

Effect of pasture allowance and cows' lactation stage on perennial ryegrass sward quality, pasture dry matter intake and milk performance of Holstein-Friesian cows

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Abstract

Efficient exploitation of grass for cattle requires the application of appropriated grassland management strategies to maximize pasture dry matter intake (PDMI) while maintaining high sward quality by allocating cows to an adequate pasture allowance (PA). The aim of this study was to investigate the effect of two PA, low (L) vs. high (H), on sward quality, PDMI and milk performance of Holstein-Friesian cows ($n = 72$) at two lactation stages (LS), early (E) vs. middle (M). Cows were randomly assigned to four groups (LE, LM, HE and HM) in a 2×2 factorial design. The low PA treatments completed 5 rotations, with more grazing days (+ 13), lower pre- (14.3) and post-grazing (5.3) sward heights (cm) and higher herbage utilization (81.7%). The low PA had higher stocking rate than the high PA treatments (4.8 vs. 3.9 cows ha^{-1}) and lower PDMI (13.4 kg vs. 14.4 DM $\text{cow}^{-1} \text{day}^{-1}$) with higher ($p < 0.05$) (g kg^{-1} DM) protein (149.1), carbohydrates (166.7) and digestibility (746.8) while lower ($p < 0.05$) DM (18.4%), acid (283.5) and neutral detergent (508.6) fibers (g kg^{-1} DM). Sward quality is deteriorated ($p < 0.05$) from rotation 1 to 5, lower decrease was found on low PA treatments. Milk yield (MY) was higher ($p < 0.05$) in cows at early LS (24.8 kg $\text{cow}^{-1} \text{day}^{-1}$), with the lowest ($p < 0.05$) protein (28.9) and fat (36.9) content (g kg^{-1}). No differences were found on MY between PA treatments, but higher protein and fat content were observed on low PA. Decreasing PA resulted in higher sward and milk quality without penalizing MY.

Additional key words: calving date; daily herbage allowance; grass nutritive value; grassland management; herbage intake; pasture-based milk production systems; stocking rate.

Resumen

Efecto de la disponibilidad de hierba y del estado de lactación sobre la calidad del pasto de raigrás inglés, la ingestión de materia seca y la producción de leche de vacas Holstein-Friesian

Un uso eficiente de la hierba por el ganado requiere de la aplicación de apropiadas estrategias de manejo del pasto para maximizar la ingestión de materia seca (PDMI) mientras se mantiene una alta calidad del pasto con una adecuada disponibilidad de hierba (PA). El objetivo de este estudio fue investigar el efecto de dos PA, baja (L) vs. alta (H), sobre la calidad del pasto, PDMI y producción de leche de vacas Holstein-Friesian ($n = 72$) en dos estados de lactación (LS), inicio (E) vs. mitad (M). Los animales fueron asignados al azar a cuatro grupos (LE, LM, HE y HM) en un diseño factorial 2×2 . Los grupos con baja PA completaron 5 rotaciones, con más días de pastoreo (+ 13), menores alturas de la hierba (cm) pre- (14,3) y post-pastoreo (5,3) y mayor utilización del pasto (81,7%). Los tratamientos con baja PA mostraron una carga ganadera mayor que los de alta PA (4,8 vs. 3,9 vacas ha^{-1}) y una PDMI menor (13,4 vs. 14,4 kg MS $\text{vaca}^{-1} \text{día}^{-1}$) con mayores ($p < 0,05$) contenidos (g kg^{-1} MS) en proteína (149,1), carbohidratos (166,7) y digestibilidad

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Abbreviations used: ADF (acid detergent fibre); BCS (body condition score); BW (body weight); CP (crude protein); DIM (days in milk); GP (grazing pressure); HM (herbage mass); IVODM (digestibility *in vitro* of organic matter); LS (lactation stage); MY (milk yield); NDF (neutral detergent fibre); PA (pasture allowance); PDMI (pasture dry matter intake); SEM (standard error of the mean); SH (sward height); SR (stocking rate).

(746,8) pero menores ($p < 0,05$) MS (18,4%), fibra ácido (283,5) y neutro (508,6) detergente (g kg^{-1} MS). La calidad del pasto disminuyó ($p < 0,05$) de la rotación 1 a la 5, siendo el descenso menor con baja PA. Las vacas de inicio de lactación ($24,8 \text{ kg vaca}^{-1} \text{ día}^{-1}$) produjeron más leche (MY) ($p < 0,05$), pero con menores ($p < 0,05$) contenidos de proteína (28,9) y grasa (36,9) (g kg^{-1}). No se observaron diferencias en MY entre tratamientos, pero la baja PA mostró mayores contenidos de proteína y grasa. La disminución en PA provocó mayor calidad del pasto y de leche sin penalizar MY.

Palabras clave adicionales: carga ganadera; disponibilidad diaria de pasto; fecha de parto; ingestión de hierba; manejo del pasto; sistemas de producción de leche en pastoreo; valor nutritivo de la hierba.

Introduction

Galician agrarian economy is highly oriented to husbandry with dairy sector as the most important social driver, accounting for more than 35% of the total Spanish milk quota ($2.2 \times 10^6 \text{ kg}$ over $6.0 \times 10^6 \text{ kg}$). For milk production, however, only the 8% of permanent pastures are used in Galicia (NW Spain), being around 16% agricultural land associated to sown pastures, forage maize and crops (MARM, 2010). Over the past 25-years, high milk prices have encouraged Galician dairy farmers to thrust in milk production systems with high inputs of supplements (mainly maize silage and concentrates) to feed high genetic merit Holstein-Friesian dairy cows, machinery for forage conservation and high inputs of fertilizer. Nevertheless, with an expected increase on feeding costs and low milk prices in the next years (motivated by abolition of milk quotas in 2015), limitations will appear to these high inputs milk production systems (Barbeyto-Nistal & López-Garrido, 2010) due to higher competitiveness between and within countries for dairy market (Peyraud *et al.*, 2010). As a result, the Dairy Section in the Animal Production Department at the *Centro de Investigaciones Agrarias de Mabegondo* (CIAM) highlights that an increased effort has to be made in Atlantic regions as Galicia on studying effective pasture-based milk production systems by supplying high quality fresh forage, ensuring good herbage use, whilst maintaining acceptable milk performance of the grazing animal. The use of available farm resources is the best way of reducing feeding costs of milk production by maximizing pasture dry matter intake (PDMI). Through the application of adequate grassland management strategies oriented to get high sward quality and good efficiency of herbage utilization across the grazing season is possible to achieve high quality milk production per cow and per hectare (Roca-Fernández *et al.*, 2011). The key point of research in most of the European dairy research centers (Mayne *et al.*, 2000; Dillon,

2006; Peyraud *et al.*, 2010) is an efficient conversion of grass into milk due to fresh forage is the cheapest source of nutrients to feed dairy cows (French *et al.*, 2007). Nevertheless, the studies on grassland management strategies to improve profitability of milk production systems under grazing conditions are low in Spanish humid areas (Mosquera-Losada & González-Rodríguez, 1998; González-Rodríguez, 2003) and need to be increased for implementing appropriate grazing practices at farm level. Despite the high site differences and seasonality of grass production in Galicia (González-Rodríguez *et al.*, 1996), high proportion of herbage in the ration of dairy cows should be the basis of low inputs milk production systems operating in Galician agricultural land. Enhancing the competitiveness of pasture-based dairy systems has important benefits: 1) feeding costs would be reduced; 2) rural landscape would be preserved; 3) a clean, animal-welfare-friendly image for dairy cattle production would be promoted (Dillon, 2006).

