Effect of the coconut oil on the consumption, digestion of nutrients and methane production in sheep fed with forage and concentrate

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Four Pelibuey male sheep, with average liveweight of 25 kg ± 3.5 and a fistula in the rumen were used to study the effect of coconut oil on the consumption, nutrients digestion and methane production in sheep fed with low-quality forage and concentrate. A two-treatment change design and two animals per treatment was applied. *Pennisetum purpureum*, clone Cuba CT-169, with 120 d of age was used as basal forage. The diets were formulated in forage: concentrate ratio of 50:50, with coconut oil in the concentrate (14 %) or without it. The consumption, apparent digestibility of the organic matter (ADOM) and methane production were determined. The tunnel method was used for measuring the methane. The results showed the diminishing effect of coconut oil in the ingestion ($P < 0.001$) of DM (3.03 and 2.39 % TP) and OM (0.93 and 0.63 % TP) for the treatments with or without coconut oil, respectively. The level used did not affect the ADOM. The methane production was reduced ($P < 0.05$) when using the coconut oil in the diet (18.73 and 12.16 L kg DM^{-1}). The results showed the possibility of reducing the ruminal methane production by using coconut oil in the diet at the expense of a diminishing of DM ingestion. The optimum levels for not affecting the animals' voluntary intake should be established in further studies.

Key words: *methanogenesis, coconut oil, ingestion, apparent digestibility, sheep*.

The methane emissions by ruminants and their strategies for its reduction is, at present, one of the most interesting topics worldwide, not only for the energy lost in the diet due to the production of this gas, but also because methane is an environment polluting gas. Besides, it is the second in importance among those of greenhouse effect.

There are different nutritional and of management strategies that can reduce the emissions of enteric methane in ruminants. The inclusion of lipids is one of the most fallible techniques implemented by the producers, due to the anti-methanogenic properties of these compounds (Bauchemin *et al*. 2008 and Rasmussen and Harrison 2011). Among the most used vegetable oils are linseed, coconut, canola, radish, sunflower and soybean (Machmüller and Kreuzer 1999, Beauchemin and McGinn 2006, Beauchemin *et al*. 2008 and Mao *et al*. 2010). Coconut oil has high content of fatty acids, mainly myristic, palmitic, stearic, oleic and linoleic (Blas *et al*. 2003 and Kobayashi 2010). Its content of saturated fatty acids is of at about 90 %, propitiating it to be one of the most used acids to reduce ruminal methanogenesis.

The objective of this study was to study the effect of coconut oil on the consumption, nutrients digestion and methane production in sheep fed low-quality forage and concentrate.

Materials and Methods

Animals. Four Pelibuey male sheep, with average liveweights of 25 kg ± 3.5 and a fistula in the rumen were used in a two-treatment change over design and two replicates (two animals per treatment). The treatments consisted on diets with forage-concentrate ratio of 50:50, with or without coconut oil in the concentrate, respectively. The coconut oil was included in the concentrate at 14 % (table 1).

Feeds. The forage used was *Pennisetum purpureum*, clone Cuba CT-169, with 120 d of age, established in red ferralitic soils of the Institute of Animal Science, Mayabeque province, Cuba. Its chemical composition was: 89.41 % DM, 92.71 OM, 14.0 % CP and 74.12 % NDF.

The feeding was offered equally, twice a day. The feed and its rejection were daily weighed for determining the consumption.

Experimental procedure. The study comprised two periods of 18 d, 12 d for adapting to the experimental diets, five for collecting the feces and the two last for determining the methane production. The feces of each animal were mixed and weighed daily and 10 % of the total weight was frozen for its further chemical analysis. There were determined DM and ash for calculating the apparent digestibility of organic matter (ADOM), according to the formula: ADOM, % = [(OM feed, g – OM feces, g) / OM feed, g] X 100.

Methane measure. The method described by Lockyer and Jarvis (1995), modified by Delgado *et al*. (2009) was used. Four metabolism cages (200 x 82 x 147 cm) were used for adapted sheep to obtain chambers or individual tunnels. Each cage had a cover of polyethylene fabric of 9 x 12 m, as those used for the protected cultures houses. The covers were made a hole in the back part (5 cm diameter) for air flow. A plastic tube of 5 cm diameter, connected to vacuum bomb, was placed in it to remove the inner air. Another

Table 1. Chemical composition of the concentrates, %

Composition, %	Control Without coconut oil	Experimental feedstuff, with coconut oil
Soybean meal	49.0	52.8
Maize meal	48.2	30.4
Coconut oil	0.0	14.0
Dicalcic carbonate	0.4	0.5
Dicalcic phosphate	0.4	0.3
Sodium chloride	1.0	1.0
Mineral premixture	1.0	1.0
ME, MJ/ kg DM	10.6	10.4
CP, %	29.2	29.6
NDF, %	30.10	21.20
OM, %	94.7	93.7
Ca, %	1.6	0.9
P %	0.8	0.7

hole was opened in the side part close to the outlet for taking samples and measuring the air rate when going out the tunnel.

The samples of the gas expired by the animals were manually collected for two consecutive days every one hour. Preferably, it was collected at the windows exit. A 100 mL syringe was used. The air flow was determined with a digital manual anemometer (EXTECH Instruments, series 451126), together with the methane measurements. Air samples were taken in and out the chamber. The gas samples collected were stored in 60 mL vacuum flasks, taken to the lab and analyzed by gas chromatography. During the adaptation period, the tunnel had the fabric up to keep the air flow. The tunnels were closed when determining methane. The animals were previously adapted to remain in the polyethylene covers.

