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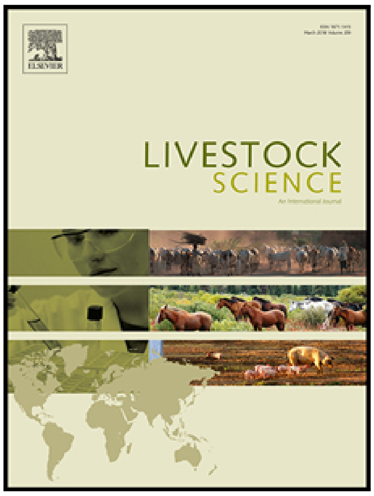

Comparative grazing behaviour of lactating suckler cows of contrasting genetic merit and genotype

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Highlights

- Genotype had no effect on any recorded grazing behaviour variables
- High genetic merit cows grazed for longer with more bites but had a lower grass dry matter intake
- No significant differences across genetic merit or genotype were observed for rumination measures.
- Beef x dairy cows more efficiently convert herbage to milk production than beef

Comparative grazing behaviour of lactating suckler cows of contrasting genetic merit and genotype

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Abstract

The objective of this study was to determine if differences in grazing behaviour exist between lactating suckler cows diverse in genetic merit for the national Irish Replacement index and of two contrasting genotypes. Data from 103 cows: 41 high and 62 low genetic merit, 43 beef and 60 beef x dairy (BDX) cows were available over a single grazing season in 2015. Milk yield, grass dry matter intake (GDMI), cow live weight (BW) and body condition score (BCS) were recorded during the experimental period, with subsequent measures of production efficiency extrapolated. Grazing behaviour data were recorded twice in conjunction with aforementioned measures, using Institute of Grassland and Environmental

Research headset behaviour recorders. The effect of genotype and cow genetic merit during mid- and late-lactation on grazing behaviour phenotypes, milk yield, BW, BCS and GDMI were estimated using linear mixed models. Genetic merit had no significant effect on any production parameters investigated, with the exception that low genetic merit had a greater BCS than high genetic merit cows. Beef cows were heavier, had a greater BCS but produced less milk per day than BDX. The BDX cows produced more milk per 100 kg BW and per unit intake and had greater GDMI, intake per bite and rate of GDMI per 100 kg BW than beef cows. High genetic merit cows spent longer grazing and took more bites per day but had a lower rate of GDMI than low genetic merit cows, with the same trend found when expressed per unit of BW. High genetic merit cows spent longer grazing than low genetic merit cows when expressed on a per unit intake basis. Absolute rumination measures were similar across cow genotype and genetic merit. When expressed per unit BW, BDX cows spent longer ruminating per day compared to beef. However, on a per unit intake basis, beef cows ruminated longer and had more mastications than BDX. Intake per bite and rate of intake was positively correlated with GDMI per 100 kg BW. The current study implies that despite large differences in grazing behaviour between cows diverse in genetic merit, few differences were apparent in terms of production efficiency variables extrapolated. Conversely, differences in absolute grazing and ruminating behaviour measurements did not exist between beef cows of contrasting genotype. However, efficiency parameters investigated illustrate that BDX will subsequently convert herbage intake more efficiently to milk production.

Keywords: beef, cows, grazing behaviour, genetic merit, replacement

1. Introduction

Understanding the interactions between animal behaviour and their environment is necessary to optimise the management of livestock within a pasture-based system. Improving animal production and efficiency is dependent on their ingestive behaviour (Hejcmanová *et al.*, 2009), with herbage quality and utilisation by grazing livestock a key focus of grassland management. Under grazing conditions, the ideal suckler cow should consume sufficient quantities of herbage which is efficiently converted to milk and meat production (Buckley *et al.*, 2005). Determinants of herbage intake are the combined relationships between time spent grazing, bite rate, and intake per bite (Allden and Whittaker, 1970). Therefore, animal behaviour under grazing conditions and subsequent efficiency measures could highlight the suitability of a particular breed or genotype of beef cow to grass-based systems. Indeed numerous studies have reported differences in grazing behaviour amongst dairy cows of diverse genetic merit (McCarthy *et al.*, 2007), size (Laborde *et al.*, 1998) and breed (Prendiville *et al.*, 2010). However, few studies have investigated the grazing behaviour of lactating beef cows (Gary *et al.*, 1970; Lathrop *et al.*, 1988; Funston *et al.*, 1991) and contrasting results have been reported. Visual observation used by Gary *et al.* (1970) on beef cows reported an average 6.08 hours grazing per day plus supplementary feed, whereas Funston *et al.* (1991) reported a range of 11.6 to 12.3 hours using vibracorders (Stobbs, 1970). Lathrop *et al.* (1988) reported that beef cows with greater levels of milk production spent more time grazing. Conversely, Walker (1962) considered beef and beef x dairy crossbred lactating primiparous heifers, but only outlined on a herd basis the frequency of grazing and resting cycles. The current study is the first to undertake a detailed appraisal of contrasting beef cow genotype and genetic merit for grazing and ruminating behaviour measurements under grazing conditions.

