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EFFECT OF SEASON AND HARVESTING METHOD ON CHEMICAL COMPOSITION, PREDICTED METABOLIZABLE ENERGY AND IN VITRO ORGANIC MATTER DIGESTIBILITYOF ROTATIONALLY GRAZED TROPICAL PASTURES

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ABSTRACT: *The nutritive value of pastures is influenced by several factors. The objective of this study was to quantify the effects of season, and harvesting method on the nutritive value of rotationally grazed tropical pastures. Herbage was harvested at ground level (G-L) and by hand-plucking (H-P) during the dry, intermediate and wet seasons from 5 dairy and 2 beef farms. Nutritive value was evaluated by quantifying crude protein (CP), neutral detergent fiber (NDF), acid detergent fiber (ADF), acid detergent lignin (ADL), predicted metabolizable energy (ME) and 12, 24 and 48 h in vitro organic matter digestibility (IVOMD). Season and harvesting method significantly (P < 0.05) affected chemical composition on all farms. Crude protein and ME content were 36 % and 27 % higher in H-P herbage than G-L herbage, respectively. Crude protein concentration of G-L and H-P harvested herbage was highest in the wet season. ME increased from dry to intermediate season then declined in the wet season. H-P herbage NDF, ADF and ADL was 9.6 %, 9.9 % and 9.7 %, respectively, lower than G-L herbage across all farms and seasons. ADF (351 – 403 g/kg DM) and ADL (43.0 - 90.3g/kg DM) contents were lowest in the wet season. Approximately 60 – 65 % of final IVOMD for G-L and H-P herbage occurred within 12 h post incubation across all farms. The 12 h IVOMD of H-P herbage was 17 % – 25 % higher than G-L harvested herbage. The 12, 24 and 48 h IVOMD of both H-P and G-L herbage were highest in the intermediate season. Dry and wet season IVOMD did not differ (P > 0.05) on most farms. It is concluded that H-P herbage is of superior quality to herbage cut at ground level. This indicates that rotational grazing is the most suitable system of feeding unless sward structure is augmented by mowing to reduce accumulation of residual dry matter. The nutritive value of these tropical pastures was found to be highest during the intermediate season and lowest in the dry season*

ORIGINAL ARTICLE

Key words: *Harvesting Method, Season, Nutritive Value, Tropical Pastures*

INTRODUCTION

A reliable supply of good quality pasture is critical for successful pasture-based production systems. However, in the tropics, the nutritive characteristics of pasture forage fluctuate throughout the year. This is likely to result in an increase in cost of feeding and reduced profitability, as farmers revert to commercial supplementary feeds to offset herbage deficit. Failure to supplement animals leads to a sharp decline in animal performance. Optimum production responses from pasture require intimate knowledge of pasture nutritive value combined with appropriate management strategies for its exploitation. Rotational grazing is traditionally the preferred system of managing pastures in Jamaica. Under this system, dairy cows remain in one paddock for a maximum of 24 – 48 h before being moved to another paddock. The grazing duration for beef cattle is generally longer (3 – 7 days). Rotational grazing is presumed to afford animals an opportunity to practice selective grazing. As a result, under medium and low grazing pressure, the nutritive value of the ingested herbage might be substantially higher than that of the total herbage offered – as conventionally measured at ground level (Sollenberger and Burns, 2001).

It has been shown that tropical pastures exhibit a distinctly vertical heterogeneity in chemical composition and digestibility (Newman et al., 2003; Bernard et al., 2004) as well as in morphological composition (Sollenberger and Burns, 2001). The upper sward horizons contain a greater proportion of green leaf than at the lower levels of the

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canopy. Therefore, evaluation of rotationally grazed tropical pastures harvested at ground level will under-estimate the nutritive value of the pastures consumed by the grazing animal particularly when herbage supply is not limiting. On the other hand, simulated grazed samples harvested by hand-plucking may give a more accurate representation of the pasture most likely to be consumed when tropical pastures are rotationally grazed. This can suggest that pasture evaluation from ground level harvesting is more suited for "cut-and-carry" system. Sustained performance of grazing animals is mediated by the nutritive value of the available herbage, in particular its protein and energy contents throughout the year.

From a previous study of seasonal variation in nutritive value of whole grass samples collected from Jamaican pastures (Hughes et al., 2011), it was found that crude protein was lowest while fiber and lignin were highest during the dry season. Digestibility (*in vitro*) was not different between dry and wet season but was highest in the intermediate season. Apart from this study, current information on the nutritive value of pastures in Jamaica is lacking. In addition, very little is known of the differences in nutritive value between the total pasture presented to the animal for grazing and that which is more likely to be consumed under existing grazing systems for beef and dairy cattle throughout the year. This information would be useful for developing more efficient and effective systems of pasture utilization which is prerequisite to being able to more accurately predict nutrient intake from pastures by the grazing animal. Also, this information can assist to more precisely determine the type and level of supplementation which might be needed to compensate for nutrient and herbage deficits at different times of the year in order to consistently meet production targets. The objective of this study was therefore to quantitatively determine and compare the nutritive value of the total pastures presented for grazing under rotational grazing system versus simulated-grazed samples collected by hand-plucking and the extent of these differences between season on commercial beef and dairy farms in Jamaica.

MATERIALS AND METHODS

Site description

The study was conducted on 5 dairy farms; Serge Island Dairies (17° 56' 52"N, 76° 28' 46"W), FM Jones Dairy (17° 57' 0" N, 76° 15' 0" W), Edward's Dairy (18° 19' 0" N, 77° 59' 0" W), Ponderosa Dairy, (18° 6' 0" N, 77° 1' 0" W) and Unity Valley Dairy, (18° 15' 0" N, 77° 7' 0" W) and 2 beef farms; Grove Place (18° 7' 0" N, 77° 31' 0" W) and Barkeith Farms, (17° 58' 0" N, 77° 45' 0" W). Pastures were fenced into several paddocks and rotationally grazed by small to large herds, ranging approximately 26 – 209 lactating dairy cows and 53 – 300 adult breeding beef animals. Dairy cows were predominantly of the Jamaica Hope breed and beef cattle were a mixture of Jamaica Red and Jamaica Brahman breeds. Variations in pasture and grazing management between seasons were negligible (Hughes et al., 2011). Soil samples taken in 2009 showed that the soils on the farms were slightly acidic to neutral pH (5.3 - 7.6) and that nitrogen, phosphorus and potassium ranged from 0.20 - 0.42 %, 9 - 141 ppm and 0.14 – 0.39 ppm, respectively. Rainfall during the experimental period and the long-term (1971 – 2000) monthly mean for each site was described in Hughes et al., (2011). The period between January to March, May to July and September - November represented the dry, intermediate and wet seasons, respectively. Total rainfall during the study period (mm) at FM Jones Dairy, Serge Island Dairies Ltd., Ponderosa Dairy, Unity Valley Dairy, Edwards Dairy, Grove Place and Barkeith Farms was recorded at 2 406, 1 916, 2 219, 2 209, 2 962, 1 948 and 1 657, respectively.

