FEASIBILITY OF ALKANES AS FLOW AND DIGESTIBILITY MARKERS, AND THE EFFECTS OF SODIUM BICARBONATE ON SITE OF DIGESTION AND METABOLISM IN THE GASTROINTESTINAL TRACT OF SHEEP

A. R. Askar
Animal and Poultry Nutrition Department, Desert Research Center, P.O. Box 11753, El-Matareya, Cairo, Egypt

(Received 20/1/2010, Accepted 8/3/2010)

SUMMARY

Two experiments were conducted to study the evaluation of long chain n-alkanes as flow and digestibility markers and the effect of sodium bicarbonate (SB) on the metabolism and digestion throughout the gastrointestinal tract in lambs fed high concentrate diets using Ytterbium-chloride ($YbCl_3$) as a flow marker. Eighteen and twelve Raza Aragoneza lambs were used for experiment 1 and 2, respectively. Lambs were individually employed directly after finishing the fattening period (24 kg live weight), continuing on same diet, with free access of whole barley grain and protein supplement. Each experiment lasted 3-week period when offered feeds and orts were recorded daily. Lambs were slaughtered after a 7-day period of daily continued dose of chromium EDTA (Cr- EDTA) and $YbCl_3$ ($YbCl_3$ only in the second experiment). Lambs were slaughtered 3 hours post feeding and the digestive tract was sectioned and their contents were sampled. Results of experiment 1 indicated that C_{31} was the predominant alkane in the diet, followed by C_{29} and C_{33}. Recovery of C_{29}, C_{31} and C_{33} in respect to $YbCl_3$ was much higher in abomasum and significantly dropped in ileum and rectum reflecting upon digestibility coefficients through the gastrointestinal tract sections. Rumen digestibility values using alkane C_{31} were similar to those obtained by $YbCl_3$, while C_{29} and C_{33} showed much higher values. Digestion in small intestine was very low with using alkanes in comparison with $YbCl_3$. C_{33} has a significant higher recovery in faeces as compared to C_{29} and C_{31}. In the second experiment, two treatments were conducted, with or without SB. Adding SB did not affect the intake of DM, OM, and N but negatively affected rumen nutrient digestibility and enhanced small intestine digestibility. Therefore, the site of digestion might be affected by SB. Efficiency of rumen N utilization and microbial protein synthesis were low and not improved by SB addition, resulting in loosing 48% of N intake in rumen. Rumen N degradation was high and not affected by SB addition. Results can conclude that long chain n-alkanes, particularly C_{31}, which is a useful rumen digestibility marker. However, Cr-EDTA can not be recommended as flow marker. Additionally, Cr-EDTA and long chain n-alkanes can be used as total tract digestibility markers, taking into consideration their faecal recovery. SB addition can manipulate the site of digestion through the gastrointestinal tract but does not seem to regulate protein intake and degradation in lambs. The present study suggested that the use of low degradable N source would be a solution for not selecting diets rich in protein by growing lambs fed high concentrate diets.

Keywords: long chain n-alkane, Cr-EDTA, $YbCl_3$, lambs, high concentrate diet

INTRODUCTION

Three key elements are required for sustainable research efforts in animal nutrition. The amount of feed intake (the quantity), diet composition (the quality), and nutrients actually made available for absorption in the digestive tract after rumen digestion (Dove and Mayes, 1991) which is difficult to be directly measured. Individual and metabolic cages are used to measure the individual intake and digestibility but they are not representative for the intensive production system in which feeding behaviour can alters and affect the accuracy of obtained results. Therefore, the use of nutritional markers allows monitoring of the process of interest (Kotb and Luckey 1972).

The estimation of digestibility throughout the digestive tract, and microbial protein contribution to post-ruminal flow requires an appropriate flow and microbial markers (Askar *et al.*, 2005). The characteristics of an ideal marker and procedures for its use have been reviewed earlier (Kotb and Luckey 1972; Faichney 1975; Owens and Hanson, 1992). Several markers have been used, either as internal or external (Mayes and Dove, 2000). Internal markers have several advantages over external markers, including their performance and representation in feed and digesta. Long chain n-alkanes are presents naturally in the cuticular surface wax of plants and have recently reported to estimate feed intake, composition, and digestibility in grazing animals (Mayes and Dove, 2000; Valiente *et al.*, 2003; Dove and Mayes, 2005) but their application as flow (Askar *et al.*, 2005) and transit (Giráldez *et al.*, 2006) markers has been limited with scarce information (Mayes *et al.*, 1988; Ohajuruka and Palmquist, 1991).

On the other hand, the quantity of nutrients digested in rumen is a function of two rates, the rate of passage and the rate of digestion in which sodium bicarbonate (SB) has been reported to affect both of them. Inclusion of SB is recommended to improve rumen pH (Santra *et al.*, 2003; Tripathi *et al.*, 2004) and increase dilution rate in the rumen, as well as the rate of the passage (Harrison *et al.*, 1975; Kellaway *et al.*, 1978; Okeke *et al.*, 1983; Owens and Goetsch, 1986). This leads to improve the efficiency of microbial protein synthesis (Harrison *et al.*, 1975; Chamberlain and Thomas, 1980; Mees *et al.*, 1985), enhance bacterial fixation of ammonia (Newbold *et al.*, 1988 and 1991), and increase dietary nutrients by-passing ruminal degradation (Okeke *et al.*, 1983, Kovacik *et al.*, 1986). A little is known about the effect of SB on rumen and post rumen metabolism and digestibility in lambs fed on high concentrate diets.

However, the first experiment aimed to study the validation of long chain n-alkanes as flow markers in comparison with traditional markers, such as Ytterbium chloride ($YbCl_3$) and chromium-EDTA (Cr-EDTA), while the second experiment dealt with the effect of SB inclusion on nutrient utilization and metabolism throughout the gastrointestinal tract, using $YbCl_3$ as a flow marker.

MATERIALS AND METHODS

Animals and treatment

Experiment 1

Eighteen growing Raza Aragonesa male lambs, with an average body weight of 24.7 kg (SE = 0.48), were employed in individual cages to study the feasibility of n-alkanes as flow and digestibility markers throughout the gastrointestinal tract compared with $YbCl_3$ and Cr-EDTA as traditional markers. All animals were fed on whole barley grain and protein supplement ad libitum in separated troughs. Protein supplement was formulated from a mixture of soybean meal and barley grain to obtain approximately 34% of crude protein (Table 1).

Table (1). Chemical composition (g/kg DM), purine bases (μmol PB/g DM), and n-alkanes content (mg/kg DM) in feed ingredients.