Beef cow breed type in Ireland is predominantly crossbred (DAFM, 2015/16), with replacements either generated within the beef herd or are beef x dairy crossbred (BDX) sourced from the dairy herd. At present, BDX cows account for approximately 25% of Irish replacements (Evans *et al.*, 2014), and approximately 80% of cows within the beef herd were bred to a late-maturing bull (AIM, 2016). The contrasting replacement strategies, or cow genotypes, are associated with differences in performance (McCabe et al., 2018). The development of an Irish national maternal breeding programme, known as the Replacement Index utilises breeding values with the aim to improve maternal efficiency by identifying superior cows for maternal traits (McHugh et al., 2014). Included within this national genetic index are indirect measures of cow efficiency such as maternal weaning weight (i.e. milk yield of the cow) and feed intake, which have a relative emphasis of 18% each within the overall Replacement Index. With the option of two contrasting cow genotypes and development of a new Replacement Index, further possibilities exist to ascertain the most suitable cow type for the efficient use of the pasture-based system implemented in Ireland (McCabe *et al.*, 2017).

Therefore, the objective of this study was to investigate the grazing behaviour of beef and BDX cows under intensive pastoral conditions and to determine if differences existed in grazing behaviour characteristics between cows of diverse genetic merit for the Irish beef Replacement Index.

2. Materials and Methods

This experiment was carried out at Teagasc, Grange Beef Research Centre, County Meath, Ireland. Animal procedures undertaken in this experiment were approved by the Teagasc Animal Ethics Committee and were licensed by the Health Products Regulatory Authority in accordance with the protection of animals used for scientific purposes (Directive 2010/63/EU). This study was conducted over a single grazing season in 2015.

Aberdeen Angus (AA; an early maturing breed) and Limousin (LM; a late maturing breed) sired heifers were sourced nationally at c. 8 months of age from the suckler herd and from the dairy herd. Heifers sourced from within the suckler herd were bred from either Aberdeen Angus (AA), Hereford (HE), Limousin (LM), Charolais (CH), Simmental (SI) or Belgian Blue (BB) cows. Heifers sourced within the dairy herd were bred from Holstein-Friesian (FR) cows only. Heifers were selected from sires with a high reliability (>70%) for the Irish beef Replacement Index. A total of 103 cows: 41 high genetic merit (HIGH), 62 low genetic merit (LOW); 43 beef and 60 BDX cows were available (Table 1).

Cows were bred over a thirteen week breeding season during 2014 to either AA or LM bulls that were in the top 20% for the Irish national terminal index and had a subsequent mean calving date of 18 March 2015 (±23 d). For the purposes of this trial cows could only rear singleton calves, so in the incidence of twins one calf was removed from the cow and artificially reared. All cows and their calves (47 female; 56 male) were turned out to pasture during the spring months of March and April and grazed in four groups; two beef and two BDX groups. The groups were managed under a rotational grazing system as described by O'Donovan *et al.* (2002) on a predominantly perennial ryegrass (*Lolium perenne*) sward.

Mineral supplementation was supplied to the cows during periods of fast grass growth to assist in reducing the risk of hypomagnesaemia.

2.1. Sward Measurements

Throughout the grazing season (March to November) pre- and post- grazing sward heights were recorded using a rising plate meter (Filip's Manual Plate Meter, Grasstec, Cork, Ireland). Forty pre-grazing heights were taken across the paddock. Over the duration of the grazing season cows grazed an average pre-grazing height of 10.0 (SD = 2.28) cm and had a post-grazing height of 4.0 (SD = 0.41) cm. Herbage mass (>4 cm) was determined on each paddock by cutting three strips per paddock (1·2 m wide × 5·0 m long) with an Etesia HYDRO 124 (Etesia UK Ltd, Warwick, UK). Ten grass height measurements were recorded before and after harvesting on each cut strip using the rising plate meter. This allowed calculation of the sward density [herbage mass ha^{-1}/(pre-cutting height − post-cutting height); kg DM cm^{-1} ha^{-1}] (McEvoy *et al.*, 2010). The harvested material from each cut strip was collected, weighed and a sample collected. A subsample (100 g) of this was dried overnight at 98°C to determine DM content. Herbage from the three strips was bulked; a sub-sample (approx. 100 g) was taken and dried at 40°C for 48 h and milled. Samples were then bulked by fortnight prior to chemical analysis. Samples were analysed in vitro for acid detergent fibre (ADF), crude protein (CP), neutral detergent fibre (NDF), organic matter digestibility (OMD) and ash.

2.2. Animal Performance Measurements

Cow live weight (BW) was recorded every three weeks using a calibrated 'Titan Weigh Crate' (O'Donovan's Engineering, Cork, Ireland) combined with Tru-Test software (New Zealand). Body condition score (BCS) was measured concurrently to cow BW by a single evaluator on a scale of 0 to 5 (Lowman *et al.*, 1976). Cow milk yield estimates were collected using the weigh-suckle-weigh technique (McGee *et al.*, 2005a) as modified by McCabe *et al.* (2017) at 131 ± 34.5 (13 – 15 July) and 186 ± 23.1 (21 – 23 September) days in milk (DIM). Briefly, milk yield estimates were determined twice daily at 8 am and 3 pm to give a 24 hour average yield. This was conducted for three consecutive days on each cow during the measurement periods and an overall yield determined. Milk yield data on a day where a cow was not fully suckled out or a calf gained access to suckle the cow before the allotted measurement period were excluded from the analysis.

Milk yield estimates coincided with establishing grass dry matter intake (GDMI), which was done using the n-alkane technique (Dillon, 1993). In brief, alkane dosing was conducted twice daily (8 am and 3 pm) for twelve consecutive days, beginning on the first day of the weigh-suckle-weigh technique. Faecal sampling was conducted twice daily (6 am and 1 pm) for 6 days commencing on day 7 of the alkance dosing. Establishing GDMI was conducted in the periods prior to and post- grazing behaviour recording, which was at 137 ± 34.5 (19 – 24 July) and 192 ± 23.1 (27 September – 2 October) DIM, respectively. Measures of gross efficiency were subsequently calculated and expressed as: milk yield per 100 kg BW and milk yield per unit intake and GDMI per 100 kg BW.