Grass sampling

Sampling during the dry, intermediate and wet season was done between January - March, May - July and September - November, respectively. The same pastures were sampled on all occasions. Sampling was done to coincide with the normal grazing cycle of the respective farm, thus representing the forage presented to the grazing animal during the respective season. This was done during the last two weeks of the respective sampling month between 12 and 24 hours prior to grazing. Prior to sampling, the pastures were notionally divided into two equal-sized halves. Harvested samples were bulked for each half and sampling frequency within season were used as the replicates (r = 4). Observably weed infested and hard to reach areas (such as inundated sections) were isolated and not included in the sampling.

Harvesting methods

Grass samples were collected by cutting at ground level (G-L) and by hand-plucking (H-P) to simulate grazing. The G-L sampling method was done according to Hughes *et al.* (2011). Hand-plucked samples were collected by "plucking" grass herbage by hand (to simulate the grazing action of cattle) from at least 20 randomly selected locations within either half of the pasture while walking in a zig-zag pattern. These samples comprised mainly the upper portions of the sward canopy and represented an estimate of the forage that would most likely be consumed by the grazing cattle (Cook, 1964). These "plucks" were pooled to give an average representation of the respective half. Hand-plucked samples were collected by the same individual on all occasions.

Sample preparation and analysis of chemical composition

After harvesting, the samples were transported to the Animal Nutrition Laboratory at the Bodles Agricultural Research Station (17° 56' 0" N, 77° 7' 0" W) where they were temporarily stored in a deep freezer at -4 ^{0}C prior to drying at 60 ^{0}C in a force draft oven to constant weight. Dried samples were then ground in a stainless steel hammer

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mill (Thomas Wiley Laboratory mill, model 4; Thomas Scientific USA) to pass through a 1 mm sieve in preparation for chemical analysis. Neutral detergent fiber (NDF) and acid detergent fiber (ADF) were determined by the filter bag technique using the ANKOM^{2000} Fiber Analyzer (model: A2000I) (ANKOM Technology, Macedon NY). Sodium sulphite and amylase (α) were included in the NDF analysis. Acid detergent lignin [72% H_2SO_4 - (ADL)] was determined according to Van Soest et al. (1991). Acid detergent lignin was expressed on an ash-free basis while NDF and ADF values were expressed inclusive of residual ash. Nitrogen was determined at the analytical laboratory of the Bureau of Standard, Jamaica, by the Kjeldahl method (AOAC, 2005; 976.05) using an automated steam distillation/titration unit (FOSS – Kjeltec 2300 Analyzer) with 1% boric acid as the receiving solution and 0.1 M hydrochloric acid as the titrant. The end point was determined photometrically. Crude protein content was calculated by multiplying the nitrogen content by 6.25 (CP = N × 6.25).

In vitro organic matter digestibility

In vitro organic matter digestibility (IVOMD g/kg) determinations were conducted at the Bodles Animal Nutrition Laboratory using the modification of the Tilley and Terry (1963) procedure of Moore *et al.,* (1972). Approximately 0.5 g grass samples were weighed into 100 ml round-bottom plastic tubes to which 50 ml of incubation medium (rumen fluid and buffered McDougal's artificial saliva) was added. The incubation medium was prepared in a 1:4 ratio; i.e. 10 ml rumen fluid to 40 ml buffer solution. One ml 4 % calcium chloride solution was added per litre of incubation medium prior to use. Anaerobic condition was maintained by flushing the medium with CO_2. The tubes were incubated in a water bath at 39 ^{0}C. Microbial digestion of forage organic matter was measured at 12, 24 and 48 h post incubation. This was followed by the addition of 6 ml of 20 % HCL and 2 ml of 5 % pepsin. Tubes were incubated again at 39° C for 48 hours, after which their contents were filtered and oven dried for 24 hours at 105 ^{0}C. The dried residue was weighed before being ashed in a muffle furnace for 6 hours at 600 ^{0}C and reweighed. *In vitro* organic matter digestibility (IVOMD) was estimated as the loss of organic matter after microbial and pepsin digestion and was expressed as a ratio of sample organic matter content before digestion.

Metabolizable energy

Metabolizable energy (ME) was predicted from digestible organic matter in the dry matter (DOMD) content of the forages after 48 h incubation in buffered rumen fluid according to the following predictive equation proposed by McDonald *et al.,* (2002):

ME (MJ/kg DM) = 0.016 DOMD;

where DOMD is expressed in grams digestible organic matter per kg dry matter.

The validity of the McDonald et al., (2002) equation for grasses under Jamaican conditions was assessed by comparison with ME derived from gross energy values (Minson, 1979). Gross energy determinations (MJ/kg DM) were conducted using the Parr 1261 Adiabatic Bomb Calorimeter at the Chemistry Department, UWI, Mona Campus, Jamaica. Metabolizable energy was derived from bomb calorimetric values as follows:

1. Digestible energy (DE) = gross energy (GE) x IVOMD (after correcting GE for ash)
2. ME = 0.81DE (Minson, 1979)

Statistical analysis

Statistical analysis was done separately for each farm using the Minitab 15 software (Minitab 2007). The level of significance was set at P < 0.05. Proximate chemical components, predicted metabolizable energy and IVOMD were analyzed by analysis of variance (ANOVA) according to the general linear model procedure with season (dry, intermediate and wet), harvesting method (hand-plucking and ground level harvesting) and their interactions as the fixed effect as represented by the mathematical model:

$Y_{ijk} = \mu + S_i$ (i = 1– 3) + H_j (j = 1-2) + $S_i \times H_j + E_{ijk}$

From the model, Y_{ijk} = dependent variable, μ = overall mean, S_i = effect of season, H_j = effect of harvest method, $S_i \times H_j$ = interactive effects of season and harvest method and E_{ijk}, = random error. Incubation time as a main effect was not of interest thus analysis was done separately for each incubation time. Treatment means were separated using Tukey's multiple comparison. Simple linear regression was performed using the Minitab 15 statistical software to determine the relationship ME (McDonald et al., 2002) and ME derived from GE. An assessment of the validity of the McDonald et al., (2002) equation for tropical grasses, under Jamaican conditions, was done by comparing the energy derived from bomb calorimetry {GE [MJ/kg DM]} (Minson, 1979) with predicted ME using Pearson's correlation coefficient and simple linear regression analysis.

RESULTS

Chemical composition

Comparisons of DM, CP, NDF, ADF, and ADL as influenced by harvesting method and season are presented in Figures 1 - 5. Herbage DM concentration was significantly influenced by season (P < 0.05) and harvesting method (P < 0.05) on all farms except Edwards Dairy and Grove Place where DM was influenced by season only (Figure 1). Significant season × harvesting method interaction on DM was found at FM Jones Dairy (P = 0.030) and Unity Valley Dairy (P = 0.036). Dry matter concentration of herbage harvested by H-P decreased from dry to wet season. The DM concentrations of H-P herbage were approximately 25% and 15% lower than G-L herbage in the dry and intermediate

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seasons, respectively. During the wet season, concentrations of herbage DM differed significantly between H-P and G-L samples (P < 0.05) only at Ponderosa Dairy and Barkeith Farms. Pasture herbage CP concentration was significantly (P < 0.05) affected by season and harvest method (Figure 2).

