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Effects of Supplement Feed on Cattle Behaviour on Pasture.

Effekt av tilleggsfôr på atferd hos storfe på beite.

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Sammendrag

Genetikk, tilleggsfôr, miljø og driftsstyring påvirker atferd og døgnrytme hos storfe på beite, som i sin tur kan gjenspeiles i ulike tidsbudsjett for individ og/eller grupper av dyr. Målet med denne oppgaven var å undersøke effekt av tilleggsfôr på beiteatferd og tilbakelagt distanse hos Zebukviger under regnsesongen i Tanzania. 18 kviger på 3-5 år ble fordelt på tre behandlinger; kun beite (PO), beite med tilleggsfôr (PS) og kun tilleggsfôr (SO). Tilleggsfôret ble distribuert to ganger daglig før og etter beitetid, og bestod av fri tilgang til ubehandlet halm og kraftfôr (5 kg / kvige / dag) for PS-gruppen, og fri tilgang til behandlet halm og kraftfôr (5 kg / kvige / dag) for SO-gruppen. Daglig beitetid var på åtte timer (0900-1700) og inkluderte kun PO- og PS-gruppene. I 11 sammenhengende dager på beite ble kvigenes atferd og tilbakelagt distanse samt vær og temperatur registrert i to daglige observasjonsperioder fra 0900-1200 og 1400-1700. Observasjonene bestod i skanning intervaller hvert tiende minutt, registrering av lokalisering på beite ved bruk av rutenett, og aktivitetsregistrering innenfor en av seks følgende atferder: (1) beiter, (2) går uten å beite, (3) drøvtygger stående, (4) drøvtygger liggende, (5) hviler og (6) andre atferder. Det ble også gjennomført atferdsobservasjoner ved fôringstidspunkt i seks dager. Gjennomsnittlig kroppsvekt forut forsøket var 229 ± 39 kg for samtlige kviger, og etter en måneds behandling var vektøkning for PO-, PS- og SO-gruppene på henholdsvis 13.2 ± 4.2 kg, 31.3 ± 6.8 kg, and 23.2 ± 7.4 kg.

Som forutsett førte tilleggsfôring til redusert beitetid for PS gruppen (i % av total tid), både ved morgen- (PO=88.4 ± 2.1, PS=78.5 ± 2.9, $P \leq 0.05$) og ettermiddagsobservasjoner (PO=72.1 ± 4.8, PS=60.3 ± 4.8, P=0.10). Dette førte til signifikant forskjell mellom gruppene i tid brukt på hvile (PO=2.9 ± 1.3, PS=7.5 ± 1.7, $P \leq 0.05$) og andre atferder (PO=2.2 ± 0.6, PS=5.4 ± 0.7, $P \leq 0.01$) under morgenobservasjonene. På ettermiddagen førte en ytterligere reduksjon i beitetid til en påfølgende økning i hvile (PO=7.7 ± 2.6, PS=11.5 ± 1.8, P=0.25) og andre atferder (PO=2.9 ± 0.5, PS=6.6 ± 1.2, $P \leq 0.05$). Drøvtygging stående hadde den største økningen i prosent av tid fra morgen (PO=1.0 ± 0.6, PS=1.8 ± 0.6, P=0.40) til ettermiddag (PO=7.2 ± 2.5, PS=10.9 ± 2.9, P=0.34).

Tilbakelagt distanse var lik mellom PO og PS gruppene på beite, hvorav avstanden var noe lengre om morgenen (PO=692.9 ± 64.6 m, PS=643.3 ± 50.3 m, P=0.55) enn om ettermiddagen (PO=600.4 ± 68.5 m, PS=595.5 ± 63.7 m, P=0.96). Når avstand ble arrangert etter værkategori gikk PO gruppen (1575.0 m) signifikant lengre enn PS gruppen (1362.5 m)

når det var overskyet ($P \leq 0.05$). I tillegg beitet PS gruppen konsekvent mindre enn PO gruppen, og forskjellene var signifikante i tre av fire værkategorier (delvis overskyet: P=0.18, overskyet: $P \leq 0.0001$, delvis sol: $P \leq 0.0001$ og sol: $P \leq 0.05$).

Ved fôringstider var det signifikante individuelle forskjeller i tid bruk på å spise kraftfôr ($P \leq 0.01$), gå/flytte seg ($P \leq 0.05$) og spise halm ($P \leq 0.05$) innen PS gruppen, men ingen individuelle forskjeller ble funnet i beitetid (P=0.54).

Abstract

Genetics, supplement feed, environment, and management affect cattle behaviours and diurnal patterns on pasture, thus reflecting individual and/or group difference in time budgets. The aim of this study was to investigate effects of supplement feed on grazing behaviour and distance travelled by Zebu heifers during mid-rainy season in Tanzania. 18 heifers aged 3-5 years were assigned to one of three treatments: pasture only (PO), pasture plus supplement (PS), and supplement only (SO). Supplements were distributed twice daily before and after pasture, and consisted of ad lib access to untreated straw plus concentrate (5 kg / heifer / day) for the PS group, and ad lib access to treated straw plus concentrate (5 kg / heifer / day) for the SO group. The restricted pasture management of 8 hours daily grazing time (0900-1700) included the PO and PS groups only. For 11 consecutive days on pasture, behavioural observations, distance travelled, weather type, and temperature was recorded during two daily observation bouts from 0900-1200, and 1400-1700. Behavioural observations included scan intervals every 10 min, registering location on pasture according to a grid map, and activity within one of six behaviours: (1) grazing, (2) walking without grazing, (3) ruminating while standing, (4) ruminating while lying, (5) resting, and (6) other. Additionally, six days of behavioural observations during supplement feeding times were conducted. Mean initial bodyweights (BW) prior to trial was 229 ± 39 kg for all animals, and after one month on trial mean BW gains were 13.2 ± 4.2 kg, 31.3 ± 6.8 kg, and 23.2 ± 7.4 kg, for the PO, PS, and SO groups, respectively.

As predicted, providing heifers with supplement feed decreased time spent grazing (in % of total time) during morning (PO=88.4 ± 2.1, PS=78.5 ± 2.9, $P \leq 0.05$) and afternoon (PO=72.1 ± 4.8, PS=60.3 ± 4.8, P=0.10) observation bouts. Thus, morning activity created significant differences in resting (PO=2.9 ± 1.3, PS=7.5 ± 1.7, $P \leq 0.05$) and other behaviours (PO=2.2 ± 0.6, PS=5.4 ± 0.7, $P \leq 0.01$). During the afternoon, a further decline in time spent grazing successively increased time spent resting (PO=7.7 ± 2.6, PS=11.5 ± 1.8, P=0.25) and other behaviours (PO=2.9 ± 0.5, PS=6.6 ± 1.2, $P \leq 0.05$). Ruminating while standing had the largest increase in percent of time from morning (PO=1.0 ± 0.6, PS=1.8 ± 0.6, P=0.40) to afternoon (PO=7.2 ± 2.5, PS=10.9 ± 2.9, P=0.34).

Distances travelled remained equal between PO and PS groups on pasture, with slightly longer distances travelled during morning (PO=692.9 ± 64.6 m, PS=643.3 ± 50.3 m, P=0.55)

than afternoon (PO=600.4 ± 68.5 m, PS=595.5 ± 63.7 m, $P=0.96$) bouts. When blocked by weather categories, the PO group (1575.0 m) walked significantly farther than the PS group (1362.5 m) during overcast weather ($P \leq 0.05$). In addition, the PS group consistently spent less time grazing than the PO group, and differences were significant in three of four weather categories (mixed overcast: $P=0.18$, overcast: $P \leq 0.0001$, mixed sunny: $P \leq 0.0001$, and sunny: $P \leq 0.05$).

During supplement feeding, there were significant individual differences in time spent eating concentrate ($P \leq 0.01$), walking/relocating ($P \leq 0.05$), and eating straw ($P \leq 0.05$) within the PS group, yet no individual differences were found in time spent grazing on pasture ($P=0.54$).

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1.0 Introduction

To grazing cattle individual aspects of breed, age and sex (Aharoni et al., 2009), feed composition (Caton and Dhuyvetter, 1997), management (Arachchige et al., 2013), and environmental circumstances (Butt, 2010), influence behaviour on pasture. In Tanzania, utilization of accessible pasture is essential to the majority of small-scale farmers (MLFD, 2010), yet livestock production during dry seasons is limited by both low biomass productivity and crude protein (CP) concentration of the standing hay forages in preserved grazing lands (Rubanza et al., 2005).

Introducing supplement feed can help sustain productivity throughout seasons, but as with other factors, they affect grazing behaviour depending on feed composition (Hess et al., 1994), supplement method (Brandyberry et al., 1991), substitution rate (Pérez-Prieto et al., 2011), associative effects (Dixon and Stockdale, 1999), time of supplementation (Adams, 1985), etc. Thus, a better understanding of forage utilization and energy expenditure in livestock calls for a greater ethological focus on productivity measures (Vavra and Ganskopp, 1998).

The aim of this study was to investigate effects of supplement feed on cattle behaviour and distance travelled by Zebu heifers on a restricted mountain plateau pasture in Tanzania during mid-rainy season. Additionally, behavioural observations were conducted during supplement feeding times to investigate potential individual time-budget differences on pasture. Based on previous findings I predicted a decrease in time spent grazing and distance travelled for supplemented animals on pasture, and a decrease in time spent grazing during sunny weather for all animals (and even more so for supplemented heifers). I also predicted an individual decrease in time spent grazing for heifers spending most time eating supplement.

The current project involved the departments of International Environment and Development Studies (Noragric), and Animal and Aquacultural Sciences (IHA) at The Norwegian University of Life Sciences (NMBU), and the Sokoine University of Agriculture in Tanzania (SUA). The two universities are involved in cooperating projects undertaken the "Enhancing Pro-poor Innovation in Natural Resources and Agricultural Value Chains" (EPINAV) initiative of 2011, which purpose is to "enhance productivity, livelihood security and human capacity of target communities to utilize pro-poor and climate change adapted innovations in agriculture and natural resources value chains" (SUA, 2010).

