquent, la consommation totale d'énergie était la même pour les 4 traitements. Pour cette raison, aucune différence significative (P.0.05) n'a été observée pour le gain moyen quotidien (ADG) ou pour le poids vivant final. La supplémentation de protéine au-delà de 368g/animal/jour n'a pas amélioré le ADG ou le poids vivant (P>0.05). Il n'y a pas eu de différence (P>0.05) dans les mesures de la carcasse (rendement de la carcasse, gras du rein ou épaisseur du tissu (GR)). Les résultats indiquent que l'addition supplémentaire de concentré dans la diète n'est pas efficace pour stimuler le taux de croissance.

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Introduction

1. Introduction.

Deer farming is not a new concept in North America. Samuel de Champlain, in the early 17^{th} century, named the Iroquois: "those who tend deer". Archaeological studies even showed that the Iroquois had managed deer since year 1000 AD. However, commercial deer farming is a relatively new type of animal production and represents an emerging and promising industry in North America. Based on the success of deer farming in New Zealand, a world leader in deer farming with over 1.6 million animals, it is not unrealistic to expect a bright future for North America. Deer farming is also an attractive alternative to conventional animal production because it contributes to the diversification of livestock production, which helps to stabilize rural economies and encourage new investments in agriculture. Commercial deer farming in Canada started in the early 1970's, and today, Canada ranks 9^{th} in the world in the number of deer farmed. Deer farming in Canada includes several species, from which red deer show the highest population in Québec.

The main products arising from deer farming are venison (deer meat), velvet (antler not yet calcified), and breeding stock. Venison has always been part of the North American culture. In 1997, the number of deer killed by hunters in North America was close to 7 million. This number reveals a human taste for wild game meat. Although red meat is an important food in the North American diet, it contains high level of saturated fat and cholesterol, and is associated with high risks of coronary heart diseases, one of the leading causes of death in North America. Given its substantially low fat and cholesterol content and consumers, who are becoming more conscious of this relationship between nutrition and health, venison represents an attractive alternative to traditional red meat.

One of the most important constraints encountered in deer farming, and more specifically in venison production, is the poor winter growth rate of the deer. This is associated with seasonal depression in voluntary feed intake, and a cyclical pattern of animal performance that is related to photoperiod. The Canadian climate consists of relatively long and severe winter, and this makes difficult the adoption of an all-year pastoral system of deer farming that is typical in New Zealand. For those reasons, the global tradition of finishing deer on pasture might not be applicable to Québec or to North America. Therefore, there is a need for the development of effective winter feeding strategies to achieve market weight earlier, and supplying venison on a more year-round basis. This would certainly contribute to the growth of the American venison industry. Developing nutritional programs, such as supplemental feeding, to overcome the decrease in winter growth rate could be one strategy to increase the efficiency of venison production in Eastern Canada.

The objectives of this study are to determine the effects of providing supplemental energy and protein on the growth performance of weaned red deer stags, and to assess the impact of supplemental feeding on the carcass characteristics of venison.

We hypothesized that providing supplemental energy and protein would cause and increase in average daily gain and therefore growth, without modifying carcass traits. We also hypothesized that there would be an interaction between energy and protein upon growth performance.

Literature review

2. Literature review

2.1. Overview of deer farming

2.1.1. Development of the deer farming industry

Cervus elaphus, or red deer, is a ruminant animal and a member of the *Cervinae* subfamily of the deer family, *Cervidae*. Herding of deer is not a new concept, but commercial deer farming is a relatively new form of animal production. New Zealand was one of the first countries to engage in deer farming for commercial purposes. Red deer were introduced to New Zealand between 1851 and 1909, and due to the total absence of predators and a very favorable climate, the population of deer increased very rapidly. This led to tremendous environmental pressure, depletion of forest understorey and an increase in soil erosion (Drew, 1976). This caused the New Zealand government to take action, and over 1 million deer were killed by official decree between 1930 and 1967.

A commercial venison industry developed in New Zealand in the late 1950's when venison (deer meat) was sold as game meat. Deer farming began in 1969 (Barry and Wilson, 1994) and by 1997, approximately 1.4 million deer were being farmed in New Zealand (Hudson, 1999). Predictions from the New Zealand Game Industry Board (GIB) are that by the year 2000, the population of farmed deer will reach 2.2 million, equivalent to the population of dairy cattle (Barry and Wilson, 1994). Along with venison from farmed deer, New Zealand emphasizes deer farming for velvet, the term used to describe the antler, at a stage of maturity where the tissue has not yet calcified. The antler is cut, dried and processed into different kinds of products destined for the Asian markets, where velvet has been used for medicinal and health purposes for over 2000 years. Other valuable by-products of deer farming include skins, ligaments, eyes, teeth, testicles and tails. In Europe and Russia (with 400,000 head), where the combined population of farmed deer reached 754,000 in 1997, the main product of deer farming is venison; removal of velvet antlers is prohibited in most Western European countries due to animal welfare concerns (Hudson, 1999).

North America is also participating in the world trend towards deer farming. Approximately 90,000 animals are being farmed in the United States, and 98,000 in Canada, which, in 1997, ranked 9th in the world for its deer population (Hudson, 1999). The main species of deer farmed in Canada are wapiti (*Cervus elaphus canadensis*), red deer (*C. elaphus*), fallow deer (*Dama dama*), white-tailed deer (*Odocoileus virginianus*) and reindeer (*Rangifer tarandus*) (Hudson, 1996). However, because of individual provincial government regulations, only defined species of deer are allowed to be farmed in each province. For example, British Columbia allows only fallow deer and reindeer to be farmed, in Alberta, only wapiti, white-tailed deer, mule deer (*O. hemionus*) and moose (*Alces alces*) are farmed. Fallow and native deer are allowed to be farmed in Saskatchewan, and deer farming was prohibited until recently in Manitoba (Hudson, 1996). Quebec and Ontario also have laws concerning the species of deer that are allowed to be farmed; both provinces allow farming of red deer, wapiti and fallow deer, but farming of white-tail deer is more strictly regulated.

The total population of red deer farmed in Canada in 1994 was 6,099 animals and by 1998, the population was estimated to be 13,122 (Agriculture and Agri-food Canada, 1998), representing a 115 % increase over four years. In 1998, Quebec accounted for 49 % of the total red deer population, Ontario, 46 %, and the Maritimes, 5 %. Red deer are distributed throughout Eastern Canada where interbreeding with the wild wapiti is not a concern, because wapiti is not found in Eastern Canada (the eastern race being extinct).

The total consumption of venison in Canada and United States increased from 744,000 tonnes in 1993 to 1,356,000 tonnes in 1996, which represents an increase of 82% (Harpur, 1998). According to the North American Deer Farmer Association (2000), the U.S. venison market is growing at an annual rate of 30 %, and the domestic supply only provides 25 to 30 % of the produce demanded by the market. This may, in part, be a reflection of the fact that North American consumers are showing increased preference for lean meat because of health risks associated with cholesterol and fat intake from red meat consumption. Venison represents an attractive alternative to other red meat because of its low fat and cholesterol content (Kyle, 1994).

The Canadian Venison Council reported that, in 1997, the total value of farmed deer in Canada was $468,7 million, and that the value of the velvet harvested was $7 million. Harpur (1998) concluded from his analysis of the potential market for venison in North America that there is substantial room to increase venison production because the demand, mainly by high-end restaurants, greatly exceeds current supply. He predicted is that over the next 15 years, the value of venison in the North American market is likely to show a linear increase. In this context, deer farming for venison production represents an opportunity for Quebec and Canadian producers to meet the consumer demand for lean or luxury meat, and to enhance their revenue from livestock.

2.1.2. Management factors in deer farming and venison production

The main objectives of deer farming are to attain high fertility rate of hinds (female deer), low mortality rate of calfs (calves) from birth to weaning, and rapid growth of the weaned calfs up to slaughter at 15 to 18 months of age when they will weigh approximately 120 kg (70 kg carcass weight). Management is an important factor in deer farming both to ensure the quality of the product, and to improve efficiency of the production system. Under

Canadian conditions of farming red deer, the hind is bred to give birth in late spring and early summer (May-June).

The main type of deer that is used for venison production is the young stag (male deer) which will ideally be slaughtered at the age of 12 to 16 months. There are several reasons to use stags at that age; slaughtering stags at the end of their second summer allows them to exhibit high growth rate associated with the summer long daylength. Keeping them over winter becomes uneconomical because they will decrease their growth rate, and even loose weight. However, in order to ensure constant supply of venison throughout the year, males that have attained slaughter weight in the fall can be kept for winter supply, as their growth rate during winter will be very low. Stags that did not reached market weight by the end of their second fall are kept for a third summer, when high growth rate will resume. Stags over 27 months of age (third fall) are generally not used for venison. Deer start to deposit fat at a greater rate once they achieve about 50% of their mature body weight. Since low fat content is one of the most important attributes of venison, it is important to slaughter the animals when the fat content is at its minimum. This explains why animals destined for the venison market are slaughtered before 27 months of age.

Other animals slaughtered for venison include adult stags after years of velvet production, and hinds (female deer) that are culled from the herd (Thériez, 1989). Fertile hinds are rarely slaughtered because of their high reproductive value. In the management of deer, removal of the antlers prior to transportation is essential, because bruising and carcass damage can occur, and this reduces the quality of the meat.

Housing young deer during their first winter may be adopted as a management practice. In fact, Suttie *et al.* (1996) pointed out several reasons for housing deer in their first winter of life. These include improved animal welfare by providing shelter against wind, cold and humid weather, improved feed utilization, reduced age at slaughter, increased overall farm stocking rate, and sparing spring pasture. Housing also minimizes the reduction in winter growth rate by lowering the animal's maintenance requirements. Among the most important factors required for housing are a suitable barn, a good water supply, and adequate floor and trough space (Suttie *et al.*, 1996).

The type of animals kept indoors during the winter months will depend on the production objectives. According to Suttie *et al.* (1996), small weaned calves could benefit from being kept inside, and given access to high quality feed under controlled management conditions. It could be advantageous, however, to keep the largest calves indoors during winter to allow them to achieve slaughter weight at an earlier age.

Health management is also an important aspect of deer farming. Compared to other livestock species, deer are relatively very resistant to diseases, but are very susceptible to stress. In most cases, mortality is the result of stress-related circumstances and poor management. Stress leads to a decrease in the animal's immune defense mechanism, which in turn leads to increased susceptibility to infectious agents or risks of development of internal, dormant, parasites (Brelurut *et al.,* 1990).

The pathology of the deer is closely related to that of other domestic ruminants but deer rarely present clinical symptoms until the disease is at a very advanced stage. The lack of clinical symptoms is probably due to their instinct of survival in the wild, and this can often lead to late veterinarian interventions. Vaccination programs have, therefore, become crucial in prevention of disease on deer farms. It is a common practice to vaccinate farmed deer against rabies, Leptospirosis, several strains of *Clostridium* bacteria, Yersiniosis, and intestinal worms (Lemire, Pers. Comm.).

2.2. Growth performance and seasonality in growth pattern of deer

The calf usually weighs between 8 and 12 kg, depending on the gender, and the growth rate of the calf between birth and weaning (3 to 4 months of age) varies from 250 to 450 g/day, depending on the gender, its birth weight and the nutrition of the hind (Thériez, 1989). For each kilogram increase in birth weight, the growth rate of the calf increases by 14 g/day (Moore, 1988). After weaning, the growth rate decreases by 40-100 g/day, depending on the milk production of the hind during late lactation, quality of weaning management and the quality of feed available (Thériez, 1989).