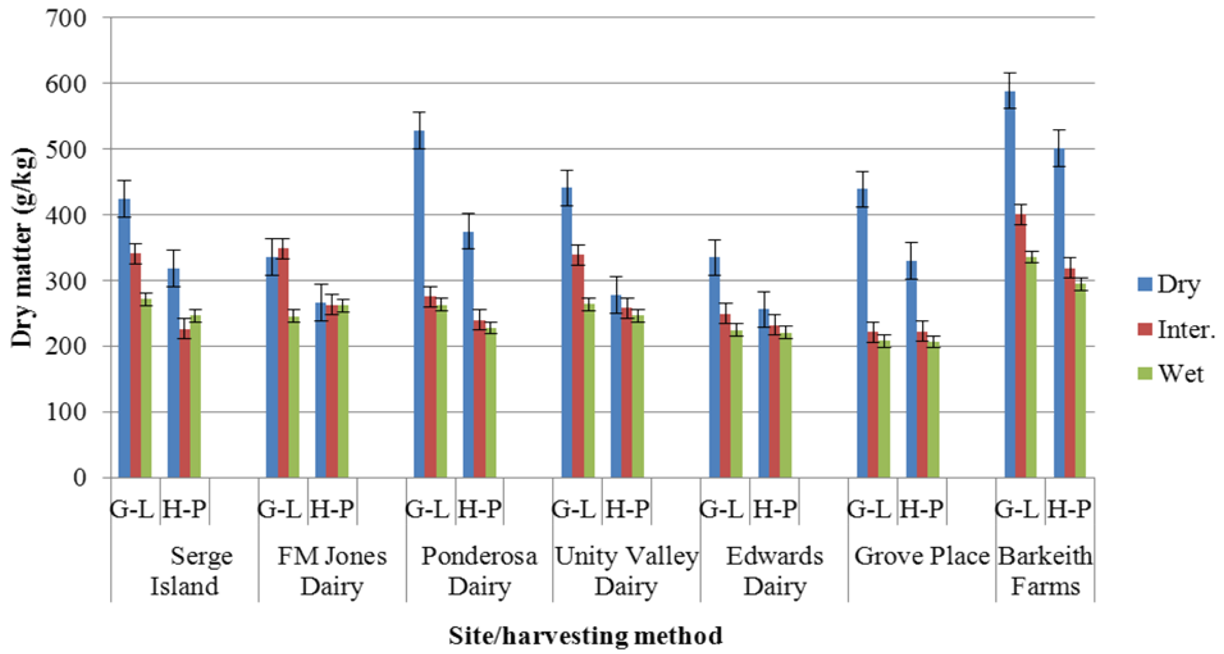

Figure 1 - Effect of season and harvesting method on dry matter concentration (g/kg) at the respective site

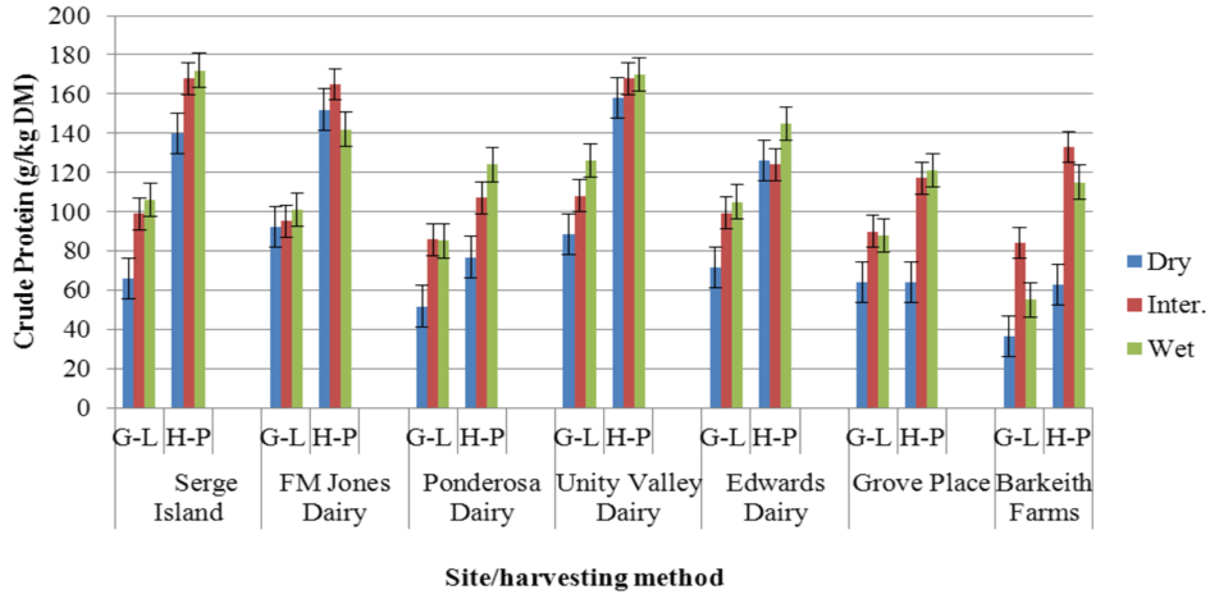

Figure 2 - Effect of season and harvesting method on crude protein concentration (g/kg) at the respective site

Wet and intermediate season H-P herbage CP concentrations differed significantly (P < 0.05) on all farms except Ponderosa Dairy and Edwards Dairy. Crude protein concentrations of H-P harvested herbage were lowest in the dry season. Season × harvesting method interaction on CP concentration was significant only at Edwards Dairy (P = 0.032). Hand - plucked herbage (62.7 ± 7 – 172 ± 8 g/kg DM) had significantly higher CP than those harvested at G-L (36.5 ± 1 – 126 ± 14 g/kg DM) on all farms across the three seasons. Concentrations of NDF were significantly (P < 0.05) affected by season and method of harvest at Edwards Dairy, Ponderosa Dairy and Grove Place (Figure 3). Season, harvesting method and their interaction, significantly (P < 0.05) influenced pasture NDF at Serge Island Dairies, FM Jones Dairy and Unity Valley Dairy. Neutral detergent fiber at Barkeith Farms was only affected by season (P = 0.001). Herbage harvested at ground-level had 14.6%, 8.1% and 5.6 % more NDF than hand - plucked herbage in the dry, intermediate and wet season, respectively. NDF in H-P herbage increased from dry (548 ± 12 – 672 ± 16 g/kg DM) to wet (681 ± 16 – 749 ± 12 g/kg DM) season. Season and harvesting method significantly (P < 0.05) influenced ADF content at Serge Island Dairies, Ponderosa Dairy, Unity Valley Dairy and Barkeith Farms (Figure 4).

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Acid detergent fiber concentrations were significantly affected by harvesting method at Edwards Dairy (P = 0.000), Grove Place (P = 0.001) and FM Jones Dairy (P = 0.004).