Calves suckled their dams and were weighed every three weeks coinciding with when cow BW was recorded. Calves were weaned at 224 ± 29 days of age using the gradual weaning technique (Enríquez et al., 2011) with weaning weight recorded (Table 3).

2.3. Grazing Behaviour

Grazing behaviour data were recorded twice during the grazing season at mid- (period 1: August 11 to August 23) and late- (period 2: August 24 to September 26) lactation, corresponding to 159 ± 23.1 and 178 ± 23.4 DIM. Cows were fitted with Institute of Grassland and Environmental Research headset behaviour recorders (Rutter *et al.*, 1997) for a 24 hour period to account for the diurnal patterns of grazing behaviour (Champion *et al.*, 1994). To acclimatise the animals to the headsets a standard head collar was fitted to each cow 24 hours before the grazing headsets. Headsets were available to collect measurements on up to 22 cows per day; 13 headsets were used on BDX (HIGH and LOW) and 9 on beef (HIGH and LOW) cows, respectively. A total of 310 attempts yielded 186 (77 beef, 109 BDX, 115 LOW and 71 HIGH) records from the two measurement periods (Table 2). The failed attempts occurred due to the propensity of the transponders located under the jaw of the cow to physically break from the noseband (58%), broken leads to and connections within the monitor (30%), issues with downloading of recorded data from the storage devices (memory card; 9%) and the unreliable battery life of the headsets (3%). Due to failures in the recording equipment, the grazing behaviour measurement periods were extended and consequently overlapped with the second GDMI measurement period in an attempt to achieve a successful reading for each experimental animal. In some cases (n=5) three attempts at data collection were made before a successful reading was achieved and 2 cows were removed from this study as sufficient grazing behaviour data was not collected.

The grazing behaviour data collated was analysed using Graze analysis software (Rutter, 2000) to generate a number of grazing behaviour measures. Grazing behaviour measures extrapolated included: grazing and ruminating time (minutes/day), number of grazing and ruminating bouts (n/d), number of grazing bites (n/d), number of grazing and ruminating mastications (n/d), number of ruminating boli (n/d), bite rate (n of bites/min), grazing and ruminating bout duration (min/bout), rate of grazing mastications (n of mastications/min) and bolus size. Intake per bite (g/bite), rate of intake per minute (g/min), rate of ruminating mastications (n of mastications/min) and bolus size (g) were also extrapolated when the grazing behaviour data was combined with the intake data.

2.4. Statistical Analysis

The effect of cow genotype (beef or BDX) and cow genetic merit (high or low) on grazing behaviour phenotypes, cow milk yield, BW, BCS, GDMI and WW were estimated using linear mixed models in PROC MIXED (version 9.3; SAS Institute Inc., Cary, NC). Fixed effects included in all models were: genetic merit (high and low), breed (AA and LM), cow genotype (beef and BDX), DIM and parity. The interaction between cow genotype and genetic merit was also included as a fixed effect in the model for each trait. Calf sex and the calves sire PTA for carcass weight were also included as a fixed effect in the model for WW. Cow was included as a random effect which also accounted for the repeated records per cow.

Correlations between GDMI per 100 kg BW and efficiency variables (milk yield per 100 kg BW and per unit intake) with grazing and ruminating behaviour variables across cow genotype and cow genetic merit were investigated using partial Pearson correlations. The effect of breed, genotype, cow genetic merit, parity and DIM were adjusted for in the analysis using PROC CORR procedure of SAS.

3. Results

3.1. Sward Measurements

Pre- and post-grazing sward surface heights along with pre-grazing herbage yield were similar in both measurement periods across all groups (Table 3), with the nutrient composition of the herbage offered of high quality (McEvoy *et al.*, 2010).

3.2. Cow milk yield, BW, BCS and WW

The effect of genetic merit and cow genotype on milk yield, BW and BCS across mid- and late-lactation, along with calf WW is presented in Table 4. The interaction between genetic merit and genotype proved non-significant for all traits. Genetic merit had no significant effect on milk yield or cow BW. The LOW cows had a 0.24 greater (P<0.001) BCS than HIGH cows. Significant differences were found between cow genotypes, where beef cows were 61 kg heavier (P<0.001) and had a 0.42 greater BCS (P<0.001) than BDX. However, BDX cows produced 1.7 kg per day more milk (P<0.01) than beef cows and subsequently weaned calves which were 19 kg heavier (P<0.05).

3.3. GDMI and Efficiency Parameters

The interaction between genetic merit and cow genotype was investigated and proved non-significant for GDMI and all related efficiency parameters. The LOW cows tended (P=0.057) to consume an additional 0.9 kg per day of grass than the HIGH cows. The BDX cows also tended to consume 0.8 kg DM more than beef cows (P=0.072; Table 4).

Although non-significant, there was a tendency (P=0.079) for HIGH cows to produce 0.08 kg more milk per unit intake than LOW cows. Cow genotype showed significant differences in the efficiency parameters investigated (Table 4). The BDX cows produced 0.39 kg more milk per 100 kg BW (P<0.001) and 0.11 kg more milk per unit intake (P<0.01) than beef cows. The BDX cows also consumed an additional 0.28 kg DM per 100 kg BW than beef cows (P<0.001).