The post-weaning period of growth of the calf may be divided into three different phases. The first phase (September to end of October) consists of an adaptation of the animal to roughage and concentrate feeding. During this period, the animal maintains the potential for high growth rate, and therefore, a good feeding management strategy is crucial to take maximum advantage of this growth potential. The second phase (November to March) is characterized by low growth rate, associated with decreased voluntary feed intake as a consequence of short day length. The performance during this second phase may vary depending on the nature of winter feeding management and the quality of winter feed (Thériez, 1989). The third phase is characterized by high growth rate as a result of increased day length and improved quality of feed if animals are placed on pasture. It is therefore important to understand some aspects of the physiology of the deer in order to maximize the response to nutrition.

The red deer has adapted to variations in vegetation and feed supply in temperate regions by altering their voluntary feed intake (VFI) during the winter months, when food supply is limited and feed intake is restricted (Hoffman, 1985). Experiments involving red deer fed fresh herbage or hay, have shown as much as 35% decrease in VFI, and associated reduction in growth rate, during winter compared to summer (Milne *et al.* 1978; Barry *et al.* 1991). The higher VFI observed during the summer does not lead to any decrease in the apparent digestibility, because of in an increase in rumen retention time and in the digesta load (Sibbald *et al.* 1993; Freudenberger *et al.* 1994). For example, the rumen capacity of the red deer varies from 10 liters in winter to 20 liters in summer (Hoffman, 1985). Freudenberger *et al.* (1994) also reported that, during summer, there are increases in total rumen pool size, rumen ammonia production and pool size, and rumen total volatile fatty acids (VFA) pool size; those changes were found to be independent of VFI. The authors concluded that many of the seasonal changes in rumen function were endogenous rather than mediated by changes in VFI. Forbes *et al.* (1981) also reported an increase in gut fill for lambs when exposed to long compare to short daylength. This response was observed even without increase in VFI, implying an increase in rumen pool size.

The seasonality in VFI, growth performance and rumen metabolism in deer is related to variations in photoperiod and is mediated by seasonal cycles in plasma hormone concentrations (Suttie *et al.*, 1985; Adam *et al.*, 1996). In the adult red deer stags, the reduction in feed intake starts during fall (early

September), and is associated with onset of the mating season (rut). These variations in feed intake and growth rate in deer, as well as the seasonal changes in digestion and metabolism are important factors to consider when planning feeding strategies in deer farming.

The decrease in feed intake and growth rate exhibited by deer during winter is followed by a period of compensatory growth during spring and summer (Suttie *et al.*, 1983; Adam and Moir, 1985; Milne *et al.*, 1987) this is responsible for the dramatic animal performance during the summer compared to winter. Adam and Moir (1985) and Milne *et al.* (1987) investigated this phenomenon of compensatory growth in deer by placing animals on summer pasture following restricted or *ad libitum* feeding during the winter. The results showed that animals restricted on feed during winter exhibited as much as 40% greater weight gain on summer pasture compared to animals fed *ad libitum*. This suggests that animals not subjected to feed restriction in the winter have a decreased capacity for compensatory growth during the following summer. The studies also revealed that the animals fed *ad libitum* during winter and exhibiting much higher values of average daily gain (ADG) had a lower feed conversion rate. This is similar to what is observed in other livestock species. However, depending on the length of the period of feed restriction, animals restricted on feed during the winter might not be able to fully compensate and catch up by the end of the summer with animals fed *ad libitum*.

In their study, Wairimu *et al.* (1992) also observed this phenomenon of compensatory gain in Wapiti, and made some comparison with red deer. The study revealed that feed conversion during summer did not change between groups fed restricted during winter and groups that were not. They concluded that the main factor contributing to compensatory gain on summer pasture was the increase in forage intake, especially in relation to metabolic body weight. They also revealed that wapiti seem to have a better capacity for compensatory growth than red deer, which could explain why their wapiti stags fed restricted fully compensated by the end of the summer, while red deer stags of other studies did not (Suttie *et al.*, 1983; Adam and moir, 1985; Milne *et al.*, 1983). Wairimu *et al.* (1992) hypothesized that those differences between red deer and wapiti could have environmental or genetic causes. The relative pasture conditions could have been better in their experiment, allowing higher feed intake and quality. Wapiti also mature earlier than red deer and therefore have more reserves to endure feed restriction in the winter.

2.2.1. Photoperiod-induced changes in growth rate of deer.

It is possible to manipulate growth performance of deer during the winter by exposing them to the same amount of light that they would receive during the summer months. Davies and Wade (1993) compared the growth responses of red deer weaned in the fall and subjected to natural or artificial lighting regime (16 hours of light and 8 hours of darkness (16L:8D)). The animals were subjected to low or high levels of feeding and slaughtered at either 85 or 100 kg liveweight. The results showed that animals under 16L:8D during winter reached slaughter weights 50 to 90 days earlier than those under natural daylength. Animals subjected to artificially long daylength regime had a better overall feed conversion than those exposed to normal daylength. This difference in efficiency of feed utilization was even more marked during mid-winter, with values of 70 MJ/kg gain for long daylength group, compared to 121 MJ/kg gain for normal daylength.

The initial response of deer to changes in photoperiod is characterized by a lag time of approximately 6 weeks (Davies and Wade, 1993; Vigh-Larsen and Davies, 1994). However, Suttie *et al.* (1996) reported slower initial growth rate in animals exposed to artificially long daylength compared to animals exposed to normal daylength during the winter. The growth response to artificially extended daylength becomes refractory after 5 to 6 months (Vigh-Larsen *et al.*, 1994; Suttie *et al.,* 1996) after which a decrease in growth rates is observed. Vigh-Larsen *et al.* (1994) explain the refractoriness in growth to artificially extended lighting program by the fact that most of the annual growth potential has already been expressed by the animal. The study by Davies *et al.* (1993) also reveals an interaction between photoperiod and the plane of nutrition on growth performance of red deer, and suggests that long daylength has to be combined with a high-energy intake to get the maximum effect of extended photoperiod.

Based on the studies of photoperiod manipulation (Davies *et al.,* 1993; Vigh-Larsen *et al.*, 1994), the ideal time to slaughter animals for venison would be in the spring; otherwise, the advantages gained with extended lighting during winter would be progressively lost. Furthermore, Vigh-Larsen *et al.*, (1994) reported that animals exposed to artificially extended daylength during winter have a reduced capacity for compensatory growth in the following summer when placed on pasture. They exhibit a summer growth rate 32-74% less than animals exposed to natural daylength, depending on feeding regime.

2.3. Energy and protein requirements of red deer.

2.3.1. Energy.

Simpson *et al.* (1978) compared lambs with young red deer with regards to their capacity to digest energy and protein, and to partition digested energy and protein between protein and fat deposition, and heat production. They noted that at similar body weight, the ME requirements of deer were higher than for sheep. Furthermore, when expressed in relation to metabolic body size, this difference in ME requirements was greater as the level of stress of the animals increased (38 to 58% higher than in sheep as the stress increases). However, when expressed in relation to metabolic body size, the requirements of sheep decreases as their weight increases. In contrast, the requirements of deer increase as the weight increases. No difference was found between species regarding losses of energy in feces, urine, or methane production, and no difference in dietary protein digestibility and nitrogen retention. They concluded that the efficiency of utilization of dietary energy and protein for protein deposition was similar for both species. However, deer lose more dietary energy as heat of production (Brockway and Maloiy, 1968), while sheep convert dietary energy into fat at a greater extent, explaining the high proportion of fat in the carcass (three times more fat than red deer).

In an experiment with 18 to 24-month-old deer, Suttie *et al.* (1983) determined that the maintenance requirements for animals fed restricted was 83 to 113 kcal of metabolizable energy per kg of metabolic weight (kcal ME/kg $^{0.75}$). However, those maintenance requirements increased to 120 to 200 kcal ME/kg $^{0.75}$ for animals fed *ad libitum*. This suggested that red deer have the capacity to reduce their maintenance requirement when the feed supply is limited. However, the change might be in the efficiency of utilization rather than an actual change in maintenance metabolizable energy. Another factor that could explain the differences observed in maintenance requirements is related to the fasting metabolism. In an animal deprived from food, or fasting, the energy needed for functions necessary for life, such as synthesis of enzymes and hormones, chemical and mechanical work, is supplied by the catabolism of body reserves. The amount of energy released from this catabolism of the tissue is equal to the heat produced, and is known as fasting metabolism (McDonald *et al.* (1988). Maintenance requirements for energy can be estimated from the fasting metabolism rate (FMR), but the translation is difficult to obtained because of several practical reasons. First, animals on farm use more energy for voluntary muscular activity, which is part of maintenance requirements. Productive livestock must also operate with more intense metabolism than fasted animals, therefore increasing the maintenance costs. In addition, animals on high plane of nutrition show greater maintenance requirements for energy than animals kept on a lower plane. Finally, animals on farms are subjected to greater extremes of climate and need to use more energy to maintain their body temperature (McDonald *et al.* (1988). Therefore, under fasting conditions, where the heat of production involves energy conservation due to undernutrition, maintenance estimates may be underestimated (Van Soest, 1982). Pauls *et al.* (1981) had shown that ecological maintenance is equal to 1.6 times the physiological maintenance, which is similar to the results of Suttie *et al.* (1983) shown above. In considering the energy requirements of deer, another factor to take into account is the variations over seasons. In an experiment where the effects of cold conditions on the heat production in young sambar (*Cervus unicolor*) and red deer were studied, Semiadi *et al.* (1996) reported a 16% increase in heat production when the temperature decreased from 20 to 5°C. This response increased to 20% with the wind effect. Milne *et al.* (1987) also reported changes in efficiency of utilization of energy over the winter months. They reported that 53 to 57 MJ of ME were necessary for each kg of gain in November and December, 87 MJ of ME in January and February, and 41 to 56 MJ of ME in March and April. However, Fennessy and Moore (1981) showed that animals kept indoors for the winter had energy requirement for maintenance 50 % lower than for animals kept outside (0.57 compared to 0.85 MJ ME/kg $^{0.75}$/day). In another experiment, Semiadi *et al.* (1998) found that metabolizable energy for maintenance in red deer was lower during winter months.

In wapiti, Jiang and Hudson (1993) have noted small seasonal variations in fasting metabolism, but associated with differences in seasonal maintenance energy requirements. They hypothesized that the increase in maintenance requirements from winter to summer could be the consequence of an increase in the energy costs of activity, thermo-regulation and heat production associated with tissue accretion.

2.3.2. Protein.

Only a few studies have been conducted on the protein requirements of deer, but nitrogen metabolism of deer does not differ very much from that of sheep (Simpson *et al.*, 1978b). Adam (1991) recommends 130 to 340 g of crude protein/d from 6 to 15 month old deer. However, Adam (1991) also pointed out that those requirements would be altered in the case of changes in growth rate, as in the manipulation of the deer natural physiological cycles, as with daylength manipulations. Factors such as climatic conditions can also affect the protein requirements of deer, as is the case with other animals. In an experiment where they studied energy and nitrogen metabolism of red deer in cold environment, Simpson *et al.* (1978) showed that cold stress elevated nitrogen excretion. They also showed that protein oxidation contributed nearly 30% to elevated heat production of the deer in cold environment, compared to less than 10% in warm environment.

There are few studies dealing with the growth response of deer to protein supplementation. The response to protein supplementation is very much dependent of the energy level. For example, in a study with steers, McKinnon *et al.* (1993) reported that the increase in ADG associated with increased protein level in the diet was greater at low energy level. In fact, increasing the protein level when the energy content was high caused no significant difference in ADG. They concluded that the growth response to supplemental protein depended on the energy level. However, increasing the protein level at low energy content also resulted in linear increased in rate of carcass fat deposition. The authors concluded that the energy balance rather than the protein status was improved by increasing protein supplementation. The increase in fat deposition observed with steers might not be applicable for young deer because they only accumulate fat at a greater rate once they reach about 50% of their mature body weight (about 18 months of age) (Thériez, 1989).