The main factors responsible for the dairy farm productivity in pasture-based milk production systems are considered to be: stocking rate (SR) (McCarthy *et al.*, 2011), cows' lactation stage (LS) (Dillon *et al.*, 1995), nitrogen fertilization (Delaby *et al.*, 1998) and concentrate supplementation (Bargo *et al.*, 2002). The balance between feed demand and supply at grazing is mainly determined by the relation between SR and cows' LS (Dillon *et al.*, 1995) due to the energy requirements for milk production of cows at the early lactation stage are not the same than those of animals at the middle lactation stage. In grazing systems, an imbalance demand-supply is complicated to control as over/under-grazing of pasture may affect the successive pasture growth, the leave senescence or grass nutritional value (Holmes *et al.*, 2002). Studies for strategic supplementation of grazing cow diets and appropriate grassland management strategies to be implemented by dairy farmers are now very necessary when trying to apply research results at farm level (Peyraud *et al.*, 2010). High ge-

netic merit dairy cows can achieve high levels of milk performance, with high economic returns, from a moderate concentrate input, although they do not fully exploit their milk potential (Delaby *et al.*, 1999). An annual production of 15,000 kg of milk per hectare from only 500 kg of concentrate fed per cow was reported by Horan *et al.* (2005) in Ireland on grazing conditions.

The SR, defined as the number of animals (cows) per unit of area of land (hectare) for a given time period, is a determinant factor of milk output per cow and per hectare in grazing systems (Hoden *et al.*, 1991). SR affects directly the grazing pressure (GP), defined as the number of animals (cows) per unit mass of herbage (kg DM ha⁻¹), and indirectly the pasture allowance (PA), defined as the weight of herbage dry matter allocated to animals (kg DM cow⁻¹) per unit of time (day), due to an increased competition between cows for the available herbage (Baker & Leaver, 1986). The theoretical negative relationship between SR and cow milk performance, described by Mott (1960), brings a significantly increase in the efficiency of herbage utilization, expressed as the proportion of herbage removed relative to that is available, when SR is increased. O'Donovan *et al.* (2004) found that cows grazing at high SR removed less herbage (-1.9 kg DM cow⁻¹ day⁻¹) than cows at medium SR, and this may lead to improve sward quality in subsequent grazing rotations. A state of equilibrium, however, must be attained whereby animal production from pasture and sward quality are optimized, as low rates of herbage utilization will result in wastage and may reduce cow performance during the grazing season (McEvoy *et al.*, 2009). Since the studies carried out by McMeekan & Walshe (1963), it has been shown that increasing the SR significantly affects milk output per cow and per hectare (MacCarthy, 1984; Hoden *et al.*, 1991; González-Rodríguez, 2008) and influences milk composition (O'Donovan *et al.*, 2004; Kennedy *et al.*, 2007; Stakelum & Dillon, 2007a,b; Stakelum *et al.*, 2007; MacDonald *et al.*, 2008; McCarthy *et al.*, 2011). The objective of our work was to study the effect of two levels of PA (low vs. high) on perennial ryegrass swards quality, PDMI and milk performance of Holstein-Friesian cows contrasting nutritional needs of animals at two LS (early vs. middle) under Galician grazing conditions.

Material and methods

The study was conducted at the CIAM, situated in Galicia, Spain (43°15'N; 81°18'W), from March 16 to August 2 in 2007. The soil was acid (pH_{KCl} 5.5) and has

a silt-loam texture (32% sand, 50% silt and 18% clay). The experimental area was a 5-yr old pasture with a high proportion of perennial ryegrass, low proportion (less than 10%) of white clover and other species (less than 20%). The pasture was initially sown in autumn with a mixture of 22 kg ha⁻¹ of *Lolium perenne* cv. Brigantia and 4 kg ha⁻¹ of *Trifolium repens* cv. Huia.

Weather climatic conditions

The mean daily temperature and total rainfall were slightly low during the experimental period in 2007 (14.8°C and 318 L m⁻²) when compared with the last 6-yr average (2001-06) (15.4°C and 389 L m⁻²). The highest monthly temperature and the lowest rainfall in the 7-yr considered were recorded in August, stopping grass growth due to summer drought. February was extremely a rainy month in 2007 when compared with the last 6-years average (Fig. 1).

Experimental design and treatments

The experiment investigated the effect of offering two target levels of PA, low (L- 15 kg DM cow⁻¹ day⁻¹) vs. high (H- 20 kg DM cow⁻¹ day⁻¹), on perennial ryegrass sward quality, PDMI and milk performance of Holstein-Friesian cows at two LS, early (E- 15th February 2007) vs. middle (M- 30th October 2006). A randomized block design with a 2 × 2 factorial arrangement of treatments was applied and results in this paper are expressed as means of 20 weeks at spring-summer grazing using 4-5 rotations per paddock. The following grazing treat-

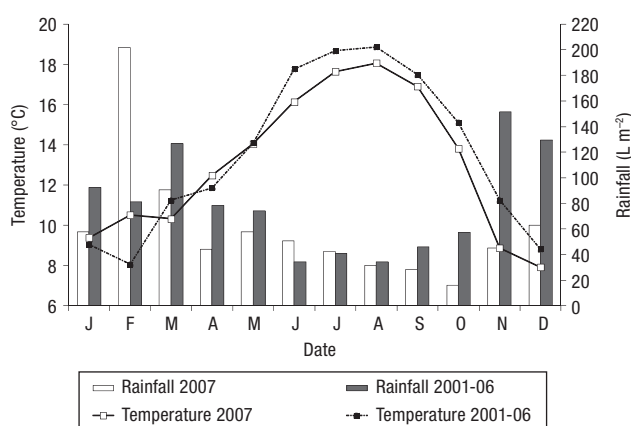


Figure 1. Monthly temperature and rainfall in 2007 compared to the last average 6-years.

ments were imposed in four separately farmlets: LE (L, sward at low pasture allowance and E, cow at early lactation stage), LM (L, sward at low pasture allowance and M, cow at middle lactation stage), HE (H, sward at high pasture allowance and E, cow at early lactation stage) and HM (H, sward at high pasture allowance and M, cow at middle lactation stage).

Animals and supplementation at pasture

Seventy-two multiparous (lactation number, 3.4 ± 1.52) Holstein-Friesian cows at two LS, early (E, $n = 44$) vs. middle (M, $n = 28$), were selected from the experimental dairy cattle at CIAM and randomly assigned to two PA, low (L, $n = 36$) vs. high (H, $n = 36$). Animals were rotationally grazing four independent areas of pasture and cows at different stages of lactation were never grazing in the same group: LE ($n = 22$), LM ($n = 14$), HE ($n = 22$) and HM ($n = 14$). The total area for grazing was 16.7 ha divided in 26 paddocks of around 0.65 ha each. Days in milk (DIM) when the trial started were 29 and 167 days for dairy cows at the early and at the middle lactation stage, respectively. All cows were supplemented at pasture from calving to the second grazing rotation with silage, 60% grass and 40% maize, mixture and concentrate. The silage and concentrate composition is presented in Table 1. From the beginning to the end of the grazing experiment, the amount of concentrate fed by each cow was measured daily as the difference between the amount of concentrate offered and the amount not fed. The level of concentrate gave to the animals was progressively reduced as grazing season and cows' LS advanced. At the beginning of the experiment, cows at the early lactation stage and cows at the middle lactation received 6 and 4 kg DM cow⁻¹ day⁻¹ of concentrate, respectively. At the end of April concentrate was reduced to 2 and nil kg DM cow⁻¹ day⁻¹ for cows at the early lactation stage and cows at the middle lactation, respec-

tively. The concentrate contained a mixture of six ingredients: barley (81%), soya flour (14%), vitamin mineral corrector (0.2%), dicalcium phosphate (2%), calcium carbonate (2%) and sodium chloride (0.8%).

