# Evaluation of Some Agri-industrial By-products Available in Samoa for Goats

**E. M. Aregheore, S. A. Abdulrazak[1,]* and T. Fujihara[1]**
Department of Animal Science, School of Agriculture, The University of the South Pacific, Alafua Campus, Apia, Samoa

**ABSTRACT :** Nutritional evaluation of some agro-industrial byproducts available in Samoa [dry brewers' grains (DBG), cocoa shell (CS), cocoa dust (CD) and desiccated coconut waste meal (DCWM)] available in Samoa was carried out using both the *in vivo* and *in vitro* techniques. In the *in vivo* study 24 Anglo-nubian goats were offered by-products with other feed ingredients to compound four different diets. The goats were randomly allocated to 4 diets on the basis of liveweight (18.7-0.3kg). The ADF content of the byproducts followed a similar trend to NDF. The byproducts have a high content of organic matter (91.0-95.4%). Gross energy (GE) content was higher in DCWM (25.1 MJ/kg DM), closely followed by CD (23.2 MJ/kg DM). Concentrate intake was significantly different ($p<0.05$) among the goats. Average daily live weight gains were 105, 92, 88 and 97 g/goat/day for DBG, CS, CD and DCWM, respectively. Daily live weight gains were higher ($p<0.05$) in the goats that received DBG, while the least gain was obtained in the goats that received CS byproduct diet. DM digestibility was significantly higher ($p<0.05$) in the goats on DBG diet than in the other goats. The least DM digestibility was obtained in the goats that received CD diet ($p>0.05$). CP digestibility followed a similar pattern to DM digestibility. The digestibility of NDF and ADF was influenced by the nature of the diets. The digestibility of OM and GE were best ($p<0.05$) in the goats that received DBG, DCWM and CS byproduct diets than in CD. Significant differences ($p<0.05$) among the byproducts were recorded for net gas production. Potential gas production (a+b) ranged from 7.064 to 42.17 ml. Organic matter digested (OMD) from gas production value at 24 h was higher in DBG (47.6 g/kg DM) and this was followed by DCWM (42.5 g/kg DM). The least OMD was obtained in CD (17.9 g/kg DM). A significant difference ($p<0.05$) in DM disappearance after 4, 8, 16, 24, 48 and 72 h was recorded. The potential and effective degradability varied significantly ($p<0.05$) from 85.95-99.6 g/kg DM and from 39.9-65.8%, respectively. The digestibility of the byproducts in both the *in vivo* and in *in vitro* techniques demonstrated that they are potential source of feed ingredients for ruminant livestock in Samoa and possibly in the other small Pacific Island countries. On the basis of their potential degradability the byproducts could be ranked in the following order:DCWM>DBG>CD>CS. In conclusion, the results obtained suggest that all the byproducts can contribute to ruminant livestock diets without adverse effects on feed intake, growth rate and apparent nutrient digestibility coefficients. ***(Asian-Aust. J. Anim. Sci. 2003. Vol 16, No. 11 : 1593-1598)***

**Key Words :** By-products, Intake, Goats, *In vivo*, *In vitro* Digestibility

## INTRODUCTION

One of the identified factors limiting the livestock industry in the Pacific Island countries has been the rapid and continuous increase in the cost of imported cereals (sorghum) and protein concentrates which form the basis of compounded animal feeds. This has necessitated the identification and research into cheaper alternative feed sources.

Some agri-industrial byproducts of economic value in Samoa are brewers' grains, cocoa byproducts (cocoa shell, cocoa dust and desiccated coconut waste). Most of these byproducts are discarded. Brewers' grains, the most main by-product resulting from the manufacture of beer, are the extracted residues of malt (generally barley). They contain the insoluble material remaining after the process of mashing and cooking with water, which include the fibre fractions, fats, proteins, together with residues of starch and dextrin. It constitutes a quality byproduct and the major use of this material has been as a feed for livestock (Preston et al., 1973; Bovelenta et al., 1998).

After drying, which is performed to improve storage quality and nutrient concentration, the product becomes known as dried brewers' grains (Bolvolenta et al., 1998). The concentration of fibre fractions and the low protein degradability means that the brewers' grains are preferentially used for feeding ruminants. In most Pacific Island countries, it is available and wasted. The product can be fed wet or dry to livestock.