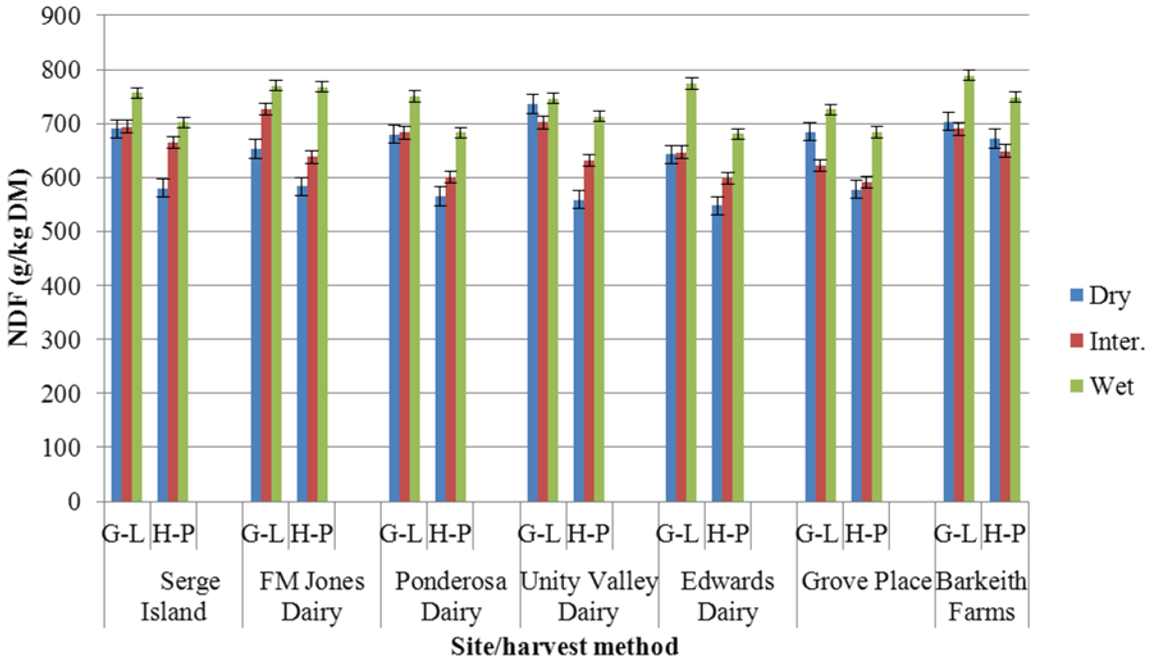

Figure 3. Effect of season and harvesting method on neutral detergent fiber (NDF) concentration (g/kg) at the respective site

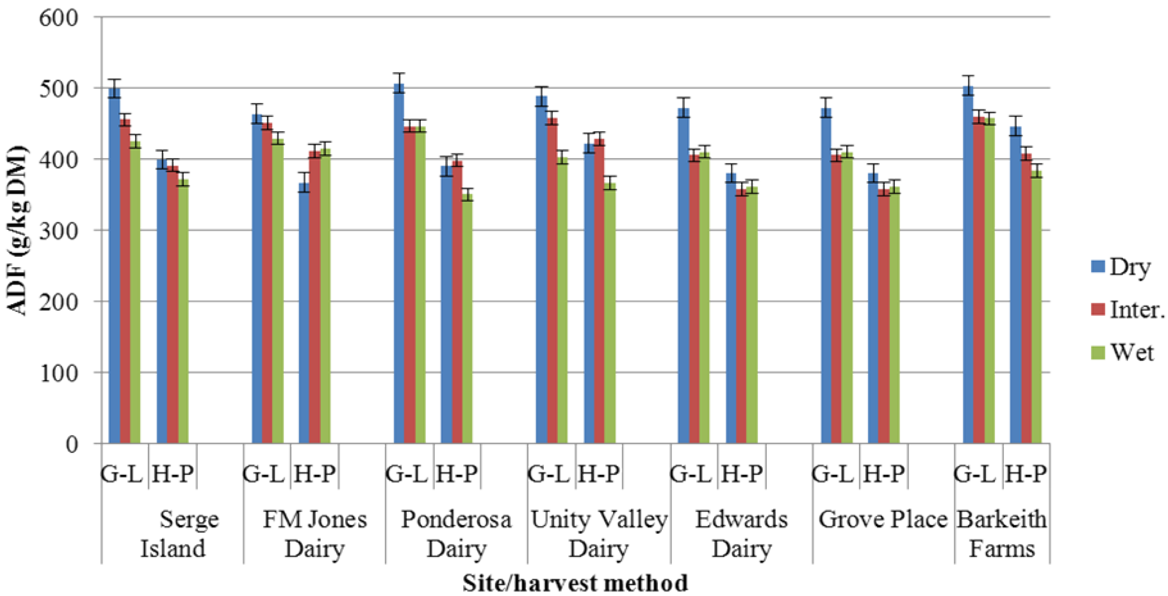

Figure 4. Effect of season and harvesting method on acid detergent fiber (ADF) concentration (g/kg) at the respective site

Acid detergent fiber concentrations in G-L harvested herbage were significantly (P < 0.05) higher (403 ± 16 – 507 ± 15 g/kg DM) than those harvested by H-P (351 ± 14 – 447 ± 18 g/kg DM) on all farms except for FM Jones Dairy. Acid detergent fiber concentrations decreased from dry to wet season for H-P harvested herbage on all farms except at Ponderosa Dairy and Unity Valley Dairy where ADF was highest during the intermediate season. Concentrations of ADL were significantly (P < 0.05) affected by season and harvesting method at Serge Island Dairies, FM Jones Dairy, Grove Place and Barkeith Farms (Figure 5). Harvesting method significantly (P < 0.05) influenced ADL concentration at Edwards Dairy and Ponderosa Dairy. Season × harvest method interaction was significant for ADL (P = 0.032) at Ponderosa Dairy. Dry and wet season H-P harvested herbage ADL differed significantly (P < 0.05) only at Grove Place.

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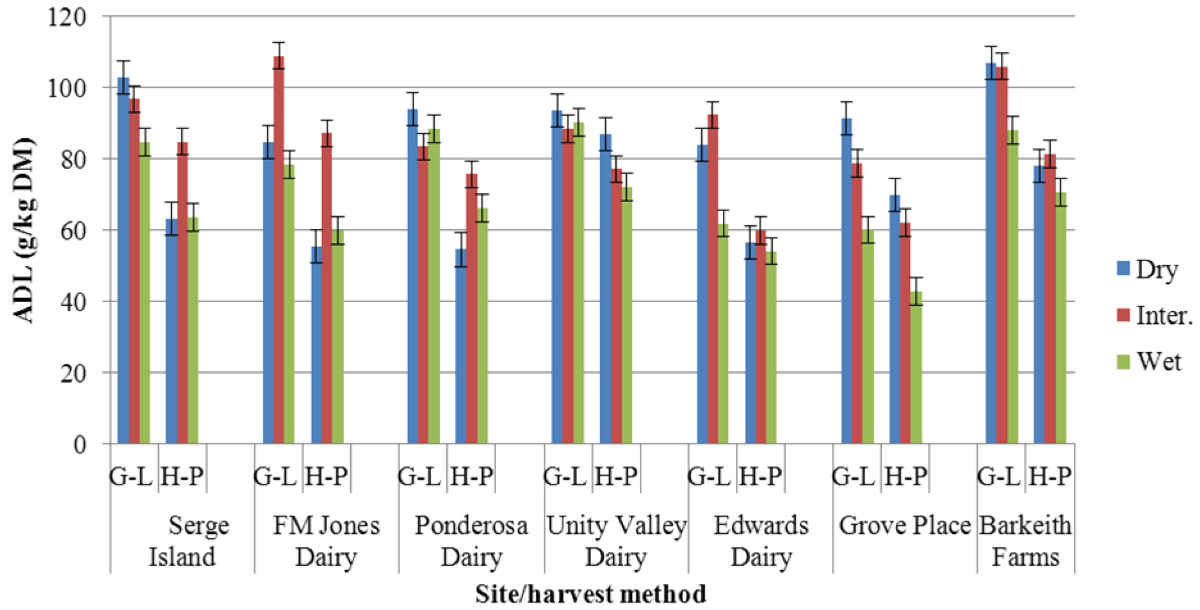