Grazing management

At the end of the grazing season two different levels of SR, low vs. high, corresponding to two different levels of GP, low vs. high, will be obtained due to cows were allocated to two different target levels of PA, high (H- 20 kg DM cow⁻¹ day⁻¹) vs. low (L- 15 kg DM cow⁻¹ day⁻¹). The grazing interval was optimized with a flexible grazing management system based on using different grazing areas (total surface and number of paddocks to graze), previously established before starting the experimental period, and allocating animals to each individual treatment. The planned decision rules imposed at the beginning of the experiment for grazing management were the same for the four grazing treatments: 1) all cows entered into paddocks when sward height reached on average 15-20 cm and 2) left paddocks when the residual sward height was around 4 cm, assessed by a rising plate meter (Frame, 1981), in order to avoid under- or overgrazing pastures. Paddocks in the four grazing treatments were rotationally grazed, modifying daily the subarea to graze using a strip electric wire, in order to offer the two PA (L, 15 vs. H, 20 kg DM cow⁻¹ day⁻¹) for the high vs. low SR, respectively. Fresh herbage (> 4.0 cm) was allocated to each individual herd on a daily basis after the morning milking. No access to the previous day grazed surface was allowed to cows by back fencing with temporary electric wire moved daily and all paddocks had water supply. Weekly, it was monitored farm pasture cover (Mosquera-Losada & González-Rodríguez, 1998) during all the main grazing season (from spring to summer) up to the drought in August restricting grass supply. Average residency time

Table 1. Chemical ingredients of the diets (grass and maize silage and concentrate)

	Silage		Concentrate
	Grass	Maize	
Dry matter (%)	22.32	33.44	88.60
Organic matter (g kg ⁻¹ DM)	894	962	563
Crude protein (g kg ⁻¹ DM)	103	76	165
Acid detergent fibre (g kg ⁻¹ DM)	376	242	249
Neutral detergent fibre (g kg ⁻¹ DM)	535	460	468
Digestibility <i>in vitro</i> of organic matter (g kg ⁻¹ DM)	650	712	787

per paddock will be 3–4 days and cows only returned to the same paddock when a minimum of two leaves have appeared on the majority (> 66%) of perennial ryegrass tillers. This condition was established in order to keep similar sward structure in all the paddocks to graze for later comparison of sward quality responses in function of the two PA treatments. Swards were not topped during the experimental period.

Annual fertilizer application to the grazed and silage area was 84 kg ha⁻¹ of P₂O₅ and K₂O in February. The nitrogen fertilizer application was 135 kg ha⁻¹ in three splits, 45 kg ha⁻¹ in February and after the first and second grazing rotations in March and April, respectively. The silage area received 80 kg N ha⁻¹ in mid-March and 40 kg N ha⁻¹ after the first harvest in spring. The maize silage area had 600 kg ha⁻¹ of 8-15-15 (N, P₂O₅ and K₂O, respectively).

Sward measurements and chemical composition

Five random samples (0.33 m × 0.33 m) were taken per paddock before and after grazing, cutting to 4 cm above ground level with battery-operated shears, to determine herbage mass (HM) per hectare. Each sample was dried at 70°C for 24 h and 0.5 kg was milled, vacuum packed and stored at -20°C until later chemical composition analysis at CIAM using infrared reflectance spectroscopy by NIRS System 6500 (Foss Analytical, Hillerød, Denmark), applying the Castro-García's (1994) equations of calibration for determination of crude protein (CP), acid (ADF) and neutral (NDF) detergent fibers, water soluble carbohydrates (WSC) and digestibility *in vitro* of organic matter (IVODM). Five pre- and post-grazing sward heights (SH) were made using a rising plate meter (Frame, 1981) before cutting grass in each sample.

Pasture, silage and concentrate dry matter intake

Estimates of HM before and after grazing were used in order to calculate the following variables (Freer, 1960; Campbell, 1966; Hodgson, 1979):

— Herbage mass (HM) as kg DM ha⁻¹: $(A_i) + n_i * [(A_i - D_{i-1}) * r_i^{-1}]$

— Pasture allowance (PA) as kg DM cow⁻¹ day⁻¹: $HM * (cow * day)^{-1}$

— Pasture dry matter intake (PDMI) as kg DM cow⁻¹ day⁻¹: $[(A_i - D_i) + n_i * [(A_i - D_{i-1}) * r_i^{-1}]] * (cow * day)^{-1}$

— Herbage utilization as %: $(PDMI * PA^{-1}) * 100$, where A_i = kg DM ha⁻¹ before grazing; D_i = kg DM ha⁻¹ after grazing; D_{i-1} = kg DM ha⁻¹ after the previous grazing; n_i = number of grazing days (standing time) and r_i = number of days between D_{i-1} and A_i .

The second term in HM and PDMI estimations $n_i * [(A_i - D_{i-1}) * r_i^{-1}]$ is a correction factor. No direct measure was made of grass growth during grazing but the grass growth during the previous days' rest period was known and the mean estimate for each paddock for each rotation was applied to the results for each paddock in each rotation as a correction factor. It was assumed that the difference between the mean growth rate of a sward during the rest period after defoliation and the mean growth rate during the grazing (less than 2.5 days) would not be large enough to invalidate the estimate of intake, HM and PA (Freer, 1960).

Cows at the two levels of PA and the two LS examined were supplemented at pasture. The silage and concentrate DM intakes were daily determined from the difference between the amount offered and the residue on each day, summing these values during the experimental period for each treatment. DM losses were estimated from other studies, considering 20% for grass silage (González *et al.*, 1989) and 12% for maize silage (Phipps & Wilkinson, 1985).

Animal measurements

Body weight and body condition score. Weekly individual body weight (BW) was registered and body condition score (BCS) was scored twice a month, by one experienced observer on a 1 to 5 scale (1 = severe undercondition and 5 = severe overcondition) with 0.25 increments as described Wildman *et al.* (1982), during all the experiment.

Milk yield and composition. Milk yield (MY) from each cow was daily recorded by Alpro System (Alfa DeLaval, France) and samples were weekly collected, from two successive evening (Tuesday) and morning (Wednesday) milkings. Samples were preserved with potassium dichromate and stored at -20°C for milk composition. Milk protein and fat were determined in the *Laboratorio Interprofesional Gallego de Análisis de Leche* (LIGAL) using infrared spectroscopy by MilkoScan FT6000 (Foss Electric, Hillerød, Denmark).

Statistical analysis

All statistical analyses were carried out by SAS (SAS Inst., 2005). Sward measurements (pre- and post-grazing sward heights, herbage utilization and pasture dry matter intake) were analyzed using analysis of variance by a mixed model: $Y_{ijkl} = \mu + H_i + D_j + R_k + W_l(R_k) + H_i \times D_j + e_{ijkl}$ where: Y_{ijkl} represents the response of sward k to pasture allowance i and cows' lactation stage j ; μ is the mean; H_i is the pasture allowance ($i = 1$, low to 2, high); D_j is the cows' lactation stage ($j = 1$, early to 2, middle of the lactation period); R_k is the rotation ($k = 1$ to 5); $W_l(R_k)$ is the week within rotation ($l = 1$ to 20); $H_i \times D_j$ is the interaction between pasture allowance and cows' lactation stage; and e_{ijkl} is the residual error term. Least square means (LSM) and standard error of the means (SEM) were calculated for each variable. Mean differences were declared significant at $p < 0.05$ for the main effects.