In the manufacture of chocolate, cocoa shell (CS) and cocoa dust (CD) is the waste byproducts. There is scanty information on the utilization of cocoa shell (CS) and cocoa dust (CD) in ruminant nutrition. The value of these byproducts as possible livestock feeds has received very little attention in Samoa because they have not been previously considered important in ruminant nutrition.

Copra meal (CM) and desiccated coconut waste meal (DCWM) are two important by products of the coconut industry. DCWM is a by-product from coconut cream production and have a large potential as a feed resource in Samoa and in other Pacific Island countries. The objective

* Corresponding Author: S. A. Abdulrazak. Division of Research and Extension, Egerton University, P. O. Box 536 Njoro, Kenya. Tel: +254-37-62550, Fax: +254-37-62442, E-mail: sabdulrazak @yahoo.com
[1] Laboratory of Animal Science, Faculty of Life and Environmental Science, Shimane University, Matsue-shi, 690-850 Japan.
Received May 16, 2002; Accepted July 9, 2003

**Table 1**. Percentage composition of experimental diets and batiki grass

| Ingredients (%) DM | DBG | CS | CD | DCWM |
|---|---|---|---|---|
| Brewers' dried grains | 50.00 | - | - | - |
| Cocoa shell | - | 56.00 | - | - |
| Cocoa dust | - | - | 60.00 | - |
| Desiccated coconut waste meal | - | - | - | 61.50 |
| Cassava flour* | 47.00 | 39.50 | 35.20 | 35.00 |
| Urea (46 % N) | 1.00 | 2.50 | 2.80 | 1.50 |
| Mineral-vitamin mix** | 1.50 | 1.50 | 1.50 | 1.50 |
| Salt (NaCl) | 0.50 | 0.50 | 0.50 | 0.5 |

Batiki grass. Dry matter, 28.4%; CP 9.0% NDF 38.5%; ADF, 24.2%; EE, 1.2%; OM, 95.4%; GE 5.6 $MJ/kg^{-1}$ DM; *Cassava flour-dry matter 91.9 %; CP 2.5%; Neutral detergent fiber; Acid detergent fiber; ether extract 1.0; Ash 1.2; Organic matter 98.8%; Gross energy 17.4 MJ/kg
** Summit multi-mineral salt (Auckland, New Zealand). The mineral/vitamin block contained salt (NaCl), 120 g/kg calcium, 60 g/kg phosphorus, 600 mg/kg manganese, 150 mg/kg copper, 1.5 mg/kg cobalt, 7.5 mg/kg iodine, 600 mg/kg manganese, 750 m/kg iron, 600 mg/kg zinc, 1.5 mg/kg selenium; vit. A, D and E with copra meal and molasses added.

of this study was to evaluate some agri-industrial byproducts (dry brewers' grains, cocoa shell, cocoa dust and desiccated coconut waste meal) available in Samoa for ruminant nutrition using both *in vivo* and *in vitro* methods of assessment.

## MATERIALS AND METHODS

### Experimental site

The study was conducted at the Goat unit, School of Agriculture, The University of the South Pacific, Alafua Campus, Apia, Samoa (Latitude≈13.50 S, Longitude ≈1720W).

### Feed ingredients and preparation of experimental diets

Brewers' grains were collected wet from Western Samoa Breweries Ltd., Apia. These were spread in an open but concrete floor, turned regularly until dry (DBG). Desiccated coconut waste meal was collected wet from Samoa Tropical Products Ltd., Apia. This was dried under shade for 4-7 days until the product became brown. During the period the product was continuously turned for even drying and proper aeration. Cocoa shell (CS) and cocoa dust (CD) were obtained from Wilex C & C Products Ltd., Moatia, Apia. Cassava tubers, of a sweet variety (*Manihot dulcis*), were from the Crop Science Department Farm located in the School of Agriculture, The University of the South Pacific, Apia, Samoa. The tubers were peeled and the pulp cut into chips, sun dried to constant moisture content and ground in a stainless mill through 1 mm screen into flour. The by-products were combined with other feed ingredients including cassava flour to formulate four separate diets (Table 1). Each by-product formed the basis of a treatment diet. The diets were formulated isonitrogenous by adjusting the level of urea (46% N) inclusion.