3.4 Grazing Behaviour

3.4.1 Recorded Measurements

A genetic merit by cow genotype interaction was observed for GDMI per bite where LOW beef cows consumed 0.15g more DM per bite than HIGH beef cows (P<0.05) while the inverse was noted for BDX. No significant differences were found in the interaction for all other grazing behaviour variables recorded.

Grazing time, grazing bouts, grazing bout duration, total bites, bite rate, grazing mastications, grazing mastication rate, GDMI per bite and rate of GDMI were similar across cow genotype (Table 5). The HIGH cows spent 42 minutes per day longer grazing (P<0.05) and took 3574 more bites per day (P<0.01) than LOW cows. In spite of this, LOW cows had an increased rate of GDMI of 3.2 g per minute (P<0.05) than HIGH cows.

3.4.2. Grazing Behaviour Expressed Per 100 kg BW

The interaction between genetic merit and cow genotype was investigated for grazing behaviour variables of grazing time, total bites, bite rate, mastications and GDMI per bite expressed per unit BW, but proved non-significant.

The HIGH cows grazed for 11 minutes longer (P<0.01) and took 773 more bites per day (P<0.001) than LOW cows when expressed per 100 kg BW. However, LOW cows had a greater bite rate of 0.1 more bites per minute (P<0.01) and an increased intake per bite of 0.01 g DM (P<0.05) than HIGH cows.

The BDX cows tended to spend 6 minutes per day longer grazing (P=0.067) than beef cows per unit BW. A greater intake per bite of 0.013 g was also observed for BDX cows relative to beef cows per unit BW (P<0.05). Subsequently, BDX cows had a greater rate of GDMI of 0.6 g per minute than beef cows (P<0.01; Table 5).

3.4.3 Grazing Behaviour Expressed Per kg GDMI

An interaction was observed between genetic merit and cow genotype for total bites per day required to consume one unit of GDMI. Beef HIGH cows took 607 more bites than LOW beef cows (P<0.05) whereas HIGH BDX cows took 203 more bites than LOW BDX cows (P>0.05). Grazing behaviour variables of grazing time, bite rate and mastications expressed per unit intake were non-significant.

The HIGH cows spent 5 minutes per day longer grazing than LOW cows (P<0.05) when expressed on a per unit intake basis. Beef cows tended to spend 3.2 minutes per day longer grazing (P=0.072) than BDX. No significant difference was found across genetic merit or cow genotype for bite rate per unit intake or grazing mastications per unit intake (Table 5).

3.5. Ruminating Behaviour

3.5.1 Recorded Measurements

The interaction between genetic merit and cow genotype was investigated for all recorded ruminating variables but proved non-significant. Ruminating time, bouts, bout duration, ruminating mastications and mastication rate, ruminating boli, bolus size, ruminating time and mastications per bolus and number of boli per ruminating bout were all similar across cow genotype (Table 6). No significant differences were observed between cows of contrasting genetic merit for any of the aforementioned traits with the exception of a tendency (P=0.085) for LOW cows to have 2.7 more mastications per minute than HIGH cows.

3.5.2 Ruminating *Behaviour Expressed Per 100 kg BW*

The interaction between genetic merit and cow genotype was non-significant for ruminating variables of ruminating time, mastications and bolus size expressed per unit BW. Ruminating variables expressed per 100 kg BW were also similar between HIGH and LOW cows. Overall, cows spent an average of 66.3 minutes per day ruminating, took 4364 ruminating mastications and produced a bolus 5.7 g, when expressed per 100 kg BW. However, a significant difference was observed for cow genotype where BDX cows ruminated 5.9 minutes longer per day when expressed per 100 kg BW compared to beef cows (P<0.05; Table 6).

3.5.3 Ruminating *Behaviour Expressed Per kg GDMI*

The interaction between genetic merit and cow genotype was non-significant for ruminating variables of ruminating time and mastications expressed per unit intake. No differences were observed between HIGH and LOW cows for all ruminating variables expressed on a per unit intake basis. Beef cows ruminated for 3.1 minutes more per day and had 244 more mastications per unit intake (P<0.05) than BDX cows. Collectively, cows spent an average of 31.4 minutes per day ruminating and took 2124 ruminating mastications for each kg GDMI.

3.6 Correlations between GDMI per 100 kg BW, Production Efficiency and Grazing Behaviour

Grazing time, bouts, bout duration, total bites or bite rate were found not to be correlated (P>0.05) with either GDMI per 100 kg BW or milk yield expressed per unit intake or per 100 kg BW (Table 7). Intake per bite had a moderate positive correlation with GDMI per 100 kg BW (P<0.001) and tended to be weakly negatively correlated with milk yield per unit intake (P=0.059). Similarly, a moderate positive correlation was found between rate of intake and GDMI per 100 kg BW (P<0.001) while a weak negative correlation was evident with milk yield per unit intake (P<0.05). A moderate negative correlation was found between grazing time per kg GDMI and GDMI per 100 kg BW (P<0.001) whereas a weak positive correlation was observed between grazing time per kg GDMI and milk yield per unit intake (P<0.05). For all aforementioned traits, no association was found with milk yield per 100 kg BW. Grazing time per 100 kg BW was positively weakly correlated with milk yield per

100 kg BW (P<0.05) and moderately correlated per unit intake (P<0.01), but no association was found between grazing time per 100 kg BW and GDMI per 100 kg BW.