Based on studies with cattle, it appears that the response to protein supplementation varies with the energy level, and that increasing the levels of protein and energy can result in increase in fat gain. Pirlo *et al.* (1997) studied the response of energy and protein allowances in the diets of heifers and suggested that the optimal diets for the development of heifers should be rich in both energy and protein. From their results, heifers showed higher response in growth rate when fed high energy than low energy diets. Heifers fed high compared to low protein level also showed better growth rate, but at a smaller magnitude. In deer, the interaction between energy and protein upon growth performance and carcass traits has not been explored.

2.4. General and comparative aspects of nutrition and feeding of deer

2.4.1. Supplemental and concentrate feeding of red deer.

Supplemental feeding of farmed deer is most critical in winter, when the animal decreases its feed intake considerably. Adam and Moir (1985) emphasized the point that this reduction in intake can result in sub-maintenance nutrition, which makes some feed to be unsuitable for young deer in late winter and in spring. Concentrate feeding during winter can improve the growth rate of calfs, but animals have a lower feed conversion than in the summer. Blaxter *et al.* (1988) reported that 100 g of concentrate per day in the winter resulted in a smaller increase in average daily gain than the same amount fed in summer. However, the same study also revealed that high level of supplementation during winter decreases the potential for compensatory growth in the subsequent summer when animals are placed on pasture. Brelurut *et al.* (1995) studied the effects of high levels of concentrate during winter on the performance of red deer calves from weaning to 15 months of age. In this experiment, weaned red deer stags were kept indoors, offered hay *ad libitum* and fed a supplement either restricted or *ad libitum*. The results revealed that at turn-out on pasture, the animals fed restricted during winter were 19.6 kg lighter than animals fed *ad libitum*. However, this difference decreased to 8.8 kg by September (15 months of age). Suttie *et al.* (1996) compared deer calfs kept indoors during winter with animals kept outside (off pasture) and fed either *ad libitum* or maintenance. Feed intake and growth rates were similar in stags fed *ad libitum*, whether they were kept inside or outside. Stags kept outside and restricted on feed ate about 15 % more and grew significantly faster than those kept inside and restricted on feed. They also observed that the *ad libitum* groups showed growth rate between 150-180 g/day during winter compared to a growth rate close to zero for the restricted groups. When released on pasture in the spring, deer in restricted groups showed some compensatory growth, but was not sufficient to allow full catch up with the *ad libitum* groups. Those studies (Brelurut *et al.*, 1995; Suttie *et al.*, 1996) illustrate a disadvantage of high grain feeding during winter if one wants to exploit compensatory growth on summer pasture. Milne *et al.* (1987) studied the effects of nutrition on the growth of red deer stags for venison production. In their experiment, the animals were fed one of three planes of nutrition: maintenance, *ad libitum*, and intermediate. The experiment involved feeding maintenance or *ad libitum* levels of feeding throughout the winter up to turn-out on pasture in the spring. The intermediate level of feeding involved maintenance feeding up to March, followed by *ad libitum* feeding until turn-out at pasture in the spring. They concluded that the approach of using the intermediate, then *ad libitum* feeding was economically and biologically the most efficient.

Deer can accommodate relatively high levels of grain to forage ratio because the soluble portion of rumen digesta is rapidly washed out of the rumen and therefore offers less opportunity for high levels of acids accumulation and acidosis (Hoffman, 1985). It has been found that deer can handle high levels of soluble carbohydrates and protein more efficiently than sheep or goats (Hoffmann, 1985; Domingue *et al.*, 1991). In deer, soluble protein is rapidly washed out of the rumen before a stable foam is formed (Barry and Wilson, 1994) and since bloat is the result of the formation and accumulation of soluble protein foam in the rumen (Mangan, 1959), bloat is not as frequent in deer than in other ruminant species

2.5. Feed intake and feed utilization by deer

Several members of the cervid family, including moose (*Alces alces*), roe deer (*Capreolus capreolus*) and white-tail deer, are classified as "concentrate selectors", or browsers (Hoffman, 1985). These animals are very selective for cell contents and more easily digestible parts of the plants. However, most of the cervids species, including red deer, are classified as intermediate opportunistic feeders, i.e. a mixed between true "grazers" (non selective roughage eaters), such as cattle and sheep and "concentrate selectors" (Hoffman, 1985). Deer seem to have a greater flexibility than sheep or goats (browser) regarding their feeding strategy and therefore can adapt better to food scarcity (Ramanzin *et al.* 1997). The differences between these three types of feeders go further than the feeding behavior seen in the members of those groups. They also include important morphophysiological differences in the gastro-intestinal tract. Hoffman (1985) showed important variations in relative size of the different compartments of the four-stomach ruminant. For example, deer has a relative greater rumen capacity, which result in increase in feeding time (Hoffman, 1985); red deer spend 67 % of their time feeding in the summer, compared to 50 % for sheep. It was also found that deer have lower digestibility of forage than sheep (grazer) (Kay *et al.* 1976; Milne *et al.* 1978). Since red deer has been shown to have faster rumen outflow rates than sheep, and consequently shorter rumen mean retention time, they digest fibrous grasses less completely, but mixed diets of hay and concentrate more fully than sheep (Ramanzin *et al.,* 1997).

According to Webster *et al.* (1996), the regulation of feed intake by deer is determined by energy as the primary feedback signal regulating feed intake by deer. They investigated the feed intake of young male deer in two experiments. The first one consisted of *ad libitum* feeding of six diets with different levels of energy while keeping the protein level constant. The second experiment consisted of four diets with different protein levels, while the energy level was kept constant. The results of the first experiment showed a negative linear relationship between the energy level in the diet and the dry matter intake. As a consequence of this decrease in dry matter intake the energy level in the diet increase, there was no difference in the energy intake for all diets. The authors concluded that the appetite was regulated by the energy intake. In contrast, the second experiment showed no evidence of an effect of the protein content in the diets on the DM intake or ME intake, from which they concluded that protein intake was not regulated in deer. When fed high forage diets, feed intake may be limited by physical limitation, as in the case of cattle and other ruminants (Church and Pond, 1988).

2.6. Carcass characteristics in red deer.

Venison is known to have all of the positive nutritional attributes of other red meat, without the negative features usually associated with red meat, such as high fat levels, saturated fatty acids and cholesterol (Drew, 1990). However, venison can have high fat levels, particularly in adult stags, in the period prior to the rut (end of summer). At this particular time, carcass fat can reach up to 20%, which is comparable to beef. However, 88% of the fat accumulated during the summer prior to the rut is mobilized during the rut which lasts six to eight weeks, and the fat content declines to 1 to 2 %. Therefore, it is necessary to manage time of slaughter to keep carcass fat low.

Most of the fat accumulation in pre-rut animals is in the form of subcutaneous fat (31%), internal depot (34%), and inter-muscular depots (28%) (Wallace and Davies, 1985). Intramuscular fat deposition, or marbling, is very low in deer, with 0.6 to 2.0 % lipid in muscles of five to eleven-month, and 1.2 and 2.2% for 15 and 27 month old stags respectively (Blaxter, 1988). A carcass from a 16 month old or younger deer is very lean and low in fat (5 to 7%). Because of this low fat content, the energy value of the meat is also lower than that of more traditional red meat. A loin portion of farmed venison has a fat content of 502 kJ per 100 g, compared to 828, 1184, 1297 kJ per 100 g for pork, beef and lamb respectively (USDA, 2000).

The ratio of polyunsaturated to saturated fatty acid is higher in deer (1.12) than in lamb (0.26), beef (0.22), or pork (0.75) (Sinclair and O'Dea, 1990). The high level of polyunsaturated fatty acid in the tissue of red deer, moose, white-tail deer, and roe deer compare to cattle can be explained by the lower level of saturation of fatty acids in the rumen of deer Hoffman, 1998).

Because the low fat content of the venison is one of the important marketing tool utilized to promote the product, New Zealand developed a grading system based on carcass weight and fatness, and producers are penalized for overfat carcasses (Drew, 1990). The measurement used to determine fatness is the grade ruler, or GR, or tissue depth. The GR was initially developed for lamb, in which it consists of the total tissue thickness over the 12th rib, measured at 11 cm from the midline (Frazer, 1976). Because of the larger size of the carcass, the measurement in deer is taken at 16 cm from the midline. This measurement does not give the fat depth, but rather the tissue depth. However, as the animal deposits fat, the muscle at this location stays relatively constant, and the proportion of fat will increase. A top quality carcass represents a cold carcass weight (CCW) of over 70 kg, with a GR limit for overfatness of 14 mm. Even in the absence of any fat, lighter animals will exhibit a smaller tissue depth than heavier animals. Therefore, a carcass of 50.5 to 70 kg CCW is allowed a GR of 12 mm before being penalized for overfatness, and a carcass smaller than 50 kg CCW, only 10 mm.

Based on studies with lambs, Kirton and Johnson (1979) evaluated the relationship between the GR and other carcass fatness measurements. They included in their analysis, among other measurements, carcass weight, GR, subcutaneous fat thickness, kidney fat and omental fat, and chemical fat content. Their results showed that all measurements were interrelated in a positive manner, but that none could be predicted from any other measurements. However, Fennessy and Drew (1986) showed a relationship between the carcass fat and the tissue depth, or GR. From their graph, a GR of 5 mm would represent between 2.5 and 6 % of carcass fat, while a GR of 10 mm would mean between 7 and 11 % carcass fat.

2.7. Influence of nutrition and management on carcass characteristics.

According to Drew (1985), deer are very efficient meat producers, yielding more than 700 kg of carcass per hectare in 170 days. The carcass yield ranges from 52 to 58%, depending on factors such as age and nutrition. At six months, a calf will produce a 54.8% dressing yield, compared to 56.9% for a 27 months old stag. Animals that are fed concentrates can produce a carcass yield of 59%. Values ranging from 52 to 54% have been reported for animals raised on hillside (Thériez, 1989). Studies (Suttie and Hamilton, 1983; Suttie et al., 1983; Adam and Moir, 1985) have shown that, at similar body weight, energy intake and rate of growth have only limited effects on the carcass composition of deer at 15 month of age. This is due to the fact that deer only start to deposit fat at a higher rate when they have reached about 50% of their mature body weight of about 200 kg (Thériez, 1989). Sheep and cattle, on the other hand, begin to partition substantial part of their tissue growth in the form of fat when they reach 35 to 40% of their mature weight. Since stags do not reach 50% of their mature body weight before they attain about 17 to 18 months of age, animals slaughtered before that age will show little fat deposition in the carcass.

Another unique characteristic of the deer carcass compared to that of other domestic ruminants is the high percentage of prime cuts. A 16 month old stag of 66 kg will produce 34.3% of lean liveweight from which the leg and saddle represent 54.8%. In contrast, a 6 month-old lamb weighing 52.8 kg will produce 23.8% of lean liveweight with 50.4% in the leg and saddle (Blaxter *et al.*, 1988).

Based on the review of the literature, deer farming has an interesting potential as an alternative red meat production. However, because it is also a relatively young animal production, there are many questions that need to be addressed. Some bases or concepts could be extrapolated from other ruminant species like cattle or sheep, but deer show some unique characteristics, and responses with deer need to be confirmed. For example, the interaction between protein and energy supplementation, which has been studied in cattle, was not verified in deer. The response of the red deer might be different from cattle, and need to be further explored. The aspect of protein supplementation and winter feeding also need to be explored, as most of the studies have been done in New Zealand and Europe, where the climate and consequently the management is different.