Animal measurements (daily milk yield, milk composition, body weight and body condition score) were analyzed using the model as follows: $Y_{ijk} = \mu + H_i + D_j + H_i \times D_j + b_1 X_{ijk} + e_{ijk}$ where: Y_{ijk} represents the response of animal k managed at pasture allowance i and cows' lactation stage j ; μ is the mean; H_i is the pasture allowance ($i = 1$, low to 2, high); D_j is the cows' lactation stage ($j = 1$, early to 2, middle of the lactation period); $H_i \times D_j$ is the interaction between pasture allowance and cows' lactation stage; $b_1 X_{ijk}$ is the respective pre-experimental variable and e_{ijk} is the residual error term associated with the observation ijk .

Results

Grazing management

The effect of PA and cows' LS on grazing management for each of the four grazing treatments considered is shown in Table 2 (a). On average, cows were allocated to 16.4 kg DM cow⁻¹ day⁻¹ for the low PA treatments vs. 18.9 kg DM cow⁻¹ day⁻¹ for the high PA treatments. The grazing management imposed made a small difference in SR ($p < 0.05$, + 0.9 cows ha⁻¹) between the low and high PA treatments. The average grazing area was lower ($p < 0.05$, - 0.5 ha) in the high SR groups (4.8 cows ha⁻¹) than in the low SR groups (3.9 cows ha⁻¹). The low PA treatments had 5 over 4 grazing rotations ($p < 0.05$) compared to the high PA treatments. Lower rotation length was observed in the

low PA treatments ($p < 0.05$, - 3.7 days) in comparison to the high PA treatments (31.4 days), with higher total number of grazing days ($p < 0.05$, + 13 days) in the low PA treatments than in the high PA treatments (126 days).

Sward measurements and chemical composition

The effect of PA and cows' LS on sward measurements for each of the four grazing treatments considered is shown in Table 2 (b). The low PA treatments had lower pre- and post-grazing SH ($p < 0.05$, - 2.1 and - 1.0 cm) when compared with the high PA treatments (16.4 and 6.4 cm, respectively). The low PA treatments presented higher ($p < 0.05$, + 5.8%) herbage utilization in comparison to the high PA treatments (81.7%). The highest herbage utilization value was found in the LE group, allocated to the low level of PA (15.9 kg DM cow⁻¹ day⁻¹), while the lowest value was observed in the HE group, allocated to the high level of PA (18.9 kg DM cow⁻¹ day⁻¹). Pasture DM intake was higher ($p < 0.05$, + 1.0 kg DM cow⁻¹ day⁻¹) in the high PA treatments when compared with the low PA treatments (13.4 kg DM cow⁻¹ day⁻¹). The highest value of PDMI ($p < 0.05$) was found in the HM group (14.6 kg DM cow⁻¹ day⁻¹) while the lowest value was found in the LE group (13.2 kg DM cow⁻¹ day⁻¹). No significant differences were found between cows at different LS for pre- and post-grazing SH, herbage utilization, PDMI and silage (grass and maize) intake. Cows at the middle lactation stage showed lower concentrate intake ($p < 0.05$, - 2.2 kg DM cow⁻¹ day⁻¹) than those at the early lactation stage (3.2 kg DM cow⁻¹ day⁻¹) due to feeding requirements for milk production were not the same for animals at different LS. The total DM intake of the four grazing groups was 22.3, 18.9, 21.8 and 19.3 kg DM cow⁻¹ day⁻¹ for LE, LM, HE and HM, respectively. There were no differences in concentrate intake (on average, 20.6 kg DM cow⁻¹ day⁻¹) when comparing high vs. low PA treatments. Total DM intake was the highest ($p < 0.05$, + 2.0 kg DM cow⁻¹ day⁻¹) in cows at the early lactation stage than in cows at the middle lactation stage (19.1 kg DM cow⁻¹ day⁻¹) due to differences on energy requirements of animals as lactation progressed. The sward chemical composition is affected by the level of PA allocated to cows, as it is showed in Table 2 (c), with long-term effects on subsequent grazing rotations. The low PA treatments showed lower ($p < 0.05$) DM, ADF and NDF content and higher ($p < 0.05$) CP, WSC and IVOMD values in comparison to the high PA treatments, with no differences in any of the sward

chemical constituents considered when cows were at different LS. The highest CP, WSC and IVOMD ($p < 0.05$, + 26.3, + 21.9 and 24.8 g kg⁻¹ DM, respectively) values were found in the swards managed at the lowest level of PA, in the LE group, using cows at the early lactation stage while the lowest ($p < 0.05$) CP, WSC and IVOMD values (127.5, 145.9 and 756.5 g kg⁻¹ DM, respectively) were found in the swards managed at the highest level of PA, in the HM group, using cows at the middle lactation stage. Moreover, the ADF and NDF content of the swards were the lowest ($p < 0.05$, - 18.9 and - 18.3 g kg⁻¹ DM, respectively) in the LE group when the lowest level of PA was applied to cows at the early lactation stage while the highest ($p < 0.05$) ADF and NDF

content of the swards were found in the HM group (309.6 and 536.3 g kg⁻¹ DM, respectively) when the highest level of PA was applied to cows at the middle lactation stage. There were differences on sward chemical composition between rotations for the two PA treatments. The DM content, ADF and NDF of the swards (+ 9.8%, + 138.0 and + 192.7 g kg⁻¹ DM, respectively) were the highest ($p < 0.05$) in the rotation 5, when higher proportion of senescent material was found in the swards, compared to the rotation 1 with the lowest values of these sward variables (16.4%, 231.4 and 433.3 g kg⁻¹ DM, respectively) when higher proportion of leaf material was found in the swards. The contrary response was observed for CP content, WSC and IVOMD. In fact, the highest ($p < 0.05$)

Table 2. Effect of pasture allowance (L, low vs. H, high) and cows' lactation stage (E, early vs. M, middle) on: a) grazing management; b) sward measurements and intake; c) grass composition and d) animal performance for the four groups of Holstein-Friesian dairy cows