2.0 Literature review

2.1 Agriculture and livestock challenges in Tanzania

Pastoralism, the use of extensive grazing on rangelands for livestock production, is considered to be one of the key production systems in the world's drylands (FAO, 2001), and Tanzania has major unexploited agricultural resources within increased utilization of arable land, accessible pasture and productivity of livestock. Despite these possibilities, agricultural growth is not reaching its' potential. Factors such as shifting climates, extensive low input-low output production systems, livestock holders' restricted opportunities of economic investments and few collective breeding goals within traditional husbandry contribute to Tanzania's developmental challenges (MLFD, 2010).

Tanzanian cattle are kept primarily for beef production, and secondary for milk, but delayed first calving, low calving rates and associated long calving intervals give rise for concern for the current state of productivity (MLFD, 2010, Mukasa-Mugerwa, 1989). Of Tanzania's 19.2 million cattle, less than 90.000 are bred within commercial beef production, thus the greater proportion of cattle exist within traditional (pastoralist) livestock management. Productivity figures remain well below the expected standards in both sectors. Additionally, milk yields are far from reaching processing capacities, and the demand supply gap for processed dairy products is filled by imports (MLFD, 2010).

2.2 Cattle behaviour, breed differences and behavioural adaptations to climate

2.2.1 Cattle behaviour and diurnal rhythm

Natural behaviour repertoires exist in all species, and in mapping such of cattle, Kilgour (2012) reviewed a series of studies made on various parts of the cattle behaviour repertoire. In total, 40 identifiable behaviour categories were recognized, of which the most abundant were grazing, ruminating (more lying than standing) and resting. When investigated, most grazing was performed during daytime and little during nighttime. Furthermore, Kilgour et al. (2012) found that 95 % of cattle time budgets on pasture were occupied by grazing, walking, ruminating and resting (the latter two included both standing and lying), including observations of two main grazing concentrations during sunrise (0600) and sunset (1800). Brandyberry et al. (1991), Krysl and Hess (1993), Sheahan et al. (2011), and Sheahan et al.

(2013b) reached similar conclusions regarding diurnal grazing activity. Even in intensive rearing systems with bulls stocked in pens on ad lib access to a total mixed ration, Cozzi and Gottardo (2005) found predominant feeding activities during morning and evening, with subsequent reductions in feeding behaviour during the evening and overnight. Also, nighttime grazing was more likely to occur when daytime temperatures exceeded 25°C (Krysl and Hess, 1993), and occurred more frequently for non-supplemented animals than supplemented animals (Scaglia et al., 2009)

Grazing behaviour in itself can be separated into intense grazing (stand-still grazing) or search grazing (walking and grazing, a more selective process). Under a continuous grazing system, approximately equal amounts of time were dedicated to both grazing modes (Walker and Heitschmidt, 1989), and search grazing was generally observed towards the end of a grazing bout whereas supplemented animals spent more time intense grazing than non-supplemented animals (Barton et al., 1992).

2.2.2 *Bos indicus* (Zebu) traits

Grazing behaviour is affected by cow genetics (Sheahan et al., 2011), with different dispositions related to different breeds of cattle and ruminant species. The indigenous cattle of Tanzania, most prominently represented by the *Bos indicus* breed shorthorn Zebu, are well adapted to tropical climates due to their coat, hide, skin and hematological attributes (Francis, 1965, Hansen, 2004, Turner, 1980).

Zebu cattle have acquired genes that confer thermotolerance at the physiological and cellular levels, meaning that Zebu cattle are better able to regulate body temperature in response to heat stress than are cattle from a variety of *Bos taurus* breeds of European origin (typically adapted to a more moderate climate) (Hansen, 2004). This ability for regulation of body temperature during heat stress is due to lower metabolic rates as well as increased capacity for heat loss, thus reductions in milk and meat yields for *B. indicus* breeds are less than those for *B. taurus* breeds. Zebu cattle also experience less reduction in feed intake, growth rate, and reproductive function in response to heat stress, all of which are important adaptive factors for survival in extreme climates (Hansen, 2004). Even so, compared to *B. taurus* cattle, Zebus are lower in reproduction, later maturing, slower growing and lower in beef quality (Turner, 1980). They also reach low mature live bodyweights (BW) because of low genetic potential and poor husbandry practices, and the time taken by an animal to attain puberty and sexual maturity also depends on the quality and quantity of feed available, which affects growth rate (Mukasa-Mugerwa, 1989).

There is controversy regarding the use of Zebu cattle in crossbreeding: on one hand they have preferable genetic adaptations and high heterosis effects (Turner, 1980), while on the other hand success may have been limited due to other unfavorable characteristics of Zebu, which calls for emphasis on heritability of desirable versus undesirable traits (Hansen, 2004).

2.2.3 Performance and comparisons of low versus high productive cattle

Compared to *B. taurus* cattle (often high productive), the evolution of cattle in tropical climates (often low productive) can reflect in different displays of behaviour, time budgets, and energy expenditure (Aharoni et al., 2009, Langbein and Nichelmann, 1993, Prendiville et al., 2010).

Smaller cattle spend more time grazing and walking than larger cattle, demonstrated by Aharoni et al. (2009) when comparing native Baladi (BA) cattle to Beefmaster × Simford (BM) cattle in Israel. BA cattle also spent less time standing still and travelled longer distances than the larger BM cattle. In contrast, Prendiville et al. (2010) found no initial difference between the smaller Jersey cattle and the larger, more productive Holstein-Friesian (HF) cattle. Yet, when behaviour was expressed per unit of BW, Jerseys spent more time grazing, less time ruminating, had more bites per minute and day, a greater bite size, and a higher rate of grass dry matter intake (GDMI). Similar masked behaviours were found when Langbein and Nichelmann (1993) separated native Siboney de Cuba (SC) cattle from mixed groups with HF cattle. When mixed, both breeds showed the same pattern of reduced grazing activity from dry season to rainy season, yet when separated, the SC cattle significantly increased time spent grazing during the rainy season. Results also found that HF cattle were severely challenged by the change in climate from dry to rainy season and withdrew to shade more often than SC cattle.

Despite reduced costs for locomotion, estimated heat production of the BA cattle was greater than the BM cattle in all seasons due to their greater level of activity (Aharoni et al., 2009). Similar conclusions for energetic cost of travel were drawn by Havstad and Malechek (1982) and Brosh et al. (2010), reporting higher energy expenditure for animals grazing and walking compared to standing still, and higher for vertical travel than horizontal.

In comparison to other ruminant species, Zebu crossbreds were surpassed by river buffaloes (Fundora et al., 2003). Even though feeding behaviour was much alike between the two species, buffalo BW gains were higher than Zebus' despite less time spent eating. River buffaloes also spent more time ruminating and resting than the bulls, suggesting a higher total feed utilization for buffaloes.

2.2.4 Tanzania mountain climate and the effects of weather on grazing behaviour

The northwestern parts of Tanzania are characterized by a mountain savannah climate consisting of mild and wet winters, and dry and hot summers. The rainy season lasts from November to April and brings a mean annual rainfall of 479 mm (registered on-site at Mulbadaw Farm) while July through October moths are completely dry. Such seasonal constraints affect forage availability and feeding habits, requirements and plant species preferences of livestock (Ngwa et al., 2000, Selemani et al., 2013) which is important to management and knowledge of local rangeland (Selemani et al., 2012). Across seasons, the change in sward characteristics and chemical compositions of plant species on pasture also affect behaviour in livestock (Selemani et al., 2013, Stobbs, 1975, Scarnecchia et al., 1985).

Studies of seasonal effect on grazing behaviour in both Africa and USA found that more grazing took place when pasture forages were abundant (during wet season in Africa and summer in USA) (Brandyberry et al., 1991, Butt, 2010, Dodzi and Muchenje, 2012, Selemani et al., 2013), while in opposite seasons, more time was spent walking. In contrast, Allden and Whittaker (1970) and Scarnecchia et al. (1985) found that grazing time increased with decreasing forage availability, and Butt (2010) also observed an increase in simultaneous grazing and walking during dry season, indicating more search as forage became scarce.

Different weather types also affect cattle behaviour within seasons (Charlton et al., 2011, Langbein and Nichelmann, 1993, McGuire et al., 1991, Tucker et al., 2008, Uzal and Ugurlu, 2010). Feeding behaviour and optimum feed intake of cattle increases when weather conditions are optimal, hereby decreasing during rain (Charlton et al., 2011) and during high ambient temperatures and increased sunlight (Uzal and Ugurlu, 2010). Furthermore, Langbein and Nichelmann (1993) observed that nearly all activity ceased when temperatures exceeded 28°C, contributing to the importance of access to shade with increasing solar radiation and withdrawing from direct sunlight (Tucker et al., 2008).

2.3 Effect of pasture management on grazing behaviour of cattle

Traditional pastoralist herding is often the case of native cattle in Tanzania, and maintaining high frequencies of grazing and walking throughout the dry season (Bayer, 1986, Butt, 2010) can be results of tracking strategies and altered destinations (Butt, 2010). On the other hand, management factors such as size of pasture (Hart et al., 1993) and time on pasture (Kennedy et al., 2009, Smith et al., 2006) can influence cattle behaviour differently. Whether on continuous large or small pastures, or time-controlled rotations systems, Hart et al. (1993) found that the major factor controlling distance travelled was, in fact, distance to water. Thus, utilization of the larger pastures declined with distance from water. Longer travelling distances resulted in lower BW gains of both cows and calves, yet both heifer and dry cow BWs remained unaffected by grazing systems and pasture size.

Kennedy et al. (2009) and Kilgour et al. (2012) found that decreased daily access time to pasture increased percentage of total time spent grazing, indicating adaptive abilities in cattle to consume forage based on availability. When continuously on pasture (22 hours), grazing time amounted to 41-61 % of total time, but when time was restricted to either 9 hours, 2 × 4.5 hours, or 2 × 3 hours, Kennedy et al. (2009) discovered that time spent grazing increased to 81, 81, and 96 %, respectively. Even so, total time spent grazing (in minutes) was highest for animals continuously on pasture, and post-grazing sward height indicated better pasture utilization by this group and the 2 × 4.5 h group. In contrast to this, Smith et al. (2006) did not find significant differences in time spent grazing between groups (7 hours, 11 hours, or 7 hours plus nocturnal supplement), and grazing efficiency was significantly reduced with more time on pasture. Nocturnal supplements did not affect grazing behaviour.