Figure 5 - Effect of season and harvesting method on acid detergent lignin (ADL) concentration (g/kg) at the respective site

***In vitro* organic matter digestibility (IVOMD)**

Digestibility after 12 h incubation: The effect of season and harvesting method on IVOMD after 12 h incubation ($IVOMD_{12}$) is presented in Table 1. Season and harvesting method significantly ($P < 0.05$) affected $IVOMD_{12}$ on all farms. Interactive effect of season × harvest method was significant ($P = 0.047$) only at Serge Island Dairies. Ground-level harvested herbage $IVOMD_{12}$ increased from dry (204 ± 7 – 299 ± 29 g/kg) to intermediate (281 ± 33 – 372 ± 13 g/kg) season then decreased in the wet (210 ± 10 – 268 ± 11 g/kg) season. Similarly, H-P herbage $IVOMD_{12}$ increased from dry (237 ± 5 – 380 ± 19 g/kg) to intermediate (355 ± 17 – 440 ± 12 g/kg) season then decreased in the wet (258 ± 17 – 355 ± 4 g/kg) season. Hand plucked harvested herbage $IVOMD_{12}$ was significantly greater ($P < 0.05$) than G-L herbage on all farms. Dry and wet season G-L harvested herbage $IVOMD_{12}$ differed only at Unity Valley Dairy ($P = 0.028$).

Table 1 - Effect of season and harvesting method (G-L & H-P) on *in vitro* organic matter digestibility (Mean ± SEM) after 12 h incubation

Farm	Season/harvesting method					
	Dry Season		Intermediate season		Wet Season	
	G-L	H-P	G-L	H-P	G-L	H-P
Serge Island Dairies	23 5±27^{a}	377±16^{b}	367±21^{b}	440±12^{c}	268±11^{a}	326± 4^{d}
FM Jones Dairy	274±26^{a}	380±19^{b}	285±30^{a}	374±14^{b}	210±10^{c}	262± 5^{a}
Ponderosa Dairy	236 ±25^{a}	289±18^{b}	314±16^{bd}	370±20^{c}	254±2^{a}	330± 3^{d}
Unity Valley Dairy	234±12^{a}	349±52^{bc}	315±34^{b}	401± 21^{c}	267±11^{d}	299±23^{d}
Edwards Dairy	299±29^{a}	360±9^{b}	372±13^{bc}	383±8^{c}	260±28^{a}	355±4^{b}
Grove Place	247±37^{a}	306±13^{b}	303±18^{b}	355±17^{c}	217±13^{a}	284±10^{b}
Barkeith Farms	204 ±7^{a}	237±5^{c}	281±33^{b}	360±44^{d}	215±17^{a}	258±17^{bc}

^{a,b,c,d,}: Items within row for the respective farm with different superscripts differ significantly ($P < 0.05$)

Digestibility after 24 h incubation: *In vitro* organic matter digestibility after 24 h incubation ($IVOMD_{24}$) was significantly ($P < 0.05$) influenced by season and harvesting method on all farms (Table 2). Significant interactive effect between season × harvesting method was found at Edwards Dairy ($P = 0.003$) and Serge Island Dairies ($P = 0.024$). The $IVOMD_{24}$ of H-P harvested herbage was significantly higher ($P < 0.05$) than G-L harvested herbage except during the dry season at Ponderosa Dairy and the wet season at Unity Valley Dairy. Ground -level herbage $IVOMD^{24}$ increased from dry (285 ± 25 – 372 ± 22 g/kg) to intermediate (389 ± 38 – 455 ± 38 g/kg) season then decreased in the wet (233 ± 22 – 363 ± 9 g/kg) season. Similarly, H-P herbage $IVOMD_{24}$ increased from dry (331 ± 5 – 525 ± 11 g/kg) to intermediate (491 ± 40 – 562 ± 32 g/kg) season then decreased in the wet (325 ± 20 – 425 ± 8 g/kg) season. Dry and wet season $IVOMD_{24}$ for both G-L and H-P harvested herbage were not significantly different ($P > 0.05$) at Ponderosa Dairy and Barkeith Farms. Similarly, there were no significant differences ($P > 0.05$) between dry and wet season G-L herbage $IVOMD_{24}$ at Serge Island Dairies, Unity Valley Dairy and Grove Place.

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Table 2 - Effect of season and harvesting method (G-L & H-P) on *in vitro* organic matter digestibility (Mean ± SEM) after 24 h incubation

Farm	Season/harvesting method					
	Dry Season		Intermediate season		Wet Season	
	G-L	H-P	G-L	H-P	G-L	H-P
Serge Island Dairies	313±18^{a}	498±10^{b}	455±38^{b}	545±17^{c}	311±10^{a}	380±12^{d}
FM Jones Dairy	362±22^{a}	513±14^{b}	389±38^{a}	562±32^{c}	277±12^{d}	337±12^{a}
Ponderosa Dairy	309±47^{a}	375±34^{ab}	408±28^{b}	522±22^{c}	330±16^{a}	389±14^{b}
Unity Valley Dairy	372±22^{a}	483±17^{b}	430±34^{b}	522±16^{c}	363±9^{a}	382±6^{a}
Edwards Dairy	369±20^{a}	525±11^{b}	454±12^{c}	501±10^{b}	329±6^{d}	425±8^{c}
Grove Place	346±55^{ad}	435±15^{b}	432±12^{b}	492±23^{c}	305±13^{a}	336±8^{d}
Barkeith Farms	285 ± 25^{a}	331 ± 5^{b}	404±36^{c}	491±40^{d}	233±22^{a}	325±20^{b}

^{a,b,c,d}: Items within row for the respective farm with different superscripts differ significantly (P < 0.05)

Digestibility after 48 h incubation: *In vitro* organic matter digestibility after 48h incubation ($IVOMD_{48}$) was significantly (P < 0.05) affected by season, harvest method (P < 0.05) and their interaction (P < 0.05) at FM Jones Dairy and Edwards Dairy (Table 3). *In vitro* organic matter digestibility ($IVOMD_{48}$) at Unity Valley Dairy was significantly (P < 0.05) affected by harvesting method (P = 0.000) and season × harvesting method interaction (P = 0.011). Season and harvesting method significantly influenced $IVOMD_{48}$ (P < 0.05) on the other farms. "Hand – plucked" herbage $IVOMD_{48}$ was significantly (P < 0.05) higher than G-L harvested herbage on all farms. The $IVOMD_{48}$ of G-L harvested herbage increased from dry (312 ± 13 – 494 ± 8g/kg) to intermediate (444 ± 24 – 613 ± 8g/kg) season then decreased in the wet (326 ± 19 – 489 ± 15g/kg) season. Hand – plucked herbage $IVOMD_{48}$ followed the same pattern; increasing from the dry (451 ± 16 – 676 ± 10g/kg) to intermediate (589 ± 26 – 672 ± 15g/kg) season then fell in the wet (447 ± 6 – 617 ± 6g/kg) season except for FM Jones Dairy where H-P herbage $IVOMD_{48}$ decreased from dry to wet season. Dry and wet season $IVOMD_{48}$ for G-L harvested herbage was significantly different (P = 0.028) only at Unity Valley Dairy.