	Protein supplement	Barley grain
Chemical composition (g/kg DM)		
OM	858	975
CP	341	100
EE	16.5	22.5
NDF	155	197
ADF	82.7	51.8
Purine bases (μmol PB/g DM)	12.8	8.83
N-alkanes content (mg/kg DM)		
C_{21}	-	-
C_{23}	0.62	1.51
C_{24}	-	-
C_{25}	1.54	3.16
C_{26}	-	-
C_{27}	1.20	2.72
C_{28}	0.04	1.09
C_{29}	3.34	9.24
C_{30}	0.06	-
C_{31}	3.71	11.13
C_{32}	-	-
C_{33}	1.61	2.67

Experiment 2

Twelve growing Raza Aragonesa male lambs, with an average body weight of 24.1 kg (SE = 0.11), were employed in individual cages to study the effect of adding SB on metabolism, and digestion throughout the gastrointestinal tract system. Lambs were divided into two treatments, 6 in each, and fed the same diet as in experiment one except for protein supplement that was mixed, either without (treatment 0) or with 30 g SB / kg dry matter (treatment 30) as proposed by Askar *et al.* (2006). Moreover, when lambs were

fed similar diet with free access of SB in separated troughs on the side, Askar *et al.* (2002) found that female selected much SB than male lambs with an average of 17 g SB / kg dry matter intake for both sexes (38.8 g SB per kg protein supplement). This selected amount was significantly decreased in male at the last 2 weeks of the fattening period (around 30 g SB per kg protein supplement) which has been taking into consideration in the present study.

Experimental procedures

Lambs, in both experiments, were moved to individual cages directly after finishing the fattening period (24 kg live weight or 8 weeks of fattening after early weaning at 6 weeks of age, see Askar *et al.*, 2006) in which the same diet was fed before and after fattening.

Both experiments lasted 3-week period during which offered feed and orts were recorded daily. Lambs were slaughtered after a 7-day period of daily continuous dose of 80 ml of Cr-EDTA (2821 mg Cr/L) and 20 ml of $YbCl_3$ (4960 mg Yb/L), $YbCl_3$ was used in the second experiment only. The daily amount of marker solution was infused at 6 hours intervals. At that period, feeds were offered at levels very close to ad libitum to avoid much feed refusal and reduce fluctuations in feed intake. Offered feed and orts were recorded daily and sampled to determine the dry matter contents by drying at 65°C for 48 h. An appropriate pooled sub-sample for each animal was also preserved for further analysis.

After the marker infusion period, animals were slaughtered by exsanguination previous intramuscular administration of 0.3 mg Xilacine/kg live weight (Xilagesic® 2%) and 10 mg/kg live weight of Tiopental (Tiobarbital® BRAUN). Lambs were slaughtered 3 hours post feeding in sets of 3 for the first experiment and 4 (2 per treatment) for the second experiment. The digestive tract was sectioned and their contents were sampled. The flow of abomasal, ileum, and rectum were determined by $YbCl_3$ and Cr-EDTA (only $YbCl_3$ in the second experiment), and then used to validate the use of n-alkanes as flow and digestibility markers in experiment one or to study the nutrient utilization and metabolism throughout the gastrointestinal tract in experiment two. Whole rumen content was strained and liquid fraction was centrifuged at 500*xg* for 10 min, then bacteria was extracted from the supernatant fluid by centrifugation at 20.000xg, for 20 min at 4°C. Bacterial pellets were rinsed with saline solution (9 g NaCl/L, at 4°C), then centrifuged again. Samples of bacterial pellets, and abomasum, ileum, and rectum contents were stored at -20°C and freeze dried for later analysis.

Analytical procedures

Dry matter content of feed ingredients, was determined by drying at 105°C for 24 hours. In feed ingredients, digesta, and faeces, organic matter was detected by ashing at 550°C for 8 h, total N content by the Kjeldahl method, using Se as catalyst, and non ammonia N (NAN) also by Kjeldahl method but after NH_3 evaporation by 1M NaOH addition. In feeds, ether extract was determined following the method of the Association of Official Analytical Chemists (2005), and neutral detergent fibre (NDF) and acid detergent fibre (ADF) were determined as described by Van Soest *et al.*, (1991).

Marker preparation and analysis

Cr-EDTA was prepared following the method described by Downes and McDonald (1964), in which 71 g $CrCl_3.6H_2O$ were weighed and dissolved in 1 L distilled water, additionally 100 g disodium salt of the etilenediaminotetraacetic acid (EDTA, $Na_2C_{10}H_{14}N_2O_8.2H_2O$) were dissolved in 1.5 L of distilled water and added to the first solution. The mixture was heated until boiling with small glass balls as anti-bump, and kept boiling gently for 1 hour using a reflux system. Once the solution was cooled down, the small excess of EDTA was neutralized with 20 ml 1M $CaCl_2$ (7.35 g $CaCl_2$ $6H_2O$ in 50 ml distilled water) and pH was adjusted between 6 and 7 with 5 M NaOH. Then, the final volume up to 5 L with distilled water was made, and allow to stand at room temperature for 12-18 hours. Solution was filtered by Whitman filter paper (82 g/ m^2) before its use.

On the other hand, ytterbium chloride solution was prepared by a suitable dilution of $YbCl_3.6H_2O$ in distilled water.

The analysis of Cr and Yb in flow and faeces samples was determined according to de Vega and Poppi (1997). Briefly, 15 mL of a 5:1 mixture of nitric acid: perchloric acid was added to 0.2 g dry matter of sample, and allow to stand overnight. Then, samples were gradually heated in a sand bath until their fully digestion. Once cooled down, samples were quantity transferred to 25 ml volumetric flasks by adding distilled water. After precipitation of silica, a 10 ml aliquot was taken and transferred to a plastic vial for atomic absorption spectrophotometric analysis.

N-alkanes extraction and analysis

For alkane extraction, 1.0 or 1.5 g of digesta flow and feed samples was weighed into 200 x 20 mm thick-walled screw-topped Pyrex test-tubes, adding 100 mg for flow, and 25 mg for feed samples. The internal standard solution was heptane containing 1 mg/g of C_{22} and C_{34} alkanes). Then extraction of n-alkanes was carried out following the technique described by Mayes *et al.* (1986), with the modifications suggested by Oliván and Osoro (1999).

Alkane analysis was carried out by on-column injection of 0.2 µl of the elute onto a 30 m x 0.53mm HP-1 capillary column (1.5µm thickness) in an Agilent 6890 gas chromatograph fitted with an automatic injector and flame ionization detector (45 and 450 ml/min for H_2 and air, respectively). The carrier gas was helium (10 ml/min) as it was the make-up gas to the detector (45 ml/min). After an initial hold time of 0.2 min at 230°C the injector temperature was increased by 6°C /min to 303°C during 18 min. The oven was kept at 230°C for 0.2 min and then the temperature was increased by 6°C/min to 300°C, which were kept for a further 18 min. The detector oven was maintained at 350°C. Peak area data was processed using a Chemstatium computer program (integrator). Detector response factors for individual n-alkanes were determined by injecting onto the chromatograph a standard n-alkane mixture (C_{21}-C_{36} inclusive) after every 8 sample extracts.

Microbial protein contribution:

The microbial contribution to abomasal NAN and rumen degradation were estimated using purine bases (PB) as microbial marker. Purine bases in isolated bacteria and abomasal digesta were analysed by HPLC following the technique reported by Martín-Orue *et al.* (1995). Microbial contribution was estimated by dividing the PB/N ratio in abomasal digesta by the same ratio in rumen bacterial extract as described by Askar *et al.*

(2005).

Statistical analysis

In both experiments, data were analysed as a one way analysis of variance with six replicates for each treatment. All analyses were made with the SAS package (SAS, 2000) and least significant differences were used to compare the means.

RESULTS AND DISCUSSION

Experiment 1

Feed intake and n-alkanes content in diet and digesta flow

Lambs dry matter intake was about 4.19% (SE = 0.157) as kg body weight (BW) bases, in which 51.7 (SE = 2.21) and 41.5 (SE = 3.60) g dry matter / kg $BW^{0.75}$ for barley grain and protein supplement, respectively, with total feed intake of 93.2 (SE = 3.44) g dry matter / kg $BW^{0.75}$.

