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In vitro digestibility and *in situ* degradability of avocado meal and macadamia waste products in sheep

A Skenjana[#], J.B.J. van Ryssen and W.A. van Niekerk
Department of Animal and Wildlife Sciences, University of Pretoria, Pretoria 0002, South Africa

Abstract

Waste products from the avocado (avocado meal, AM) and macadamia (macadamia oilcake, MOC and macadamia chips, MCH) processing industries have the potential to be included in animal diets, depending on their nutritive value. Avocado meal consisted of oil-extracted avocados unsuitable for the fruit market; MOC consisted of oil-extracted remnants of macadamia nuts, while MCH was a mixture of pieces of macadamia nuts and hull chips. The aim of this study was to determine the *in vitro* organic matter digestibility (IVOMD) and the *in situ* dry matter (DM) and crude protein (CP) degradability of these products. These waste products were also analysed for components that could influence their digestibility, *viz*. fibre components, acid detergent lignin (ADL), acid detergent insoluble nitrogen (ADIN) and condensed tannin. To determine *in situ* DM and CP degradability the products were incubated for 0, 2, 5, 8, 16, 24 and 48 h in the rumens of lucerne-fed sheep. The IVOMD of AM was 54.3%, that of MOC 79.2% and that of MCH 29.2%. The rate and extent of DM and CP degradation in MOC were significantly higher than those of AM. However, degradability of MCH was very low, suggesting that it contains a high proportion of indigestible components. The NDF concentrations ranged from 404.4 g/kg DM in MOC to 558.3 g/kg DM in MCH. The ADL concentrations of AM, MOC and MCH were 258.0, 117.5 and 254.6 g/kg DM, respectively, which could explain some of the differences in digestibility and degradability between the products. It was concluded that AM and MOC could be used as ingredients in the diets of ruminants, but that MCH is not suitable as a feedstuff for ruminants.

Keywords: Tropical fruit waste, acid detergent lignin, acid detergent insoluble nitrogen, condensed tannin, digestibility
[#] Corresponding author. E-mail: akho@dohne1.agric.za
[#] Present address: Dohne Agricultural Development Institute, Private Bag X 15, Stutterheim 4930, South Africa

Introduction

The scarcity of feed sources often imposes a major challenge in livestock production in the tropics (Aregheore, 2000). The challenge can be alleviated by the use of unconventional feedstuffs in animal feeding depending on their nutrient content, availability and acceptability to animals; and provided it is economical compared to conventional feed ingredients. The potential of by-products in animal nutrition has long been identified. Avocado meal (AM, 95 g crude protein (CP)/kg dry matter (DM), macadamia oilcake meal (MOC, 245 g CP/kg DM) and macadamia chips (MCH, 89 g CP/kg DM) have been identified as potential feedstuffs based on their nutrient content (Skenjana *et al.*, 2002). However, very little is known about their digestibility. This is important because the true value of any feedstuff depends on the amount of nutrients that can be utilised upon ingestion by the animal (Nsahlai & Umunna, 1996). It was the aim of this study to determine the *in vitro* organic matter digestibility (IVOMD) and *in situ* DM and CP degradability of these waste products as well as trying to identify feed components that might affect their digestibility.

Materials and Methods

Eight samples of each waste product were obtained from fruit processing factories in Mpumalanga and Limpopo Provinces of South Africa. Avocado meal consisted of oil-extracted avocados unsuitable for the fruit market. The MOC consisted of oil-extracted remnants of macadamia nuts, while MCH was a mixture of pieces of macadamia nuts and hull chips.

The neutral detergent fibre (NDF), acid detergent fibre (ADF), acid detergent lignin (ADL) and acid detergent insoluble nitrogen (ADIN) content of the products were determined according to the methods of Goering & Van Soest (1970). For ADIN, the N content of the residue was determined using the Dumas

method (AOAC, 2000) with a Leco machine (FP 428 model). The concentration of condensed tannins (CT) was determined according to the method described by Makkar (1995).

The IVOMD of the samples was determined according to the method described by Tilley & Terry (1963). The method described by AFRC (1992) was used to measure the *in situ* DM and CP degradability. Samples were incubated for 0, 2, 5, 8, 12, 24 and 48 h in the rumen of sheep. An internal laboratory lucerne sample was used as a control for all incubations. After a thorough wash, bags were dried in an oven at 60 °C for 48 hours and DM degradability was determined. The residues were further analysed for N content. Dry matter and N disappearance percentages with time were fitted in a nonlinear equation using the iterative squares method (NLIN, SAS, 1994) to an exponential equation (Ørskov & McDonald, 1979):

$$P = a + b\,(1-e^{ct})$$

where P = the amount of protein/DM degraded at time t; a = the rapidly soluble fraction; b = insoluble but fermentable fraction in time; c = degradation rate constant of the b fraction.

An analysis of variance with the ANOVA model (SAS, 1994) was used to determine the significance of differences between products. Means were compared using the Tukey's studentized range test, using the 95% level of confidence (Samuels, 1989).