Materials and Methods

3. Materials and Methods

3.1. Animal management.

The experiment was initiated in autumn 1996 at a commercial farm in Lachute (north of Montréal), Québec. Forty-eight weaned red deer stags were purchased from a commercial deer farm in Eastern Ontario. The animals were four months old and had an average live weight of 47.4 kg ± 3.4. They were housed in an unheated barn and randomly assigned to eight pens (six animals per pen) of similar size and floor space (2.5 m^2 per animal). Each pen had facilities for group feeding of hay and concentrate. The linear feeder space was of 45 cm per animal. Straw was provided as bedding and was changed regularly. The deer were subjected to 16 h of light and 8 h of darkness (16L:8D). The light intensity was 300 lux, measured using an illuminometer placed at 1 meter from the ground.

Three weeks prior to weaning, each animal was vaccinated against yersiniosis (Yersiniavax®, AgVax Developments Ltd., New Zealand). At weaning, in mid- September, they were vaccinated against rabies (IMRAB® Plus, Rhone Merieux Inc., Mississauga, Ontario, Canada), leptospirosis (Leptoferm-5®, Smithkline Beecham Animal Health, Mississauga, Ontario, Canada) and several strains of *Clostridium* bacteria (Covexin-8, Mallinckrodt Veterinary, Ajax, Ontario, Canada), and were treated for intestinal worms with ivermectin (IVOMEC®, Merck Agvet, Pointe-Claire, Quebec, Canada).

Upon arrival at the experimental site and for a period of two weeks, the animals received hay *ad libitum* and a concentrate mixture containing 25% oats, 33% corn, 41% protein supplement (Protein supplement 36%, #96490 (1-2-3), Shur-Gain, Brossard, Québec) and 1% mineral-vitamin premix. The composition of the mineral/vitamin premix was Ca, 7%; P, 7%; Na, 12%; Mg, 2.5%; K, 1.5%; S, 1.0%; Cu, 1,200 mg/kg; Mn, 2,800 mg/kg; Zn, 4,000 mg/kg; Co, 80 mg/kg; Se, 24 mg/kg; vitamin A, 375,000 I.U./kg (minimum); vitamin D, 125,000 I.U./kg; and vitamin E, 1,400 I.U./kg (Minerals for cervids (red deer and wapiti) #48845 (6-7-8), Shur-Gain, Brossard, Québec). The concentrate mixture was offered once daily to groups of animals in each pen at the level of 1% of average body weight. The hay (second cut, early bloom) was grown on-site and was a mixture of 80% timothy grass (*Phleum pratense*) and 20% legume (85% alfalfa (*Medicago sativa*), 15% white clover (*Trifolium repens*)) and was presented in the form of small square bales. The animals had free access to water.

For the safety of the personnel as well as the animals, an experienced veterinarian removed the antlers at a semi-hard stage. The animals were first immobilized by intramuscular injection of 1.5 to 2.5 ml of 2% xylazine hydrochloride (Rompun®, Miles Canada Inc., Etobicoke, Ontario, Canada).

Each deer then received Lidocaine® 2% (MCT Pharmaceuticals Ltd, Cambridge, Ontario, Canada) as a local anesthetic injected at four positions at the base of the pedicle, at a dose of 15 ml on each side. The antlers were cut, and the animals were injected Tolazine® 100mg/ml (Vet-a-mix. Iowa, U.S.A.) (4 ml/100 kg live weight) as an antidote to Rompun®. If the deer remained immobilized for an extended period of time, rumen function would be impaired. Tolazine®100mg/ml was administered to shorten the period of immobilization.

3.2. Experimental design and feeding.

Duplicate pens of six animals were randomly assigned to each of four dietary supplements (2 pens per treatment) consisting of four different combinations of oats (energy source) and soybean meal (SBM) (protein source). The supplements were offered over a total feeding period of 48 weeks. Throughout the growth trial, each deer was offered hay *ad libitum* (described earlier) and had free access to water. The four supplements were represented as low energy, low protein (LE-LP); high energy, low protein (HE-LP); low energy, high protein (LE-HP); and high energy, high protein (HE-HP). The level of supplemental feeding was controlled over two distinct phases.

In Phase I (week 0 to 32), the LE-LP and HE-LP supplements consisted of oats alone offered at 0.5 and 1.0 kg per animal per day, respectively. The

LE-HP and the HE-HP supplements consisted of oats and SBM (0.15 kg oats plus 0.30 kg of SBM per animal per day and 0.5 kg oats plus 0.35 kg SBM respectively). These levels of supplementation were applied for the first 32 weeks of the experiment. The level of supplemental feeding during Phase I of the experiment corresponded to 1 and 2 % of initial body weight for LE-LP, LE-HP and HE-LP, HE-HP respectively. At week 32 and beyond (Phase II), the level of feed for all supplements was increased by a factor of 1.77 to maintain the fixed level of supplementation established in Phase I.

During Phase I, the supplements were offered once a day (7h00 a.m.), and during Phase II, twice a day (7h00 a.m. and p.m.). The commercial vitamin-mineral mixture described earlier was incorporated with the supplements at a level to provide 20 g per animal per day.

3.3. Sample collection and measurements.

Samples of the oats and SBM were taken daily and composited monthly. Hay samples were taken on every bale fed using a core sampler attached to a power drill. Hay samples were composited every two weeks. Body weight of each animal was measured using an electronic platform scale (Norac, model 2500U, Saskatoon, Canada). Initial and final body weights were recorded after the animals had been deprived of food (not water) for 12 hours. The animals were also weighed every 14 days to monitor interim changes in live weight.

Group feed consumption of hay and supplement by animals in each pen was recorded weekly.

At the end the feeding trial, two animals (randomly selected) from each pen were slaughtered each week; it required a three week period to slaughter all animals. Animals selected for slaughter on a particular day were weighed in the morning and transported to a federally inspected commercial abattoir for slaughter. Hot carcass weight (HCW) was recorded, and then the carcass was refrigerated for 48 h and weighed again to obtain estimates of cold carcass weight (CCW). Dressing percentage was calculated from HCW. Measurements were taken on each carcass of kidney fat (by physical separation), loin weight, and of GR (grade ruler) measurement; this represents the tissue depth taken using a steel ruler over the 12^{th} rib, 16cm from the midline and is a common measurement used in New Zealand to determine fatness.

3.4. Analytical methods.

3.4.1. Chemical analysis.

Feed samples were ground with a hammer mill (Thomas-Wiley Laboratory Mill, model 4, U.S.A.) to pass through a 1 mm screen. The samples were analyzed for dry matter, crude protein, calcium, phosphorus, and magnesium by a commercial laboratory (Stratford Agri Analysis, Ontario, Canada). Crude protein was determined by the macro-Kjeldhal method (A.O.A.C., 1984), using a 6-place LABCONCO digestion and distillation unit, model 21232 (LABCONCO, Kansas City, MO). The mineral content of feeds was determined by the Direct Current Plasma (DCP) method (Isaac et al., 1985) and a Spectra Span V Spectometer (Spectrametrics Inc., Andover, MA 01810). Samples of oats and hay were analyzed for neutral detergent fiber (NDF) and acid detergent fiber (ADF), and ADF-N was analyzed on hay samples only (A.O.A.C., 1984). The ADF content was measured by using Fibertec System Method (Tecator, Höganäs, Sweden) according to procedures of A.O.A.C. (1984). The same procedure was used for ADF-N, in conjunction with macro Kjeldhal method (A.O.A.C., 1984) to determine protein content.

3.4.2. Statistical analysis:

All data were analyzed as a 2 x 2 factorial, with subsampling using the Statistical Analysis System for MIXED procedures. The eight pens represented the experimental units, and stag within a pen represented subsampling units. The data were analyzed with unequal number of observations because in four of the eight pens, one animal was removed for reasons unrelated to the treatments. Analysis of data for body weight, average daily gain (ADG), and feed consumption involved the use of repeated measure analysis (Littell *et al.*, SAS® System for Mixed Models, 1996). Three statistical models were used, and included "fixed" and "random" effects:

1) For the individual measurements of body weight and average daily gain, the following model was used:

$$Y_{ijklm} = \mu + E_i + P_j + ExP_{ij} + pen_{ijk} + stag_{ijkl} + week_m + e_{ijklm}$$

Where

Y_{ijklm} = the observation for the *ijklm*th measurement

μ = the fixed effect of the mean

E_i = the fixed effect of the *i*th Energy (E) level (i = 1, 2)

P_j = the fixed effect of the *j*th Protein (P) level (j = 1, 2)

ExP_{ij} = the fixed interaction

pen_{ijk} = the random effect of the *k*th pen at the *i*th E level and the *j*th P level (k = 1, 2), pen ~ $N(\phi, I\sigma^2_{pen})$

$stag_{ijkl}$ = the random effect of the lth stag on the *k*th pen at the *i*th E level and the *j*th P level (l = 1-6)

$week_m$ = the fixed effect of the *m*th week

e_{ijkl} = the random error term

2) For the analysis of data related to group feed consumption (hay and grain), and nutrient intake, the following model was used:

$$Y_{ijkm} = \mu + E_i + P_j + ExP_{ij} + week_k \, e_{ijkm}$$

Where

Y_{ijkm} = the observation for the $ijkm^{th}$ measurement

μ = the fixed effect of the mean

E_i = the fixed effect of the i^{th} E level (i = 1, 2)

P_j = the fixed effect of the j^{th} P level (j = 1, 2)

ExP_{ij} = the fixed interaction

$Week_k$ = the fixed effect of the m^{th} week

e_{ijkm} = the random error term

3) For carcass measurements; HCW, CCW, dressing %, GR, loin weight, and kidney fat.

$$Y_{ijkl} = \mu + E_i + P_j + ExP_{ij} + pen_{ijk} + e_{ijkl}$$

Where

Y_{ijk} = the observation for the ijk^{th} measurement

μ = the fixed effect of the mean

E_i = the fixed effect of the i^{th} E level (i = 1, 2)

P_j = the fixed effect of the j^{th} P level (j = 1, 2)

ExP_{ij} = the fixed interaction

pen_{ijk} = the random effect of the k^{th} pen at the i^{th} E level and the j^{th} P level (k = 1, 2), pen ~ $N(N, I\sigma^2_{pen})$

e_{ijkl} = the random error term, ~ $N(N, I\sigma^2_e)$

Results

4. Results

4.1. Diet composition and animal performance.

The chemical composition of the dietary ingredients is presented in Table 1. The effects of the low and high levels of energy and protein on the animals' performance are shown in Table 2. There were no significant effects ($P>0.05$) of dietary treatment on initial weight, final weight or average daily gain of the animals. At both low and high protein level, increasing the level of energy supplementation tended to increase both final weight and average daily gain ($P>0.05$), there was 10 and 12 % increase in final weight and ADG, respectively, in response to energy supplementation. Increasing the level of protein supplementation had no effect on performance ($P>0.05$).

Figure 1 shows the changes in liveweight of the stags throughout the entire 48 weeks of the study. With the exception of week 30 to 34 (mid May to mid June), where the rate of growth decreased, growth rate appeared relatively constant throughout the trial.

4.2. Dry matter and nutrient intake.

Estimates of total dry matter intake (DMI) and hay intake are presented in Table 3. There was no interaction ($P>0.05$) between energy and protein supplementation on total dry matter intake, but the interaction with regard to hay intake and the proportion of grain in the diet was significant ($P<0.05$).