### Animals, management and feeding

Twenty-four 17-18 months crossbred Anglo-Nubian goats, (pre-experimental average body weight of 18.7±0.30 kg) were randomly allocated on the basis of liveweight to four diets. Each treatment group consisted of six goats and they were housed in concrete pens and covered with wood shavings to serve as litter material. Each pen had feed and water troughs. The concentrate portion was offered *ad libitum* to the goats for 60 days and was supplemented with batiki grass (*Ischeamum aristatum* var. *indicum*).

Batiki grass was harvested fresh and chopped into pieces of about 6-7 mm length. The forage was offered twice a day at 09:00 and 16:00 h to ensure maximum intake and to reduce wastage. Feeds offered were increased or decreased depending on intake of the goats to ensure a 15% refusal. Feeds not consumed within 24 h were collected, weighed and discarded.

Prior to the start of the trial the goats were dewormed with Levicare (Ancare, Auckland, New Zealand). The litter material was changed periodically. The animals were allowed a 7 day adaptation period to get used to the concentrate supplements. Group feed intake and live-weight changes were recorded. The initial average and final average live weights were used to calculate live weight gain and voluntary feed intake.

### *In vivo* digestibility studies

A digestibility study was carried out at the end of the growth phase of the experiment. The total faecal collection method was used. Feces voided were carefully collected, weighed and recorded to determine the actual fecal output before a sample of 25% was taken for moisture determination. Feces were dried in a forced-air oven at 7:00 C for 24 h. Daily dried feces for each goat over the collection period were bulked, sampled and milled with Christy and Norris Hammer mill, to pass through a 1.77 mm sieve. These were stored in airtight containers until required for chemical analyses.

### *In vitro* gas production

Samples (DBG, CS, CD and DCWM) were incubated *in vitro* with rumen fluid in calibrated glass syringes following the procedure of Menke and Steingass (1988) as described by Abdulrazak et al. (2000). Rumen liquor was obtained from three sheep fed twice daily with 800 g DM timothy hay and 200 g DM concentrates, and had free access to water and mineral mix. About 200 mg of 1 mm milled samples were weighed into 100 ml calibrated glass syringes in duplicate. Pure oil was applied to the piston to ease movement and to prevent escape of gas. The syringes were pre-warmed (39°C) for 1 h, before addition of 30±1.0 ml of

**Table 2**. Chemical composition of brewers' grains (DBG),cocoa shell (CS), cocoa dust (CD) and desiccated coconut waste meal (DCWM)

| Nutrients | DBG | CS | CD | DCWM |
|---|---|---|---|---|
| Dry matter | 89.5 | 91.0 | 88.0 | 89.6 |
| Crude protein | 25.6 | 13.8 | 15.9 | 22.2 |
| Ether extract | 8.5 | 11.0 | 22.0 | 27.7 |
| Neutral detergent fibre | 58.4 | 53.2 | 43.3 | 48.8 |
| Acid detergent fibre | 30.8 | 29.4 | 24.0 | 38.6 |
| Organic matter | 95.4 | 91.0 | 94.0 | 95.2 |
| Gross energy (MJ/kg DM) | 21.6 | 21.3 | 23.2 | 25.1 |

* % Dry matter unless otherwise stated.

rumen-buffer mixture into each syringe. All the syringes were incubated in a water bath maintained at 39±0.10°C. The syringes were gently shaken every hour during the first 8 h of incubation and readings were recorded after 3, 6, 12, 24, 48, 72 and 96 h. The mean gas volume readings were fitted to the exponential equation p=a+b (1-e-ct) (Ørskov and McDonald, 1979). Where p=gas production at time t; a+b=the potential gas production, c=the rate of gas production and a, b, and c are constants in the exponential equation using the Neway computer program (X. B. Chen, Rowett Research Institute, Aberdeen) was used in the calculation.

Organic matter digestibility (OMD, %) and metabolizable energy (ME, MJ $kg^{-1}$ DM) were calculated using the following equations: OMD=14.88+0.889×Gv+ 0.45×CP, and ME=2.20+0.136×Gv+0.057×CP.