Results and Discussion

Factors affecting digestibility of feeds include components such as fibre (Boucqué & Fiems, 1988; McDonald *et al*., 1995) and secondary plant compounds such as condensed tannins (McLoed, 1974; Muller-Harvey, 1999). There were significant differences between the products in the concentration of some of these components. The NDF and ADF concentrations of MCH were higher ($P < 0.05$) than those of AM and MOC (Table 1). The ADL concentrations of MCH and AM were higher ($P < 0.05$) than in MOC (Table 1). MCH contained the highest (254.6 g/kg DM) and MOC the lowest (117.5 g/kg DM) ADL concentrations. The ADIN concentration of AM was the highest and that of MOC the lowest (Table 1). The CT concentrations differed ($P < 0.05$) between the products, with MOC having the lowest and AM the highest concentrations.

Table 1 The concentration (g/kg DM - full-fat basis) of components affecting digestibility and i*n vitro* organic matter digestibility (IVOMD) of avocado and macadamia waste products (n = 8/product)

	Waste products		
	Avocado meal	Macadamia oil cake	Macadamia chips
Neutral detergent fibre	518.2 [a] ± 63.1	404.4 [a] ± 114.8	558.3 [b] ± 80.6
Acid detergent fibre	393.3 [a] ± 36.7	327.4 [a] ± 124.1	527.1 [b] ± 75.6
Acid detergent lignin	258 [a] ± 29.2	118 [b] ± 71.6	255 [a] ± 53.0
Acid detergent insoluble nitrogen (% of N)	3.8 [a] ± 0.3	0.3 [b] ± 0.1	0.7 [b] ± 0.3
Condensed tannin	143.1 [a] ± 44.0	36.2 [c] ± 20.4	65.3 [b] ± 26.1
IVOMD (%)*	54.3 [b] ± 81.5	79.2 [a] ± 199.8	29.2 [c] ± 72.4

[a, b, c] Means with different superscripts, within rows, differed significantly at $P < 0.05$

* - defatted sample

There were significant differences ($P < 0.05$) between the three waste products in IVOMD (Table 1). The fibre fractions, ADIN and CT concentrations were higher in AM than in MOC. In general, MOC had the lowest concentrations of the chemical components affecting that could affect digestibility. The low IVOMD of MCH could suggest that the product is valueless in animal nutrition. The difference among the products could be linked to the high ADL concentrations of the AM and MCH. The high proportion of pieces of hull in MCH and the inclusion of the seed in the AM could explain their low digestibility. According to Meissner & Paulsmeier (1995) the intake decreases with a decrease in IVOMD caused by an increase in fibre fractions. This implies that low intakes could be expected for high fibrous products such as AM and MCH.

The ADIN of AM was higher compared to that reported for soyabean meal (SBM) and peanut oil cake meal (POCM) (NRC, 2001), whereas the ADIN concentration of MOC is comparable to that of SBM. The higher ADIN levels could suggest lower solubility of N of the products in the rumen. Therefore the availability of CP in the rumen of the AM would be lower compared to the other waste products considered in this study. This was confirmed by the low rumen degradability of the CP in AM compared to that in MOC.

The *in situ* DM and CP degradability of the AM and MOC are presented in Table 2. The MCH could not produce any definite trend as it was relatively indigestible and it was omitted from the statistical analyses.

The soluble fraction, potential degradability and effective degradability for DM of MOC were significantly higher compared to those of AM. The CP rumen degradability of MOC was significantly higher than that of AM, in all fractions.

Table 2 Dry matter and crude protein rumen degradation characteristics (mean ± s.d.) of avocado meal and macadamia oil cake (n = 8/product)

	Degradation parameters					
					Effective degradability (%)	
	a (%)	b (%)	c	PD	k = 0.03	k = 0.05
Dry matter						
Avocado meal	32.3 [b] ±0.2	34.9 [a] ±2.1	0.07 [a] ±0.01	67.1 [b] ±2.0	56.9 [b] ±1.3	52.9 [b] ±1.2
Macadamia oil cake	47.6 [a] ±1.2	36.7 [a] ±7.3	0.04 [a] ±0.01	84.3 [a] ±6.3	69.2 [a] ±1.9	64.6 [a] ±1.1
Crude protein						
Avocado meal	28.2 [a] ±2.4	33.5 [a] ±1.9	0.09 [a] ±0.03	61.7 [a] ±0.6	53.2 [a] ±1.6	49.7 [a] ±1.8
Macadamia oil cake	73.5 [b] ±1.1	18.7 [b] ±2.5	0.19 [b] ±0.04	92.2 [b] ±1.5	89.6 [b] ±0.9	88.2 [b] ±0.7

a - soluble fraction; b - potentially degradable fraction; c - degradation rate constant of the b fraction; PD - extent of degradation (a + b); ED - effective degradability; k - outflow rate

[a, b] Means with different superscripts, within columns within nutrient differed significantly at $P < 0.05$

Conclusion

The avocado and macadamia waste products considered in this study were fairly fibrous. The fairly high DM degradability of AM suggests that the product is suitable for ruminant receiving maintenance and low production diets. The MOC can be regarded as a highly degradable protein and energy source. These products can be included in livestock diets as energy sources, especially in that of ruminants. In terms of cost per unit of energy, the MOC could be cheaper than other energy sources as it can be available at salvage value as waste from the processing plants. The MCH is not at all suitable as an animal feed.

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