2.4 Effects of supplement feed and feed distribution systems on cattle behaviour

2.4.1 Supplement feed and livestock production

Forage intake and digestibility are often affected by supplements (Adams, 1985, Sheahan et al., 2013a), and livestock production is usually either enhanced or unaffected by energy supplementation (Caton and Dhuyvetter, 1997). Effects of supplements can be observed as minimized BW losses during winter grazing, improved intake and utilization of forage (DelCurto et al., 1990), as well as improved BWs and reduced time spent grazing (Schauer et al., 2005), the latter of which is a fairly consistent finding in supplement feed trials (Arachchige et al., 2013, Barton et al., 1992, Scaglia et al., 2009, Sheahan et al., 2013a, Hess et al., 1994). Even enhanced reproductive development was seen in beef replacement heifers consuming low and medium quality forages when low-starch supplements were given daily (Moriel et al., 2012), as well as increasing milk yields (Kakengi et al., 2001, Sheahan et al., 2013a, Sheahan et al., 2013b).

2.4.2 Effects of supplement feed content on behaviour and feed utilization

Supplement feed and content, whether concentrate, minerals, silage or forage, affects grazing and DMI (Hess et al., 1994, Valente et al., 2013, Bodine and Purvis, 2003), BW gains (Rubanza et al., 2007, Rubanza et al., 2005), and utilization of forage (Barton et al., 1992).

Change in feed intake and digestibility of feed can be related to interactions between feed components, called associative effects. Positive associative effects (increased energy intake) are usually due to the grain providing a nutrient that is deficient in the forage, and negative associative effects (decreased energy intake) are normally associated with lower intake and digestion of forage components (Dixon and Stockdale, 1999). As for low quality forages, a minimum level of 7 % crude protein (CP) is necessary in the diet to sustain microbial growth and support efficient fibrous carbohydrate digestion, and for cattle in tropical climates supplementation with nitrogenous compounds that raise CP levels up to 11 % optimize the use of low quality tropical forage (Lazzarini et al., 2009). Similarly, studies of ruminants in Tanzania found that native pasture forages alone could not sustain animal productivity unless corrected for protein. Leaf meal supplements provided for steers grazing native pastures during dry season improved BW gains and prevented weight loss (Rubanza et al., 2005), which also applied to East-African goats receiving different types of browse tree leaves supplements (Rubanza et al., 2007).

Substitution effects, or substitution rate (SR), involves pasture refused relative to supplement fed and reflects a decrease in time spent grazing (Pérez-Prieto et al., 2011, Sheahan et al., 2013b, Stockdale, 2000). SR is affected by different parameters such as supplement content, and the quality and quantity of pasture. Stockdale (2000) studied effects of supplements on different pastures, and found that grass-dominant pastures resulted in a higher SR than white clover-dominant pastures, as well as an increase in SR with increasing amounts of supplement given. Sheahan et al. (2013b), on the other hand, investigated effects of different treatments on the same pasture. Results showed that animals fed starch-based concentrate reduced pasture DMI more so than animals fed fiber-based concentrate, thus SR was higher for the starch group than the fiber group even though time spent eating was similar between the two treatments. Odadi et al. (2013) compared forage selection between protein-supplemented and non-supplemented cattle. During dry season, the supplemented cattle reduced consumption of forbs by 76 %, and increased selection of grasses otherwise avoided, suggesting a change in forage preference and intake due to supplement feed.

Both Valente et al. (2013) and Bodine and Purvis (2003) studied effects of carbohydrate and protein supplements on grazing behaviour, the former of young bulls on tropical pastures and the latter of steers on the USA prairie. Combined, results showed that carbohydrate supplements reduced pasture intake (Valente et al., 2013) and grazing intensity and harvesting efficiency (Bodine and Purvis, 2003) more so than protein supplements. Yet, while Valente et al. (2013) observed no effect of supplements on grazing behaviour, Bodine and Purvis (2003) found that carbohydrate supplemented animals reduced grazing time.

In addition to protein and carbohydrate concentrate supplements, Hess et al. (1994) also included a treatment of alfalfa hay, while Phillips and Hecheimi (1989) studied effects of forage supplementation only. Hess et al. (1994) discovered that grazing time was related to type of supplement feed and a decrease in biomass availability: in March, animals receiving alfalfa and protein concentrate grazed significantly less than others, while in April, alfalfa animals grazed most of all the supplemented groups. This highlights the importance of customizing supplements to current pasture forage content. The study also revealed that harvesting efficiency was greater for animals receiving protein concentrate compared to the other groups. Phillips and Hecheimi (1989) offered first and third cut silage supplements to cows grazing 4- or 8-cm pastures, but no effects of silage type were detected on ingestive behaviour. Grazing time decreased when silage was fed at 4- rather than at 8-cm pastures, and supplements increased time spent ruminating.

2.4.3 Effects of supplement feed management on behaviour and feed utilization

Grazing behaviour, diurnal rhythm, time budgets and feed intake can be affected by time of supplementation (Adams, 1985, Barton et al., 1992, Scaglia et al., 2009, Schauer et al., 2005, Sheahan et al., 2013a) and supplementation method (Arachchige et al., 2013, Brandyberry et al., 1991). Generally, supplement feed decreases time spent grazing, but alternating feeding times have had less consistent effects.

Barton et al. (1992) found no effect on grazing behaviour between morning (0600) and midday (1200) protein supplements. A similar study also included corn supplements in the afternoon (1600), whereas the afternoon group grazed less and had a lower bite rate than those supplemented in the morning and midday (Scaglia et al., 2009). Sheahan et al. (2013a) found little effect of time of supplementation, but in contrast to Scaglia et al. (2009) the small reduction in grazing time occurred after morning milking for cows supplemented in the morning. No such effect was detected for afternoon supplemented cows following afternoon milking. Additionally, afternoon supplemented cows spent more time ruminating, whereas morning supplemented cows spent more time resting.

When feeding with forage only (FO), forage plus supplemental corn in the morning (AM), or afternoon (PM), Adams (1985) discovered that forage intake was greater for FO than both AM and PM steers. Thus, corn supplements substituted forage, and total intake was lower for morning than afternoon supplemented steers. AM steers also grazed less than both FO and PM steers. Similar for the supplemented groups was the fact that both refrained from grazing 2-4 h after supplementation, but compensated by shifting grazing activity to other times of the day compared to the non-supplemented steers. Distance travelled was lower for FO steers than for AM and PM steers, with no difference between the latter (however, this study did not distinguish between grazing and walking without grazing).

Schauer et al. (2005) altered frequency of supplement distribution, and treatments included no supplement, protein supplement every day, and protein supplement every 6 days. Cow BW and body condition scores were greater and grazing was less for supplemented than non-supplemented cows, but with no difference between supplemented groups. Distance travelled, maximum distance from water, cow distribution, DMI, dry matter digestibility, and harvest efficiency were not affected by protein supplementation or frequency.

As well as altering distribution times for supplement feed, the feed itself can be managed differently (Arachchige et al., 2013, Brandyberry et al., 1991). Arachchige et al. (2013) studied cows on ryegrass pasture assigned to one of two treatments: grains fed in dairy twice daily with silage offered in the paddock, or a mixed ration offered twice daily on a feed-pad. Cows receiving mixed rations spent less time grazing than cows fed grains and silage separately. In addition, each treatment had four different amounts of supplement (8, 10, 12, 14 kg DM/cow/day), and grazing time declined significantly with increasing levels of supplement. Time spent ruminating was least for cows in the treatment with the lowest amount of supplementation, and increased but was not different for the three higher amounts.

Brandyberry et al. (1991) altered supplement methods of steers by self-feeding with salt as limiting agent, and hand-feeding with and without salt. Supplementation method had no or slight positive effects on forage utilization, and little influence on grazing behaviour.

2.4.4 Individual and group behaviour during supplement feeding

Even though cows can adjust daily dry matter intake (DMI) by altering number of daily meals and the average meal size (Grant and Albright, 1995), grouping strategy is a primary component of the cow's environment that can influence DMI as a result of its potential impact on cow comfort, competition for feed, water, and other resources, and herd health. Feed intake will generally improve when cows are allowed access to feed when they want to eat (Grant and Albright, 2001). Even so, a highly competitive time period at the feed bunk coincides with return of cows from milking and when fresh feed is delivered (Friend and Polan, 1974).

Even though early research with small groups of cows indicated that the maximum effect of dominance hierarchies and competition lasted for 30 to 45 min after delivery of fresh feed (Friend et al., 1977), Olofsson (1999) found that when a competitive situation existed at the feed bunk, dominant cows typically spent more total time eating than cows of lower social rank. Cows showed highly adaptive abilities as competition per feeder increased, e.g. shorter average eating times and accelerated eating rates, but if feed was limited, dominant cows consumed 14% more feed than submissive cows, thus DMI of submissive cows suffered. These observations indicate that relative to group size, bunk space and feed availability should not be limited in order to avoid reductions in DMI for the more submissive cows.

2.5 Aim of study

The aim of this study was to investigate effects of supplement feed on cattle behaviour and distance travelled by Zebu heifers on a restricted mountain plateau pasture in Tanzania during mid-rainy season.

Results are discussed based on the literature presented above, and includes additional paragraphs on supplement feed content and management.

3.0 Materials and methods

The present study was conducted on Mulbadaw Farm in the Hanang district and Manyara region of Tanznia (longitude 34°36'E, latitude 4°6'S, altitude 1750 m ASL) in February – March, 2014, and was part of a 9-month supplement feeding trial to investigate effects on growth performance and conception rates of Zebu heifers. In order to improve milk production to meet local demands, the present heifers are planned to be inseminated with Norwegian Red. The Norwegian Red is a dual-purpose breed with a significantly higher milk producing capacity, thus the next generation of Zebu crosses are expected to show an improved milking yield.

3.1 Experimental design

This study involved 18 heifers in a 9-month supplement feeding trial, with six heifers assigned to each of three treatments; pasture only (PO), pasture plus supplement (PS), and supplement only (SO). Supplements consisted of untreated straw plus concentrate for the PS group, and treated straw plus concentrate for the SO group. A restricted pasture management of 8 hours daily grazing time (0900 – 1700) was assigned to the PO and PS groups, while the SO group was held in an outdoor enclosure during the entire duration of the supplement feed study.