3.6.1 Correlations between GDMI per 100 kg BW, Production Efficiency and Ruminating Behaviour

Ruminating time, bouts or bout duration were found not to be correlated with GDMI per 100 kg BW, milk yield per 100 kg BW or per unit intake (Table 8). Ruminating time per unit intake was moderately negatively correlated with GDMI per 100 kg BW (P<0.001) but no correlation was apparent with the efficiency measures investigated. Ruminating time per 100 kg BW had a moderate positive correlation with GDMI per 100 kg BW (P<0.001) and with milk yield per 100 kg BW (P<0.001). An increase in ruminating mastications per 100 kg BW was correlated with a higher GDMI per 100 kg BW (P<0.001) and increased milk yield per 100 kg BW (P<0.001). Conversely, ruminating mastications per unit intake were weakly negatively correlated with GDMI per 100 kg BW (P<0.01). Bolus size per 100 kg BW had a weak positive correlation with GDMI per 100 kg BW (P<0.05) but had no correlation with milk yield per 100 kg BW or per unit intake. Of all ruminating variables investigated there was no correlation with milk yield per unit intake.

4. Discussion

Numerous studies have been carried out, primarily on dairy cattle, which have provided a comprehensive description of animal behaviour at pasture (O'Connell et al., 2000; Kennedy et al., 2009; Prendiville et al., 2010). Studies that related specifically to beef cattle were typically conducted using small datasets (Zemo and Klemmedson, 1970; Hejcmanová et al., 2009) through the means of visual observation (Gary *et al.*, 1970; Kilgour *et al.*, 2012; Da Silva *et al.*, 2013). Often these omit large periods, being spread out over different time points throughout the grazing season (Hejcmanová et al., 2009; Da Silva et al., 2013). With visual observation, studies are predominantly carried out during daylight hours which led to large variation in results presented in the literature as a proportion of grazing occurs during darkness along with the majority of rumination (Kilgour et al., 2012) which is often omitted from results (Gary *et al.*, 1970; Lathrop *et al.*, 1988; Funston *et al.*, 1991). Absence of herbage intakes and sward characteristics in behavioural studies also created gaps in knowledge in comprehending the complexities of the grazing process in ruminants (Krysl and Hess, 1993). The use of technologies to record animal behaviour and herbage intake continuously over a 24 hour period (Funston et al., 1991; Schauer et al., 2005; Mezzalira et al., 2014) has provided more accurate determinations of the length of time spent by cattle in performing the three major behaviours – grazing, ruminating and resting (Kilgour, 2012). Simultaneously, it also provides us with a concise breakdown of the mechanisms surrounding these behaviours.

Despite the improvements in the use of technologies, no study has evaluated the grazing and ruminating behaviour of lactating suckler beef cows to intensive pasture based systems. Although few significant differences were observed in the present study, the values extrapolated for all variables on grazing and ruminating investigated over one grazing season are of great importance in a novel research area lacking a comprehensive overview of the basic behaviours governing intake and subsequent animal performance of beef cows. Previous work on dairy cows has illustrated how differences in grazing behaviour can dictate a cow's production efficiency (Prendiville *et al.*, 2010), highlighting that potential exists for future work to identify beef cows most suitable for specialised grazing systems.

4.1. Cow milk yield, BW, BCS, GDMI and sward quality

Although not the focus of this study, the additional information on cow performance conformed to differences already reported between BDX and beef cows. Consistent with the findings of the current study, McGee *et al.* (2005b) reported that BDX cows were lighter by approximately 100 kg, with Wright *et al.* (1994) and McGee *et al.* (2005a) reporting 27% and 31% greater milk production, respectively, for BDX which resulted in greater calf weaning weights (McGee *et al.* 2005a). The results from the current study were also in agreement with Murphy *et al.* (2008) who reported greater GDMI per 100 kg BW of BDX as a result of an increased GDMI of 0.5 to 1.0 kg as the proportion of beef ancestry decreased. Cows suited to grazing systems should have a high intake capacity. In the current study this proved in favour of BDX cows in the efficiency variables due to a greater GDMI combined with smaller cow size, as previously reported by Prendiville *et al.* (2009).

A preliminary study on some of the current experimental animals (n=76) when primiparous cows was conducted by McCabe *et al.* (2017). The divergence between HIGH and LOW cows was therefore as anticipated due to expected differences in predicted transmitting ability (PTA) between genetic merit groups, which appear to have developed as parity progressed. The expected PTA difference between genetic merit groups were 0.0003 (SD = 0.18) kg/d, 2.55 (SD = 5.99) kg/d and -7.16 (SD = 12.49) kg for feed intake, milk and BW, respectively, in favour of the HIGH group. Greater milk yield and lighter BW for the HIGH cows follows the expected trend in PTA, albeit differences between genetic merit groups were non-significant. The only transgression from these expected differences occurred for GDMI, where for every increase in PTA for feed intake HIGH cows were expected to consume -0.0016 kg/day, whereas the LOW group had -0.0019 kg/day, which is in contrast to what was observed in the current study. It must be noted however the reliability within the genetic index for the trait feed intake is only half of that for milk yield and BW (22% compared to 42% and 43%, respectively). The resulting efficiency parameters investigated proved more favourable for HIGH cows for the Replacement Index.

As demonstrated by Mezzalira *et al.* (2014), herbage intake is dependent on the interaction between animal behaviour and composition and quality of the herbage on offer. The sward measurements taken in the present study demonstrated that sufficient quantities of high quality herbage (Curran *et al.*, 2010) were available to all groups over the one grazing season the experiment was conducted and therefore did not have an influence on behavioural characteristics investigated.

