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Artificially extending photoperiod improves milk yield in dairy goats and is most effective in late lactation

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ABSTRACT

Short day length (i.e. winter) is associated with reduced milk yield from dairy animals. Dairy cows and sheep have been successfully housed under lights throughout winter to extend the day length and increase milk yield, very little data exists on the effect of extended day length on the milk yield of dairy goats. The current study was conducted over an eight week period from June to August, 2009. A total of 542 Saanan and Saanan British Alpine cross goats were used, all producing ≥1.5 L of milk per day, 253 in early lactation (5–20 days in milk) and 289 in late lactation (190–210 days in milk). Does were randomly allocated to either the control or the long day photoperiod (LDPP) groups, both were housed in open sided sheds with the LDPP group exposed to 16 h of light, while the other received a natural lighting regime. Milking was conducted by machine and yield was automatically recorded daily. Doe weights were measured at the beginning of the study and subsequently at four-week intervals. Milk and blood samples were collected from a subset ($n = 30$ and $n = 18$ respectively) of animals in each of the four groups, at day 0 and then every four weeks. Milk was analysed for protein, lactose, bulk milk cell count (SCC), fat and solids-not-fat. Blood plasma was assayed for glucose, non-esterified fatty acids (NEFA) and prolactin. Treatment with LDPP significantly increased ($P < 0.001$) milk yield, with the greatest response occurring in late lactation animals, who were producing 20% more milk than their control counterparts (+0.28 kg/d). An increase in milk yield was evident by week 1 in late lactation and week 4 in early lactation. Overall, goats exposed to LDPP showed a decrease in milk fat % ($P = 0.003$), milk protein % ($P < 0.001$), milk solids not fat ($P < 0.001$) and somatic cell count ($P = 0.012$), but a slightly higher milk lactose % ($P = 0.010$), when compared to control animals. LDPP increased milk protein ($P = 0.010$), lactose ($P = 0.032$) and SNF yield ($P = 0.034$) in late lactation animals with the response being greater after 8 weeks than after 4 weeks of treatment. Plasma prolactin ($P = 0.007$) and glucose increased with exposure to LDPP while the same animals showed a decrease in plasma NEFA. Liveweight increased ($P < 0.001$) with LDPP exposure, was greater ($P < 0.001$) in late lactation than in early lactation and increased ($P < 0.001$) with week of treatment. Exposure to LDPP significantly increased milk yield and lactation persistence in Australian dairy goats, most substantially in late lactation.

1. Introduction

The seasonal reproductive activity of subtropical and temperate goats is primarily influenced by changes in photoperiod (Bissonnette, 1941; Shelton, 1978). In autumn, as the days begin to shorten, a regular oestrus cycle is initiated

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and in spring when days are lengthening; anoestrus occurs. The effects of photoperiod have been exploited in the commercial goat industry by exposing goats to 16 h of light during winter through the use of artificial lighting. The goats are then returned to natural lighting and shorter day lengths, which results in mating activity in spring. Hence, the goats are six months out of phase with when they would naturally cycle, enabling year round milk production. Artificially extending day length has also resulted in increased milk production in several domesticated species. For example, a cycle of 16 h light and 8 h dark have, on average, resulted in dairy cows yielding 3–10% more milk (reviewed by Dahl and Petitclerc, 2003). This response generally occurs within three to four weeks of treatment imposition, can occur at all stages of lactation and may persist for up to twenty weeks. An even greater response has been seen in lactating sheep, with a 15% increase in milk yield after eight weeks exposure to artificially extended days (Morrissey et al., 2008) and a similar response has been observed in dairy goats (Garcia-Hernandez et al., 2007; Rodriguez-Martinez et al., 2011; Flores et al., 2011). The study by Garcia-Hernandez et al. (2007) indicates that the milk yield response to extended periods of artificially lengthened days may vary with either stage of lactation or time of year. Alternatively, goats may eventually become refractory to the stimulatory effects of prolonged day length (Flores et al., 2011). While the data are somewhat confounded, the greatest response occurred in late lactation during autumn, when the goats were exposed to long days only from the time of the summer solstice, rather than for the whole of lactation.

Imposing an extended photoperiod on lactating dairy goats may represent a practical, non-invasive method to substantially increase their milk yield. However, to date it has not been tested in Australia nor has the magnitude of the response at different stages of lactation or the duration of the response been defined. Therefore, the objectives of this study were to compare the magnitude of the effect of artificially extending day length (to 16 h day length) on milk yield in dairy goats in early and late lactation. Additionally, the study will determine whether a refractory response to the stimulatory effects of extended day length is seen within an eight-week period. It is proposed that artificially extending day length (to 16 h day length) would positively influence milk yield in dairy goats and the magnitude of this effect could vary depending on the stage of lactation.