Methane was determined by gas chromatography, with a flame ionization detector (FID). A µL of the gas collected in the flasks was injected in the chromatographer. Pure methane (99.9 % purity) was used as comparison pattern. Pure hellium (1mL/min.) was used as transporter gas. The oven temperature was of 60 ºC, attenuation 200 ºC, as well as that of the detector.

Chemical composition. The DM, ash, OM and CP were calculated according to AOAC (1995). The NDF was determined according to Goering & van Soest (1970).

Statistical analysis. A general linear model of the system SSPS was used for controlling the effects of treatment, animals and period. When necessary, the differences between means were analyzed according to Duncan (1955).

Results

The results of ingestion and those of the ADOM are presented in table 2.

Coconut oil diminished the ingestion of DM and OM total or as function of the animals' LW ($P < 0.001$), with a reduction of the DM ingestion (% LW) of 21 %, in respect to the control. The level used did not affect the ADOM.

The methane production, expressed in total liters or liters/d^{-1}, was similar between treatments. However, when calculating in L/kg DM consumed^{-1}, methane was reduced ($P < 0.05$) in 35 %, when using coconut oil in respect to the control diet (table 3).

Table 2. Effect of coconut oil on the total ingestion and apparent digestibility of DM and OM in sheep fed forage-concentrate rations

Medidas	Tratamientos		Sign
	Controlsin aceite de coco	Experimental con aceite de coco	
IMS, kg	1.06 ± 0.01	0.70± 0.03	***
IMS, % PV	3.03 ± 0.05	2.39 ± 0.08	***
IMO, kg	0.93 ± 0.01	0.65 ± 0.02	***
DAMO, %	56.37 ± 1.63	64.18 ± 2.84	

DMI = DM ingestion, OMI= OM ingestion, AD= apparent digestibility
***($P < 0.001$)

Table 3. Effect of coconut oil on methane emission in sheep fed forage-concnetrate diets.

Methane production	Control without coconut oil	Experimental with coconut oil	SE(±)
CH4, L	12.93	11.58	1.88
CH4, L/d	14.19	12.63	1.97
CH4, L/kg DM ingested	18.73	12.16	1.72*
CH4, L/kg PV	0.48	0.36	0.06
CH4, L/kg PV0.75	1.12	0.88	0.15

* ($P<0.05$) PV0.75 = metabolic weight

Discussion

Beauchemin *et al*. (2008) reported marked differences in the response to the supplementation with lipid sources, in respect to the reduction of the ruminal methanogenesis. This depends on the basic diet and the level, as well as on other factors that could influence on the results (Rasmussen and Harison 2011), such as the experiments duration, type and number of animals ad quantification method. Coconut oil is rich in medium-chain fatty acids, mainly myristic, palmitic, stearic, oleic and linoleic, proved to be effective to inhibit the ruminal methanogenesis (Blas *et al*. 2003 and Kobayashi 2010).

The results of this study agree with that reported in the literature. Different authors (Jordan *et al*. 2006a and 2006b and Kongmun *et al*. 2011) found negative effects on the DM ingestion, due to supplementation with coconut oil. Macmüller *et al*. (2000) reduced the methane production in 26 % in lambs, without affecting digestibility. McMüller *et al*. (2003) observed that the use of this oil in ruminants reduced methanogenesis, without affecting the total nutrients digestion in the digestive tract.

It is accepted that, generally, the total fats should not exceed 6-7 % of the ration DM as they may produce a negative effect on the ingestion and digestibility of nutrients (Bauchemin *et al*. 2008 and Holman *et al*. 2012). Jordan *et al*. (2006 a, b) found that high levels of coconut oil (42 % of the DM) in beef cattle fed with forage-concentrate 50:50, reduced the consumption and digestibility of the diet, but inferior levels of oil (between 10 - 28 % of the DM) did not affect these indicators.

In this experiment, the oil inclusion level did not surpass 7 %. The intakes were between 2.4 and 3.0 % LW, considered normal for fibrous diets. This may justify, in part, the results in respect to the no affection of the ADOM. Another possible explanation of the effect of coconut oil on the voluntary intake could be related with the direct inhibitory effect of fatty acids on the ruminoreticular motility (Chilliard 1993).

In respect to the methane production in the rumen, the gas emission in this study (L.kg DMI-1) was 35 % reduced when using coconut oil compared with the control diet. Machmüller and Kreuzer (1999) observed decreases of 63.8 % on methane production when using 7 % of coconut oil in the diet. On this respect, literature states that coconut and sunflower oil (McGinn *et al*. 2004), as well as the olive oil (Ungerfield *et al*. 2005) among others, reduce the methane emissions through the competence with other methanogenic microorganisms for equivalent reducers or the direct toxic effect on the ruminal microorganisms degrading the fiber. This seems to explain the antimethanogenic effects observed in this study.

The studies of Galindo *et al*. (2009) justify these results in collateral experiments to this research. They, working with the same animals and diets, demonstrated that coconut oil reduced the cellulolytic and methanogenic bacteria and the ruminal protozoa. However, Lee *et al*. (2011) found, in cows canulated in the rumen, that adding coconut oil to the diet diminished the protozoa counting without affecting the methanogenic population. The variable experimental conditions and the type of animals could be the main cause of the contradictions found in the literature.

The indirect effect on the methanogenesis is evident, due to the reduction of the protozoa in the rumen that keeps symbiotic relations with the methanogenic microorganisms. The reduction of DM intake could also justify the low methane production. This was evident when the gas concentration was expressed in function of the DM ingestion.

It is concluded that the inclusion of coconut oil in the diet could reduce effectively methane production in sheep in respect to the DM intake, without affecting the OM digestibility.

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