The present study indicated that only odd chain n-alkanes were present in a significant amount in the diet, and alkane C_{31} was the most abundant alkane, followed by C_{29} and C_{33}. Alkane C_{31} is accounted for by 35 and 31% of the total for barley grain and protein supplement, respectively. However, even chain n-alkanes were also detected in feed ingredients but in a minor amount. Results are in agreement with Van Soest (1994) who reported that over 90% of n-alkanes have odd numbers of carbon atom, with C_{29}, C_{31}, and C_{33} alkanes being dominant in most plant species. Therefore, these three alkanes were selected to be evaluated as a flow and digestibility markers.

The quantitative importance of C_{29} and C_{31} has been previously reported in concentrates (Piasentier *et al.*, 1995; Valiente *et al.*, 2003) and in forages (Dove and Mayes, 1991 and 1996; Dove, 1992; Pueyo *et al.*, 2005). In general, alkane content in concentrates is always less than that detected in forage (Mayes *et al.*, 1986; Valiente *et al.*, 2003) in which adding concentrates to the diet (mixed diet) leads to reduce faecal concentration of alkanes as a simple dilution effect (Malossini *et al.*, 1994).

Odd n-alkanes content (mg/kg dry matter) in diet and digesta flow of abomasums, ileum, and rectum are presented in Table (2). Concentrations of alkanes C_{29}, C_{31}, and C_{33} was much higher in faeces and ranked as diet < abomasum and ileum < rectum. Increasing the concentration in faeces, than that found in abomasum, ileum, or diet, is logical and complies with the natural dilution of digesta through the gastrointestinal tract.

Cr-EDTA and $YbCl_3$ as reference and flow markers

The $YbCl_3$ was selected for the validation of n-alkanes as a flow marker because the recovery of Cr-EDTA in respect to Yb throughout the gastrointestinal tract was very low ($P<0.01$), particularly in abomasum and ileum as compared to rectum (0.30, 0.49, and 0.64 (SE = 0.028), respectively, Fig. 1). Moreover, $YbCl_3$ was selected because it is associated with the digesta solid fraction. This marker is assumed to adhere to the particulate phase of the digesta (Faichney, 1995). Therefore, n-alkanes are known to be associated to the solid phase (Mayes *et al.*, 1988, 1997; Marais *et al.*, 1992; Giráldez *et al.*, 2006). The contrary is true for Cr-EDTA which is associated with the liquid phase of digesta (Faichney, 1975;

Van Soest, 1994). Kotb and Luckey (1972) recommended that Cr is more suitable as a digestibility marker than as a passage marker. This is because Cr passes more rapidly from the rumen than coarse fiber and tends to be associated with the movement of the liquid fraction. On the other hand, about 4 – 5% of Cr-EDTA is absorbed by ruminants and excreted in the urine (Van Soest, 1994). This absorbed quantity increased at higher osmotic pressures obtained by feeding more rapidly fermentable matter (Dobson *et al.*, 1976) as it may be expected in the current study on lambs fed high concentrate diet.

Table (2). Odd n-alkanes content (mg/kg DM) in diet and digesta flow of abomasum, ileum, and rectum.

N-alkanes (mg/kg DM)	Diet (D)	Gastrointestinal tract sampling site		
		Abomasum (A)	Ileum (I)	Rectum (R)
C_{23}	1.10 (SE = 0.028)	2.51 (SE = 0.092)	2.04 (SE = 1.305)	2.55 (SE = 0.161)
C_{25}	2.26 (SE = 0.073)	4.20 (SE = 0.184)	4.23 (SE = 1.515)	4.01 (SE = 0.261)
C_{27}	2.05 (SE = 0.044)	4.82 (SE = 0.201)	3.90 (SE = 0.189)	5.07 (SE = 0.331)
C_{29}	6.65 (SE = 0.169)	14.44 (SE = 0.963)	10.55 (SE = 0.615)	16.46 (SE = 1.327)
C_{31}	7.87 (SE = 0.214)	13.34 (SE = 0.497)	12.51 (SE = 0.657)	17.53 (SE = 1.165)
C_{33}	2.19 (SE = 0.031)	5.71 (SE = 0.373)	5.88 (SE = 0.287)	8.47 (SE = 0.429)

Total tract digestibility by using Cr-EDTA was significantly ($P < 0.01$) different than that obtained by $YbCl_3$ (72.4 vs. 82.5% (SE = 0.93), for Cr-EDTA and $YbCl_3$, respectively, Fig. 2). Total tract digestibility coefficients estimated by $YbCl_3$ were similar to those obtained in metabolic cages by Askar *et al.* (2006), on lambs fed similar concentrate diets and at similar age, while those of Cr were much lower. This lower digestibility reflected the lower recovery of Cr as shown in Fig. 1, and is in agreement with our adjacent study (Keli *et al.*, 2009) that reported 34% drop in Cr recovery in respect to Yb in sheep located in metabolic cages. The authors attributed this drop to the analytical procedure as reported by Vicente *et al.* (2004).

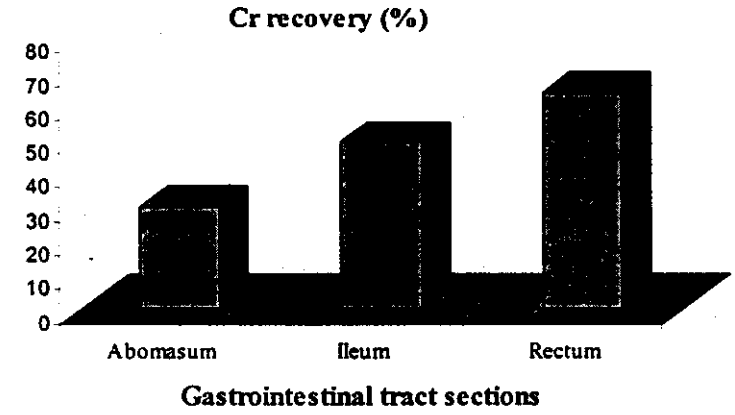

Figure (1). The recovery of Cr in respect to Yb throughout the gastrointestinal tract sections in lambs fed on high concentrate diet.

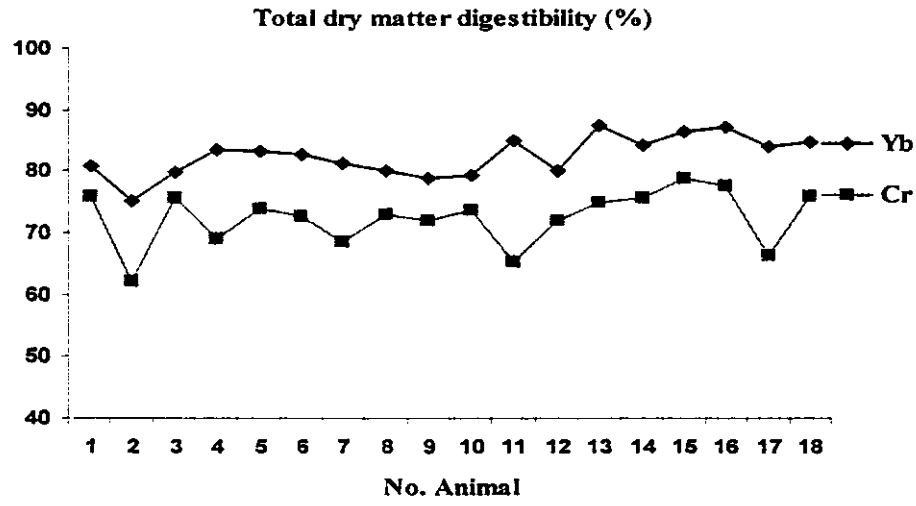

Figure (2). Total dry matter digestibility (%) estimated by Cr-EDTA and $YbCl_3$ in eighteen slaughtered lambs fed on high concentrate diet.