4.2. Grazing Behaviour

Differences observed in grazing behaviour in the current study between BDX and beef cows were primarily attributed to differences in cow BW and GDMI, which were expressed in the efficiency variables extrapolated, and not the absolute measures recorded during grazing. The smaller physical size of BDX compared to beef created no constraints on bite mass in contrast to the suggestion by Rook (2000) that animal anatomy imposed limitations on bite mass, i.e. muzzle and body size. In fact, BDX in the current study exhibited more intensive grazing behaviour in terms of an increased grazing time, intake per bite and intake rate compared to beef cows when expressed on a per 100 kg BW basis. This intensive grazing behaviour becomes more apparent when expressed per unit intake where BDX cows required less time and bites to consume the same quantity of herbage as beef cows.

Despite few differences being observed between contrasting cow genotypes, relatively large differences in absolute grazing patterns were detected over one year between HIGH and LOW cows in the current study. Albeit no comparison between high and low genetic merit animals were assessed in the following studies, HIGH cows in the current study spent a similar time grazing to the mean time reported by Lathrop *et al.* (1988) of 564 minutes and Schauer *et al.* (2005) of 574 minutes per day. Celaya *et al.* (2007) however observed non-lactating beef cows grazed for only one minute less (510 minutes/day) than the LOW cows in the current study. A greater GDMI for the LOW group, in spite of reduced grazing time and number of bites compared to the HIGH group, can be elucidated by behaviour outlined by Da Silva *et al.* (2013) who suggested that increased intake per bite had a larger influence on overall daily intake relative to grazing time and bite rate. These behavioural relationships are also in agreement with Mezzalira *et al.* (2014) who found that bite mass was the major determinant of intake in heifers. While LOW cows had an increased bite mass and overall GDMI, the greater production level by the HIGH group may be attributed to a voluntary reduction of bite mass which could potentially assist greater selectivity of herbage to increase nutritional quality (Mezzalira *et al.*, 2014) and was possibly facilitated by a longer overall grazing time.

Previous work on dairy cows has shown that cows most suitable for intensive grazing systems are capable of achieving high intake of grazed grass per unit BW, i.e. have a high intake capacity (Buckley *et al.*, 2005). Results from the current study have illustrated that cow with higher intakes have achieved it from longer grazing times on a per 100 kg BW basis than absolute grazing times. Cows with high GDMI per 100 kg BW are more efficient and intensive grazers. Increased intake per bite and rate of intake combined with reduced time grazing per unit intake were fundamental in the cow type that achieved an increased GDMI per 100 kg BW. The lack of association between any of the mastication efficiency traits is as reported by Prendiville *et al.* (2010), who hypothesised that the greater GDMI per 100 kg BW may therefore be essentially a direct result of a greater rumen capacity per unit of BW (rumen-reticulum mass and volume) than an increased passage rate due to reduction in particle size from masticating.

4.3. Ruminating Behaviour

Rumination is a process of regurgitating ingesta from the rumen into the mouth where the bolus is masticated, mixed with saliva and re-swallowed followed by a short pause before repeating the process (Welch, 1982). In the current study, neither cow genotype nor genetic merit exhibited differences in absolute ruminating behaviour. The lack of association between ruminating time and genetic merit or cow genotype is in line with the findings of Gregorini *et al.* (2013) on lactating dairy cows of diverse genetic merit and Kropp *et al.* (1973) on Hereford and Hereford x Holstein heifers. Values for ruminating time in the current study fall within the range outlined in a review by Kilgour (2012) of 22 studies on grazing beef and dairy (non-milking) cattle encompassing a diversity of production systems, breeds, ages and animal types (heifers, steers, bulls, cows) of 4.7 h to 10.2 h. The values for ruminating time extrapolated in the current study equated to the same proportion of the day (75% of time spent grazing) spent ruminating as outlined by Fraser and Broom (1997). Longer ruminating time per 100 kg BW was extrapolated where cows had a greater GDMI per 100 kg BW, a result of the greater intake per unit BW. Number of ruminating boli per day in the current study were similar to that reported by Prendiville *et al.* (2010) for lactating Jersey cows at 422, but on average were 163 boli less than that reported by Gregorini *et al.* (2013) for Jersey cows.

Rook (2000) outlined how cow anatomy can influence behaviour, with body and muzzle size creating physical limitations, which was also observed in bolus movement during rumination by Prendiville *et al.* (2010). This however had no effect on the pattern of bolus movement for cows of varying genotype despite the beef cows being 61 kg BW heavier than BDX. The weak positive correlation between GDMI per 100 kg BW and bolus size per 100 kg BW observed in the present study, which differs from that reported by Prendiville *et al.* (2010), suggested that physical size had no effect on bolus production in the current study. Cows exhibiting a greater GDMI per 100 kg BW had increased ruminating mastications per 100 kg BW which suggest an increased herbage particle reduction post grazing, facilitating increased herbage intake, digestion and milk production (Gregorini *et al.*, 2013). The paucity of reported data in terms of ruminating behaviour among beef cattle within the literature was evident, highlighting the need for more detailed research into rumination behaviours such as that available for grazing behaviour.