3.2 Animals

18 heifers aged 3-5 years (*B. indicus* breeds mature slowly) of the breed short horn Zebu were used for the supplement feeding trial, of which 13 belonged to Mulbadaw Farm, and the remaining five were voluntarily contributed by surrounding local pastoralists. Prior to study, all 18 animals were stocked for one week together as a single group, marked with identifiable ear tags, and BW estimated by use of Rondo weight measuring tape. Mean BW of the group was 228.6 ± 9.2 kg. The size difference was mainly related to the more uneven BWs of the heifers belonging to the pastoralists.

The heifers were then blocked by weight and randomly allotted into the three treatment groups (now containing six heifers each), with mean initial BWs of 218.2 ± 13.4 kg, 231.3 ± 11.5 kg, and 239.2 ± 21.6 kg for the PO, PS and SO groups, respectively (Table 1). Throughout the study, heifers were BW measured on a weekly basis before access to morning supplements (and pasture).

Table 1. Mean ± SE (kg) of initial BW, BW after first month of treatment, and BW gain for PO, PS and SO groups after first month of treatment.

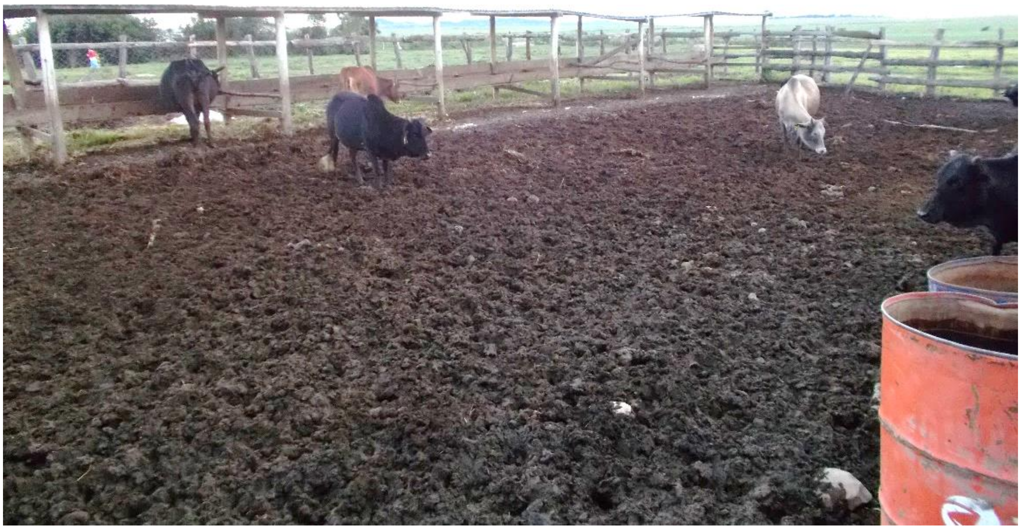
	PO	PS	SO
Initial BW	218.2 ± 13.4	231.3 ± 11.5	239.2 ± 21.6
Weight after one month	228.3 ± 13.4	259.7 ± 19.2	262.3 ± 24.7
Mean BW gain	13.2 ± 4.2	31.3 ± 6.8	23.2 ± 7.4

The PS group had the highest mean BW gain throughout the first month of the trial, followed by the SO and then the PO group (Table 1). Variation changed similarly, with most variation within the PS group, followed by the SO group, while the PO group remained equal. This indicates a larger variety of feed utilization and feeding behaviour within the PS group.

3.3 Enclosures

The PS (Picture 1) and SO (Picture 2) groups were kept in separate enclosures located outside the pasture site, while the PO group (Picture 3) had an isolated enclosure on the pasture site. The PS and SO enclosures were approximately 380 m^2 and 270 m^2, respectively. The enclosures were situated adjacent to one another, both surrounded by the same 1.5 m tall fence, consisting of wooden pillars, boards, and a chain link fence. The PO enclosure was approximately 200 m^2.

Picture 1. PS enclosure with feeding trough at far end.



Picture 2. SO enclosure with feeding trough.

Picture 3. PO enclosure on pasture site.

The PS and SO enclosures each had one feeding trough, measuring 14.0 m in length and 0.4 m in depth. Troughs were evenly divided into 14 feeding spaces; the seven feeding spaces on the right hand side used for concentrate distributions, and the seven feeding spaces on the left hand side for distribution of straw. Each trough had a 14 × 2.5 m built-over roof of aluminum that provided cover for the feeding area. The roofs also functioned as shelter during heavy rain. Additionally, the enclosures both contained holding pens suited for 1-3 cattle. Also, all enclosures contained one water source made out of one half of a tractor tire (Picture 1).

Pictures 4 and 5. Feeding trough at SO (left) and PS (right) enclosures.

Picture 6. PS enclosure with holding pen to the right with white heifer partly inside.

Starting with the initiation of the feeding trial and main behavioural observations, the PS group was led from the outer enclosure to the pasture site every morning, either by an animal caretaker or the study observer. Simultaneously, the PO group was let out of its' respective enclosure, and from here on the two groups were rejoined at approximately the same pasture starting point and grazed as a single herd. In the afternoon, the two groups were separated and led back to their respective enclosures at the same time.

3.4 Pasture site

The topography of the land was generally flat, with little slopes or hills. The pasture site surrounded the farm center and main buildings, which, in turn, had restricted access through gates extended by a two-meter tall acacia hedge. As well as keeping the heifers within a controlled area, the restricted pasture also functioned as a barrier against intermixing with nomadic cattle herds on the outside of the gated area. Available pasture space was approximately 7.3 ha. While on pasture heifers were followed by a herder (or study observer), during which time they were free to graze anywhere within the boundaries of the pasture site.

There were several trees (acacia) and other shaded areas on pasture, including a walk-through shed, access to the goat stall, and tall buildings casting shadows at various times during the day. Plant species important to pasture foraging is presented in Table 2. Mean CP content of pasture species was 7.2 % of DM.

Table 2. Chemical composition of key forage species on pasture, expressed in DM percentage and other components as percent of DM: experiment carried out during mid-rainy season at Mulbadaw Farm in 2013.

Sample	DM	Ash	CP	NDF	ADF	INVDMD	INVOMD
Bothriochloa isculpta	93.33	14.59	2.32	72.16	43.23	34.41	29.86
Cenchrus ciliaris	92.59	6.25	6.37	67.21	46.26	51.74	53.47
Cynodon dactylon	92.89	5.44	4.77	73.67	49.58	28.37	31.24
Cyperus rutondus	90.37	17.79	8.53	67.21	39.34	42.85	41.60
Hyparrhenia rufa	93.36	7.62	1.90	86.24	53.86	31.94	34.08
Indigofera indica	90.41	21.62	12.08	49.87	37.61	60.36	56.21
Tribulus terrestris	90.55	20.29	14.20	45.19	33.19	33.39	31.71

Plant species on pasture have rapid growth starting with the onset of the rainy season (vegetative state), thus leaving a short period of time for consumption of protein rich grass before plants further develop and replace CP with NDF (flowering state). Late season diets consisting of low-protein and high-fiber content, tend to limit intake and digestibility (Safari et al., 2011a), resulting in a higher forage consumption in vegetative than flowering stages of grasses due to characteristics of each phenological stage (Neto et al., 2013). Despite the lack of analysis of the current pasture, chemical content of plant species were assumed to be comparable to findings carried out at the same location the year before (Table 2), and with the general findings and development of pasture and grazing species in similar tropical areas by Safari et al. (2011a). Thus, the current pasture was concluded to be of mediocre to good nutritional value, as it was mid-rainy season and the PO heifers gained an average BW of 10.1 kg during the behaviour study on pasture.

The pasture site had one water source located in square F-4 (Attachment 1). Additionally, during rainfall, pits would fill rapidly, offering scattered and multiple access points to rainwater.

3.5 Feeds, feed treatments and feed distribution

The supplement feed consisted of untreated wheat straw (UTS), treated wheat straw (TS) and concentrate. All supplements were farmland residue, and straw had been stored for nine months since last year's harvest and baling in June 2013. Both UTS and TS was offered at ad libitum basis (20 % refusal rate), and both supplemented groups received 30 kg of concentrate daily, in theory providing each heifer with 5 kg (63 MJ) of concentrate every day.

The supplemented groups, though stocked in separate enclosures, were fed simultaneously and as groups twice daily, based on the daily pasture rhythm of the PS group: once in the morning before PS release to pasture (0730), and once upon return from pasture in the afternoon (1700). Each morning, prior to new supplement distributions, all refusals from the previous day were collected, weighed and discarded.

The TS was submitted to a process of additives consisting of urea (H_2NCONH_2), calcium oxide (CaO) and water (H_2O), where large plastic sacks ensured conservation and fermentation of the treated straw. The Norwegian fermentation method, described by Mo (2004), dissolves the lignified cellulose of straw into nutritionally accessible cellulose for the ruminal microbes. In tropical climates, the use of urea as source of ammonia is more efficient than in colder climates, as the enzyme which cleaves urea (urease) has an activation temperature above 20° C.

Straw bales weighed approximately 11 kg and each individual sack contained 17 bales of straw, totaling at 187 kg of straw per sack. Even amounts of urea and calcium oxide (6 kg each) were diluted in 200 liters of water, which was the treatment solution calculated for each sack. The straw was blown into the sack through a motorized pipe system, simultaneously with dispensing the water solution of additives over the straw. Each plastic sack weighed approximately 400 kg including both straw and the weight of the diluted water solution. The sacks of TS were then sealed and left to fermentation processes for the next 7-10 days.

The concentrate supplement content included maize bran (70 %) and sunflower seed cake (27 %) (Table 3), as well as mineral mix (2 %) and salt (1 %). The mineral mix consisted of (in %) Calcium (29.94), Sodium (0.4), Phosphorous (11.0), Chloride (27.0), Nitrate (27.0), Magnesium (3.0), Iron (0.5), Manganese (0.5), Zinc (0.5), and Copper (0.16). The concentrate fragments were grinded and fed to the heifers as a dry mash mix. DM content of the concentrate was approximately 93 %, and the CP level was approximately 15.5 %, thus improving the total intake of CP for the PS group when pasture grasses contained an average of 7.2 % of DM.

Table 3. Chemical composition of concentrate fragments: experiment carried out in Mulbadaw in 2013, expressed in DM percentage and other components as percent of DM.