### In sacco degradability

3 g of dry sample milled through a 2 mm screen was weighed in nylon bags (140×75 mm, pore size 40 to 60 μm). The bags were incubated in the rumen of three cannulated sheep. The animals were offered timothy hay *ad libitum* plus 200 g DM of concentrate twice a day at 08:00 and 17:00 h. Animals had free excess to water and mineral/vitamin licks. Nylon bags were withdrawn at 4, 8, 16, 24, 48 and 72 h after insertion. The 0 h measurement was obtained by soaking the two bags of each sample in warm water (37°C) for 1 h. Nylon bags were then washed with cold water for 20 min in a washing machine and dried for 48 h at 60°C. The DM degradation data were fitted to the exponential equation $p=a+b\ (1-e^{-ct})$ (Ørskov and McDonald, 1979; McDonald, 1981) to determine the degradation characteristics (a, b, A, B, A+B, c and ED). Where p=is DM degradation at time t, A=washing loss (representing the soluble fraction of the feed); B=(a+b)-A. i.e. insoluble but fermentable fraction; c=the rate of degradation of B; a=zero intercept; b=insoluble but fermentable fraction; ED=effective degradability, calculated at an outflow rate of 0.05/h.

**Table 3**. Chemical composition of experimental diets and batiki grass

| Nutrients % | DBG | CS | CD | DCWM |
|---|---|---|---|---|
| Dry matter (DM) | 85.5 | 84.0 | 85.0 | 83.6 |
| In DM, % | | | | |
| Crude protein | 16.8 | 16.0 | 16.0 | 16.5 |
| Neutral detergent fiber | 48.2 | 52.6 | 42.3 | 49.8 |
| Acid detergent fiber | 26.4 | 28.5 | 23.8 | 28.2 |
| Ether extract | 6.3 | 5.2 | 8.5 | 29.3 |
| Organic matter | 93.1 | 84.0 | 89.0 | 94.7 |
| Gross energy, $MJ/kg^{-1}$ DM | 17.5 | 17.6 | 19.0 | 20.4 |

### Analytical methods

The AOAC (1995) method was used for the analyses of feed ingredients, diets, forage and feces. Dry matter was determined by drying at 102°C for 24 h, ash by firing at 600°C for 24 h, protein by the micro-Kjeldahl procedure (N×6.25). Gross energy ($MJ/kg^{-1}$ DM) value of concentrates, forage and fecal samples were determined by an adiabatic bomb calorimeter (Parr Instrument Co., Moline, IL) using thermochemical benzoic acid as standard. Neutral detergent fibre (NDF) and acid detergent fibre (ADF) were determined by the procedures of Van Soest et al. (1991).

### Statistical analysis

Data obtained were analyzed by ANOVA and significant differences between means were compared using Duncan's multiple range tests with the aid of SAS/STAT program (Statistical Analysis Systems Institute Inc. 1988).

## RESULTS

### Nutrient composition of the by-products and experimental diets

Chemical composition of the byproducts is presented in Table 2. CD had lowest crude protein (CP) content. DCWM and CD have higher ether extract contents than DBG and CS. DCWM had higher content of NDF and this was closely followed by DBG. ADF contents of the byproducts followed a similar trend like NDF.

Proximate chemical composition of the experimental diets is presented in Table 3 including the forage (batiki-*Ischaemum aristatum* var. *indicum*). The four byproducts had high GE. Gross energy (GE) content was higher in DCWM (25.1 MJ/kg DM) and this was closely followed by CD with a value of 23.2 MJ/kg DM.

### Voluntary feed intake and growth rate of goats

The performance of goats fed the different byproduct diets is presented in Table 4. Concentrate intake was higher ($p<0.05$) in the goats that received the DBG diet and this was followed by the goats on the CS diet with a value of 0.248 kg/head/day. The intakes of concentrate were however lower in the goats on CD and DCWM diets with