Conclusion

The current study was the first to provide a detailed insight into the comparative grazing behaviour of lactating beef and beef x dairy crossbred suckler cows of diverse genetic merit for maternal traits based on the Irish beef Replacement Index under grazing conditions. Results from one grazing season highlighted that despite large differences in grazing behaviour between HIGH and LOW cows, no differences were apparent in terms of production efficiency variables extrapolated, with the exception of a tendency for HIGH cows to produce more milk per unit intake. The current study found no differences in absolute grazing and ruminating behaviour measurements between beef cows differing in genotype over this one grazing season. However, BDX were more intensive grazers when expressed per unit intake and per 100 kg BW and consumed greater quantities of herbage despite a lighter BW, which indicated their suitability within an intensive pasture based system.

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Table 1: Number of animals by cow genotype and parity, Replacement Index value ± SD (€) and mean calving date ± SD across genetic merit

	Beef		BDX[1]	
	High GM[2]	Low GM	High GM	Low GM
Replacement Index (€)	111 ± 35	41 ± 27	138 ± 26	76 ± 29
Total number of cows	19	24	22	38
Primiparous cows	1	9	4	13
Second parity cows	18	15	18	25
Mean calving date	19/3/15 ± 27	21/3/15 ± 17	12/3/15 ± 24	17/3/15 ± 23

[1]BDX = beef x dairy

[2]GM = genetic merit

Table 2: Number of animals by cow genotype and parity for headset recording success across genetic merit and breakdown of failed attempts.

	Beef		BDX[1]	
	High GM[2]	Low GM	High GM	Low GM
Number of headsets/day	4	5	6	7
Behaviour recording attempts	62	69	82	97
Recording successes - total	35	42	36	73
One record/animal	4	8	10	4
Two records/animal	14	14	10	33
Three records/animal	1	2	2	1

[1]BDX = beef x dairy

[2]GM = genetic merit

Table 3: Pre- and post-grazing sward surface heights, pre-grazing herbage yield and chemical composition of grass offered to cows during the measurement periods.

	August 11 to August 23		August 24 to September 26	
Item	Mean	SD	Mean	SD
Pre-grazing sward surface height (cm)	11.0	1.4	11.4	1.9
Post-grazing sward surface height (cm)	4.1	0.5	4.2	0.7
Pre-grazing grass yield (kg DM/ha)	1715	225	1785	300
Crude Ash (g/kg DM)	105	0.2	92	8
CP[1](g/kg DM)	175	7	178	41
ADF[2] (g/kg DM)	232	10	234	11
OMD[3] (g/kg OM)	768	16	792	6
NDF[4] (g/kg DM)	430	16	421	15

[1]Crude protein=crude protein

[2] ADF= Acid detergent fiber

[3]OMD= Organic matter digestibility

[4]NDF= Neutral detergent fiber

Table 4: Effect of genetic merit and cow genotype on milk yield, body weight, body condition score, calf weaning weight, grass intake, grass dry matter intake per 100 kg BW and production efficiency measures.

	Genetic Merit (GM)			Genotype (G)			Significance[1]		
Item	High	Low	S.E.M.	Beef	[2]BDX	S.E.M.	GM	G	GM*G
Milk yield (kg/d)	8.4	7.9	0.39	7.3	9.0	0.40		<0.01	
Body weight (kg)	614	643	11.1	659	598	11.1		<0.001	
Body condition score	2.76	3.00	0.035	3.09	2.67	0.034	<0.001	<0.001	
Calf weaning weight (kg)	281	279	5.1	271	290	5.5		<0.05	
[3]GDMI (kg)	12.9	13.8	0.31	13.0	13.8	0.31	0.057	0.072	
GDMI/100kg body weight (kg)	2.11	2.15	0.059	1.99	2.27	0.056		<0.001	
Milk yield/100kg body weight (kg)	1.38	1.27	0.072	1.13	1.52	0.074		<0.001	
Milk yield/GDMI (kg/kg)	0.67	0.59	0.029	0.57	0.68	0.029	0.079	<0.01	

[1]Non-significant (p>0.05) unless p value stated

[2]BDX = beef x dairy

[3]GDMI = Grass dry matter intake

Table 5: Grazing behaviour of high and low genetic merit cows and beef and beef x dairy cows.

	Genetic Merit (GM)			Genotype (G)			Significance[1]		
Item	High	Low	S.E.M.	Beef	[2]BDX	S.E.M.	GM	G	GM*G
Grazing time (min/d)	553	511	11.6	536	528	11.6	<0.05		
Grazing bouts (number/d)	7.2	7.5	0.37	7.6	7.1	0.37			
Grazing bout duration (min/bout)	83.9	74.3	4.57	77.0	81.1	4.52			
Total bites (number/d)	29837	26263	818.5	28235	27864	817.0	<0.01		
Bite rate (number bites/min)	67	71	1.3	69	69	1.3	<0.05		
Grazing mastications (number/d)	9198	9310	532.2	9154	9353	530.3			
Grazing mastications rate (number/min)	16.42	18.64	1.186	17.70	17.35	1.18			
[1]GDMI/bite (g)	0.45	0.54	0.019	0.48	0.51	0.018	<0.01		<0.05