Table 1: Chemical composition of dietary ingredients (% DM).

Item	oats [z]	soybean meal [z]	hay [y]
Crude protein	12.0 (±0.4)[x]	53.9 (±0.6)	14.4 (±1.2)
Neutral detergent fiber	28.2 (±1.4)	---	50.0 (±1.7)
Acid detergent fiber	---	---	33.6 (±2.2)
Calcium	0.08 (±0.01)	0.28 (±0.02)	0.62 (±0.09)
Phosphorus	0.41 (±0.02)	0.79 (±0.03)	0.29 (±0.04)
Magnesium	0.13 (±0.01)	0.31 (±0.01)	0.25 (±0.03)

[z] Values based on 12 samples.
[y] Values based on 24 samples.
[x] Values in parenthesis represent standard deviations.

Table 2: Effects of low (L) and high (H) levels of energy (E) and protein (P) supplementation on the performance of red deer stags.

	Treatment				Significance of effects P > F		
	LE		HE				
Item	LP	HP	LP	HP	E	P	E x P
Initial weight (kg)	46.8	46.5	47.3	48.8	0.4065	0.7258	0.5622
	(1.49)[z]	(1.46)	(1.49)	(1.46)			
Final weight (kg)	92.0	91.0	99.0	101.8	0.1467	0.5486	0.9669
	(3.98)	(3.94)	(3.98)	(4.02)			
Average daily gain (g/d)	135	143	154	158	0.1674	0.6597	0.6695
	(8.4)	(8.1)	(8.4)	(8.6)			

[z] Standard error of the mean

Figure 1: Least square means of liveweight of red deer fed supplements of low (L) or high (H) levels of energy (E) and protein (P).

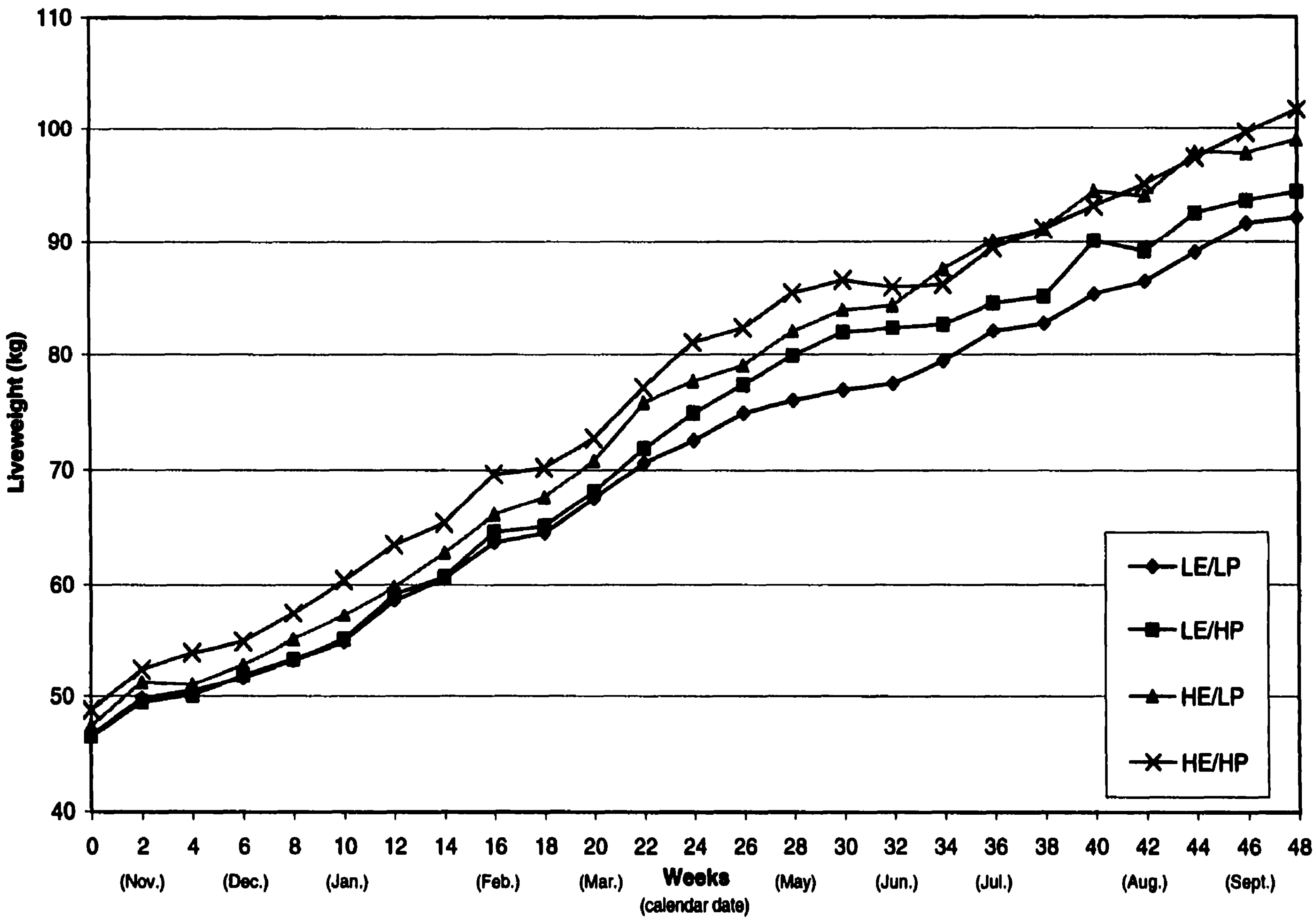


Table 3: Average feed intake by red deer stags fed supplements of low (L) or high (H) levels of energy (E) and protein (P).

	Treatment				s.e.m.	Significance of effects P > F		
	LE		HE					
Item	LP	HP	LP	HP		E	P	E x P
Total DMI (kg/d)	2.67	2.68	2.69	2.84	0.035	0.0633	0.0866	0.0920
Hay intake (kg/d)	2.03	2.10	1.40	1.75	0.035	0.0001	0.0038	0.0150
Grain (% diet)	25	22	48	39	0.51	0.0001	0.0003	0.0025

As energy supplementation increased, hay consumption decreased. At the low level of protein supplementation, increasing the level of energy supplementation (from LE/LP to HE/LP) resulted in a 31% decrease in hay consumption. At the high level of protein, increasing the level of energy supplementation (from LE/HP to HE/HP) caused a 17 % reduction in hay intake. Protein supplementation increased the consumption of hay. The effect was greater at the high level of energy supplementation.

Figure 2 shows variations in hay intake throughout the 48 weeks of the performance trial. During the first 8 to 10 weeks of the experiment, the daily consumption of hay was constant, irrespective of treatment. At about 10 weeks and up to about 30 weeks, hay intake from all treatments increased sharply. Beyond 30 weeks the rate of hay consumption tended to decrease; the decrease in hay intake was more pronounced with the high levels of energy supplementation (HE/LP and HE/HP).

The average nutrient intake by red deer stags is presented in Table 4. The prediction formula developed by Seoane *et al.* (1991) was used to convert the ADF content of hay to its TDN value (TDN (%) = 112.6 - 1.372 x ADF (%)). The TDN value was then converted (DE (Mcal) = 4.4 TDN (kg)) to digestible energy (DE) and finally to ME (ME (Mcal) = 0.82 x DE (Mcal)) according to NRC (1985). Values for ME intake for hay were calculated for

Figure 2: Least square means of hay intake of red deer stags fed low (L) or high (H) levels of energy (E) and protein (P).

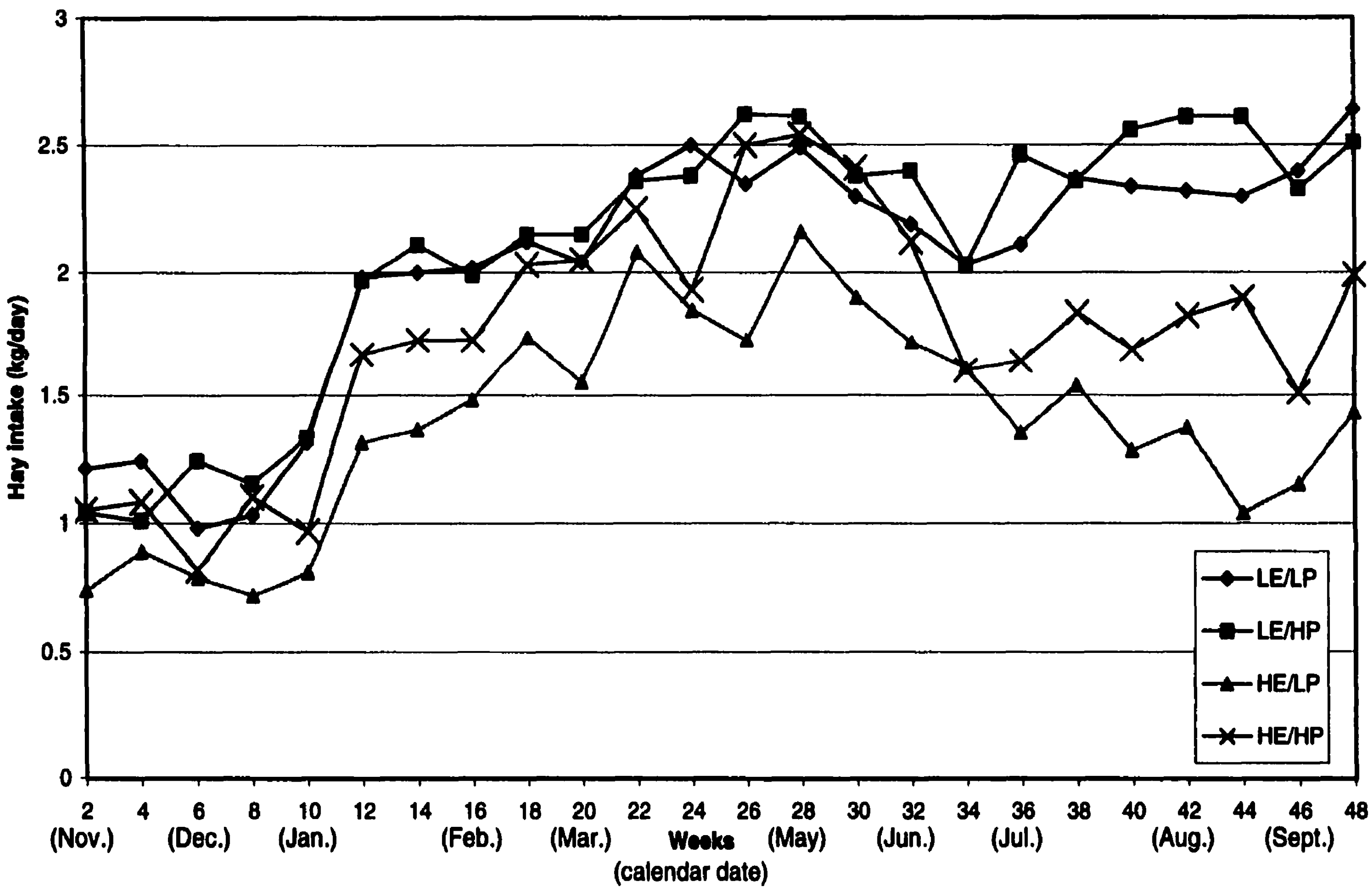


Table 4: Least square means of average nutrient intake by red deer stags fed supplement of low (L) or high (H) levels of energy (E) and protein (P).