Table 3 - Effect of season and harvesting method (G-L & H-P) on *in vitro* organic matter digestibility (Mean ± SEM) after 48 h incubation

Farm	Season/harvesting method					
	Dry Season		Intermediate season		Wet Season	
	G-L	H-P	G-L	H-P	G-L	H-P
Serge Island Dairies	380±24^{a}	592±16^{b}	472±18^{c}	640±1^{d}	437±10^{c}	568±39^{b}
FM Jones Dairy	465±32^{ad}	661±12^{b}	444±24^{a}	662±18^{b}	434±10^{a}	494±18^{d}
Ponderosa Dairy	413±28^{a}	561±32^{b}	588±34^{c}	654±22^{d}	449±9^{ac}	603±12^{e}
Unity Valley Dairy	405±25^{a}	600±22^{b}	478±16^{c}	619±26^{b}	489±15^{c}	547±13^{d}
Edwards Dairy	494±8^{a}	676±10^{b}	577±7^{c}	672±15^{b}	478±24^{a}	617±6^{d}
Grove Place	474±73^{a}	622±29^{bc}	613±8^{b}	650±16^{c}	462±26^{a}	571±3^{d}
Barkeith Farms	321±13^{a}	451±16^{b}	444±25^{b}	589±34^{c}	326±19^{a}	447±6^{b}

^{a,b,c,d}: Items within row for the respective farm with different superscripts differ significantly (P < 0.05)

Metabolizable energy

Metabolizable energy (McDonald *et al.,* 2002) after 48h ruminal *in vitro* fermentation was significantly affected by season (P < 0.05) and harvesting method (P < 0.05) on all farms (Table 4). Interactive effect of season × harvesting method was significant at Edwards Dairy (P = 0.005), Unity Valley Dairy (P = 0.018) and FM Jones Dairy (P = 0.008). Metabolizable energy of H-P harvested herbage (6.7 ± 0.1 – 10 ± 0.1MJ/kg DM) was higher than G-L harvested herbage (4.8 ± 0.2 – 9.1 ± 0.1MJ/kg DM) on all farms across the three seasons except for Grove Place during the intermediate season. Ground level harvested herbage ME ranged from 4.8 ± 0.2 -7.4 ± 0.1 MJ/kg DM in the dry season, 6.6 ± 0.4 - 9.1 ± 0.1 MJ/kg DM in the intermediate season and 4.9 ± 0.3 - 7.3 ± 0.2 MJ/kg DM in the wet season. The ME of herbage harvested by H-P varied from 6.8 ± 0.2 - 10.0 ± 0.1 MJ/kg DM, 8.7 ± 0.5 - 9.9 ± 0.2 MJ/kg DM and 6.7 ± 0.1 - 9.1 ± 0.1 MJ/kg DM in the dry, intermediate and wet season, respectively.

Table 4 - Effect of season and harvest method on metabolizable energy (MJ/kg DM) [McDonald et al., 2002] of tropical pastures grazed by beef and dairy cattle in Jamaica

Farm	Season/harvesting method					
	Dry		Intermediate		Wet	
	G-L	H-P	G-L	H-P	G-L	H-P
Serge Island Dairies	5.7 ± 0.3^{a}	8.7 ± 0.2^{d}	7.1 ± 0.3^{b}	9.4 ± 0.1^{e}	6.5 ± 0.2^{c}	8.3 ± 0.6^{d}
FM Jones Dairy	7.0± 0.4^{ab}	9.8 ± 0.2^{c}	6.7 ± 0.3^{b}	9.3 ± 0.3^{c}	6.5 ± 0.1^{b}	7.4 ± 0.2^{a}
Ponderosa Dairy	6.2 ± 0.4^{a}	8.2 ± 0.4^{c}	7.2 ± 0.5^{b}	9.7 ± 0.3^{d}	6.7 ± 0.1^{a}	9.0 ± 0.1^{d}
Unity Valley Dairy	6.1 ± 0.4^{a}	8.8 ± 0.4^{c}	7.1 ± 0.2^{b}	9.1 ± 0.4^{c}	7.3 ± 0.2^{b}	8.2 ± 0.2^{d}
Edwards Dairy	7.4 ± 0.1^{a}	10.0 ± 0.1^{c}	8.5 ± 0.1^{b}	9.9 ± 0.2^{c}	7.1 ± 0.3^{a}	9.1 ± 0.1^{d}
Grove Place	7.1 ± 1.1^{a}	9.2 ± 0.4^{bc}	9.1 ± 0.1^{b}	9.6 ± 0.3^{b}	6.8 ± 0.4^{a}	8.5 ± 0.1^{c}
Barkeith Farms	4.8 ± 0.2^{a}	6.8 ± 0.2^{b}	6.6 ± 0.4^{b}	8.7 ± 0.5^{c}	4.9 ± 0.3^{a}	6.7 ± 0.1^{b}

^{a,b,c,d}: Items within row for the respective farm with different superscripts differ significantly (P < 0.05)

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Significant difference ($P < 0.05$) between dry and intermediate season ME for H-P harvested herbage was observed only on Serge Island Dairies, Ponderosa Dairy and Barkeith Farms. The relationship between ME derived from GE (Y) (Minson, 1979) and that calculated from IVOMD (X) (McDonald et al., 2002) (Figure 6) was described by the simple linear regression:

$Y = - 0.072 + 0.927X$ ($R^2 = 0.752$); $P > 0.05$

The relationship between the ME derived from both methods was highly correlated with correlation coefficient of $r^2 = 0.867$.

DISCUSSION

Chemical composition

Observable differences in pasture chemical composition between farms can be attributable to differences in pasture species, management, climate, and soil type. For example, pastures at Ponderosa Dairy, Edwards Dairy and Grove Place were planted to *Brachiaria spp* while the remaining farms had *Cynodon spp*. On the beef farms (Grove Place and Barkeith Farms), pastures are grazed for longer periods and at longer intervals than on the dairy farms. The difference in chemical composition between H-P and G-L herbage "within site" highlights the contrast in nutritive value of the total herbage offered versus potentially grazed herbage.

It has been previously pointed out that tropical grasses are distinctly vertically heterogeneous in chemical composition and morphology (Stobbs 1975; Sollenberger and Burns 2001). Herbage harvested by "hand-plucking" would have comprised mainly of portions of the upper sward canopy; hence a higher proportion of leaf than stem. In fact, Holderbaum *et al.,* (1992) showed that leaf percentage may be as much as three times greater in the upper half than in the lower half of a *Limpograss (Hermarthria altissima)* canopy. Several authors (Laredo and Minson, 1973; Moreia *et al.,* 2004; Hare *et al.,* 2009) have confirmed that the concentrations of cell wall fractions (NDF, ADF and lignin) of tropical grasses are usually lower and crude protein (Moreia *et al.,* 2004; Newman *et al.,* 2003; Hare *et al.,* 2009) usually higher in leaf than stem. This is expected to positively influence diet selection of the grazing animal (Weir and Torell 1959; Stobbs, 1975; Burns *et al.,* 1992). In fact, Laredo and Minson (1973) separated leaves and stems of similar digestibility from five grasses and found that intake of leaf was 46% higher than stem when fed to sheep. Stobbs, (1975) noted that under rotational grazing, cattle graze the uppermost leaves first, followed by leaf-bearing stems. This grazing behaviour was identified as critical to the animal being able to satisfy its nutrient and intake requirements (Stobbs, 1975). The lower DM of H-P herbage in the current study may have been the result of higher moisture content of the upper-most leafy portion of the grass canopy, particularly during the intermediate and wet seasons. Higher CP concentration of H-P herbage in this study is consistent with literature (Holderbaum *et al.,* 1992; Newman *et al.,* 2002) and is also attributable to the upper horizons of the sward canopy having a greater proportion of green leaf than stem. Holderbaum *et al.,* (1992) observed a 43 % decrease in CP concentration from top to bottom of a *Limpograss* canopy.