**Table 4**. Weight gain, feed intake and feed efficiency of crossbred anglo-nubian goats fed dried brewers' grains (DBG), cocoa shell (CS), cocoa dust (CD), desiccated coconut waste meal (DCWM) diets

| Parameters | Diets | | | | |
|---|---|---|---|---|---|
| | DBG | CS | CD | DCWM | SEM |
| Initial average live weight (kg) | 18.5 | 18.3 | 19.2 | 18.8 | 0.30 |
| Final average live weight (kg) | 24.8 | 23.8 | 24.5 | 24.6 | 0.38 |
| Live weight gain (kg) for 60 days | 6.3 | 5.5 | 5.3 | 5.8 | 0.38 |
| Average daily live weight gain (g) | 105[a] | 92[ab] | 88[b] | 97[a] | 6.34 |
| Intake, kg/d of concentrate | 0.258[a] | 0.248[b] | 0.242[b] | 0.239[bc] | 7.26 |
| Forage intake (kg) | 0.340[a] | 0. 348[a] | 0. 344[a] | 0.328[b] | 7.48 |
| Total feed intake (conc.+forage) (kg) | 0.598[a] | 0.596[a] | 0.586[b] | 0.567[c] | 12.28 |
| Feed efficiency (feed/gain) | 5.7 | 6.5 | 6.7 | 5.8 | 0.43 |

[a, b, c] Means within each row with different letters differ significantly at p<0.05. SEM; Standard error of mean.

**Table 5**. Apparent nutrient digestibility of the byproduct based diets fed to crossbred anglo-nubian goats

| Nutrients (%) | Diets[b, c] | | | | |
|---|---|---|---|---|---|
| | DBG | CS | CD | DCWM | SEM |
| Dry matter | 68.2[a] | 61.5[b] | 59.6[bc] | 63.4[b] | 3.19 |
| Organic matter | 68.0[a] | 62.1[b] | 59.4[b] | 65.3[a] | 3.24 |
| Crude protein | 60.8[a] | 53.2[b] | 55.0[b] | 57.7[ab] | 2.87 |
| NDF | 69.1[a] | 65.5[b] | 60.4[c] | 66.2[ab] | 3.13 |
| ADF | 60.8[a] | 55.0[b] | 52.0[b] | 59.6[a] | 3.54 |
| Gross energy | 68.2[a] | 63.4[ab] | 58.6[c] | 66.8[ab] | 3.69 |

[b] DBG; Dried brewers' grains, CS; Cocoa shell, CD; Cocoa dust, DCWM; Desiccated coconut waste meal. [c] Means within each row with different letters differ significantly at p<0.05. SEM; Standard error of mean.

values of 0.242 and 0.239 kg/head/day, respectively. The variation in concentrate intake might be associated with the byproduct.

Forage intake was close for the goats on DBG, CS and CD while the goats on DCWM had the least forage intake and this was significantly lower (p<0.05) from the intake of the goats on other byproducts. Total feed intake (concentrate+forage) followed the trend of the intakes of concentrate and forage separately among the goats. Goats on DBG had higher total feed intake (concentrate+forage) and the least total feed intake (p<0.05) was obtained in the goats that received DCWM diet.

Daily live weight gain was higher (p<0.05) in the goats that received DBG, while the least gain was obtained in the goats that received CS diet. Although, daily live weight gain was different between the goats on DBG and CD, the difference observed was of no statistical significance. This was also the case between the goats on DBG and DCWM. Feed efficiency (feed/gain) followed the pattern of feed intake and daily live weight gains.

### *In vivo* digestibility

Data on apparent nutrient digestibility coefficients are presented in Table 5. DM digestibility was significantly higher (p<0.05) in the goats on DBG based diet compared to the goats on the other diets. The goat on CD diet had the least DM digestibility. CP digestibility followed a similar trend (p<0.05) as DM. The fibre content of the diets

**Table 6.** Gas production (ml/200 mg DM) after 12, 24, 48, 72, 96 h and gas production characteristics in the by-products

| Period (h) | Diets | | | |
|---|---|---|---|---|
| | DBG | CS | CD | DCWM |
| 3 | 2.5 | 3.9 | 1.9 | 2.8 |
| 6 | 3.9 | 5.9 | 3.9 | 4.7 |
| 12 | 7.5 | 7.8 | 6.8 | 10.3 |
| 24 | 20.5 | 8.8 | 7.7 | 13.6 |
| 48 | 30.5 | 7.8 | 6.8 | 15.5 |
| 72 | 36.5 | 8.8 | 6.8 | 16.4 |
| 96 | 38.5 | 8.8 | 6.8 | 17.3 |
| a | -2.5 | 0.059 | -3.16 | -1.05 |
| b | 44.7 | 8.5 | 10.2 | 17.7 |
| c ($h^{-1}$) | 0.028 | 0.198 | 0.219 | 0.078 |
| a+b | 42.17[a] | 8.56[c] | 7.065[c] | 16.62[b] |
| RSD | 1.682 | 0.435 | 0.551 | 0.765 |
| ME (MJ/kg DM | 6.4 | 4.2 | 4.2 | 5.3 |
| OMD 24 (g/kg DM) | 47.6[a] | 34.8[b] | 17.9[c] | 42.5[a] |