2. Materials and methods

2.1. Experimental animals, housing and diet

The study was conducted on a total of 542 Saanan and Saanan British Alpine cross dairy goats from Meredith Dairy Victoria, Australia (Latitude 37°, 51′S, 144°, 4′E). The does ranged in age from two to five years and had all kidded prior to the experiment, with weaning occurring within one day of parturition. Does were stratified according to milk yield in the week before the experiment, and only does producing greater than 1.5 L/d were included in the experiment. Does selected were either in early (5–20 days in milk) ($n = 253$) or late (190–210 days in milk) ($n = 289$) lactation.

The animals were housed within their treatment groups, in open sided sheds with fresh bedding applied daily, with 1.5 m^2 of floor space per animal provided. Feed was provided ad libitum as a total mixed ration consisting of cereal and vetch hay, wheat, oats, canola meal and molasses, calculated to provide 32% NDF, 14% crude protein and 10 MJ ME per kg dry matter. The proportions were 400 g oats (in the bail), 1 kg barley hay, 0.5 kg vetch hay, 700 g barley and 300 g canola meal. A commercial mineral mix was added, along with 15 g sodium bicarbonate and 15 g bentonite.

2.2. Experimental design

Animals were randomly allocated to either the control ($n = 271$) or the long day photoperiod (LDPP) ($n = 271$) group. The control group received natural lighting and the LDPP group received 16 h of light, a combination of natural and artificial lighting. Treatment groups were housed in separate but co-located sheds so as to not expose the control animals to any additional lighting. The treatments were imposed for an eight-week period beginning on June 29th 2009 (Southern Hemisphere winter) which was 1 week after the winter solstice when the daylength was 9 h and 42 min. Prior to the beginning of the study each group was housed in their allocated sheds for one week as an acclimatisation period, during which time both groups received a natural lighting regime. Artificial lighting was provided by overhead fluorescent lights, calculated to provide 200 lx at eye level and was controlled by a 24 h timer. The lights came on at 1700 and turned off at 2330 h each day, as sunrise during this period was at approximately 0730 h and sunset at approximately 1730 h.

2.3. Measurements

The does were milked twice daily at 0600 and again at 1600 h, in a 36 sided herringbone system fitted with automatic cup removers and in-line electronic milk meters. The milking sheds were fitted with ICAR approved MM25SG milk meters (DeLaval), and the data was managed with an ALPRO processor and accessed through ALPRO – a Windows based program provided by De Laval. Milk volume was recorded daily and the average for the entire week was taken. Liveweight was recorded after the morning milking on the day before commencing the study (week 0) and at the end of weeks 4 and 8.

Milk samples were collected at day 0 before treatment and then at week 4 and end of week 8. The milk samples were collected from a randomly selected subgroup of animals consisting of 30 animals from each of the treatment groups, totalling 120 animals. The milk samples were chilled before being submitted to the Milk Analytic Services at DTS Food Laboratories, Victoria. The bulk milk cell count (SCC), fat, protein, solids-not-fat (SNF) and lactose content were then determined. Following IDF regulation, milk composition samples were heated prior to analysis for 10 min at 40 °C. Milk was then analysed for fat, protein and lactose using Milkoscan 4000.

Blood samples were collected at the same intervals as the milk samples, and were taken directly after milking. They were collected from a subgroup of animals, $n = 18$ per group totalling 72 goats and were repeated on the same individuals at each measurement point. All of the animals that had blood samples taken were also included in the milk sampling groups. Blood (10 mL) was removed by jugular venipuncture, using evacuated tubes containing the anti-coagulant lithium heparin and placed on ice. Plasma was then separated by centrifugation at 3000 rpm, collected and stored at −20 °C. The plasma was thawed after the eight week experimental period and assayed for prolactin, glucose and non-esterified fatty acids (NEFA) concentrations.

Plasma NEFA concentrations were analysed using Wako NEFA C Kit: Cat # 990-5401 which has been modified to enable analysis of large quantities of plasma in 96-well microtitre trays (Johnson and Peters, 1993). This assay is based around light absorption which is directly proportionate to the amount of NEFA present in the sample. Plasma glucose concentrations were measured using the Infinity™ Glucose Oxidase kit from Thermo Electron, Australia. The plasma prolactin concentrations were assayed at Monash University, Victoria in duplicate using Sigma (St. Louis, MO, USA), Lot 114F-0558, NOL-7135 as standard.

2.4. Statistical analysis

The effects of photoperiod treatment, week and stage of lactation, as well as the interaction between them, were all evaluated using restricted maximum likelihood (REML) suitable for a repeated measure analysis with individual goat as a random effect (Genstat: Version 13, release 13.1.0.4470). Some data that exhibited heterogeneity in the variance (e.g. plasma prolactin) were log-transformed before analysis and back-transformed data were graphed for presentation. When analysing the yield of milk components the assumption was made that the milk