The mean CP concentration of H-P herbage in the current study exceeded the minimum threshold level of 80 g/kg which might limit intake of tropical forages (Milford and Minson, 1966; Minson, 1980) and that which is needed to maintain optimum rumen function (Minson and Milford, 1967). In fact, H-P herbage in the present study can supplied CP more than adequate to support average daily milk yields above 15 litres per cow (NRC, 2001). Average daily milk yield of 15 liters per cow is well above current levels of production on Jamaican dairy farms (Miller, pers. comm). This, however, was not the case with G-L herbage, particularly during the dry season where CP was generally below the 80 g/kg threshold. The moderate to high CP concentrations of H-P herbage suggest that the level of production that can be sustained is dependent on the availability of such herbage in sufficient quantity to satisfy the DM intake requirement of the grazing animal.

The chemical components of H-P herbage appeared to be less sensitive to seasonal variations compared to G-L herbage. This observation was supported by Telford *et al.,* (1975) who reported that the diet selected by esophageal-fistulated cows and calves grazing *Cynodon dactylon* fertilized at three different N rates, did not vary much over two grazing trials at different times of the year. This implies that if afforded the opportunity, the grazing animal will consistently select herbage of the highest quality throughout the year, subject to the availability of adequate herbage to select from. The observation in the present study that NDF in both H-P and G-L was highest during the wet season contradicts earlier reports (Tekletsadik *et al.,* 2004; Mtui *et al.,* 2009; Lopez-Gonzalez *et al.,* 2010) in which NDF was significantly higher in the dry compared to wet season. This might have been the result of hemicellulose concentration which tends to be high in rapidly growing grass. Rapid growth rates are mostly observed in the wet season or in pastures under irrigation. Reports in the literature confirm ADF and ADL of tropical grasses being lowest in the wet season (Relling *et al.,* 2001; Mtui *et al.,* 2009). Faster rate of maturity resulting in rapid lignification (Van Soest *et al.,* 1991) due to higher temperatures and severe moisture stress in the dry season could account for this.

In vitro organic matter digestibility (IVOMD)

Digestibility after 12 h incubation: Approximately 60 - 65% of the OM of both G-L and H-P herbage was digested within the first 12h of incubation. This was in agreement with several other reports which demonstrated that the rate of forage digestion is highest during the earlier stages of incubation (Prigge *et al.,* 1984; Kamalak *et al.,* 2005a; Kamalak *et al.,* 2005b). In fact, Kamalak *et al.,* (2005a) reported that alfalfa hay and silage *in vitro* digestibility after 12h incubation was approximately 78% of the digestibility (56.3 and 61.2%, respectively) recorded after 48 hours

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incubation using the gas production technique. This high initial rate of forage digestion represents microbial degradation of the rapidly soluble forage fraction (Van Soest, 1967; Mertens and Ely, 1982) that is readily available for animal use. Prigge *et al.,* (1984) showed that total VFA from fistulated wethers and steers, peaked at 12 h post feeding a diet of perennial ryegrass (*Lolium* perenne) or swtichgrass (*Panicum vigatum L.*) hay. Juarez Lagunes *et al.,* (1999) estimated the digestion rate of non-structural carbohydrates (NSC) of *Digitaria decumbens* to be around 13.5 % DM/hour.

However, the rate of digestion at early incubation intervals seems to be dependent on the ratio of total cell wall components to NSC which might have accounted for the differences in IVOMD between G-L and H-P herbage within and between seasons.

Digestibility after 24 h incubation: Forage digestibility at 24 h might better represent digestibility by ruminant livestock compared to 48 h which may over-estimate, or 12h which may under-estimate digestibility. Several reports have suggested that the actual rumen retention time of forages by cattle is closer to 24 h (Prigge *et al.,* 1984; Prigge *et al.,* 1990; Kokkonen *et al.,* 2000). From the study of Prigge *et al.,* (1990) rumen retention time of forage diets containing 100 % alfalfa, 50 : 50 alfalfa : switchgrass, 25 : 75 alfalfa : switchgrass and 100 % switchgrass combinations fed to three fistulated cattle were 24.3, 24.8, 24.7 and 29.8 hours, respectively. It must be noted that these forages were of superior quality to those investigated in the present study, particularly the G-L herbage. This implies that the rumen retention time of H-P herbage might be shorter than that of G-L herbage.

The positive relationship between forage digestibility and intake (Laredo and Minson 1975; Cheeke, 1999) and inverse correlation with rumen retention time (Laredo and Minson 1973) would suggest that intake by grazing cattle might be expected to be greater for herbage of similar quality to that of hand-plucked samples compared to G-L herbage and correspondingly, greater in the intermediate season compared to wet and dry season. *In vitro* organic matter digestibility after 24 h incubation of H-P herbage from the present study, particularly those from the intermediate season, falls within ranges reported by Holechek *et al.,* (1989) and Kamalak *et al.,* (2005a). Similarly, $IVOMD_{24}$ of G-L herbage was comparable to 24 h digestibility of wheat and barley straw but inferior to alfalfa hay and silage and maize silage reported by Kamalak *et al.,* (2005b). These differences are mainly associated with the contrasting chemical compositions, primarily fibre fractions of the different forages.

Digestibility after 48 h incubation: The low $IVOMD_{48}$ of G-L herbage is mainly a function of the high cell wall components (NDF, ADF and ADL) which has been shown to negatively affect forage digestibility (Van Soest, 1967; Van Soest, 1994; Jung and Allen, 1995). Lignin, in particular, is the main factor that limits forage digestibility (Jung and Allen, 1995). In addition, low CP has a negative effect on forage digestibility (Minson, 1980). However, it is important to note that the relationship between forage digestibility and lignin concentration is non-linear, which implies a spatial and a chemical effect of lignin on forage digestion (Van Soest, 1967; Dryden, 2008). This could be the reason for the higher $IVOMD_{48}$ observed in the dry compared to the wet season despite similar ADL concentrations in both seasons. Van Soest (1994) pointed out that grasses and legumes of similar digestibility differ in chemical composition, with legume cell wall containing about twice the lignin as grass but ferments at a faster rate than grasses at the same stage of maturity. This suggests that forages with the lowest lignin are not necessarily the most digestible. The difference in $IVOMD^{48}$ between G-L and H-P herbage is possibly due in part to the higher proportion of leaf versus stem in the upper sward canopy represented by H-P herbage. Indeed, Newman, *et al.,* (2003) showed that IVOMD was generally greater for herbage from the upper 25 % versus next lower 50 % of a continuously stocked *Limpograss* pasture canopy.