	Treatment					Significance of the effects P > F		
	LE		HE		s.e.m.			
Item	LP	HP	LP	HP		E	P	E x P
ME (MJ/d),								
from hay	21.4	22.1	14.7	18.4	0.37	0.0001	0.0042	0.016
total	28.9	29.5	29.6	31.9	0.37	0.0145	0.017	0.092
Crude Protein,								
g/d	377	539	360	575	3.8	0.134	0.0001	0.0063
$g/kg^{0.75}$	15	21	14	22	0.3	0.473	0.0001	0.1190
NDF [z],								
g/d	1205	1118	1058	1063	17.6	0.0045	0.0753	0.0583
$g/kg^{0.75}$	49.1	44.4	41.8	40.6	1.21	0.0101	0.0679	0.2165

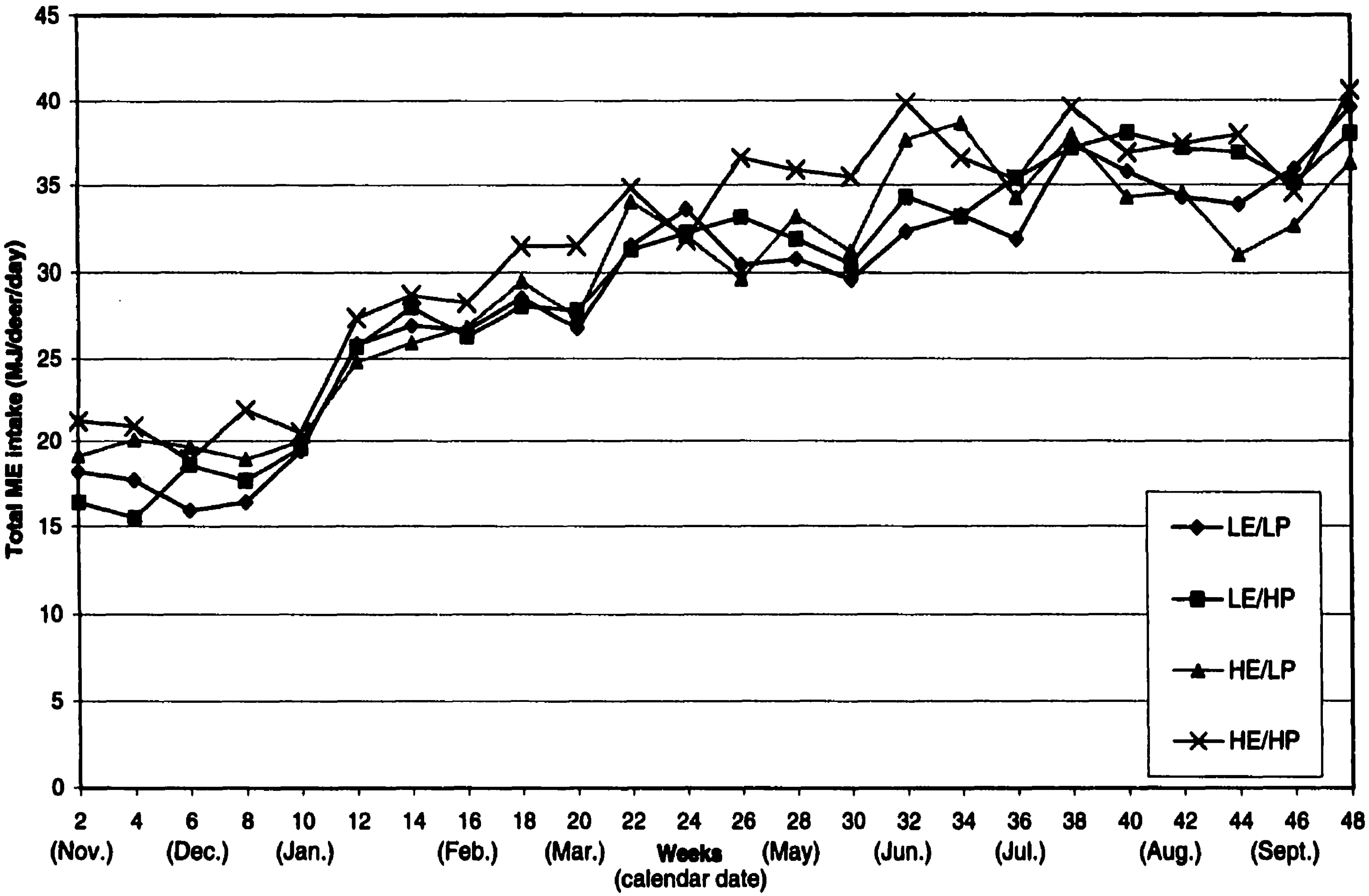
[z] NDF = Neutral Detergent Fiber

each 2-week period throughout the experiment. The ME values for oats and soybean meal were obtained from NRC (1985) tables for sheep.

There was a significant interaction between energy and protein supplementation ($P<0.05$) on ME intake from hay but the interaction with regard to total ME intake was not significant ($P>0.05$). At low level of energy supplementation, increasing the level of protein supplementation (from LE/LP to LE/HP) caused a 3% increase in ME coming from hay; increasing the level of protein supplementation at high level of energy supplementation resulted in a 25% increase. As energy supplementation increased, ME intake from hay decreased. At the low level of protein supplementation, increasing the level of energy supplementation (from LE/LP to HE/LP) resulted in a 31% decrease in ME intake from hay. At the high level of protein, increasing the level of energy supplementation (from LE/HP to HE/HP) caused a 17 % reduction in ME intake from hay. Protein supplementation increased ME intake from hay. The effect was greater at the high level of energy supplementation. The responses in ME intake from hay were identical to those observed for DM consumption from hay (Table 3). Both energy and protein supplementation increased total ME intake ($P<0.05$) by 5%.

Figure 3 shows the changes in ME intake over the entire experiment. The pattern of energy intake was similar than the ones observed in Figure2

Figure 3: Estimated metabolizable energy intake by red deer fed supplements of low (L) or high (H) levels of energy (E) and protein (P).



with hay intake. At week 8 to 10, there was a sharp increase in ME intake. However, contrarily to Figure 2, there was no decrease in ME intake at week 32.

There was a significant interaction ($P<0.01$) between protein and energy supplementation on protein intake when expressed in grams per day but not when expressed in relation to metabolic body size (Table 4). At the low level of energy supplementation, there was a 43% increment in protein intake (g/d), whereas at the high level of energy supplementation, the increment in protein intake was 60%.

The interaction between protein and energy supplementation was also significant for NDF ($P=0.0583$). At the low level of energy supplementation, increasing the level of protein (from LE/LP to LE/HP) resulted in a reduction in fiber intake; at the high level of energy supplementation, increasing the level of protein caused little change in NDF intake.

4.3. Carcass measurements.

Carcass measurements are represented in Table 5. There was no interaction ($P>0.05$) between protein and energy supplementation on the carcass measurements. With the exception of cold carcass weight (CCW), neither protein nor energy supplementation had an effect ($P>0.05$) on carcass characteristics. Increasing the level of energy supplementation caused 11% increase in the CCW.

Table 5 : Least square means of carcass measurements on red deer stags fed low (L) or high (H) levels of energy (E) and protein (P).

	Treatment				Significance of effects P > F		
	LE		HE				
Item	LP	HP	LP	HP	E	P	E x P
Initial wt (kg)	46.8 (1.49) [z]	46.5 (1.46)	47.3 (1.49)	48.8 (1.46)	0.4065	0.7258	0.5622
Slaughter wt (kg)	90.5 (4.0)	92.1 (3.9)	96.6 (3.9)	100.6 (4.0)	0.1470	0.5134	0.7695
Hot carcass weight (HCW)	51.1 (2.0)	53.4 (1.9)	56.0 (2.0)	58.2 (2.01)	0.0687	0.3245	0.9749
Cold carcass weight (CCW)	47.5 (1.77)	49.4 (1.74)	52.8 (1.77)	54.5 (1.81)	0.0430	0.3611	0.9560
Carcass yield (%)	52.5 (0.9)	53.8 (0.9)	54.8 (0.9)	54.2 (1.0)	0.2112	0.7385	0.3691
GR (mm) [y]	3.6 (0.57)	3.5 (0.51)	3.7 (0.60)	2.9 (0.63)	0.7578	0.7578	0.554
Loin (% HCW)	2.1 (0.04)	2.2 (0.04)	2.1 (0.05)	2.2 (0.05)	0.8393	0.1972	0.3349
Kidney fat (% HCW)	0.2 (0.092)	0.2 (0.089)	0.4 (0.095)	0.2 (0.095)	0.5276	0.3531	0.4786

[z] Standard error of the mean

[y] corrected for HCW

Discussion

5. Discussion

5.1. Animal performance

The study evaluated the responses of red deer stags from 5 to 16 months of age to supplementation of different levels of energy and protein. The growth performance obtained across the four treatments in terms of average daily gain varied between 135 and 158 g/d, and final liveweights, between 91 to 101.8 kg at 16 months. Those results are similar to those obtained by Adam and Moir (1985), who raised red deer to liveweights ranging from 75.6 and 94.0 kg at 16 months of age, with ADG ranging from 114 to 178 g/d . Brelurut *et al.* (1995) reported estimates of ADG (from 6 to 15 months) as high as 207 g/d for red deer raised to 115 kg liveweight (15 months of age) and offered concentrate *ad libitum*. The lower values for ADG observed in this study compared to that reported by Brelurut *et al.* (1995) could be explained by the lower level of concentrate feeding. Another explanation for the differences in animal performance between the two studies could be related to the fact that the animals in this experiment were maintained in confinement throughout the study. This causes stress on the animals. Although the floor space recommendations (Suttie *et al.*, 1996) were met at the beginning of the trial, the floor space available may have been insufficient as the animals became heavier. This would have been an additional source of stress for the animals. It is recognised (Church and Pond, 1988; Brelurut *et al.*, 1995) that stress increases maintenance requirements for energy, and therefore reduces energy available for growth and reduces feed intake.

The response in liveweight gain across treatments was smaller than what was observed in similar studies, using extended daylength. Vigh-Larsen (1994), for example, reported weights of 85 to 90 kg at 11 months of age, with a 16L:8D lighting program. In the present study, those weights were achieved at about 16 months of age. The discrepancies may be due to the fact the distribution of the light intensity within the pens was inadequate. Since deer naturally show enhanced growth when exposed to increased lighting period (i.e. in the summer), the decision to provide artificial photoperiod in the present study was taken with the objective of maximising animal response to supplementation.

The results obtained in this experiment in response to supplementation of energy and protein showed higher response in growth rate with the diet higher in energy, and higher response but at a smaller magnitude with the high compared to low protein diets. Although those responses were similar to the results obtained by Pirlo *et al.* (1997) with heifers, they were not significant in our case. While the quantities of both energy and protein supplied by the supplements were fixed, the total amount of energy and protein consumed varied depending on the intake of hay. Because the animals were offered hay *ad libitum*, the groups fed high-energy diets decreased their hay consumption. This resulted in very small differences in total energy intake among the diets. This could be one of the reasons for the discrepancies with the results of Pirlo *et al.* (1997), and also why no significant differences were observed in growth performance among all four treatments. The trend towards higher growth rate with supplementation of additional energy from the grain could be explained by the fact that high concentrate diets are energetically more efficient than high roughage diets (Owen and Bergen, 1983).

The growth response of the deer to protein supplementation was slightly higher at low compared to high energy level (8 and 4 g/d respectively). However, in both cases, supplementing protein did not improve ADG. The average crude protein intake in this experiment varied between 360 and 575 g/d. The fact that there was no response in growth rate with additional protein implies that, at the lower level of protein intake, the requirements were already met. In fact, Adam (1991) reported that the protein requirements for young red deer ranged from 130 to 340 g/d, from 6 to 15 months. Feeding protein beyond those requirements showed no improvements in growth performance.