DBG; Dried brewers' grains, CS; Cocoa shell, CD; Cocoa dust, DCWM; Desiccated coconut waste meal.
[a, b, c] Means within each row with different letters differ significantly at p<0.05.

influenced the digestibility of NDF and ADF.

The goats that received DBG and DCWM based diets had higher (p<0.05) NDF and ADF digestibility. NDF digestibility was however; better in goats on CS diet than those on CD diet. The goats that received DBG, DCWM and CS byproduct diets had higher OM and GE digestibility (p<0.05) than those goats on CD diet. OM digestibility is used to predict the value of metabolizable energy (ME).

### *In vitro* digestibility

Table 6 presents data on net gas production, OM digestibility and metabolizable energy (ME, MJ/kg of DM) of the byproducts. Significant differences (p<0.05) among the byproducts were recorded for net gas production at 12, 24, 48, 72 and 96 h. The highest rate of gas production (C) was recorded with CD (0.219 $h^{-1}$) and the lowest with DBG (0.028 $h^{-1}$). The potential gas production (a+b) ranged between 7.06-42.17 ml. The calculated OM digested from gas production value at 24 h was higher in DBG (47.6 g/kg DM) and this was closely followed by DCWM (42.5 g/kg

**Table 7.** *In situ* rumen dry matter (g/kg) disappearance and degradation characteristics of the by-products

| Period (h) | Diets | | | |
|---|---|---|---|---|
| | DBG | CS | CD | DCWM |
| 0 | 16.9 | 31.7 | 30.1 | 15.5 |
| 4 | 28.7 | 38.3 | 38.9 | 27.1 |
| 8 | 50.9 | 39.8 | 40.3 | 52.1 |
| 16 | 78.6 | 44.3 | 45.4 | 78.6 |
| 24 | 88.4 | 49.6 | 49.4 | 88.5 |
| 48 | 98.9 | 57.9 | 58.0 | 99.5 |
| 72 | 99.2 | 65.6 | 66.9 | 99.4 |
| a | -5.38 | 35.5 | 36.3 | -8.39 |
| b | 104.8 | 50.5 | 58.3 | 107.9 |
| c ($h^{-1}$) | 0.098 | 0.013 | 0.010 | 0.101 |
| a+b | 99.4 | 85.95 | 94.58 | 99.54 |
| RSD | 0.956 | 0.753 | 0.716 | 1.139 |
| LP (h) | 2.4 | 0 | 0 | 2.5 |
| ED (%) | 65.8[a] | 41.5[b] | 39.9[b] | 64.9[a] |

DBG; Dried brewers' grains, CS; Cocoa shell, CD; Cocoa dust, DCWM; Desiccated coconut waste meal. [a, b, c] Means within each row with different letters differ significantly at p<0.05.

DM). The least OMD was obtained in CD (17.9 g/kg DM).

The DM degradation characteristics of the byproducts are presented in Table 7. A significant difference ($p<0.05$) in DM disappearance after 4, 8, 16, 24, 48 and 72 h was recorded. The potential and effective degradability varied significantly ($p<0.05$) from 85.95-99.6 g/kg DM and from 39.9-65.8%, respectively. The major part of degradation loss for DBG and DCWM occurred between 4 to 24 h of incubation, 65.8 and 64.9% of the potential degradability for DBG and DCWM.

## DISCUSSION

The proximate chemical composition of the byproducts is within values reported by Bovolenta et al. (1998) and Aregheore (2000b) for DBG; Abiola and Tewe (1990) for CS and CD; and Aregheore (2000b); Aregheore and Tunabuna (2001) for DCWM. The diets had similar CP values. The CP, NDF and ADF contents of the batiki used in this experiment are similar to values reported by Ash et al. (1992).