The present experiment also does not support the use of Cr-EDTA as flow marker with lambs fed high concentrate diet but it may be used as a digestibility marker after correction for its faecal recovery.

Long chain n-alkanes as flow and digestibility markers

Concentration of long chain odd n-alkanes, C_{29}, C_{31} and C_{33}, in diet and gastrointestinal tract sections is related to that of Yb and presented in Table (3). From this relation, recovery of n-alkanes in respect to Yb is considered. Recovery was getting much higher in abomasum (1.62, 1.27, and 1.94 (SE = 0.064), $P<0.01$, for C_{29}, C_{31}, and C_{33}, respectively) in comparison with Yb. However, when Yb flow in rumen was adjusted for 0.05 rate of passage (AFRC, 1992; Askar *et al.*, 2006), recovery of C_{31} was approximately similar to that of Yb, while those for C_{29} and C_{33} were still much higher (0.93 vs. 1.19 and 1.42 (SE = 0.050), $P<0.01$, respectively, Table 3).

Table (3). The relation between long chain n-alkanes (C_{29}, C_{31} and C_{33}), and Yb in diet, and in digesta flow of abomasum, ileum, and rectum, and the recovery of n-alkanes in respect to Yb.

	Diet (D)	Gastrointestinal tract sampling site			
		Abomasum (A)	Ileum (I)	Rectum (R)	
Relation between n-alkanes and Yb					
C_{29} / Yb	0.062	0.099	0.022	0.026	
C_{31} / Yb	0.073	0.092	0.026	0.028	
C_{33} / Yb	0.020	0.039	0.012	0.014	
Recovery in respect to Yb					
	A / D (0.05)*	A / D (0.00)	I / D	R / D	SE
C_{29} / Yb	1.19	1.62[a]	0.36[b]	0.43[b]	0.067
C_{31} / Yb	0.93	1.27[a]	0.36[b]	0.39[b]	0.034
C_{33} / Yb	1.42	1.94[a]	0.60[b]	0.67[b]	0.081

[a,b]Means without a common superscript letter in the row differ ($P < 0.05$) among digesta sites.

* (0.05) = Recovery of n-alkanes in abomasum, taking into consideration 5% rate of passage in rumen.

Concentrations of n-alkane in abomasum and ileum (Table 2), which is an indicator for alkane loss in between both sites, were found to be similar, in spite of the fact that they should be different. This was confirmed by a significant drop ($P<0.01$) in long chain n-alkanes recovery in ileum (1.61 vs. 0.44 and 0.50 (SE = 0.040) in abomasum vs. ileum and rectum, respectively, Table 3). This suggests that the major disappearance of n-alkanes has been occurred in between duodenum and terminal ileum. It is likely that the incomplete recovery is due to absorption from the small intestine as suggested by Mayes *et al.* (1988) who investigated the fate of natural alkanes in the gastrointestinal tract, using sheep fitted with cannulae. They concluded that little disappearance of alkanes occurred in the fore-

stomach and that absorption occurred mainly in the small intestine. Similar findings were reported by Ohajuruka and Palmquist (1991) and confirmed by Keli (2006).

Similar rumen digestibility observed using C_{31} and Yb (Table 4) were observed, while C_{29} and C_{33} gave significant ($P < 0.01$) higher rumen digestibility values. This confirmed that C_{31} can be used as a flow marker to estimate rumen digestibility and supported the previous results reported by Askar *et al.* (2005) on growing lambs fed similar concentrate diets. They attributed its use to that C_{31} was the most abundant alkane in the diet and is the only alkane found in both barley grain and protein supplement, assuming its full recovery in duodenum (Mayes *et al.*, 1988; Ohajuruka and Palmquist, 1991). Moreover, higher recovery of alkanes in abomasums in respect to Yb suggests that rumen microflora does not metabolize alkanes as suggested by Dove and Mayes (1991). In vitro study by Keli *et al.* (2008) supported our results and demonstrated that there is neither synthesis nor degradation of n-alkanes by ruminal bacteria. They also reported, in coherent with the current study, that long chain n-alkanes can be confidently used as duodenal flow or rumen transit markers regardless of their incomplete faecal recovery. This supports the use of long chain n-alkanes as duodenal flow (Askar *et al.*, 2008) or as rumen transit markers (Giráldez *et al.*, 2004 and 2006; and Keli *et al.*, 2009).

Table (4). Rumen, post-ruminal, and total digestibility estimation in lambs fed high concentrate diet, using odd n-alkanes in comparison with $YbCl_3$.

Digestibility (%)	N-alkanes			Yb	SE
	C_{29}	C_{31}	C_{33}		
Rumen	51.25^{b}	40.09^{c}	59.57^{a}	40.37^{c}	2.037
Rumen + intestine	35.32^{c}	36.20^{c}	61.72^{b}	78.77^{a}	2.078
Total	56.72^{c}	52.72^{c}	73.44^{b}	84.16^{a}	1.854

^{a,b,c}Means without a common superscript letter differ ($P < 0.05$) among markers.

No significant difference was observed between ileum and rectum in respect to long chain n-alkane recovery (Table 3). Faecal recovery of n-alkanes is much higher for C_{33} compared to those for C_{31} and C_{29} (0.67 vs. 0.39 and 0.43 (SE = 0.064) in rectum, respectively). Mayes *et al.* (1986), Dove and Oliván (1998), and Keli (2006) reported that when the carbon-chain length increases, the faecal recovery of n-alkanes increases. Recovery values were reflected in faecal digestibility (Table 4) in which digestibility values obtained by C_{33} was about only 13% reduction than those obtained by Yb. The present study suggested the use of long odd chain n-alkane as total tract digestibility marker after correction for their faecal recovery. Askar *et al.* (2003) validated the use of odd long chain n-alkanes as a digestibility marker in growing lambs fed similar diets. They indicated that no significant differences were found between estimated digestibility using odd long chain alkane and the observed ones by total faecal collection. Findings are in agreement with those reported by Ordakowski *et al.* (2001) who indicated that accurate estimates of digestibility in horse can be obtained by using individual odd chain alkane or by using all plant wax alkane after adjusting for the mean recovery of odd chain alkane. They also indicated that digestibility values were not significantly differed than those observed by total collection.

Experiment 2

Effect of sodium bicarbonate

Intake and digestibility and metabolism through the gastrointestinal tract

The first experiment confirmed that long chain n-alkanes, particularly C_{31}, can be use as abomasal flow markers but its recovery was significantly dropped in between abomasum and ileum which will not allow its use to estimate the post-ruminal digestibility. In this regard, the second experiment was dealing with using $YbCl_3$ as a flow marker, avoiding the use of alkane, to study the effect of SB on metabolism and digestion throughout the gastrointestinal tract.