	DM	Ash	CP	NDF	ADF	INVDMD	INVOMD
Maize bran	92.53	4.40	10.89	35.58	4.88	60.81	66.87
Sunflower seed cake	93.84	5.77	19.96	60.89	42.69	57.68	60.98

At the time of the behavioural study, no nutritional analysis of energy value had yet been conducted on the supplement, but both straw (TS and UTS) and concentrate was presumed to be of similar chemical composition as the findings made by Safari et al. (2011b) (Table 4).

Table 4. Chemical composition of feed (Safari et al., 2011b).

	Concentrate	Treated straw	Untreated straw
Dry matter, DM (g/kg)	910	580	890
Crude protein (g/kg DM)	173	55	40
Ether extract (g/kg DM)	134	12	16
Ash (g/kg DM)	52	98	106
NDF (g/kg DM)	391	732	756
ADF (g/kg DM)	223	484	448
Crude fibre (g/kg DM)	146	334	340
INVDMD (g/kg DM)	546	590	360
INVOMD (g/kg DM)	546	570	360
Nitrogen free extract	405	81	388
Metabolizable energy (MJ/kg DM)	**12.6**	**7.83**	**5.64**

During the first four weeks of the supplement trial, the PS and SO groups differentiated in terms of mean amounts of supplement intake (Table 5). The PS group ate little UTS compared to TS intake by the PS group, while both groups ate similar amounts of concentrate. Even so, intakes were lower than the provided 5 kg per heifer, leaving residual concentrate amounts of 0.5 and 0.4 kg per heifer in the PS and PO groups, respectively. Mean total daily energy intake for each heifer was 60.5 MJ and 77.5 MJ for PS and SO groups, respectively, yet mean BW gain (Table 1) was 8.1 kg more for the PS group permitted grazing time on pasture.

Table 5. Mean daily supplement intake (kg + MJ) per animal for PS and SO animals first month of trial.

	PS		SO	
Supplement feed	**Kg**	**MJ**	**Kg**	**MJ**
Concentrate	4.5	56.9	4.6	58.2
Straw*	0.6	2.5	2.5	19.3
Total	5.1	60.5	7.1	77.5

*Straw constitutes of UTS and TS for PS and SO, respectively.

3.6 Weather

Ambient air temperatures during pasture observations were recorded by use of an outside wall-mounted thermometer (in shade) five times daily (0900, 1100, 1300, 1500, and 1700) (Figure 1). The lowest registered temperature was 15.0°C, and the highest was 28.0°C. Daily lowest and highest temperature changes ranged from 2.0 to 6.2°C. Weather type was registered every ten minutes as either sunny, partly cloudy, overcast, or light rain. No other weather conditions occurred during pasture observations. Based on percentage of occurrence each day, weather was categorized as mixed overcast (days 1 and 2), overcast (days 3 and 4), mixed sunny (days 6, 7 and 8), and sunny (days 5, 9, 10 and 11) (Figure 2). Days 1 and 2 had the greatest amount of variation in weather types, including the only two days with rainfall, receiving 2.0 mm and 8.4 mm of rain, respectively. No precipitation was registered during the subsequent nine days of pasture observations.

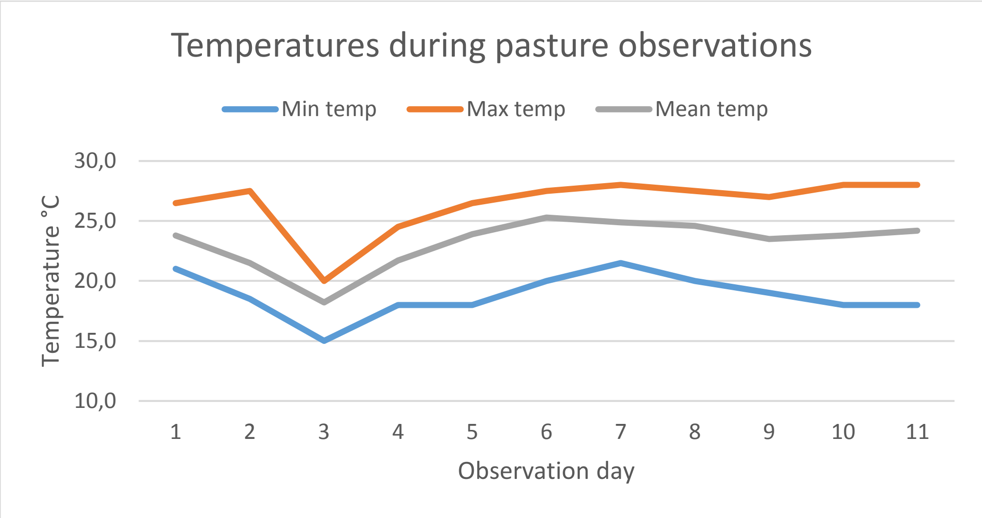


Figure 1. Min, max and mean temperatures according to observation day.

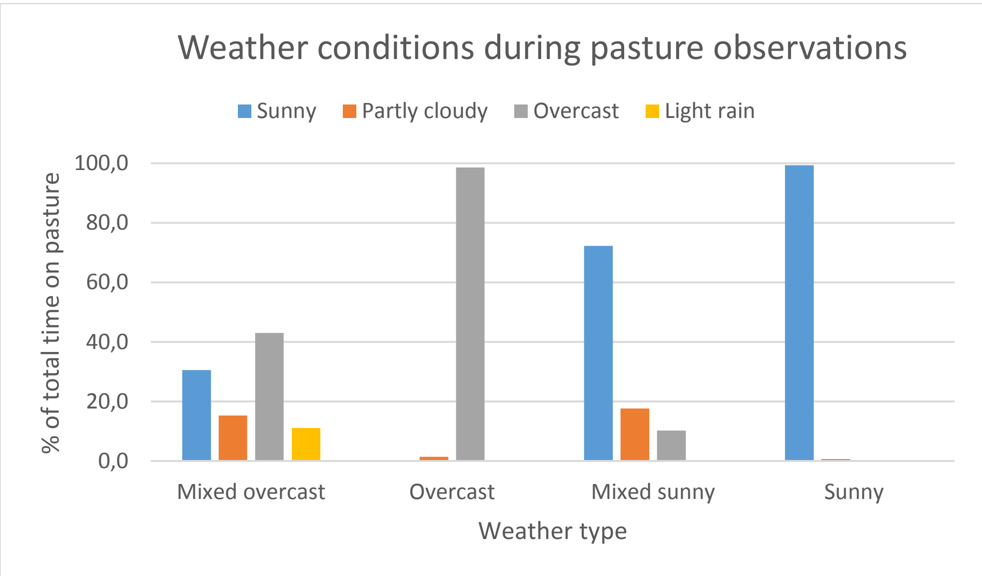


Figure 2. Weather type according to weather category, shown in percentage of total time on pasture.

3.7 Behavioural observations

3.7.1 Observations on pasture

The main behavioural study, progressing for eleven consecutive days from February 18-28, 2014, involved two daily observation bouts of the PO and PS groups on pasture, the first from 0900 to 1200 (morning), and the second from 1400 to 1700 (afternoon). The behaviour of each heifer was scored using instantaneous sampling (scan sampling) (Martin and Bateson, 2007) at 10-min intervals (36 obs. / heifer / day), using the following relevant and mutually exclusive behaviours (Hall, 1989, Kilgour et al., 2012): 1) grazing, 2) walking without grazing, 3) ruminating while standing, 4) ruminating while lying, 5) resting, and 6) other (Table 6).

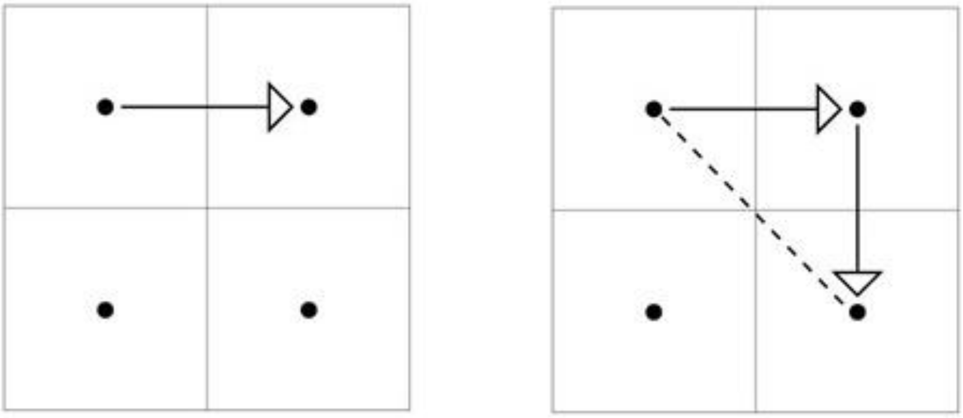
A test observation trial was conducted prior to study initiation, ensuring heifer habituation to the presence of an observer, thus minimizing effect of the observer on cattle behaviour.

Table 6. Ethogram with behaviours and descriptions.

Behavioural parameter	Description
Grazing (1)	Head and muzzle low to the ground, and actively nipping, tearing and consuming grass while standing still or slowly walking across the pasture site.
Walking without grazing (2)	Walking with head lifted from the ground, with a forward movement that involves relocation and does not involve grazing.
Ruminating while standing (3)	Processing of consumed grass while in standing position, to be separated from resting by identification of ruminating jaw movements.
Ruminating while lying (4)	Processing of consumed grass while in lying position, to be separated from resting by identification of ruminating jaw movements.
Resting (5)	Standing or lying still without grazing or ruminating behaviour, only registered when the heifer clearly is not within short bouts of either grazing, walking or ruminating.
Other (6)	Budding heads, sniffing and licking objects, drinking water, scratching and grooming one self and others, waving head and stomping feet to rid oneself of flies, throwing grass onto back (also flies), sniffing grass without grazing, vocalizing, social interactions, urinating, defecating, etc.

The pasture was divided into squares of 25 × 25 meters, with every connecting square corner marked by a wooden stick with an approximate height of 60 cm. Simultaneous with behaviour observations, each heifer's location was registered according to the square grid (Attachment 1). (Due to the pasture site not completely summarizing into even 25 meters a selected few squares were smaller/larger than the intended 25 × 25 m-size.) Some squares contained parts of buildings, silos, or agricultural machinery.