The GE content of the individual experimental diet might have influenced concentrate intake. It has been reported that animals tend to consume less before meeting their energy requirements for growth if a diet is high in energy (Montgomery and Baumgardt, 1965). The suggested energy requirements for the optimal growth of the age of Anglo-Nubian×Fiji local goats as used in this trial are 13.4 MJ GE/kg DM in the tropical environment (Kumar, 2000). The diets used in this trial were higher in energy than this. This could have also accounted for the low concentrate intake, compared to the intakes reported earlier by Kumar (2000) for the breed and ago of goats.

The high NDF and ADF digestibility values obtained in the goats on DBG, DCWM and CS diets is possibly due to a longer retention time in the reticulo-rumen than CD. It has been suggested that the longer the retention time the higher the digestibility of a diet (Aregheore, 2000c; Aregheore and Tunabuna, 2001). It therefore seems that DBG, DCWM and CS diets had a longer residence time in the digestive tract and this subsequently led to higher digestibility of available nutrients compared to CD diet. The inclusion of cassava flour and urea in the diets may also have improved the digestibility of nutrients.

It has also been observed that the higher the OM digestibility, the higher the expected ME, and therefore, the feed with higher OM digestibility is expected to provide more energy and therefore more production, i.e. high live weight gain. The daily growth rate observed in the goats' fed the different byproduct diets may have been influenced by the contents of OM and GE present in the diets (Aganga and Monyatsiwa, 1999).

Gas volume after a few hours of fermentation mainly reflect the fermentation of highly soluble feed fractions and true degradabilities at later hours reflect differences in the degradability of the structural and insoluble feed fraction, mainly NDF (Blummel et al., 1997). The values obtained on net gas production, OM digested and ME (MJ/kg of DM) of the byproducts are close to those reported for two tropical byproducts-groundnut shell (GNS) and maize cob (MC) by Aregheore (2000c).

The low values of OMD obtained in the cocoa byproducts may be attributed to the presence of *theobromine*, an anti-nutritive factor present in CS and CD. Oyenuga (1968) reported that the beans and shell of cocoa are high in the alkaloid; *theobromine* and this may have inhibited the action of rumen microbes to effectively digest these byproducts. ME, (MJ/kg DM) of the byproducts varied from 4.2 to 6.4. The byproducts had moderate ME and their inclusion with other feed ingredients in diets of ruminant animals will be beneficial since they could provide bulk in such diets.

The rate of digestion and the amount which is potentially degradable together, determine how much of the material will be digested during the time the food is exposed to rumen fermentation (∅rskov, 1991). The rate and potential extent of digestion will influence, therefore, both digestibility and rumen volume and hence, voluntary intake, (∅rskov et al., 1988). Also Pirie (1987) hypothesized that if several enzymes *in vitro* readily digest a feed nutrient, it is reasonable to expect that it will be digested in the digestive system. And if it is not digested *in vitro*, it will still be digested *in vivo* as a result of simultaneous actions of several enzymes and the possible co-operation from rumen flora.

## CONCLUSIONS

The digestibility of the byproducts in both the *in vivo* and in *in vitro* techniques demonstrated that they are potential source of feed ingredients for ruminant livestock in Samoa and possibly in the other small Pacific Island countries. On the basis of their potential degradability, the byproducts could be ranked in the following order: DCWM>DBG>CD>CS, while on the basis of effective degradability the byproducts could also be ranked as follows DBG> DCWM>CS>CD. In conclusion, the results obtained suggest that all the byproducts could contribute to ruminant livestock diets without detrimental effects on voluntary feed intake, growth rate and apparent nutrient digestibility coefficients.

## ACKNOWLEDGEMENTS

The authors are grateful to Western Samoa Breweries Ltd., Apia for the brewers' grains; Samoa Tropical Products LTD, Apia for the desiccated coconut waste meal and to Wilex C & C Products Ltd., Moatia, Apia for the cocoa shell and cocoa dust. We are grateful to Mr. Amusa Falaniko, Crop Science Department, The University of the South Pacific, School of Agriculture, Apia, Samoa for the generous gift of cassava tubers used in the trial. Finally, we are grateful to Messrs. Ashish Kumar and Daya Perera for the care of animals and chemical analyses, respectively.