Effect of adding SB on dry (DM) and organic (OM) matter intakes for last 7 days before slaughter together with rumen, post rumen metabolism and digestion, using $YbCl_3$ as a flow marker, are presented in Table (5). Similar amount of DM, OM, and crude protein intakes were observed with both treatments. This indicated that lambs were intake similar amounts of barley grains and protein supplement in both treatments. Also, results indicate that SB did not affect the protein intake that was 218 and 214 g protein per kg DM intake in treatments 0 and 30, respectively. Similar results were obtained by Askar *et al.* (2002) in lambs fed similar high concentrate diets with or without SB, either incorporated in the diet or presented as free access on the side in an independent trough. Moreover, Mandebvu and Galbraith (1999) and Santra *et al.* (2003) observed that inclusion of SB in lambs fed on high concentrate diet did not affect either DM intake or plane of nutrition.

Abomasal flow of DM tended ($P<0.10$) to be increased, while that of OM was significantly ($P<0.05$) increased by SB addition. This was reflected in rumen digestibility that was negatively ($P<0.05$) affected by SB addition. The negative effect of SB on DM and OM digestibility in rumen is probably due to increasing rumen rate of passage and dilution rate (Harrison *et al.*, 1975; Newbold *et al.*, 1991; Isaacson *et al.*, 1975; Owens and Goetsch, 1986). Results were supported by increasing the flow of nutrients to abomasum that is probably enhanced post rumen digestion as shown in Table (5). This is in agreement with the findings of Okeke *et al.* (1983) and Kovacik *et al.* (1986) who reporting that SB enhanced dietary nutrients bypassing rumen and may decrease their degradability. Kawas *et al.* (2007) suggested a reduction in rumen digestibility by SB inclusion in a diet as a result of increased NDF excretion and therefore reduce its total digestibility, in addition to lower acetate to propionate ratio. However, rumen digestibility values obtained in the current study by $YbCl_3$ were similar to those obtained by using C_{31} as flow marker on lambs fed similar diets (44 – 46%, Askar *et al.*, 2008) which confirmed the results of the first experiment dealing with the validation of C_{31} as a rumen digestibility marker.

Small intestine digestibility of DM and OM was positively ($P<0.05$) affected by SB addition. This was probably enhanced by increasing flow of nutrients going out from rumen to small intestine as explained above (Table 5). Similar digestibility values between treatments were observed up to ileum for DM, 77.1 vs. 79.0 (SE = 2.24) and OM, 80.9 vs. 82.2 (SE = 1.33), respectively for treatments 0 and 30, in which the negative effect of SB on rumen digestibility was compensated in higher digestibility values in small intestine (Table 5). At the same trend, post rumen digestibility increased ($P<0.01$) by adding SB, while faecal digestibility was quite similar. Little information is known concerning the effects of SB on small intestine or post rumen digestibility in growing lambs fed high

concentrate diet, while its effect on total tract digestibility has been reported. In this regard and in agreement with the present results, Santra *et al.* (2003) and Tripathi *et al.* (2004) found that SB inclusion had no effect on total tract digestibility of dry and organic matter in lambs fed high concentrate diet. Similar findings were reported by Kovacik *et al.* (1986) and Leventini *et al.* (1990) with lambs fed 50% concentrate in diet.

Nitrogen utilization

Nitrogen intake was similar between treatments and SB did not have any effect on non ammonia nitrogen (NAN) reached abomasum (Table 5). The current results indicated that

Table (5). Intake, flow, efficiency of microbial protein synthesis, apparent rumen nitrogen degradation, and digestion throughout the gastrointestinal tract in slaughtered lambs fed on high concentrate diet with or without adding sodium bicarbonate by using $YbCl_3$ as a flow marker and purine bases as microbial marker.

Item	Sodium bicarbonate (g/kg protein supplement)		SE	Significant
	0	30		
Intake, g / day				
DM	1071	1085	45.0	
OM	984	998	40.9	
N	37.4	37.1	2.87	
Abomasal flow, g / day				
DM	591	663	29.3	Ns
OM	513^{b}	594^{a}	26.3	*
NAN	19.3	19.3	2.33	
Microbial N	13.2	12.9	1.34	
Rumen digestion, %				
RDMD	44.7^{a}	39.0^{b}	1.72	*
AROMD	47.8^{a}	40.4^{b}	2.15	*
TROMD	62.4^{a}	55.3^{b}	2.58	Ns
Efficiency of MP				
g N / kg AROMD	28.3	32.5	3.17	
g N / kg TROMD	21.5	23.4	1.79	
Rumen N degradation, %	83.8	82.8	4.14	
Small intestine digestion, %				
DM	32.3^{b}	40.0^{a}	1.98	*
OM	33.0^{b}	41.9^{a}	1.50	**
Post-rumen digestion, %				
DM	38.2^{b}	43.6^{a}	1.86	Ns
OM	37.2^{b}	43.6^{a}	2.18	Ns
Total digestion, %				
DM	82.9	82.5	1.23	
OM	85.0	84.0	1.13	

^{a,b,c}Means without a common superscript letter differ ($P < 0.05$).
Ns = not significant ($P<0.05$), * = Significant ($P<0.05$), ** = Significant ($P<0.01$)
DM = Dry mater; OM = Organic matter; NAN = Non-ammonia nitrogen; RDMD = Rumen dry matter digestibility; AROMD and TROMD = Apparent and true rumen organic matter digestibility.

efficiency of rumen N utilization was very low in both treatments and was not affected by SB, resulting in losing almost 48% of N intake in rumen and recovered only 52% as NAN in abomasum. This inefficient N utilization justifies the lamb selection of diets rich in

protein in both treatments, although rumen N degradation was high (Table 5). Similar findings were reported by Rodr?guez *et al.* (2007) and Askar *et al.* (2008) on lambs fed similar concentrate diet at free choice. They found that amount of NAN reached the abomasum (53% of N intake, Askar *et al.*, 2008) is very close to the predicted metabolizable protein (MP) required for the observed average daily gain (AFRC, 1993). This suggests that diets rich in protein were selected to cover their MP requirements as mentioned by Askar *et al.* (2008). However, protein could be selected as a source of rumen degradable N (Tolkamp *et al.*, 1998) but high rumen N degradation observed, in the present study, seems to not support this hypothesis. A high rumen N degradation has been recently reported by Askar *et al.* (2008) in lambs fed similar concentrate diets. This high degradation was associated with high rumen ammonia concentration which is supported the results of present study. Also, James *et al.* (2001) suggested that sheep does not seem to regulate their intake to cover the required rumen degradable N. On the other hand, protein can be also selected as a buffer to reduce acidosis as suggested by Phy and Provenza (1998) but similar protein intake observed between treatments, with or without SB in the current study, does not support this hypothesis.