	Grazing treatments ¹			
	Low (L)		High (H)	
	Early (E)	Middle (M)	Early (E)	Middle (M)
<i>a) Grazing management</i>				
Total number of cows per herd	22	14	22	14
Pasture allowance (kg DM cow ⁻¹ day ⁻¹)	15.9 ^a ± 0.6 ²	16.9 ^a ± 0.7	18.9 ^b ± 0.9	19.0 ^b ± 1.1
Grazing area (ha)	4.1 ^a ± 0.6	3.4 ^b ± 0.3	5.3 ^c ± 0.4 ²	3.9 ^{ab} ± 0.4
Stocking rate (cows ha ⁻¹)	5.4 ^a ± 0.5	4.2 ^b ± 0.3	4.2 ^b ± 0.3	3.6 ^c ± 0.2
Number of rotations	5 ^a	5 ^a	4 ^b	4 ^b
Rotation length (days)	27.8 ^a ± 1.6	27.6 ^a ± 1.4	31.5 ^b ± 2.0	31.3 ^b ± 1.9
Total number of grazing days	139 ^a	138 ^a	126 ^b	125 ^b
<i>b) Sward measurements and intake</i>				
Pre-grazing sward height (cm)	13.7 ^{ab} ± 0.92	14.8 ^b ± 1.5	15.8 ^{bc} ± 1.8	16.9 ^c ± 2.0
Post-grazing sward height (cm)	5.2 ^a ± 0.2	5.5 ^a ± 0.4	6.2 ^b ± 0.7	6.5 ^b ± 0.8
Herbage utilization (%)	82.8 ^a ± 3.3	80.6 ^{ab} ± 3.0	75.1 ^c ± 2.3	76.8 ^{bc} ± 2.5
Pasture intake (kg DM cow ⁻¹ day ⁻¹)	13.2 ^a ± 0.4	13.6 ^{ab} ± 0.5	14.2 ^{bc} ± 0.6	14.6 ^c ± 0.7
Silage intake (kg DM cow ⁻¹ day ⁻¹)	5.3 ^a ± 5.5	4.7 ^a ± 3.7	5.0 ^a ± 4.8	3.4 ^a ± 3.5
Concentrate intake (kg DM cow ⁻¹ day ⁻¹)	3.3 ^a ± 0.7	1.0 ^b ± 0.8	3.1 ^a ± 0.7	0.9 ^b ± 0.8
<i>c) Grass composition</i>				
Dry matter (%)	16.78 ^a ± 0.462	16.81 ^a ± 0.44	18.48 ^b ± 0.57	19.34 ^b ± 0.68
Crude protein (g kg ⁻¹ DM)	153.8 ^a ± 6.7	137.7 ^{bc} ± 6.2	139.7 ^c ± 5.6	127.5 ^b ± 5.5
Acid detergent fibre (g kg ⁻¹ DM)	290.7 ^a ± 10.4	294.3 ^a ± 9.3	298.8 ^{ab} ± 10.6	309.6 ^b ± 10.2
Neutral detergent fibre (g kg ⁻¹ DM)	518.0 ^a ± 14.9	528.0 ^{ab} ± 12.8	528.7 ^{ab} ± 15.3	536.3 ^b ± 14.0
Water soluble carbohydrates (g kg ⁻¹ DM)	167.8 ^a ± 10.0	154.4 ^{ab} ± 10.2	155.8 ^{ab} ± 11.5	145.9 ^b ± 10.9
Digestibility <i>in vitro</i> of organic matter (g kg ⁻¹ DM)	781.3 ^a ± 10.3	768.4 ^{ab} ± 12.7	767.1 ^b ± 11.9	756.5 ^b ± 13.5
<i>d) Animal performance</i>				
Body weight (kg)	563.1 ^a ± 5.92	579.6 ^{bc} ± 9.9	574.2 ^b ± 5.6	592.9 ^c ± 8.7
Body condition score (1-5)	2.84 ^a ± 0.07	2.97 ^{bc} ± 0.08	2.95 ^b ± 0.08	3.13 ^c ± 0.09
Milk yield (kg cow ⁻¹ day ⁻¹)	24.3 ^a ± 1.3	18.5 ^b ± 1.2	25.3 ^a ± 1.2	20.5 ^b ± 1.2
Milk protein content (g kg ⁻¹)	29.1 ^a ± 0.1	32.0 ^b ± 0.2	28.8 ^a ± 0.2	30.6 ^c ± 0.2
Milk fat content (g kg ⁻¹)	37.0 ^a ± 0.4	39.9 ^b ± 0.5	36.7 ^a ± 0.7	38.3 ^c ± 0.7

¹ LE (L, sward at low pasture allowance and E, cow at early lactation stage), LM (L, sward at low pasture allowance and M, cow at middle lactation stage), HE (H, sward at high pasture allowance and E, cow at early lactation stage) and HL (H, sward at high pasture allowance and M, cow at middle lactation stage). ² SEM: standard error of the mean. ^{a-d} Values in the same row not sharing a common superscript are significantly different ($p < 0.05$).

content of CP, WSC and IVOMD in the swards were reached when the leaf proportion was at the highest level in the rotation 1 (+ 53.7, + 133.0 and + 125.4 g kg⁻¹ DM, respectively) compared to the rotation 5 when the senes-

cent material was at the highest level due to higher sward quality deterioration (105.8, 92.6 and 677.5 g kg⁻¹ DM, respectively). In Figure 2 (a-h) is shown the evolution from 1 to 5 rotations of sward variables as pre- and post-

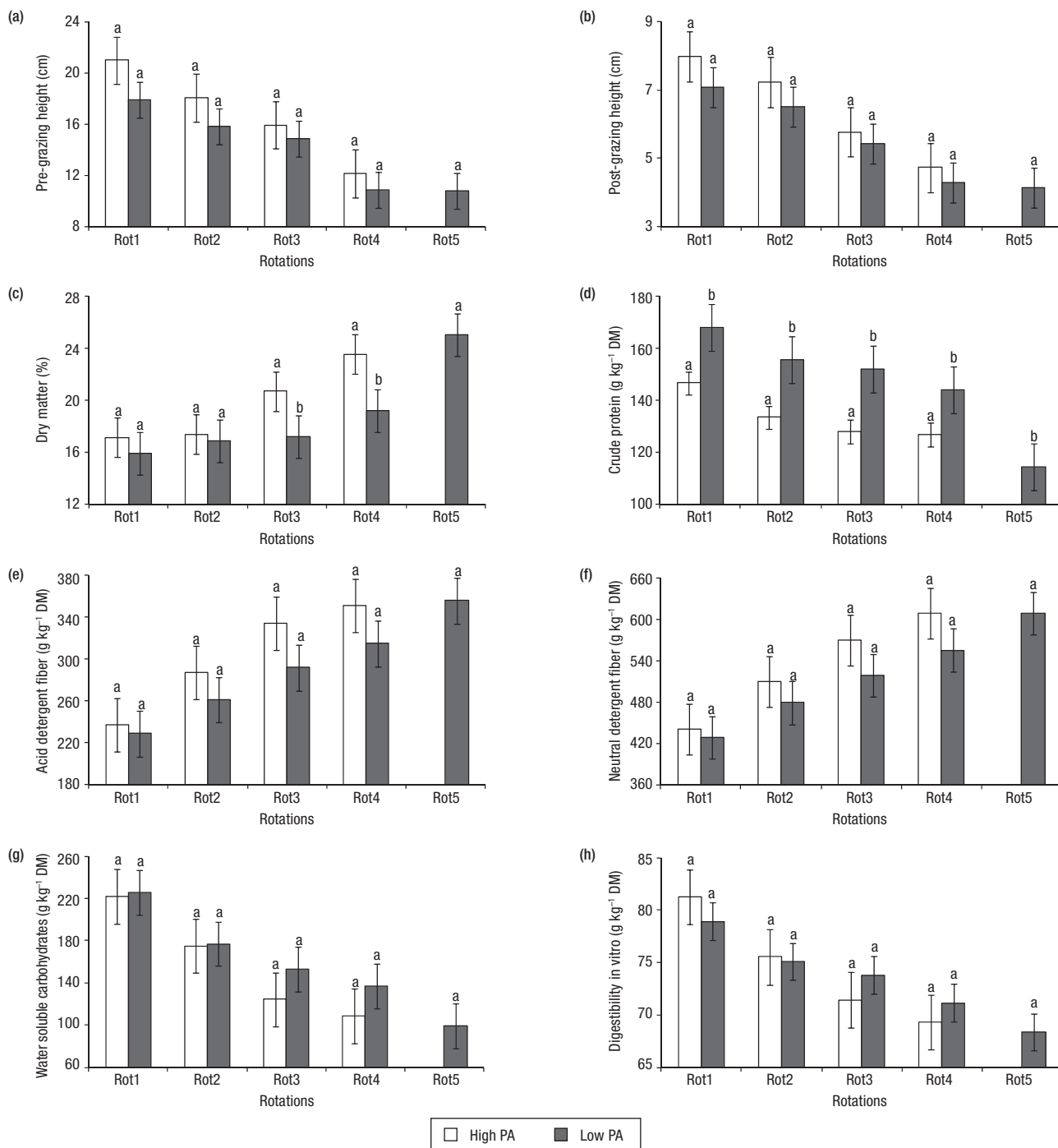


Figure 2. Evolution of herbage parameters: (a) pre- and (b) post-grazing sward heights, (c) dry matter, (d) crude protein, (e) acid and (f) neutral detergent fibers, (g) water soluble carbohydrates and (h) digestibility *in vitro* at two pasture allowances (Low vs. High). ^{a-b} Values in the same rotation not sharing a common superscript are different ($p < 0.05$).

grazing SH (a-b) and sward chemical constituents (c-h) for the two levels of PA. DM (%) content (c) was lower ($p < 0.05$) in the rotations 3 and 4 for the swards when cows were allocated to the low level of PA. The CP content was higher ($p < 0.05$) in the swards managed at the low level of PA than at the high level of PA from rotation 1 to 5, due to the visual observation of a higher leaf proportion and lower senescent material from the base to the top of the swards.