In a study reported by Lopez-Gonzalez *et al.,* (2010) i*n vitro* organic matter digestibility after 48 h incubation of *Cynodon plectostachyus* harvested at ground level, was higher than that of G-L herbage in the present study, while dry and wet season $IVOMD_{48}$ of H-P herbage was within range of the findings of Dixon and Coates (2010) for dry matter digestibility (measured by faecal NIRS) of the diet of heifers grazing buffel grass pastures *(C. ciliaris).*

Metabolizable energy

Moir *et al.,* (1979) and Kolver, (2003) indicated that the quantity of metabolizable energy (ME) supplied is the first limiting factor to milk production from pasture-based systems. The higher ME of H-P compared to G-L herbage is attributed to the higher *in vitro* digestibility of the H-P herbage, since ME was a derivative of IVOMD. McDonald *et al.,* (2002) pointed out that the main factors affecting the ME value of feedstuff are those which influence its digestibility. Feedstuffs with low energy density are usually more fibrous and are used less efficiently (Dryden, 2008). Hence, if animals are forced to consume herbage approximating the poorer quality G-L herbage, this might well result in a decrease in the quantum of energy available for milk production and growth. Using the Cornell Net Carbohydrate and Protein System, Juarez Lagunes *et al.,* (1999) predicted that the volume of milk attainable from tropical pastures based on the ME supplied, decreased by 35 % when NDF increased from 600 to 800 g/kg DM. This relationship was in agreement with an earlier finding by Moir *et al.,* (1979) and has more recently been corroborated by Meeske *et al.,* (2006). Metabolizable energy values of Kikuyu grass *(Pennisetum clandestinum)* leaf (11 MJ/kg DM^{-1}) and stem (9 MJ/kg DM^{-1}) reported by Moir *et al.,* (1979) were higher than H-P (6.7 – 10 MJ/kg DM) and G-L (4.8 – 9.1 MJ/kg DM) herbage, respectively. Other authors (Meeske *et al.,* 2006; Cardenas-Medina *et al.,* 2010) reported ME values from tropical grasses within range of those observed in the present study. Based upon NRC (2001) the range of ME [NE_l from NRC converted to ME (Dryden, 2008)] in G-L and H-P herbage during the dry season, is likely to limit milk

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production (4% fat-corrected) from a typical Jamaica Hope cow to approximately 4 - 6 litres/day and 6 - 8 litres/day, respectively.
During the intermediate and wet season, milk production from herbage with similar ME content to G-L and H-P could potentially peak at between 6.5 and 9 litres/day, respectively, provided DMI is sufficient. Jamaican pastures of the type assessed in the present study could potentially support moderate to high levels of beef production. Herbage similar to that collected by "hand-plucking" should provide enough ME (4.5 – 11.9 MJ/kg DM) to maintain ADG of 0.5 – 1.0 kg/day (NRC, 1996) for a typical Jamaica Red cattle (300 – 400 kg BW) provided DM of 3.5 – 8.5 kg is consumed daily. However, the fibrous nature of these grasses might be a limiting factor in achieving the required DMI (Jung and Allen, 1995; Dewhurst *et al.,* 2009) to achieve these levels of production. Under typical grazing management in Jamaica, in which beef cattle are allowed to graze one paddock for as long as six days; intake of the required level of ME might be inhibited after the first two days of grazing as the proportion of available leaf declines (Chacon and Stobbs, 1976). This might also be injurious to the leaf initials thus resulting in sward deterioration (Chacon and Stobbs, 1976). Therefore, farmers need to limit grazing duration to below three days in order to optimize nutrient intake. Jamaican researchers have, in the past, relied on gross energy determination (by adiabatic bomb calorimetry) to estimate ME. Determination of GE is, however, costly and time consuming. Estimation of metabolizable energy using the McDonald equation offers a simpler and more convenient method for predicting ME of feedstuffs with similar accuracy; since the difference between both methods has been found to be non- significant ($P < 0.05$).

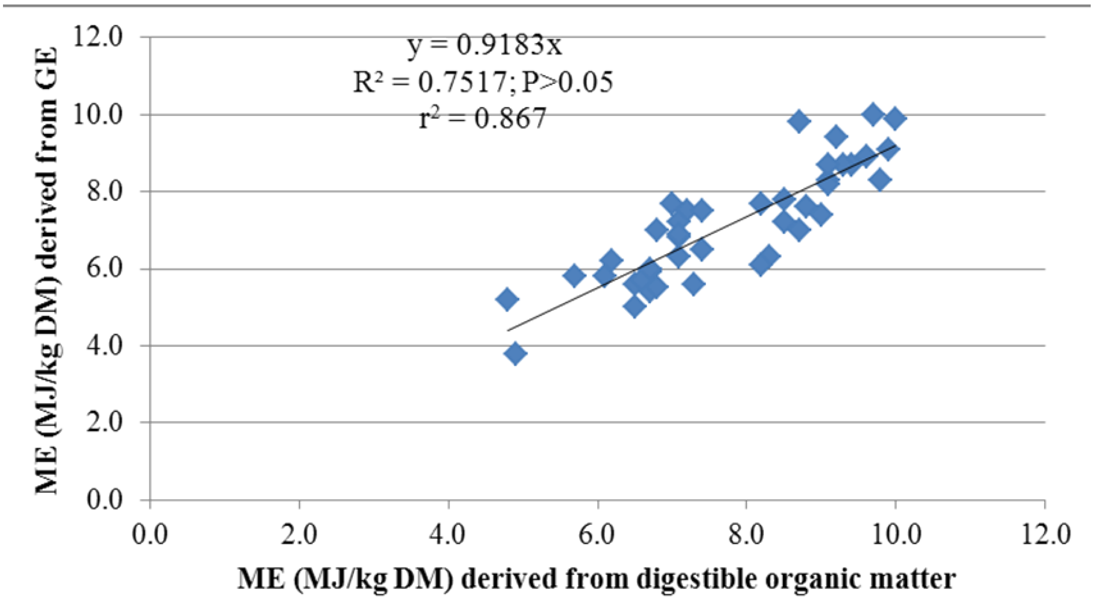

Figure 6 Relationship between ME (MJ/kg DM) derived from GE and ME (MJ/kg DM) derived from digestible organic matter

CONCLUSION

This study has demonstrated that sampling rotationally grazed tropical pastures at ground level, significantly under-estimates the nutritive value of the herbage likely to be harvested at grazing by cattle. The nutritive value of G-L harvested herbage was consistently low; with particular reference to CP, *in vitro* OM digestibility and ME concentrations. Nutritive value of hand- plucked herbage indicate great potential for sustaining moderate to high levels of milk and beef production. This highlights the importance of a previous recommendation by Hughes et al., (2011) to mow pastures at least once annually to increase the proportion green leaf relative to stems and residual OM offered for grazing. Current national production levels for milk (2 422 L/ha.) and beef (136.5 kg/ha), highlight the fact that Jamaican pasture lands are under-utilized. These performance levels indicate that only 30 % and 20 % of the productive capacity of Jamaican pasture lands is exploited for milk and beef production, respectively (Jennings, pers. comm.). The nutritive value of grazed pasture is more accurately assessed through the use of hand-pluck grass samples. Analysis of samples harvested at ground level significantly understates the productive potential of tropical pasture systems.

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