Inclusion of SB has been reported to enhance rumen microbial protein synthesis in ruminant fed high concentrate diets (Chamberlain and Thomas, 1980; Mees *et al.*, 1985) and to enhance rumen bacterial fixation of ammonia (Newbold *et al.*, 1991). This is due to its effect on increasing rumen rate of passage (Harrison *et al.*, 1975) and dilution rate (Newbold *et al.*, 1991; Harrison and McAllan, 1980; AFRC, 1992). In both treatments, the efficiency of microbial protein synthesis was similar between treatments and only numerically increased by SB addition (Table 5). In general, values for the efficiency of microbial protein observed were lower than those reported for mixed diets (ARC, 1980). This supports other results with sheep (Askar *et al.*, 2008) and cattle (Beauchemin *et al.*, 2001; Vicente *et al.*, 2004a) fed high-concentrate diets.

Results of the second experiment together with the previous work of Askar *et al.* (2008) and Rodr?guez *et al.* (2007) concluded that lambs fed on high concentrate diet preferred diets rich in protein and have high rumen N degradation with low rumen N utilization and less efficiency of microbial protein synthesis. The current study suggests the use of less N degradation source as a solution to stop selecting diets rich in protein by growing lambs fed on high concentrate diet.

CONCLUSIONS

Results of the first experiment showed that long chain n-alkanes, particularly C_{31}, can be used as a rumen digestibility marker. Long chain n-alkanes and Cr-EDTA can be used as total tract digestibility markers after correction for their faecal recovery but the use of Cr-EDTA as a flow marker is not preferred. Experiment two concluded that SB can manipulate the site of nutrients digestion throughout the gastrointestinal tract but does not seem to regulate protein feed intake in lambs according to their recommended requirements. Inclusion of SB has a negative effect on rumen digestibility and enhances small intestine digestibility. Lambs fed high concentrate diet have low efficiency of rumen N utilization and microbial protein synthesis which lead to increase protein selected in diet

to cover the required metabolizable protein in small intestine. The second experiment suggests the use of less protein degradation source as a solution to stop selecting diets rich in protein by growing lambs fed high concentrate diet.

ACKNOWLEDGEMENTS

The author would like to thank the staff of Animal Production and Food Science Department, Zaragoza University, Spain, and Dr. A. Keli, Department of Animal Production and Pastoralism, Ecole Nationale d'Agriculture, Meknes, Morocco, to help supporting this article.

REFERENCES

AFRC. (1992). Agriculture and Food Research Council. Nutritive requirements of ruminant animals. Protein. Nutr. Abs. Rev. Ser. B 62: 787-835.

AFRC. (1993). Agriculture and Food Research Council. Energy and protein requirements of ruminants. CAB International, Wallingford, UK.

ARC. (1980). The Nutrient Requirement of Ruminant Livestock. CAB international, Wallingford, UK.

Askar A. R., A. de Vega, O. Valiente and J. A. Guada (2003). Validación de la técnica de los n-alcanos para estimar la digestibilidad de la dieta y la selección de alimentos concentrados por corderos en cebo. X Jornadas (AIDA) sobre Producción Animal, Zaragoza, Spain. ITEA Vol. Extra, 24 (2): 624-626.

Askar, A, R., J. A. Guada, J. M. González, A. de Vega and M. Fondevila (2008). Rumen digestion and microbial protein synthesis in growing lambs fed high-concentrate diets: Effect of cereal processing and animal age. Anim. Feed Sci. Technol., 142: 292-305.

Askar, A.R., J. A. Guada, A. de Vega, J. M. Gonzalez and L. M. Ferrer (2002). Selección de la dieta por corderos alimentados con cebada en grano y un núcleo proteico con o sin bicarbonato sódico. XXVII Jornadas Científicas y VI Internacionales de la Sociedad Española de Ovinotecnia y Caprinotecnia (SEOC), Valencia, Spain. Producción Ovino y Caprino, 27: 121-126.

Askar, A.R., J. A. Guada, J. M. G?nzalez, A. de Vega and C. Castrillo (2006). Diet selection by growing lambs offered whole barley and a protein supplement, free choice: effects on performance and digestion. Livest. Sci. 101: 81–93.

Askar, A.R., J. A. Guada, J. Balcells, A. de Vega and C. Castrillo (2005). Validation of use purine bases as microbial marker by 15N labelling in growing lams given high-concentrate diets: Effects of grain processing, animal age and digesta sampling site. Anim. Sci. 81: 57-65.

Association of Official Analytical Chemists (2005). Official Methods of Analysis, 18th ed. AOAC, Washington, D.C., USA.

Beauchemin, K. A., W. Z. Yang and L. M. Rode (2001). Effects of barley grain processing on the site and extent of digestion of beef feedlot finishing diets. J. Sheep Sci., 79: 1925-1936.

Chamberlain, D. G. and P. C. Thomas (1980). The effects of urea and artificial saliva on rumen bacterial protein synthesis in sheep receiving a high cereal diet. J. Sci. Food Agric. 31: 432-438.

de Vega, A. and D. P. Poppi (1997). Extent of digestion and rumen condition as factor affecting passage of liquid and digesta particles in sheep. J. Agr. Sci., Cambridge, 128: 207-215.

Dobson, A., A. F. Sellers and V. H. Gatewood (1976). Dependence of Cr-EDTA absorption from the rumen on luminal osmotic pressure. Am. J. Physiol. 231: 1595-1600.

Dove, H. (1992). Using the n-alkanes cuticular wax to estimate the species composition of herbage mixtures. Austr. J. Agr. Res., 43: 1711-1724.

Dove, H. and R. W. Mayes (1991). The use of plant wax alkanes as marker substances in studies of the nutrition of herbivores: A review. Austr. J. Agr. Res., 42: 913-52.

Dove, H. and R. W. Mayes (1996). Plant wax components: A new approach to estimating intake and diet composition in herbivores. J. Nutr., 126: 13-26.

Dove, H. and R. W. Mayes (2005). Using n-alkanes and other plant wax components to estimate intake, digestibility and diet composition of grazing/browsing sheep and goats. Small Rumin. Res., 59: 123-139.

Dove, H. and M. Oliván (1998). Using synthetic or beeswax alkanes for estimating supplement intake in sheep. Anim. Prod. Australia, 22: 189-192.

Downes, A.M. and I. W. McDonald (1964). The chromium-51 complex of ethylenediamine tetraacetic acid as a soluble rumen marker. Br. J. Nutr., 18: 153-162.

Faichney, G. J. (1975). The use of markers to partition digestion within the gastrointestinal tract of ruminants. En: Digestion and Metabolism in the Ruminant. Ed: I. W. McDonald, A. C. I. Warner. University of New England, Armidale. pp. 277-291.

Faichney, G. J. (1995). Transit des digesta dans le tube digestif des ruminants. In: Jarrige, R., Ruckebusch, Y., Demarquilly, C., Farce, M. H., Journet, M., Eds, Nutrition des ruminants domestiques, ingestion et digestion. INRA Editions. 253-298.

Giráldez, F.J., S. Lamb, S. López and R. W. Mayes (2004). Effects of carrier matrix and dosing frequency on digestive kinetics of even-chain alkanes and implications on herbage intake and rate of passage studies. J. Sci. Food Agric., 84: 1562-1570.

Giráldez, F.J., S. López, C. S. Lamb and R. W. Mayes (2006). The use of even-chain alkanes sprayed onto herbage as rate of passage markers in goats. Livest. Sci., 100: 195-202.

Harrison, D. G. and A. B. McAllan (1980). Factors affecting microbial growth yields in the reticulo-rumen. Eds. Ruckebusch, Y. and Thivend, P., MTP Press, Lancaster, UK.