Milk performance and quality

According to cows' LS, animals at the early lactation stage had lower ($p < 0.05$) BW and BCS (-17.6 kg and -0.15 , respectively) than those at the middle lactation stage (586.3 kg and 3.05 , respectively) as it is showed in Table 2 (d). When cows were allocated to the low level of PA, animals presented lower ($p < 0.05$) BW and BCS (-12.3 kg and -0.13 , respectively) than cows allocated to the high level of PA (583.6 kg and 3.04 , respectively). Cows managed at the early lactation stage produced higher ($p < 0.05$) MY ($\text{kg cow}^{-1} \text{ day}^{-1}$) ($+5.3$), with the lowest ($p < 0.05$) milk protein and fat

(-2.4 and -2.2 g kg^{-1}) content, than cows managed at the middle lactation stage (19.5 $\text{kg cow}^{-1} \text{ day}^{-1}$), with the highest ($p < 0.05$) milk protein and fat content (31.3 and 39.1 g kg^{-1}). The high and low PA treatments produced 22.9 and 21.4 $\text{kg cow}^{-1} \text{ day}^{-1}$ of milk respectively. There were no significant differences between treatments for MY depending on the level of PA. Nevertheless, milk protein and fat content were higher ($p < 0.05$) in the low PA treatments ($+0.9$ and $+1.0$ g kg^{-1} , respectively) when compared with the high PA treatments (29.7 and 37.5 g kg^{-1} , respectively). In Figure 3 (a-d) is shown the milk response of Holstein-Friesian dairy cows allocated to the two levels of PA from rotation 1 to 5. Milk production decreased (b) as grazing season advanced and cows' lactation stage progressed, with no differences between the two PA treatments. Pasture DM intake (a) was increasing progressively when supplementation (silage and concentrate) was reduced in both PA treatments. Cows at the different LS considered had more PDMI in the rotation 5 than in the rotation 1. Milk protein was higher ($p < 0.05$) at the low level of PA across all rotations (c). Milk fat was higher ($p < 0.05$) at the low level of PA only in the rotations 3 and 5 (d).

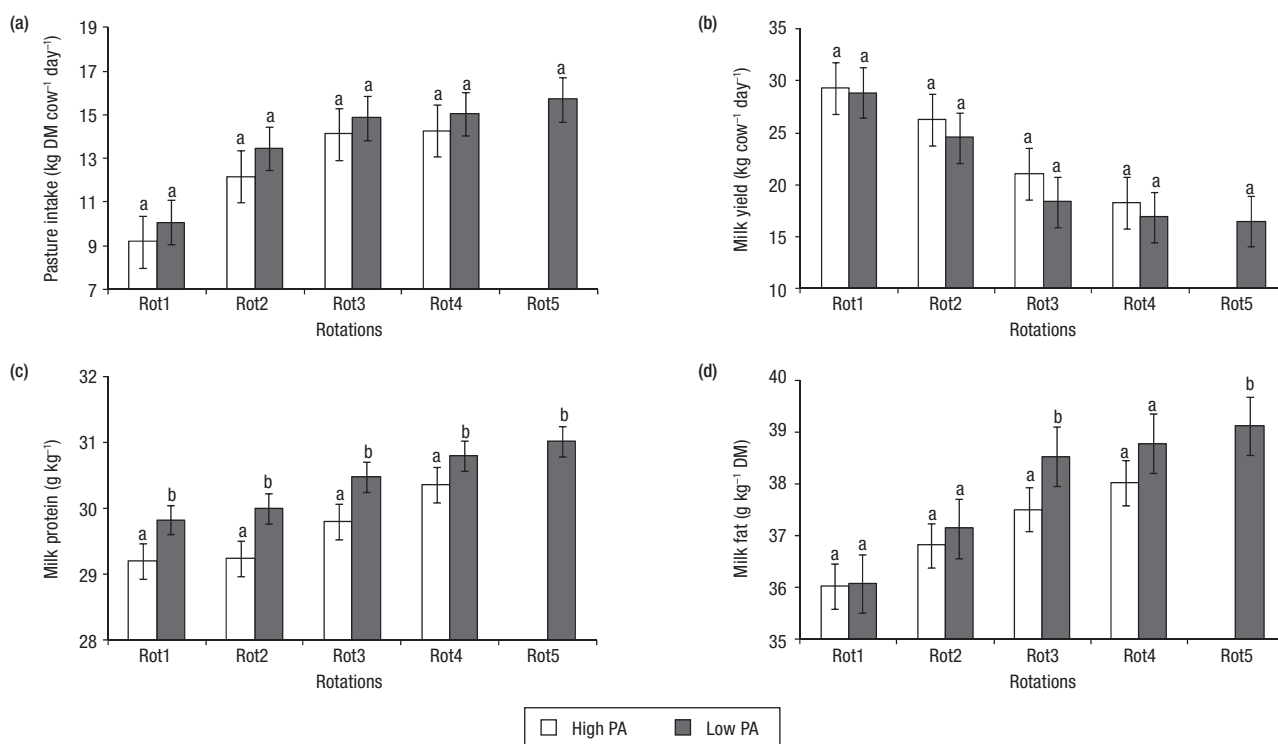


Figure 3. Evolution of (a) pasture dry matter intake and (b-c-d) animal performance variables: milk yield, milk protein and milk fat content of Holstein-Friesian dairy cows managed at two pasture allowances (Low vs. High). ^{a-b} Values in the same rotation not sharing a common superscript are different ($p < 0.05$).

Discussion

One of the primary objectives of pasture-based milk producers is to maximize profitability per hectare of grazing land through increased herbage production and utilization (Dillon *et al.*, 2008). As a result, large increases in milk output per hectare are expected (McMeekan, 1956; Gordon, 1973) but lower milk output per cow may be observed (Bargo *et al.*, 2002) in response to concentrate supplementation when cows are allocated to high levels of PA. Therefore, the base of appropriate grassland management strategies should be to study the interaction between pasture and animal as an integral part of any grassland based dairy system. Maintaining a balance between optimizing dairy cow performance and sward nutritive value should be a dual purpose of efficient pasture-based milk production systems in humid areas (Gonzalez-Rodríguez, 2003; Kennedy *et al.*, 2007). This idea was the key point of our work carried out during five months in order to go inside the relation between the sward, as part of the grazing system, and the cow, as part of the herd. Our research was focused in the study of the effect of PA and cows' LS on swards quality, PDMI and milk performance of Holstein-Friesian cows through achieving high herbage utilization, maintaining high PDMI and sward quality on subsequent grazing rotations while reaching higher milk quality output per cow and per hectare. Our intention was to obtain information about appropriate grassland management strategies which can be really extrapolated at farm level. Nevertheless, further studies will be necessary to complete our research evaluating other factors that influence in the balance between cattle needs and food supply for the future of sustainable grazing systems. Decreasing the PA during the spring-summer grazing season in cows at any LS had a positive effect on swards quality when strategic supplementation of silage and concentrate were used at grazing. Under our Galician grazing conditions, we have got the same amount of milk using less area and higher milk output and milk quality without penalizing MY per cow.