It is important to make the distinction between protein requirement for tissue and protein requirement for rumen functions, in regarding both the level and type of protein intake. Rumen degradable protein (RDP), for example, are needed in quantity sufficient to stimulate proper rumen function, as they become the N substrate for rumen bacteria (Ruminant nutrition, 1989). Those bacteria promote maximum protein synthesis and cellulolytic activity. However, both RDP and NDP (non degradable protein) are needed for cell wall, for organic matter digestibility and to increase voluntary forage intake.

In addition, an appropriate energy to protein ratio need to be reached. This ratio will be different for rumen function than for tissue accretion. In maintenance requirements, the animal's requirements is equal to the rumen micro-organism's requirements. In fast growing animals, the requirements for protein is high in relation to its energy requirements (McDonald *et al.*, 1988). Once the appropriate ratio is attained for both rumen functions and tissue accretion, the extra protein is directed toward energy balance (Ruminant nutrition, 1989). In their study with steers, McKinnon *et al.* (1993) have shown that increasing the protein level in the diet was beneficial in terms of growth, but only at the low energy level. This response could show that the energy balance rather than the protein status itself is improved by increasing protein supplementation.

5.2. Pattern of dry matter intake and substitution effect of grain

The dramatic increase in hay consumption across all treatments observed after an initial "lag period" is a response to increased photoperiod, and has been observed before (Vigh-Larsen, 1993; Davies, 1994; Suttie *et al.*, 1996). In this experiment, the lag period lasted 10 weeks, and in others, six weeks. However, in this experiment, final adjustments in lighting were performed at week 4. Therefore, the real adaptation to artificial lighting required 6 weeks, and this would be consistent with the studies reported above where similar lighting program was applied.

The decline in hay intake between weeks 28 and 34 is consistent with observations made by Vigh-Larsen (1994) and Suttie *et al.* (1996). This represents a "refractory period". Vigh-Larsen *et al.* (1994) suggested that this refractoriness to light stimulation can be explained as follows: The deer will exhibit some finite level of weight gain during the year, and will only respond to a given amount of light stimulation.

The animal's response of altering hay intake depending on the amount of supplement provided is the phenomenon of the substitution effect of grain. Minson (1990) expressed the phenomenon of substitution by an equation representing a ratio of the extent of the depression in forage intake to the amount of supplemental feed ingested. According to this equation, the substitution coefficient obtained in this experiment would be 0.83. From other experiments, Minson (1990) have deduced substitution coefficient values ranging from 0.51 to 1.67 for steers (Lake *et al.*, 1974; Adam, 1985) and from

0.79 to 0.85 for ewes and lambs (Milne *et al.*, 1979; Young *et al.*, 1980). According to Minson (1990), factors affecting the coefficient of substitution are the type of feed supplementation, the time of feeding, and the quality of the forage offered. However, it does not seem to be affected by species of ruminant or the type of production. The value of 0.83 obtained in our experiment falls within the ranges reported by Minson (1990).

Experiments conducted by Webster *et al.* (1997) with young male deer fed isonitrogenous diets with various energy levels showed the deer adjusted their DM intake in relation to energy density. He concluded that energy seems to be the primary regulator of feed intake in deer, as is the case with other animals. The present results are consistent with this observation in that the energy intake was the same across all six treatments.

5.3. Carcass measurements

The fact that carcass characteristics were not altered by supplemental feeding is in accordance with the study by Adam and Moir (1985) who raised deer to similar liveweight. Other studies have also shown that energy intake and rate of growth have limited effects on the carcass composition of young deer (Suttie and Hamilton, 1983; Suttie *et al.*, 1983). The GR values obtained in this experiment were ranging from 3 to 3.5 mm indicating very little variability in carcass fat among the animals across treatments. According to

Fennessy and Drew (1986), a GR value of 5 mm would represent between 2.5 and 6 % carcass fat. Values of GR from 3 to 5 mm are standard values for young stags (Stevenson-Barry, pers. com., 1998) and according to New Zealand standards for carcass fatness, a GR of 10 mm is allowed in carcasses of less than 50 kg (CCW) before penalising for overfatness (Fennessy and Drew, 1987). The results of GR obtained in this study revealed that all the animals had carcass fat lower than 2.5%.

The carcass yields obtained in this experiment ranges from 52.5 to 54.8% and were within normal range (Drew, 1985). Concentrate diets fed to deer can lead to carcass yields up to 59 %. Values reported here were closer to those for animals raised on hillsides (Thériez, 1989). This means that higher levels of concentrate feeding would have been required for carcass yield exceeding 55%.

Conclusion

6. Conclusion

The present study can improve the nutritional strategies for venison production by providing information applicable to North American farming. This study indicates that providing two levels of supplemental energy and protein to a diet of hay failed to improve growth performance of weaned red deer stags. Measures of carcass quality were also unaffected by supplemental feeding. Animals reduced their consumption of hay in response to concentrate feeding and this resulted in similarities in energy intake across all treatments. This substitution effect of grain feeding may explain the lack of response in growth rate to supplemental energy from grain. However, because of the substitution effect of hay for grain, observed in the present study, hay intake should be controlled in order to get the true effect of supplemental feeding on the growth performance. No improvement in growth rate was observed at protein intake beyond 360 g/d; the reason for the lack of response to additional protein needs further study. From the results obtained in this trial producers, should not be concerned about altering the carcass characteristics, such as fat content, of the young red deer.

Being an emerging industry in Québec and in North America, the venison industry needs more recognition as a serious production. It needs to supply a product of superior quality in order to justify itself as a type of production that can compete with more well established types of meat production. More studies need to be done to attain higher quality standards, such as the impact of stress on venison, the situations causing them, and the methods to eliminate them. Implanting quality standards and grading system for venison would also be important for the growth of the venison industry. The United States Department of Agriculture (USDA, 1997) has already proposed a new Institutional Meat Purchase Specifications for fresh venison, on guidelines for meat handling, refrigeration and packaging. It also proposed indications on code-referenced description of variety of venison cuts and quality assurance provision. In the last few years, Québec has certainly improved the quality and the consistency of the venison it produces. However, more work has to be done and providing adequate nutrition is certainly one of the important factors to improve. Improving growth rate can be achieved by nutritional strategies, by hormonal manipulations or a by combination of both. Nutritional modulation of seasonal metabolism could be an interesting avenue for further study. However, because of the "natural" perception surrounding venison, and the important strength it represents for the marketing of the product, hormonal manipulations on deer to modify its seasonality in growth could shadowed the "natural" image venison now reflects, and should therefore be avoided.

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7. Literature cited

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Appendices

Appendix 1a: Chemical analysis (% dry matter) of oats, soybean meal, and hay.

Ingredients	DM[1]	CP[2]	ADF[3]	NDF[4]	Ca[5]	P[6]	Mg[7]	DM	CP	ADF	NDF	Ca	P	Mg
	Week 0-2							Week 2-4						
Oats	92.0	11.9	---	33.8	0.09	0.43	0.15	92.0	11.9	---	33.8	0.09	0.43	0.15
Soybean meal	90.4	53.8	---	---	0.31	0.79	0.33	90.4	53.8	---	---	0.31	0.79	0.33
Hay	94.1	12.5	34.4	50.8	0.55	0.29	0.23	94.3	14.3	37.4	53.2	0.50	0.32	0.20
	Week 4-6							Week 6-8						
Oats	91.7	12.0	---	34.3	0.08	0.42	0.14	91.7	12.0	---	34.3	0.08	0.42	0.14
Soybean meal	90.7	54.3	---	---	0.31	0.78	0.30	90.7	54.3	---	---	0.31	0.78	0.30
Hay	94.0	14.1	33.9	50.5	0.56	0.32	0.22	94.3	14.0	33.8	51.1	0.61	0.30	0.24
	Week 8-10							Week 10-12						
Oats	91.4	12.1	---	34.8	0.08	0.43	0.14	91.4	12.1	---	34.8	0.08	0.43	0.14
Soybean meal	89.9	54.8	---	---	0.28	0.76	0.29	89.9	54.8	---	---	0.28	0.76	0.29
Hay	93.4	15.1	33.8	48.5	0.69	0.36	0.26	94.5	14.7	35	52	0.68	0.33	0.25
	Week 12-14							Week 14-16						
Oats	90.2	12.5	---	32.4	0.07	0.41	0.13	90.2	12.5	---	32.4	0.07	0.41	0.13
Soybean meal	91.4	54.8	---	---	0.30	0.79	0.31	91.4	54.8	---	---	0.30	0.79	0.31
Hay	94.5	14.7	32.8	51.2	0.71	0.27	0.28	93.7	12.8	34.2	50.6	0.47	0.29	0.22
	Week 16-18							Week 18-20						
Oats	89.9	12.7	---	31.9	0.07	0.39	0.13	89.9	12.7	---	31.9	0.07	0.39	0.13
Soybean meal	90.3	53.6	---	---	0.28	0.79	0.31	90.3	53.6	---	---	0.28	0.79	0.31
Hay	93.6	14.9	34.1	49.5	0.59	0.29	0.25	94.6	13.6	34.2	52.5	0.53	0.30	0.21

[1]DM: Dry matter; [2] CP: Crude protein; [3] ADF: Acid detergent fiber; [4] NDF: Neutral detergent fiber; [5]: Ca: Calcium; [6]P: Phosphorus; [7] Mg: Magnesium.

Appendix 1b: Chemical analysis (% dry matter) of oats, soybean meal, and hay.

Ingredients	DM [1]	CP [2]	ADF [3]	NDF [4]	Ca [5]	P [6]	Mg [7]	DM	CP	ADF	NDF	Ca	P	Mg
	Week 20-22							Week 22-24						
Oats	91.6	11.9	---	31.4	0.08	0.43	0.14	91.6	11.9	---	31.4	0.08	0.43	0.14
Soybean meal	90.2	53.9	---	---	0.27	0.81	0.31	90.2	53.9	---	---	0.27	0.81	0.31
Hay	94.7	13.9	31.3	48.7	0.64	0.28	0.27	94.2	17.1	30.0	46.4	0.74	0.30	0.29
	Week 24-26							Week 26-28						
Oats	90.5	11.9	---	29.9	0.08	0.41	0.13	90.5	11.9	---	29.9	0.08	0.41	0.13
Soybean meal	90.5	53.0	---	---	0.27	0.82	0.32	90.5	53.0	---	---	0.27	0.82	0.32
Hay	93.8	15.2	33.5	46.9	0.62	0.29	0.24	93.7	14.7	35.8	47.8	0.64	0.34	0.21
	Week 28-30							Week 30-32						
Oats	88.9	11.8	---	30.7	0.07	0.40	0.13	88.9	11.8	---	30.7	0.07	0.40	0.13
Soybean meal	89.8	53.9	---	---	0.27	0.83	0.32	89.8	53.9	---	---	0.27	0.83	0.32
Hay	92.9	15.1	34.3	50.4	0.64	0.31	0.23	93.1	13.0	35.9	48.5	0.58	0.28	0.23
	Week 32-34							Week 34-36						
Oats	89.0	11.6	---	31.5	0.07	0.40	0.12	89.0	11.6	---	31.5	0.07	0.40	0.12
Soybean meal	89.7	53.3	---	---	0.27	0.79	0.32	89.7	53.3	---	---	0.27	0.79	0.32
Hay	92.1	16.0	29.5	51.3	0.79	0.33	0.27	92.2	11.8	35.1	50.8	0.72	0.21	0.30
	Week 36-38							Week 38-40						
Oats	89.0	11.5	---	32	0.08	0.40	0.13	89.0	11.5	---	32.0	0.08	0.40	0.13
Soybean meal	89.4	54.4	---	---	0.28	0.76	0.32	89.4	54.4	---	---	0.28	0.76	0.32
Hay	93.3	14.9	28.5	49.5	0.44	0.27	0.22	92.8	15.4	31.5	47.8	0.62	0.29	0.25

[1]DM: Dry matter; [2] CP: Crude protein; [3] ADF: Acid detergent fiber; [4] NDF: Neutral detergent fiber; [5]: Ca: Calcium; [6] P: Phosphorus; [7] Mg: Magnesium.