Harrison, D. G., D. E. Beever, D. J. Thomoson and D. F. Osbourn (1975). Manipulation of rumen fermentation in sheep by increasing the rate of flow of water turnover from the rumen. J. Agric. Sci., Cambridge 85: 93-101.

Isaacson, H. R., F. C. Hinds, M. P. Bryant and F. N. Owens (1975). Efficiency of energy utilization by mixed rumen bacteria in continuous culture. J. Dairy Sci., 58: 1645-1659.

James, S. M., I. Kyriazakis and G. C. Emmans (2001). Diet selection of sheep: effects of adding urea to foods with different protein contents. Anim. Sci. 73:183-195.

Kawas, J.R., R. García-Castillo, H. Fimbres-Durazo, F. Garza-Cazares, J. F. G. Hernández-Vidal, E. Olivares-Sáenz and C. D. Lu (2007). Effects of sodium bicarbonate and yeast on nutrient intake, digestibility, and ruminal fermentation of light-weight lambs fed finishing diets. Small Rumin. Res., 67: 149-156.

Keli A. (2006). Utilización de los alcanos en el ganado ovino: comportamiento en el tracto digestivo y posibles alternatives. Ph.D. thesis, University of Zaragoza, Spain.

Keli, A., A. de Vega, A. R. Askar and J. A. Guada (2009). The feasibility of hexatriacontane (C_{36}) as transit marker, and the effect of analytical procedure on the utility of Cr-EDTA and $YbCl_3$ as flow markers. AIDA, XIII Jornadas sobre Producción Animal, Tomo I, 313-315.

Keli, A., R. W. Mayes and A. de Vega (2008). In vitro studies of the metabolism of [14C]-n-alkanes using ruminal fluid of sheep as substrate. Animal, 2: 1748–1752.

Kellaway, R. C., D. E. Beever, D. J. Thomson, A. R. Austin, S. B. Cammell, M. L. Elderfield (1978). The effect of NaCI or NaHCO 3 on digestion in the stomach of weaned calves. J. Agric. Sci, Cambridge, 91:497.

Kotb, A.R. and T. D. Luckey (1972). Markers in nutrition. Nutr. Abstr. Rev., 42: 813-845.

Kovacik, K., S. C. Loerch and B. A. Dehority (1986). Effect of supplemental SB on nutrient digestibilities and ruminal pH measured continuously. J Anim. Sci., 62: 226-234.

Leventini, M. W., C. W. Hunt, R. E. Roffler and D. G. Casebolt (1990). Effect of dietary level of barley-based supplements and ruminal buffer on digestion and growth by beef cattle. J. Anim. Sci., 68:4334-4344.

Malossini, F., S. Bovolenta, E. Piasentier and M. Valentinotti (1994). Variability of n-alkane content in a natural pasture and in faeces of grazing dairy cows. Anim. Feed Sci. Technol., 50: 113-122.

Mandebvu, P. and H. Galbraith (1999). Effect of sodium bicarbonate supplementation and variation in the proportion of barley and sugar beet pulp on growth performance and rumen, blood and carcass characteristics of young entire male lambs. Anim. Feed Sci. Technol., 82:37-49.

Marais, J.P., M. de Figueiredo and D. L. Figenschou (1992). The behaviour of insoluble n-alkane markers in the rumen. Programme and Proceedings. 31st Annual Cong. of the South African Soc. of Anim. Prod. April 13-16, 1992. Zithabiseni, Kwandebele. South African Society of Animal Production. Germiston, Republic of South Africa. p24.

Martín-Orúe, S.M., J. Balcells, J. A. Guada and C. Castrillo (1995). Endogenous purine and pyrimide derivative excretion in pregnant sows. Br. J. Nutr., 73: 375-385.

Mayes, R. W., C. S. Lamb and P. M. Colgrove (1988). Digestion and metabolism of dosed even-chain n-alkanes in sheep. Proceeding of the XIIth General Meeting of the European Grassland Federation, pp. 159-163.

Mayes, R. W., C. S. Lamb and P. M. Colgrove (1986). The use of dosed and herbage n-alkanes as markers for the determination of herbage intake. J. Agric. Sci., Cambridge, 107: 161-170.

Mayes, R.W. and H. Dove (2000). Measurement of dietary nutrient intake in freeranging mammalian herbivores. Nutr. Res. Rev. 13: 107-138.

Mayes, R.W., J. Giráldez and C. S. Lamb (1997). Estimation of gastrointestinal passage rates of different plant components in ruminants using isotopically-labelled plant-wax hydrocarbons or sprayed even-chain alkanes. Proc. Nutr. Soc. 56: 187A.

Mees, D. C., N. R. Merchen and C. J. Mitchel (1985). Effects of sodium bicarbonate on nitrogen balance, bacterial protein synthesis and sites of nutrient digestion in sheep. J. Sheep Sci., 61: 985-994.

Newbold, C. J., D, G. Chamberlain and P. C. Thomas (1991). Effect of dietary supplements of sodium bicarbonate with or without additional protein on the utilization of nitrogen in the rumen of sheep receiving a Lucerne silage-based diet. Sheep Feed Sci. Technol., 35: 191-198.

Newbold, C. J., P. C. Thomas and D. G. Chamberlain (1988). Effect of dietary supplements of sodium bicarbonate on the utilization of nitrogen in the rumen of sheep receiving a silage-based diet. J. Agric. Sci., Cambridge 110: 383-386.

Ohajuruka, O. A. and D. L. Palmquist (1991). Evaluation of n-alkanes as digesta markers in dairy cows. J. Sheep Sci., 69: 1726-1732.

Okeke, G. C., and J. G. Buchanan-Smith and W. L. Grovum (1983). Effects of buffers on ruminal rate of passage and degradation of soybean meal in steers. J. Anim. Sci. 56:1393.

Oliván, M. and K. Osoro (1999). Effect of temperature on alkane extraction from faeces and herbage. J. Agric. Sci., Cambridge, 132: 305-312.

Ordakowski, A. L., D. S. Kronfeld, J. L. Holland, B. J. Hargreaves, L. S. Gay, P. A. Harris, H. Dove and D. Sklan (2001). Alkanes as internal markers to estimate digestibility of hay or hay plus concentrate diets in horses. J. Anim. Sci., 79:1516–1522

Owens, F.N. and A. L. Goetsch (1986). Digesta passage and microbial protein synthesis. In Control of Digestion and Metabolism in Ruminants (ed. L.P. Milligan, W.L. Grovum and A. Dobson), pp.196-223. Prentice-Hall, Englewood Cliffs, N. J., USA.

Owens, F.N. and C. F. Hanson (1992). External and Internal Markers for appraising site and extent of digestion in ruminants. J. Dairy Sci., 75: 2605-2617.

Phy, T. S. and F. D. Provenza (1998). Animal fed grain prefer food and solutions that attenuate acidosis. J. Sheep Sci., 76: 954-960.

Piasentier, E., S. Bovolenta, F. Malossini, P. and Susmel (1995). Comparison on n-alkanes or chromium oxide methods for estimation of herbage intake by sheep. Small Rumin. Res., 18: 27-32.