Grazing management

The mean experimental length in our trial was of 139 days in spring-summer Galician grazing conditions, with an average SR of 3.9 and 4.8 cows ha⁻¹ for the high and low PA treatments but without significant differences in mean daily MY per cow. The SR determines in a direct proportion how much of the available herb-

age is eaten by the herd (McMeekan, 1964). Therefore, the PA applied early in the season may have beneficial or detrimental effects on the sward and hence on cow performance later in the season, as happened in our trial, when swards were managed at low and high PA level, respectively. Lax grazing leads to substantial losses in herbage production through senescence and decay (Tainton, 1974). Bircham & Hodgson (1983) have shown how net production of green herbage from continuously stocked swards represents the balance between growth and senescence of tillers and tiller population density. Furthermore, sward quality, another essential factor in milk production, tends to be positively associated with grazing severity in the previous defoliation (Lee *et al.*, 2008a), decreasing with higher grazing residuals (reduced grazing severity) and representing a potential reduction in future milk production with increasing PA and decreasing SR.

Swards measurements and chemical composition

Increasing SR tended to increase linearly pasture grown per hectare; partly offsetting the decline in available pasture per cow with low PA in our high SR groups when compared with high PA in our low SR groups (16.4 and 18.5 kg DM cow⁻¹ day⁻¹, respectively). In addition to this, the pre- and post-grazing SH declined in the low PA treatments (18.5 and 7.4 cm, respectively) compared to the high PA treatments (16.4 and 6.4 cm, respectively), reflecting an increase in herbage utilization rates with decreasing PA in the high SR groups when compared with the low SR groups (81.7 and 75.9%, respectively), that is consistent with the linear increase in pasture consumed per hectare reported by MacDonald *et al.* (2008). When pastures were defoliated early in spring, a superior sward quality (higher OMD, CP and lower NDF) resulted during the second rotation (Kennedy *et al.*, 2007). The three leaf stage is designed to graze the sward for its highest sward quality (Fulkerson & Donaghy, 2001). O'Donovan & Delaby (2008) found greater OMD values with early grazed swards with lower defoliation SH which were directly related to the higher leaf composition of the sward. Similarly, Jacobs *et al.* (1998) associated an increasing HM with a decline in DM digestibility and CP, but an increase in NDF. These differences are likely due to differences in the proportions of leaf, stem and senescent materials in the sward.

The increase in pasture production with decreasing PA could be also due to the decreased pasture residual mass. Grass plants need periodic close defoliation to renew photosynthetic efficiency and to prevent shading of tiller bases. Hunt & Brougham (1967) reported that where repeated lax defoliation of perennial ryegrass left enough herbage to intercept 95% of incident light, the amount of green leaf and the number of tillers initiated progressively declined, while the proportion of dead material increased. Lee *et al.* (2008b) found a quadratic effect of post-grazing residual mass on pasture growth, with pasture production declining at low and high residuals. Lee *et al.* (2007) reported no negative effect of grazing pastures to 1,260 kg of DM ha⁻¹ residuals (at ground level) on subsequent pasture production, suggesting that residuals must be below this to compromise grass growth.

In our spring-summer grazing trial, the effect of the low grazing residual with decreasing PA is manifested in the chemical composition of the high SR swards and it is also associated with the decline in post-grazing residual mass resulted in a low DM, ADF and NDF content and a high CP, WSC content and IVODM. Our results are in line with those reported by McCarthy *et al.* (2011) assuming that grassland management strategies related to a decrease in PA show an improvement in sward quality. The longer grazing interval, associated with advancement in pasture maturity, in the lower stocked farmlets at high PA had more mechanical cutting than the higher stocked farmlets at low PA. Fales *et al.* (1995) reported increased sward quality with higher SR and Lee *et al.* (2007) found lower ADF and NDF content and higher IVOMD in swards that had been grazed more severely in the previous grazing. Both authors show an effect of a greater proportion of live leaf and less senescent material in the swards. Roca-Fernández *et al.* (2011) also reported that the high PA, 20 over 15 kg DM cow⁻¹ day⁻¹, using a low HM swards (1,600 kg DM ha⁻¹) improved sward quality presenting lower stem and dead DM yield (> 4.0 cm), higher PDMI and MY and more milk solids per cow and per hectare. The results from Curran *et al.* (2010) highlighted the importance of using low HM swards in the early part of the grazing season by getting a low post-grazing residuals and a high herbage utilization that enabled grazing dairy cows to achieve better milk performance. Stakelum & Dillon (1990) also indicated that a high SR in the swards gives a high GP in spring grazing, increasing OMD by 39 g kg⁻¹ DM when compared with a low GP (756 g kg⁻¹ DM). Green leaf

content of the sward was higher (+ 0.13), while stem and dead proportions were reduced (– 0.06 and – 0.07, respectively). O'Donovan *et al.* (2004) reported that swards first grazed in March had higher CP content (+ 14 g kg⁻¹ DM) and OMD (+ 40 g kg⁻¹ DM) compared to swards first grazed in mid-April (CP, 198 and OMD, 785 g kg⁻¹ DM, respectively) after the first grazing rotation. These results agree with ours. Stakelum & O'Donovan (1998) pointed that daily MY declined by 1.0 and 1.3 kg cow⁻¹ for the 730 and 710 g kg⁻¹ OMD sward, respectively while DM intake was reduced by 0.6 and 1.7 kg cow⁻¹ for each level of digestibility. This also agrees with our findings due to a progressive increase in DM, ADF and NDF content was observed from rotation 1 to 5 in our swards, and the increase was higher in the high PA swards than in the low PA swards. In addition, the CP content, WSC and IVODM decreased progressively from rotation 1 to 5 and the decrease was lower in the low PA swards compared to the high PA swards. In the vegetative stages of growth, the CP content in grasses declines as the plant approaches maturity, and there is also a systematic decrease in CP from the top to the base of the sward (Duru, 2003), parallel to leaf lamina proportion down through the sward profile. Minson *et al.* (1960) determined a fall of 2.2 g kg⁻¹ DM day⁻¹ of CP between preshooting and full flowering of perennial ryegrass.

Milk performance and quality

The effect of PA on milk cow performance is not yet consistent between researchers due to different types of supplements may be fed at pasture, the potential genetic merit of animals for milk production differs a lot and the differences between cows' LS. In our experiment, a decrease of PA from 18.9 to 16.4 kg DM cow⁻¹ day⁻¹ in dairy cows at both early and middle lactation stage did not show any significant effect on MY when total DM intake of animals was similar for low and high SR groups. However, Kennedy *et al.* (2006) comparing a high and medium SR (6.5 and 5.5 cows ha⁻¹, respectively) reported a negative effect of SR on milk and milk components yield and milk protein content, consistent with the findings reported by MacDonald *et al.* (2008). Earlier studies (Gordon, 1973) pointed a negative effect of SR on MY per cow when forage was the main feed, but a positive effect on MY per hectare. Nevertheless, the no effect (Fales *et al.*, 1995) or only a very small effect (Dillon *et al.*,