## REFERENCES

Abdulrazak, S. A., E. A. Orden, T. Ichinohe and T. Fujihara. 2000. Chemical composition, phenolic concentration and *in vitro* gas production characteristics of selected Acacia fruits and leaves. Asian-Aust. J. Anim. Sci. 13, No 7:935-940.

Abiola, S. S. and O. O. Tewe. 1990. Chemical evaluation of cocoa by products. Tropical Agriculture (Trinidad), 68(4):335-336.

Aganga, A. A. and C. B. Monyatsiwa. 1999. Use of browses (Terminalia serecia, Combretum apiculatum or Euclea schimperi) as a supplement for growing Tswana goats. Tropical Animal Health and Production, 31(5):295-305.

AOAC. 1995. Official Methods of Analysis, 16th edn. Association of Official Analytical Chemists, Arlington, VA.

Aregheore, E. M. 2000b. Traditional staple foods and some feedstuffs of the Pacific Islands: Their chemistry, biochemistry and nutrient composition: A Reference Manual, Department of Animal science, School of Agriculture, The University of the South Pacific, Apia, Samoa, p. 70.

Aregheore, E. M. 2000c. Chemical composition and nutritive value of some tropical by-product feedstuffs for small ruminants-*in vivo* and *in vitro* digestibility. Anim. Feed Sci. Techn. 85:99-109.

Aregheore, E. M. and T. Tunabuna. 2001. The utilization of diets containing increasing levels of dry desiccated coconut waste meal (DCWM) by growing crossbred Anglo-Nubian goats in Samoa. Asian-Aust. J. Anim. Sci. 14, 3:316-320.

Ash, A. J., L. Solomona and W. T. Waroka. 1992. Effectiveness of low-cost protein supplement for goats in the South Pacific. J. South Pac. Agric. 1. 3:55-58.

Blummel, M., H. P. S. Makkar, G. Chisanga, J. Mtimuni and K. Becker. 1997. The prediction of dry matter intake of temperate and tropical roughages from *in vitro* digestibility/gas production data, and the dry matter intake and *in vitro* digestibility of African roughages in relation to ruminant live weight gain. Anim. Feed Sci. Technol. 69:131-141.

Bovolenta, S., E. Piasentier, C. Peresson and F. Malossini. 1998. The utilization of diets containing increasing levels of dried brewers' grains by growing lambs. Anim. Sci. 66:689-695.

Kumar, A. 2000. Energy and protein requirements of crossbred Anglo-Nubian goats in Samoa. B. Agric. Special Project. The University of the South Pacific, School of Agriculture, Apia, Samoa, p. 26.

McDonald, I. 1981. A revised model for the estimation of protein degradability in the rumen. J. Agric. Sci. (Camb.) 96:251-252.

Menke, K. H. and H. Steingass. 1988. Estimation of the energetic feed value from chemical analysis and *in vitro* gas production using rumen fluid. Anim. Res. Dev. 28:7-55.

Montgomery, M. J. and B. R. Baumgardt. 1965. Regulation of food intake in ruminants. 1. Pelleted rations varying in energy concentration. J. Dairy Sci. 48:569-574.

Ørskov, E. R. 1991. Manipulation of fiber digestion in the rumen. Proc. Nutr. Soc. 50:187-196.

Ørskov, E. R. and I. McDonald. 1979. The estimation of protein degradability in the rumen from incubation measurement weighted according to rate of passage. J. Agric. Sci. (Camb.) 92:499-503

Ørskov, E. R., G. W. Reid and M. Kay. 1988. Prediction of intake by cattle from degradation characteristics of roughages. Anim Prod. 46:29-34.

Oyenuga, V. A. 1968. Nigeria's Foods and Feeding-stuffs. Their chemistry and nutritive value 3rd ed. Ibadan Univ. Press. Ibadan, Nigeria. pp. 99.

Pirie, N. W. 1987. Leaf protein and its byproducts in human and animal nutrition. 2nd Edition. Cambridge University Press, p. 84 (Chapter 8).

Preston, R. L., R. D. Vance and V. R. Cahill. 1973. Energy evaluation of brewers' grains for growing and finishing cattle. J. Anim. Sci. 37:174-178.

Statistical Analysis Systems Institute Inc. 1988. SAS/STAT Program, Cary, NC:SAS Institute Inc.

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