Pueyo, Y., A. de Vega, A. R. Askar and J. A. Guada (2005). Effect of species and plant part on n-alkane concentrations in the cuticular wax of common browse pastures from middle Ebro valley (Spain). Sustainable Grazing, Nutritional Utilization and Quality of Sheep and Goat Products. Options Méditerranénnnes, Série A, No. 67. PP: 345.

Rodríguez, A.B., R. Bodas, B. Fernández, O. López-Campos, A. R. Mantecón, A.R. and F. J. Giráldez (2007). Feed intake and performance of growing lambs raised on concentrate-based diets under cafeteria feeding systems. Animal 1, 459–466.

Santra, A., O. H. Chaturvedi, M. K. Tripathi, R. Kumar and S. A. Karim (2003). Effect of diatery sodium bicarbonate supplementation on fermentation characteristics and ciliate protozoal population in rumen of lambs. Small Rumin. Res., 47: 203-212.

SAS (2000). Statistical Analysis Systems Institute Inc., Release 8.1, Cary, NC., USA.

Tolkamp, B. J., I. Kyriazakis, J.D. Oldham, M. Lewis, R. J. Dewhurst and J. R. Newbold (1998). Diet choice by dairy cows. II. Selection for metabolisable protein or for rumen degradable protein. J. Dairy Sci., 81: 2670-2680.

Tripathi, M. K., A. Santra, O. H. Chaturvedi and S. A. Karim (2004). Effect of sodium bicarbonate supplementation on ruminal fluid pH, feed intake, nutrient utilization and growth of lambs fed high concentrate diets. Anim. Feed Sci. Technol., 111: 27-39.

Valiente, O.L., P. Delgado, A. de Vega and J. A. Guada (2003). Validation of the technique n-alkanes to estimate intake, digestibility, and diet composition in sheep consuming mixed grain-.roughage diets. Austr. J. Agric. Res., 54: 693-702.

Van Soest, P.J. (1994). Nutritional ecology of ruminant. 2nd ed.O&B Books Inc. Oregon, USA.

Van Soest, P.J., J. B. Robertson and B. A. Lewis (1991). Methods of dietary fiber, neutral detergent fiber, and nonstarch polysaccharides in relation to animal nutrition. J. Dairy Sci., 74: 3583-3597.

Vicente, F., J. A. Guada, J. Balcells and C. Castrillo (2004)a. Microbial contribution to duodenal purine flow in fattening cattle fed concentrate diets estimated by purine N labelling (15N) of different microbial fractions. Anim. Sci. 74:159-167.

Vicente, F., A. Sarraseca, A. de Vega and J. A. Guada (2004). Performance of several Cr and Yb analytical techniques applied to samples of different biological origin (digesta or faeces). J. Sci. Food Agric. 84:2035-2040.

جدوى استخدام الألكانات كمرقم غذائى لتقدير معدل المرور وتدفق البلعة الغذائية والهضم وتأثير بيكربونات الصوديوم على مكان الهضم والتمثيل الغذائى بطول القناة الهضمية فى الأغنام

أحمد رجب عسكر

قسم تغذية الحيوان والدواجن بمركز بحوث الصحراء

الدراسة الحالية مكونه من تجربتين الأولى تهدف لدراسة جدوى أستخدام الألكانات طويلة السلسلة الكربونية كمرقم غذائى لتقدير معدل المرور وتدفق البلعة الغذائية والهضم الجزئى بطول القناة الهضمية والثانية تهدف لدراسة تأثير بيكربونات الصوديوم على الهضم والتمثيل الغذائى بالكرش وبعد الكرش بطول القناة الهضمية فى الحملان المغذاة على علائق مركزة. تم أستخدام ثمانية عشر حمل واثني عشر أخرين من سلالة Raza Aragoneza للتجربة الأولى والثانية على التوالي .الحملان فى التجربتين تم نقلهم الى حظائر فردية مباشرة بعد الانتهاء من فترة تسمين (٢٤ كيلوجرام وزن حي) مع الأستمرار فى التغذية الفردية الحرة على نفس العليقة من حبوب الشعير الكاملة والمكمل البروتينى. كل تجربة أستمرت ٣ اسابيع من التغذية الفردية مع تسجيل المقدم والمرفوض وحساب المأكول اليومى. تم ذبح الخراف بعد ٧ ايام من اعطائها جرعات مستمرة من المرقمات التقليدية من Cr-EDTA و $YbCl_3$ (فقط $YBCl_3$ فى التجربة الثانية).)، وذبحت الحيوانات بعد ٣ ساعات من تقديم العليقة فى الصباح وتم تحديد وفصل مقاطع أو غرف القناة الهضمية وأخذ عينات من محتواها. نتائج التجربة الأولى تشير الى أن الألكان C31 هو السائد بالعليقة من حيث الكمية والتركيز ويلية C29 و C33. أن معدل التغطية (Recovery) للألكانات طويلة السلسلة (C29, C31, and C33) بالنسبة لل Yb كانت عالية جدا فى المعدة الحقيقية وأنخفضت بشكل ملحوظ فى نهاية الأمعاء الدقيقة (اللفائفى) و المستقيم مما أثر بشكل معنوى على معاملات الهضم الجزئى بطول القناة الهضمية الناتجة من أستخدام الألكانات. أستخدام الألكان C31 أعطى معاملات هضم بالكرش مماثلة لتلك المتحصل عليها من ال Yb، بينما أستخدام C29 و C33 سجلوا قيما أعلى. الهضم بالأمعاء الدقيقة كان منخفض جدا مع استخدام الألكانات بالمقارنة بال Yb. الألكان C33 سجل أعلى معدل تغطية في الروث (Fecal recovery) مقارنة بال C29 و C31. في التجربة الثانية تم أستخدام معاملتين، مع أو بدون بيكربونات الصوديوم. اضافة البيكربونات لم تؤثر على المأكول من المادة الجافة والعضوية والنيتروجين ولكن أثرت بالسلب على معدل هضم المواد الغذائية بالكرش وبالايجاب على معاملات الهضم بالأمعاء الصغيرة. كفاءة استخدام النيتروجين وكفاءة بناء البروتين الميكروبى بالكرش كانت متدنية ولم تتحسن باضافة البيكربونات للعليقة ، مما أدى إلى فقد حوالى ٤٨ ٪ من النيتروجين المأكول بالكرش. معدلات هدم النيتروجين بالكرش كانت عالية ولم تتأثر باضافة البيكربونات.

النتائج المتحصل عليها تشير إلى أن الألكانات طويلة السلسلة، وخاصة C31، يمكن أن تستخدم كمرقم غذائى لتقدير الهضم بالكرش ولا توصى بأستخدام Cr-EDTA كمرقم غذائى لتقدير معدل المرور وتدفق البلعة الغذائية. Cr-EDTA والألكانات طويلة السلسلة الكربونية يمكن استخدامها كمرقم لتقدير الهضم الكلى بعد الأخذ فى الأعتبار معدل التغطية بالروث (Fecal recovery). اضافة بيكربونات الصوديوم يمكن أن تعدل أو تغير من مكان الهضم بطول القناة الهضمية ولكن لا يبدو أن لها القدرة فى تنظيم المأكول من البروتين. الدراسة الحالية تقترح استخدام مصدر بروتينى ذات معدل هدم قليل بالكرش كحل لوقف تفضيل أو اختيار الحيوان للعلائق الغنية بالبروتين فى الحملان المغذاه على علائق مركزة.