1995) (~100 kg of milk) of PA on MY per cow, like happened in our trial, were also highlighted. In the study of Fales *et al.* (1995), cows fed concentrates in proportion to milk production (0.25 kg of grain kg⁻¹ of milk, with a minimum of 4 kg of DM day⁻¹), that effectively removed the negative effect of the SR imposing feed restriction in early lactation. Dillon *et al.* (1995) studied the effect of SR and calving date; cows at the middle lactation stage (with a delay of 7 weeks respect to animals at the early lactation stage) removed the feed deficit at the beginning of the lactation period associated with the higher SR. Neither our groups of cows were purely grazing, with both PA treatments requiring supplementation at pasture during early and middle lactation stage to cover feed demand as did Delaby *et al.* (2001). McEvoy *et al.* (2009), Curran *et al.* (2010) and Roca-Fernández *et al.* (2011) showed that MY were consistently lower for the low PA treatments as happened in our experiment for cows in both LS. The reason for lower MY per cow as decreased PA in our trial may be as a result of lower PDMI in the high SR groups instead of the fact that animals in both LS were fed with supplements at pasture trying to keep similar levels of total DM intakes in both SR groups. Intakes estimated using a dual indigestible marker system (n-alkanes) by Dillon & Stakelum (1989) showed a quadratic decline in pasture consumed during the start of the grazing season and this idea is supported by the increasing deficit in pasture availability in early lactation with increasing SR. Cows at the early and middle lactation stage on the high stocked treatments received more silage (grass and maize) instead of fresh grass, but even high quality silage did not support milk production as effectively as fresh grass (Dillon *et al.*, 2002). An observation made by MacDonald *et al.* (2008) infers that if feed of equivalent quality to the pasture being consumed were purchased for the more highly stocked dairy cows in early lactation to elevate their lactation profile, and in particular their peak MY, to that of the less severely stocked cows, it may be possible to capture more than 70% of the difference in MY per cow between SR with only a modest investment in supplementary feeds in early lactation. In our study, the lack of significant effect of PA on MY per cow as it was also found by Fales *et al.* (1995) and Roche (2007), who reported responses to supplementing restricted cows, high SR, with additional pasture during the first 5 weeks of lactation that were twice greater than the immediate response measured and approximately 2.5 times greater than the average pub-

lished response (Bargo *et al.*, 2003). Further research is, however, required in order to determine the benefit of strategic use of supplementary feeds to cows on low PA systems in early lactation. Although there was a negative association between SR and MY per cow, the effect of PA on MY per hectare was positive as in earlier works (Gordon, 1973; Fales *et al.*, 1995) in which milk production per hectare increased with increasing SR irrespective to the effect of SR on MY per cow. From data of the meta-analyses carried out by McCarthy *et al.* (2011), an SR increase of one cow ha⁻¹ resulted in a decrease in daily MY per cow of 7.4% and 8.7% for Type I and Type II dataset, respectively, whereas MY per hectare increased by 20.1% and 19.6%, respectively. Within the Type II experiments, a one cow ha⁻¹ increase in SR also resulted in a 15.1% reduction in lactation length (equivalent to 42 days). Journet & Demarquilly (1979) reported that an SR increase of one cow ha⁻¹ resulted in a reduction in MY per cow of 10%, but an increase in MY per hectare of over 20%. In our study MY decreased by 4.0% and 9.8% for cows at the early and middle lactation stage, respectively. Our results are next to the range of values considered by McMeekan & Walshe (1963) as the optimum SR for grazing such that the reduction in production per cow is 10% to 12% of the potential production obtained at a low SR or high PA. The actual reduction in MY observed in dairy cows at the early and middle lactation stage for both SR groups (1.0 and 2.0 kg cow⁻¹ day⁻¹, respectively) was related to a similar decrease on PA (2.0 and 2.1 kg DM cow⁻¹ day⁻¹, respectively). However, cows at the middle lactation stage had lower total DM intake than animals at the early lactation stage. McCarthy *et al.* (2011) also found that a one cow ha⁻¹ SR increase resulted in a decrease in daily milk protein and fat content per cow of 8.2% and 6.3% and an increase in milk protein and fat content per hectare of 16.9% and 21.0%, respectively. An increase in BW ha⁻¹ of 100 kg reduced per cow yields for milk production variables by a mean value of 1.5%, whereas per hectare yields increased by 3.7%. In the current study, milk protein and fat content increased by 1.0 and 0.8% for Holstein-Friesian cows at the early lactation stage and by 4.4 and 4.0% for cows at the middle lactation stage, respectively. Peyraud *et al.* (1996) and Maher *et al.* (2003) showed increases in milk protein when cows were allocated to high PA (31.3 and 33.6 kg DM cow⁻¹ day⁻¹, respectively). Bargo *et al.* (2002) and McEvoy *et al.* (2009), however, reported no differences in milk fat between

treatments in mid- or late lactation. In our trial, BW and BCS decreased by 1.9% and 3.8% for Holstein-Friesian cows at the early lactation stage and by 2.2% and 5.1% at the middle lactation stage, respectively.

Although a decline in MY per cow is normally found with increased SR (MacDonald *et al.*, 2008) as happened in our experiment, but not significantly, with the low PA treatments in cows at both LS, over a wide range of SR the relationship is curvilinear (Mott, 1960). Previous studies have observed that as SR increases, MY per cow declines due to reduced PA and PDMI associated with increased grazing severity (Le Du *et al.*, 1981), increased feed demand relative to cow needs (Penno, 1999) and the inability of the animal to select greater quality herbage from within the sward. Our study corroborated these findings due to the low PA treatments, in Holstein-Friesian cows at both LS, showed lower pre- and post-grazing SH and PDMI, but higher SR and herbage utilization. The favorable effects on milk production per hectare with a decrease in PA are in part due to reduced herbage wastage (McMeekan, 1964), improved herbage growth and sward quality associated with increased grazing severity (MacDonald *et al.*, 2008), and increased energetic efficiency associated with reduced BW and body condition gain during lactation (McMeekan, 1964). The meta-analysis of SR carried out by McCarthy *et al.* (2011) showed that the proportion of area refused in a paddock is lower at increased SR, thus indicating greater herbage utilization. At decreased PA, the density of the herbage is also slightly increased; therefore, there is an increase in the amount of herbage harvested and energy intake per hectare is increased resulting in an increase in milk production per hectare (Hoden *et al.*, 1991). Spring calving pattern is the best way to adapt nutritional cows' needs to herbage production in temperate humid countries, but makes milk yields very seasonal. Under Galician grazing conditions, with a good autumn season to graze it is possible to avoid only one calving date in spring by keeping two calving dates, in spring and autumn, corresponding to manage cows during the main grazing season at two lactation stages on the farm, early vs. middle. Using two calving dates, two peaks of MY are reached and a more steady supply of milk through the year is achieved by a better control of the calving intervals and fertility of dairy cows.

The results in our study highlight the need to conjugate grazing management strategies, applying appropriate pasture allowances' levels, adjusted to cows' nutritional requirements throughout lactation for profitability of pasture-based milk production systems

in humid areas. Higher stocking rates were obtained by Holstein-Friesian dairy cows allocated to lower pasture allowances levels, while more concentrate was offered. Herbage utilization was higher in paddocks stocked at high grazing pressure, with lower pre- and post-grazing sward heights and lower rotation length, but more grazing days, obtaining at the end higher milk output per hectare. The pasture allowance, adapted to cows' lactation stage, affected swards chemical composition increasing grass quality as grazing season advanced, giving better milk quality, optimizing pasture production and the efficiency of conversion from grass into milk. In our trial, dairy cows used fresh forage as the main source of nutrients from spring-summer grazing and had a strategic supplementation (silage and/or concentrate) at pasture after calving in spring or autumn. Despite of the lower pasture dry matter intake reached by cows allocated to the low level of pasture allowance, with low dry matter and fiber (acid and neutral detergent) content, but high crude protein, water soluble carbohydrates and digestibility of organic matter, a good milk response was reached by animals highly stocked, with high output and quality per cow and per hectare. The balance between food demand and supply was the key point of our grazing trial for a better milk performance in sustainable dairy production systems using available farm resources. Further work will be necessary for a better knowledge of the relation between pasture intake and cattle needs in order to adopt adequate grassland management strategies throughout lactation in practical farm conditions, taking the advantages of pasture growth and sward quality for establishing a grass feed budgeting.

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