Rate of GDMI (g/min)	24.1	27.3	0.89	24.8	26.6	0.89	<0.05		
<u>per 100 kg BW</u>									
Grazing time (min)	92	81	2.6	83	89	2.6	<0.01	0.067	
Total bites (number/d)	4922	4149	160.1	4363	4708	159.8	<0.001		
Bite rate (number bites/min)	11.2	11.3	0.30	10.7	11.8	0.30	<0.01		
Mastications (number/d)	1532	1456	89.8	1410	1579	89.6			
GDMI/bite (g)	0.073	0.083	0.003	0.072	0.085	0.004	<0.05	<0.05	
Rate of GDMI (g/min)	3.9	4.3	0.15	3.8	4.4	0.16		<0.01	
<u>per kg GDMI</u>									
Grazing time (min)	43.5	38.5	1.31	42.6	39.4	1.30	<0.05	0.072	
Total bites (number/d)	2363	1958	73.6	2248	2074	73.4	<0.001	0.087	<0.05
Bite rate (number bites/min)	5.3	5.4	0.21	5.5	5.1	0.21			
Grazing mastications (number)	708	727	55.0	745	690	54.9			

[1]Non-significant (p>0.05) unless p value stated

[2]BDX = beef x dairy

[3]GDMI = Grass dry matter intake

Table 6: Ruminating behaviour of high and low genetic merit cows and beef and beef x dairy cows.

	Genetic Merit (GM)			Genotype (G)			Significance[1]		
Item	High	Low	S.E.M.	Beef	[2]BDX	S.E.M.	GM	G	GM*G
Ruminating time (min/d)	418	404	11.5	412	410	11.4			
Ruminating bouts (number/d)	10.7	11.1	0.32	11.0	10.7	0.32			
Ruminating bout duration (min/bout)	40.2	37.9	1.33	38.5	39.6	1.33			
Ruminating mastications (number/d)	27502	26775	997.3	27433	26844	998.9			

Ruminating mastication rate (number/min)	65.6	68.3	1.04	67.6	66.3	1.04	0.085	
Ruminating boli (number/d)	427	436	16.7	442	419	17.9		
Bolus size (g)	36.0	34.6	3.89	34.1	36.4	3.86		
Ruminating time/Bolus (min)	1.09	1.02	0.061	1.01	1.09	0.061		
Ruminating mastications/bolus (number)	24.5	23.9	2.96	25.2	23.2	2.95		
Boli/ruminating bout (number)	40.7	40.2	1.64	40.7	40.2	1.63		
per 100 kg BW								
Ruminating time (min)	68.9	64.7	2.10	63.9	69.8	2.10		<0.05
Ruminating mastications (number)	4514	4271	160.2	4217	4567	160.0		
Bolus size (g)	5.9	5.4	0.62	5.3	6.0	0.61		
per kg GDMI[1]								
Ruminating time (min)	33.1	30.3	1.11	33.2	30.1	1.10		<0.05
Mastications (number)	2178	2090	77.3	2256	2012	76.7		<0.05

[1]Non-significant (p>0.05) unless p value stated

[2]BDX = beef x dairy

[3]GDMI = Grass dry matter intake

Table 7: Correlations (P-values in parentheses*) between grass dry matter intake per 100 kg BW and production efficiency measures with grazing behaviour across beef and beef x dairy high and low genetic merit cows.

Item	GDMI[1] (kg/100 kg of BW)	Milk Yield (kg/100 kg of BW)	Milk Yield (kg/kg of GDMI)
Grazing time (min/d)	0.06	0.04	0.05

Grazing bouts (n/d)	0.09	0.17	0.15
Grazing bout duration (min/bout)	-0.09	-0.16	-0.13
Total bites (n/d)	0.08	0.07	0.06
Bite rate (n of bites/min)	-0.05	-0.05	-0.04
GDMI/bite (g)	0.37 (<0.001)	0.05	-0.19 (=0.059)
Rate of GDMI (g/min)	0.43 (<0.001)	0.07	-0.20 (<0.05)
Grazing time (min/kg of GDMI)	-0.38 (<0.001)	-0.03	0.23 (<0.05)
Grazing time (min/100 kg of BW)	-0.05	0.22 (<0.05)	0.30 (<0.01)
Grazing mastications (n/d)	0.03	-0.01	0.02
Grazing mastications (n/kg of GDMI)	-0.18	-0.03	0.11

*Non-significant (p>0.05) unless p value stated

[1]GDMI = grass dry matter intake

Table 8: Correlations (*P*-values in parentheses*) between grass dry matter intake per 100 kg BW and production efficiency measures with ruminating behaviour across beef and beef x dairy high and low genetic merit cows.

Item	GDMI[1] (kg/100 kg of BW)	Milk Yield (kg/100 kg of BW)	Milk Yield (kg/kg of GDMI)
Ruminating time (min/d)	0.14	0.04	-0.04
Ruminating bouts (n/d)	0.06	0.15	0.12

Ruminating bout duration (min/bout)	-0.03	-0.16	-0.15
Ruminating time (min/kg of GDMI)	-0.34 (<0.001)	-0.03	0.17
Ruminating time (min/100 kg of BW)	0.46 (<0.001)	0.39 (<0.001)	0.16
Ruminating mastications (n/d)	0.16	0.04	-0.05
Ruminating mastications (n/100 kg of BW)	0.44 (<0.001)	0.34 (<0.001)	0.13
Ruminating mastications (n/kg of GDMI)	-0.26 (<0.01)	-0.02	0.14
Total mastications (n/d)	0.14	0.04	-0.04
Bolus size (g)	0.09	0.03	-0.02
Bolus size (g/100 kg of BW)	0.21 (<0.05)	0.15	0.05
Ruminating boli (n/d)	0.14	0.15	0.07
Boli (n/ruminating bout)	0.06	0.02	-0.03
Ruminating mastications (n/bolus)	0.01	0.04	0.07

*Non-significant (p>0.05) unless p value stated

[1]GDMI = grass dry matter intake