Calculations by use of a grid can provide a reliable alternative to the use of pedometers (Anderson and Kothmann, 1980, Walker et al., 1985), and distance travelled was calculated by summing straight line distances between centers of adjacent grid squares (25 m) (Figure 3a). Travels between diagonal squares were calculated as travel across two squares: first adjacent, then diagonal square (50 m) (Figure 3b). No deductions were made for unevenly sized squares or squares containing obstacles.



Figures 3a + 3b. Calculations by use of grid for adjacent squares (left) and diagonal squares (right).

3.7.2 Observations during supplement feeding

The subsequent behavioural study, progressing for six days (March 11-14, and March 17-18, 2014), involved two daily observation bouts of the PS group during supplement distribution times, the first during morning feeding and the second during afternoon feeding. The behaviour of each heifer was scored using instantaneous sampling (scan sampling) (Martin and Bateson, 2007) at 2-min intervals, using the following relevant and mutually exclusive behaviours: 1b) eating concentrate, 2b) standing, 3b) walking/relocating, 4b) eating straw, 5b) drinking water, and 6) leaving/staying away from feeding area (Table 7). Observations started when the first heifer initiated feeding, and lasted for 90 minutes, or until 10 minutes after the last heifer had stopped eating (both concentrate and straw).

Table 7. Ethogram with supplement feeding behaviours and descriptions.

Behavioural parameter	Description
Eating concentrate (1b)	Head and muzzle into feeding trough, actively consuming concentrate or otherwise in the process of chewing mouthfuls of feed.
Standing (2b)	Still posture without movement, but staying in close proximity of the feeding trough (< 2.5 m) without any feed consumption.
Walking/relocating (3b)	Forward or sidewise movement with main intention of relocating to a different space at the feeding trough. This behaviour involves movement within close proximity of the feeding trough (< 2.5 m).
Eating UTS (4b)	Head and muzzle into feeding trough, actively consuming untreated straw or otherwise in the process of chewing mouthfulls of feed.
Drinking water (5b)	The area containing the water post was appr. 10 m away from the feeding area, which meant moving away from feed to drink water. Drinking was registered when muzzle was below water surface.
Leaving/staying away from feeding area* (6b)	Walking movement away from feeding trough, registered when in far proximity of the feeding area (> 2.5 m). Also registered when heifer kept out of feeding area.

* The feeding area was defined as the space from the edge of the feeding trough and 2.5 meters backwards.

3.8 Statistical analysis

For analyzing the effect of supplement feed on behaviours and distance travelled on pasture a one factor analysis of variance (Microsoft Office Excel) was used, with the individual heifers as the statistical unit. Mean values of each behaviour were then used as basis for group comparisons. Data were sorted and analyzed by time of day (morning or afternoon). Variance of observations were expressed as the standard error to the mean (SE), and the data were analyzed using $P \leq 0.05$ as the upper level of significance. P-values lower or similar to 0.05 indicates significant responses.

4.0 Results

4.1 Observations on pasture

The PS group spent less time grazing than the PO group during both morning and afternoon, whereas the difference was only significant in the morning ($P \leq 0.05$) due to a larger individual variation in the afternoon (P=0.10) (Table 8). This meant more time for other behaviours, mostly expressed as an increase in resting ($P \leq 0.05$) and performing other behaviours ($P \leq 0.01$) during morning, as well as an increase in performing other behaviours in the afternoon ($P \leq 0.01$).

Total time spent grazing decreased from morning (PO=88.4 %, PS=78.5 %) to afternoon (PO=72.1 %, PS=60.3 %) (Table 8). The largest increase in total time for both groups occurred in ruminating while standing from morning (PO=1.0 %, PS=1.8 %) to afternoon (PO=7.2 %, PS=10.9 %), with similar individual variations during both bouts. Resting also increased from morning (PO=2.9 %, PS=7.5 %) to afternoon (PO=7.7 %, PS=11.5 %), yet individual variation was slightly larger for the PO group during the afternoon.

Individual variation was similar between groups during both morning and afternoon bouts, with the only exceptions being resting by the PS group and other behaviours by the PO group. Variation within groups remained constant across these behaviours, indicating higher group coherency within resting for the PS group, and performing other behaviours for the PO group. Even so, other behaviours for the PO group constitute a small fraction of total time on pasture.

Distance travelled decreased for both groups from morning to afternoon, yet no significant differences were found between groups in squares visited (morning: P=0.55, afternoon: P=0.98) or distance travelled (morning: P=0.55, afternoon: P=0.96) (Table 8). Despite a slight increase for the PO group during morning observations, both groups visited similar amount of squares, thus travelling equal distances during morning and afternoon bouts.

Table 8. Time spent (mean ± SE) for PO and PS groups on different behaviours on pasture, expressed in percentage of total time, and distance travelled by squares and meters (mean ± SE), with F and P values.

	Morning				Afternoon			
Behaviour	**PO (n=6)**	**PS (n=6)**	**F**	**P**	**PO (n=6)**	**PS (n=6)**	**F**	**P**
Grazing	88.4 ± 2.1	78.5 ± 2.9	7.81	*	72.1 ± 4.8	60.3 ± 4.8	3.01	0.10
Walking without grazing	5.2 ± 0.8	6.5 ± 0.9	1.06	0.31	8.0 ± 1.5	8.7 ± 1.6	0.10	0.76
Ruminating while standing	1.0 ± 0.6	1.8 ± 0.6	0.75	0.40	7.2 ± 2.5	10.9 ± 2.9	0.94	0.34
Ruminating while lying	0.3 ± 0.2	0.3 ± 0.3	0.049	0.83	2.1 ± 1.0	2.1 ± 1.0	0	1.00
Resting	2.9 ± 1.3	7.5 ± 1.7	4.68	*	7.7 ± 2.6	11.5 ± 1.8	1.40	0.25
Other	2.2 ± 0.6	5.4 ± 0.7	11.91	**	2.9 ± 0.5	6.6 ± 1.2	7.76	*
Distance	**PO (n=6)**	**PS (n=6)**	**F**	**P**	**PO (n=6)**	**PS (n=6)**	**F**	**P**
Squares visited	27.8 ± 2.6	25.8 ± 2.0	0.37	0.55	24.0 ± 2.0	23.9 ± 2.6	0.0006	0.98
Distance travelled (m)	692.9 ± 64.6	643.3 ± 50.3	0.37	0.55	600.4 ± 68.5	595.5 ± 63.7	0.003	0.96

*P ≤ 0.05, **P ≤ 0.01

No difference was found in grazing behaviour between individuals of the PS group (p=0.54) (Table 9). The same applied to walking without grazing (P=0.74), ruminating while standing (P=0.51), and ruminating while lying (P=0.48). Individual differences were on the other hand, discovered for resting (P ≤ 0.05) and other behaviours (P ≤ 0.05). Of all six animals, heifer PS4 spent the most time resting (7.8 %) and the least time grazing (64.1 %). PS1 spent most time performing other behaviours (9.3 %), mainly reflected as a decrease in time spent walking without grazing (5.8 %), and ruminating while standing (4.3 %).

In addition, there were no individual differences between squares visited and distance travelled within the PS group (P=1.00) (Table 9).

Table 9. Time spent (mean ± SE) for PS individuals on different behaviours on pasture, expressed in percentage of total time, and distance travelled by squares and meters (mean ± SE), with F and P values.

Behaviour	PS1	PS2	PS3	PS4	PS5	PS6	F	P
Grazing	70.2 ± 4.5	65.9 ± 4.0	73.2 ± 3.6	64.1 ± 5.0	67.9 ± 3.3	73.5 ± 3.7	0.82	0.54
Walking without grazing	5.8 ± 1.5	8.6 ± 1.3	7.6 ± 2.0	8.8 ± 1.0	7.8 ± 2.0	7.1 ± 1.7	0.55	0.74
Ruminating while standing	4.3 ± 1.6	9.6 ± 2.1	5.0 ± 1.9	5.0 ± 1.9	7.1 ± 1.8	6.3 ± 2.3	0.87	0.51
Ruminating while lying	2.5 ± 1.0	0.8 ± 0.5	0.8 ± 0.5	1.3 ± 0.9	1.3 ± 0.6	0.8 ± 0.8	0.90	0.48
Resting	7.8 ± 2.6	7.8 ± 1.7	9.8 ± 1.6	16.0 ± 3.0	9.3 ± 2.0	7.0 ± 1.7	2.85	*
Other	9.3 ± 2.2	7.3 ± 1.1	3.5 ± 1.1	3.8 ± 0.7	6.6 ± 2.4	5.3 ± 1.1	2.34	*
Distance	**PS1**	**PS2**	**PS3**	**PS4**	**PS5**	**PS6**	**F**	**P**
Squares	24.6 ± 1.7	24.2 ± 1.9	25.4 ± 1.5	24.8 ± 1.7	24.8 ± 1.6	24.9 ± 1.6	0.05	1.00
Distance, m	614,8 ± 43.4	605.7 ± 46.8	634.1 ± 38.1	619.3 ± 42.2	620.5 ± 40.2	621.6 ± 39.3	0.05	1.00

*P ≤ 0.05

4.2 Effect of weather

Difference in grazing behaviour between the PO and PS groups was significant in 3 out of 4 weather categories (mixed overcast: P=0.18, overcast: P ≤ 0.0001, mixed sunny: P ≤ 0.0001, and sunny: P ≤ 0.05) (Figure 3). Grazing occupied 89.6 % of time on pasture for the PO group during mixed overcast weather, and dropped to 74.3 % during sunny weather, whereas the PS group changed from 83.6 to 64.8 % correspondingly. The largest difference between the two groups was seen during overcast weather, where grazing behaviour amounted to 83.1 and 68.3 % for the PO and PS groups, respectively (Figure 3).