Appendix 1c: Chemical analysis (% dry matter) of oats, soybean meal, and hay.

Ingredients	DM[1]	CP[2]	ADF[3]	NDF[4]	Ca[5]	P[6]	Mg[7]	DM	CP	ADF	NDF	Ca	P	Mg
	Week 40-42							Week 42-44						
Oats	88.5	11.7	---	31.4	0.07	0.39	0.12	88.5	11.7	---	31.4	0.07	0.39	0.12
Soybean meal	88.8	53.4	---	---	0.25	0.79	0.31	88.8	53.4	---	---	0.25	0.79	0.31
Hay	92.2	15.8	34.6	51.2	0.60	0.31	0.26	89.8	13.6	36.1	50.6	0.64	0.23	0.26
	Week 44-46							Week 46-48						
Oats	88.3	12.4	---	32.2	0.07	0.39	0.13	88.3	12.4	---	32.2	0.07	0.39	0.13
Soybean meal	89.1	53.9	---	---	0.25	0.73	0.31	89.1	53.9	---	---	0.25	0.73	0.31
Hay	89.4	14.3	33.9	50.4	0.62	0.29	0.25	89.0	14.9	31.7	49.5	0.80	0.22	0.30

[1]DM: Dry matter; [2] CP: Crude protein; [3] ADF: Acid detergent fiber; [4] NDF: Neutral detergent fiber; [5]: Ca: Calcium; [6] P: Phosphorus; [7] Mg: Magnesium.

Appendix 3: Average hay consumption (kg/deer/day) by pen of red deer stags fed low (L) or high (H) levels of energy (E) and protein (P).

		Week							
Treatment	Pen	0-2	2-4	4-6	6-8	8-10	10-12	12-14	14-16
LE/LP	3	1.15	1.20	0.89	0.96	1.35	2.07	2.06	1.86
LE/LP	5	1.27	1.27	1.07	1.09	1.26	1.89	1.94	2.18
LE/HP	4	0.78	0.84	0.75	0.76	0.71	1.37	1.34	1.57
LE/HP	7	0.70	0.93	0.82	0.67	0.91	1.25	1.38	1.39
HE/LP	2	0.97	1.03	1.08	1.05	1.30	1.90	1.94	1.80
HE/LP	1	1.11	0.99	1.39	1.25	1.35	2.04	2.27	2.17
HE/HP	6	0.98	0.99	0.88	1.18	0.98	1.71	1.86	1.82
HE/HP	8	1.11	1.17	0.75	1.02	0.95	1.63	1.60	1.63
		16-18	18-20	20-22	22-24	24-26	26-28	28-30	30-32
LE/LP	3	2.24	1.93	2.46	2.69	2.68	2.30	2.48	2.17
LE/LP	5	2.15	2.15	2.29	2.31	2.02	2.68	2.11	2.21
LE/HP	4	1.68	1.54	2.23	1.95	1.81	2.32	2.04	1.86
LE/HP	7	1.79	1.55	1.92	1.74	1.65	2.00	1.75	1.58
HE/LP	2	2.15	2.06	2.14	2.38	2.56	2.70	2.26	2.40
HE/LP	1	2.15	2.23	2.57	2.38	2.67	2.51	2.50	2.39
HE/HP	6	2.04	2.11	2.13	1.74	2.48	2.73	2.36	2.29
HE/HP	8	2.02	1.99	2.37	2.11	2.52	2.34	2.46	1.95
		32-34	34-36	36-38	38-40	40-42	42-44	44-46	46-48
LE/LP	3	2.04	2.15	2.56	2.55	2.58	2.17	2.06	2.58
LE/LP	5	2.01	2.06	2.18	2.12	2.05	2.43	2.74	2.69
LE/HP	4	1.76	1.51	1.81	1.19	1.12	0.81	1.01	1.34
LE/HP	7	1.46	1.19	1.26	1.36	1.61	1.26	1.29	1.52
HE/LP	2	2.15	2.62	2.35	2.56	2.60	2.58	2.39	2.55
HE/LP	1	1.90	2.29	2.36	2.55	2.61	2.63	2.27	2.46
HE/HP	6	1.46	1.60	1.60	1.88	1.73	2.07	1.94	1.97
HE/HP	8	1.73	1.67	2.08	1.49	1.93	1.73	1.07	2.00

Appendix 2: Average liveweight by pen of red deer stags fed low (L) or high (H) levels of energy (E) and protein (P).

Treatment	Pen	Weeks 0	2	4	6	8	10	12	14	16
LE/LP	3	49.5	51.7	52.8	53.8	55.3	57.6	61.9	63.9	66.3
LE/LP	5	44.6	48.9	49.0	50.0	51.5	52.4	55.4	57.4	61.3
LE/HP	4	47.3	51.5	50.6	51.2	53.9	55.1	58.8	61.7	65.4
LE/HP	7	47.5	50.9	51.0	53.3	55.1	57.9	59.3	62.4	65.1
HE/LP	2	46.5	49.5	50.8	52.2	53.5	55.2	58.6	61.3	63.8
HE/LP	1	46.4	49.4	49.5	51.4	52.8	54.8	59.7	60.0	65.5
HE/HP	6	47.7	51.2	52.7	53.8	56.3	59.9	62.2	64.4	68.2
HE/HP	8	49.8	53.5	54.9	55.7	58.4	60.8	64.9	66.4	71.0

Treatment	Pen	18	20	22	24	26	28	30	32	34
LE/LP	3	68.4	71.7	75.0	76.5	78.2	79.3	80.4	81.2	82.6
LE/LP	5	60.7	63.3	65.9	68.4	71.4	72.6	73.2	73.5	76.1
LE/HP	4	66.8	70.2	75.0	77.5	78.0	82.4	83.8	85.2	87.6
LE/HP	7	66.5	69.4	74.5	75.5	77.9	79.4	81.5	80.9	84.6
HE/LP	2	65.8	68.5	72.6	75.5	77.2	81.4	82.2	83.3	84.9
HE/LP	1	64.3	67.8	71.2	74.2	77.4	78.4	81.8	81.4	80.4
HE/HP	6	68.4	71.9	75.5	77.7	79.2	83.5	84.5	82.6	81.8
HE/HP	8	72.1	73.6	78.6	84.4	85.5	87.5	88.7	89.4	91.1

Treatment	Pen	36	38	40	42	44	46	48
LE/LP	3	85.0	87.7	91.2	92.5	95.0	97.8	98.3
LE/LP	5	78.4	77.4	78.1	80.0	82.8	84.2	85.5
LE/HP	4	90.8	91.5	95.2	97.8	102.2	100.2	101.2
LE/HP	7	86.4	87.6	90.2	90.6	94.0	95.6	96.9
HE/LP	2	86.1	86.9	92.0	90.5	94.6	96.4	97.2
HE/LP	1	83.0	83.5	88.2	87.8	90.3	90.7	91.7
HE/HP	6	85.3	85.4	88.9	91.5	94.2	96.5	98.5
HE/HP	8	94.0	97.5	97.6	98.6	100.6	102.7	105.0

Appendix 4a : Carcass measurements on red deer stags fed supplements of low (L) or high (H) levels of energy (E) and protein (P

Treatment	Pen	Stag #	Slaughter weight (kg)	Hot carcass weight (kg)	Cold carcass weight (kg)	Carcass yield (%)	GR (mm)	Loin (% HCW)	Kidney fat (% HCW)
LE / LP	3	97	95.2	55.0	52.0	55	1.5	2.1	0.1
		100	98.7	53.5	51.0	52	5.0	2.1	0.8
		105	95.9	54.0	51.0	53	4.0	2.0	0.3
		106	98.2	57.0	53.0	54	5.0	1.8	0.9
		128	98.6	52.0	43.0	44	2.5	2.1	0.1
		262	93.8	54.0	52.0	55	4.0	2.4	0.1
	5	73	84.2	46.0	43.0	51	1.5	2.2	0.0
		113	89.7	50.5	47.0	52	4.0	2.2	0.0
		165	81.8	47.0	44.0	54	1.5	2.1	0.0
		189	86.4	52.0	48.0	56	3.0	2.0	0.3
		230	78.2	43.0	40.0	51	1.0	2.0	0.0
LE / HP	4	95	104.2	60.0	57.0	55	5.5	2.1	0.5
		101	105.8	63.0	59.0	56	6.5	2.0	0.6
		141	86.8	47.5	45.0	52	-	2.5	0.1
		149	102.1	58.0	55.0	54	2.0	1.9	0.3
		195	94.4	56.0	53.0	56	2.5	2.1	0.1
	7	68	91.8	55.0	52.0	57	-	-	-
		71	108.0	63.5	59.0	55	4.5	2.4	0.0
		88	100.3	55.0	52.0	52	4.0	2.1	0.4
		152	86.4	48.5	45.0	52	2.5	2.1	0.8
		156	96.0	54.0	51.0	53	8.0	2.1	0.7
		173	84.8	55.5	52.0	61	1.5	2.0	0.2

Appendix 4b : Carcass measurements on red deer stags fed supplements of low (L) or high (H) levels of energy (E) and protein (P

Treatment	Pen	Stag #	Slaughter weight (kg)	Hot carcass weight (kg)	Cold carcass weight (kg)	Carcass yield (%)	GR (mm)	Loin (% HCW)	Kidney fat (% HCW)
HE / LP	2	50	91.6	55.0	53.0	58	4.0	2.3	0.3
		86	108.5	61.5	49.0	45	5.0	2.1	0.4
		96	89.9	50.0	46.5	52	2.0	2.3	0.0
		201	96.8	58.0	54.0	56	4.0	2.1	0.4
		218	105.0	58.0	55.0	52	2.0	2.3	0.4
		266	79.4	48.0	44.0	55	5.0	2.3	0.0
	1	53	84.8	53.5	50.0	59	5.5	2.2	0.8
		126	83.9	44.0	42.0	50	1.0	2.2	0.0
		154	91.3	50.5	47.5	52	3.0	2.1	0.1
		213	94.8	54.0	51.0	54	4.0	2.3	0.1
		221	86.8	52.0	49.0	56	2.5	2.1	0.0
		241	92.8	56.0	52.0	56	1.5	2.2	0.0
HE / HP	6	18	99.7	58.0	49.0	49	1.5	2.1	0.0
		62	99.0	60.0	56.0	57	7.5	2.2	0.7
		75	95.8	58.0	55.0	57	4.0	2.0	0.2
		80	-	-	-	-	-	-	-
		111	93.5	54.0	51.0	55	2.0	2.1	0.0
		122	100.2	55.5	54.0	54	4.0	2.4	0.4
	8	87	102.0	60.0	56.0	55	7.0	2.1	0.4
		92	-	-	-	-	-	-	-
		115	108.2	63.0	60.0	55	2.5	2.0	0.1
		199	108.0	59.5	56.0	52	2.0	2.2	0.2
		216	100.2	57.0	54.0	54	-	2.4	0.0
		252	99.8	57.0	54.0	54	1.5	2.0	0.0