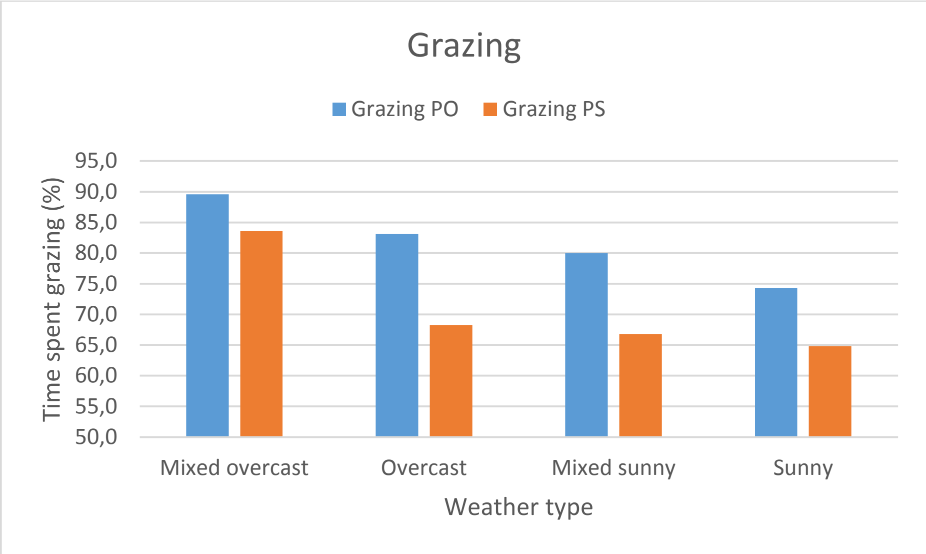


Figure 3. Grazing behaviour during different weather categories, expressed in percentage of total time on pasture.

Despite change in weather, squares visited and distance travelled were approximately equal between groups, with one exception of the PO group travelling farther than the PS group during overcast weather ($P \leq 0.05$) (Table 10). This difference occurred simultaneously with the largest difference in time spent grazing between the two groups. For all other weather categories, the heifers travelled together despite group affiliation.

Table 10. Mean squares visited and distance travelled (m) by groups according to weather categories.

	Squares				Distance, m			
	PO	PS	F	P	PO	PS	F	P
Mixed overcast	63.5	63.3	0.01	0.91	1587.5	1581.3	0.01	0.91
Overcast	63.0	54.5	5.41	*	1575.0	1362.5	5.41	*
Mixed sunny	48.3	47.3	0.23	0.63	1206.9	1181.9	0.23	0.63
Sunny	42.8	41.9	0.03	0.85	1069.8	1047.9	0.03	0.85

*P ≤ 0.05

All heifers walked significantly less during sunny and mixed sunny days (mean 45.1 squares and 1126.1 m) compared to overcast and mixed overcast days (mean 61.1 squares and 1526.5 m) ($P \leq 0.0001$).

4.3 Observations during supplement feeding

Due to individual variation within behaviours during supplement feeding, significant differences were only found within eating concentrate ($P \leq 0.01$), walking/relocating ($P \leq 0.05$), and eating straw ($P \leq 0.05$) (Table 11). Main features showed that more time spent eating concentrate resulted in less time spent away from the feeding area, and vice versa. Low values for both behaviours caused an increase in time spent performing other behaviours, mainly standing and eating UTS.

Little time was spent drinking water (0.0-0.8 % of total time) (Table 11), suggesting that this behaviour was of less priority during supplement feeding. Despite significant individual differences, little time was also devoted to walking/relocating (1.1-5.1 % of total time).

Individual heifers differed greatly in time spent eating concentrate (33.0-55.6 %) (Table 11). Heifers PS1, -2, -4, and -5, spent the least amount of time eating concentrate (33.0-39.1 %), and the most amount of time staying away from the feeding area (42.8-51.1 %). Conversely, PS3 and PS6 spent the most amount of time eating concentrate (45.9-55.6 %), and the least amount of time staying away from the feeding area (30.3-37.0 %).

More specifically, PS1, -2, and -5 spent approximately equal time eating concentrate (33.0-34.0 %), yet time spent away from the feeding area varied more (45.4-51.5 %) (Table 11). The majority of their remaining time was spent either standing (4.2-11.1 %) or eating UTS (2.0-10.9 %). PS4 spent slightly more time eating concentrate (39.1 %) than the previous three, and most time standing (13.6 %) of all six heifers. PS3 spent the least amount of time away from the feeding area (30.3 %), as well as among the most in eating UTS (45.9 %). PS6 spent most time eating concentrate (55.6 %) and mainly stayed away from the feeding area the rest of her time (37.0 %).

Personal observations during supplement feeding specify that certain individuals (mainly PS3 and PS6) sometimes monopolized access to concentrate. Such social interactions were not recorded, but may have contributed to a difference in time spent eating concentrate for individual PS heifers during supplement feeding times.

Table 11. Individual behaviours during supplement feeding times for the PS group, expressed in percentage of total time ± SE, with F and P values.

Behaviours	PS1	PS2	PS3	PS4	PS5	PS6	F	P
Eating concentrate	33.0 ± 2.5	33.1 ± 3.6	45.9 ± 3.0	39.1 ± 4.8	34.0 ± 6.2	55.6 ± 6.9	3.62	**
Standing	11.1 ± 4.6	9.4 ± 3.0	7.3 ± 2.0	13.6 ± 6.0	4.2 ± 3.0	3.5 ± 2.3	1.09	0.37
Walking/ relocating	2.5 ± 0.7	3.7 ± 1.0	5.1 ± 1.1	1.1 ± 0.5	2.7 ± 0.7	1.6 ± 0.7	3.15	*
Eating UTS	7.6 ± 2.4	2.0 ± 0.9	10.6 ± 2.8	3.4 ± 2.4	10.9 ± 4.1	2.0 ± 1.4	2.72	*
Drinking water	0.4 ± 0.3	0.8 ± 0.4	0.8 ± 0.6	0.0 ± 0.0	0.0 ± 0.0	0.2 ± 0.2	1.31	0.27
Staying away from feed. area	45.4 ± 7.1	51.1 ± 5.2	30.3 ± 3.0	42.8 ± 7.2	48.1 ± 7.1	37.0 ± 7.6	1.43	0.23

*P ≤ 0.05, **P ≤ 0.01

The individual range in time spent grazing within the PS group was 64.1-73.5 % of total time on pasture (Table 9). In context with differences during supplement feeding times (Table 11), the two heifers spending most time eating concentrate (PS3 and PS6) actually spent the most time grazing as well. PS1, -2, and -5 spent the least amount of time eating concentrate and was intermediate in grazing time (65.9-70.2 %). PS1 and PS2 also had the highest scores for performing other behaviours and ruminating while standing, respectively. PS4 spent 39.1 % of total time eating concentrate (intermediate), yet of all six heifers, she spent the least amount of time grazing and the most amount of time walking.

5.0 Discussion

Results from the current study showed that providing heifers with supplement feed decreased time spent grazing and increased time spent resting, ruminating, and performing other behaviours. Distances travelled were similar for both groups on pasture. All heifers spent less time grazing during sunny weather compared to overcast weather, and the supplemented (PS) group consistently grazed less than the non-supplemented (PO) group. There were significant individual differences in time spent eating concentrate within the PS group, but these did not reflect in individual differences in time spent grazing on pasture.

This study was based on a small sample of animals. Results are discussed in light of previous literature, but can only be true for the current study and holds caution for further generalization.

Grazing

As predicted, the PS group consequently spent less time grazing than the PO group, supporting similar studies by Barton et al. (1992), Hess et al. (1994), Schauer et al. (2005), Scaglia et al. (2009), Arachchige et al. (2013), and Sheahan et al. (2013a). Even so, both groups reduced grazing time from morning to afternoon bouts, but the decline in grazing time for the PO group may have been influenced by the change in behaviour by the PS group in response to the supplement feed (Langbein and Nichelmann, 1993). Conversely, time spent grazing for PS heifers may also have been lower if separated from PO heifers on pasture.

A decrease in time spent grazing will inevitably lead to an increase in other behaviours, and PS heifers spent significantly more time resting and performing other behaviours than PO heifers. Ruminating while standing had the greatest increase in time from morning to afternoon observations for both groups, and more so for the PS group than the PO group, which was also found by Phillips and Hecheimi (1989). This indicates an increased need to process amounts of feed ingested earlier during the day.

Distance travelled

Because supplement feed was predicted to alter behaviour on pasture, an assumed change in distance travelled was predicted for the PS group. Despite this, supplement feed had little to no effect on squares visited and distance travelled by the PS group, which might have been a result of the PO group masking the true behaviour of the PS group or vice versa (Langbein and Nichelmann, 1993). Other explanations could be alterations in search and intense fazes of grazing behaviour for the PS group (Barton et al., 1992, Walker and Heitschmidt, 1989) or reduced grazing intensity by the PS group (Bodine and Purvis, 2003), but this was not investigated in the current study. Similar distances travelled for both groups are comparable to results by Schauer et al. (2005), and highlights the importance of herd behaviour despite different treatments.

For both groups, distance travelled decreased from morning to afternoon, despite a decrease in time spent grazing and increase in time spent walking without grazing. This may indicate an increase in intense grazing (Walker and Heitschmidt, 1989), causing shorter distances covered during grazing, and/or decreased stride length during walking (Walker et al., 1985).

When blocked by weather categories, the PO group travelled significantly farther than the PS group during overcast weather. As cattle behaviour is receptive and adaptive towards weather and temperatures (Langbein and Nichelmann, 1993, McGuire et al., 1991, Uzal and Ugurlu, 2010), the increased distance for the PO group may indicate higher motivation for travel during overcast weather compared to when it's sunny.

Weather

Effect of weather was evident on time spent grazing. All heifers spent more time grazing during overcast weather than during sunny weather, supporting studies with effect of sunlight, shade and temperature (McGuire et al., 1991, Tucker et al., 2008, Uzal and Ugurlu, 2010). Again, the PS group consequently grazed less than the PO group, and the difference was significant in all but one category (mixed overcast). The lack of significance during mixed overcast may be caused by less coherent behaviours related to the wide change in weather during these two days (sunny, partly cloudy, overcast, and light rain).

Time spent grazing was highest for both PO (89.6 %) and PS (83.6 %) groups during mixed overcast weather. As weather changed from overcast to mixed sunny and sunny, time spent grazing decreased from 83.1 to 74.3 % for the PO group, and from 68.3 to 64.8 % for the PS group. This corresponds with results from previous studies on the effect of weather on grazing activity (McGuire et al., 1991, Tucker et al., 2008, Uzal and Ugurlu, 2010). The greater reduction in grazing time for the PS group is likely due to weather influence in combination with supplement feed (Arachchige et al., 2013, Barton et al., 1992, Hess et al., 1994, Scaglia et al., 2009).

Even though maximum temperatures exceeded 25°C repeatedly, mean temperatures were most often below this point and did not call for nighttime grazing (Krysl and Hess, 1993). On the other hand, it does emphasize the importance of this measure as rainy season continues to dry season.

Individual behaviours during supplement feeding

Despite significant individual differences within the PS groups in time spent eating concentrate, no individual differences were observed in grazing time on pasture. Even though trough space per heifer was more than adequate to avoid monopolization by individual animals (1 m per animal for both concentrate and UTS), personal observations and results indicate an effect of social relationships between animals in the PS group demonstrated during supplement feeding (Olofsson, 1999). Yet, as cows can readily adjust daily DMI by altering number of daily meals and the average meal size (Grant and Albright, 1995), time spent eating concentrate during observation hours does not necessarily reflect total amount of feed ingested. Because competition decreases from time of supplement distribution (Friend et al., 1977) it is possible that individuals eating less concentrate during observations compensated for this by eating later in the evening or at night. Even so, individual variation in BW gain of the PS group was large, indicating that time spent eating concentrate could reflect increased DMI for dominant heifers (Olofsson, 1999).

Management

Most grazing occurs during sunrise (0600-0900) and sunset (1500-1800) (Brandyberry et al., 1991, Cozzi and Gottardo, 2005, Kilgour et al., 2012, Krysl and Hess, 1993, Sheahan et al., 2011), and time spent grazing is often seen in relation to type of forage and forage availability (Allden and Whittaker, 1970, Scarnecchia et al., 1985). Thus, seasonal fluctuations are important to grazing management and time on pasture will, to some degree, define intake capacity of grazing animals. In this study, heifers were on pasture from 0900-1700 (8 h), which could be considered restricting when forage is abundant (Dodzi and Muchenje, 2012). On one hand, extended grazing time on pasture could result in more total time spent grazing (Kennedy et al., 2009) as well as decreased grazing intensity (Smith et al., 2006). On the other hand, limited grazing time could force animals to perform little excess behaviours besides grazing and walking on pasture (Bayer, 1986), and lead to an increase in grazing intensity (Kennedy et al., 2009).

As supplement feed can cause disruption and shifts in daylight grazing hours (Krysl and Hess, 1993, Adams, 1985), so can time of supplement distribution. Morning supplements prior to pasture can result in a lower total feed intake (Adams, 1985), and afternoon supplements can disturb major grazing activity and reduce bite rate (Scaglia et al., 2009). Although bite rate was not recorded in the current study, PS heifers spent less time grazing, which indicates a reduced forage intake on pasture, and afternoon supplements involved removing heifers from pasture during peak grazing hours. Despite this, BW gains were much greater for the PS than the PO group, and effects of extended grazing time may have involved greater benefits for the PO group in terms of total grazing time (Kennedy et al., 2009). Hart et al. (1993) discovered that nocturnal supplements may decrease effects on grazing behaviour during the day, which might suggest an alternative to the current supplement management.

Supplemented groups have also been found to refrain from grazing 2-4 hours after supplement distribution (Adams, 1985), but this was not the case in the current study.

Although not investigated in the current study, Hart et al. (1993) found that distance to water, not pasture size or system, appeared to be the major factor controlling distance travelled. Utilization of the larger continuous pasture declined with distance from water, indicating that a single water source on the current pasture might be insufficient to ensure full utilization of pasture resources.

Supplement feed

Hess et al. (1994) pointed out that type of supplement relative to quality and quantity of forage biomass influenced grazing activity differently depending on the supplemental protein source, and Odadi et al. (2013) found that foraging cattle partially traded off protein-rich forbs for protein-poor grasses when supplemented with protein. Thus, type and amounts of supplement feed should be considered in relation to season to best exploit natural resources on pasture. The CP content of the untreated straw (UTS), pasture and concentrate was 4.0, 7.2, and 15.4 %, respectively. Despite ad lib access to UTS during non-pasture hours for the PS group, energy intake through UTS was only 4.1 % of total supplement intake, thus contributing a very small fraction of total energy intake (pasture plus supplement). Minimum CP levels of 7 % are necessary in feed, and levels of 11 % optimize use of low quality tropical forages (Lazzarini et al., 2009). In light of such, results suggest positive associative effects by concentrate supplements (Stockdale, 2000) and a preference for pasture over UTS during the current season/study. This is in compliance with Rubanza et al. (2007) and Rubanza et al. (2005) where standing basal forages alone could not sustain animal productivity unless corrected for protein.

Safari et al. (2011b) found that treatment of straw increased DMI, energy intake, and the average daily gain of sheep, and animals on TS produced heavier carcasses than animals on UTS. In the current study, while SO heifers ate more TS than the PS heifers ate UTS, BW gains were higher for the PS group. This is likely a result of grazing time on pasture for the PS group, and indicates a preference for fresh feed over UTS, as well as a higher nutritional value of the current pasture forages compared to TS (in terms of comparison of BW gains). Even so, SO animals had a higher BW gain than PO animals, indicating a more complete diet in TS plus concentrate, compared to pasture alone (also in terms of BW gains). It is unknown whether PS heifers would prefer TS to pasture grass, but again, cattle tend to show a preference for fresh feed.

6.0 Conclusions and recommendations

Results from the current study showed that providing heifers with supplement feed decreased time spent grazing and increased time spent resting, ruminating, and performing other behaviours. Distances travelled were similar for both groups on pasture. All heifers spent less time grazing during sunny weather compared to overcast weather, and the supplemented (PS) group consistently grazed less than the non-supplemented (PO) group. There were significant individual differences in time spent eating concentrate within the PS group, but these did not reflect in individual differences in time spent grazing on pasture.

In future interbreeding with Norwegian red, increased needs for maintenance of productivity by supplemental feeds will most likely become even more apparent, requiring season-specific adjustments in chemical composition of supplements. This study recommends animals to be permitted entire days on pasture (0600-1900) in order to fulfill, and not abrupt, the diurnal rhythm of grazing, as well as suggesting that concentrate feeds be distributed after pasture hours and during nighttime in the enclosures. Lastly, an additional water source at the far-end of the pasture (near main gate or office building) may motivate the heifers to a more widespread use of the pasture area, hence fully exploiting all resources.

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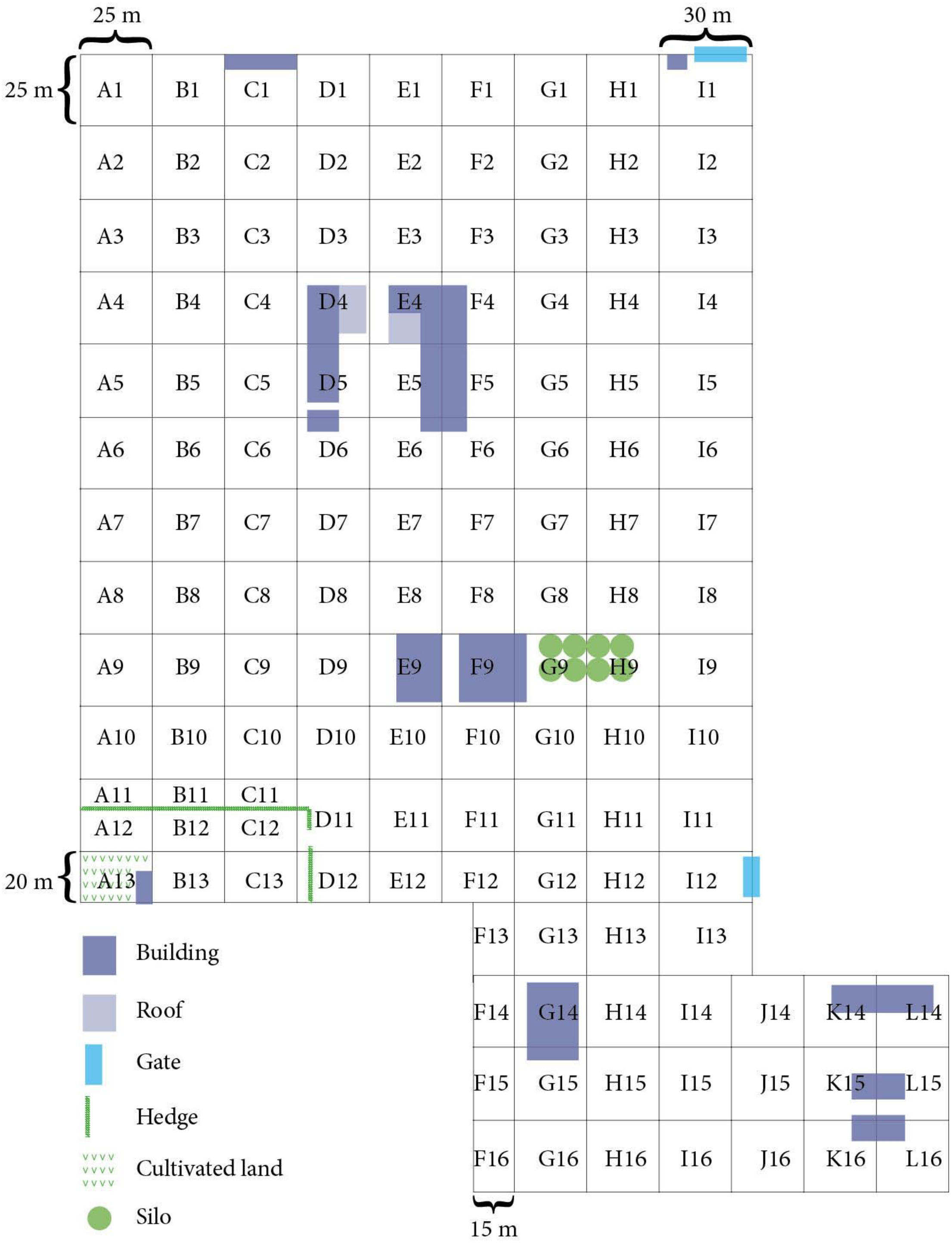
8.0 Attachments

Attachment 1. Grid map of pasture site at Mulbadaw Farm.



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