Digestion and utilization of citrus by-products by two breeds of West African goats

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SUMMARY

TWELVE young goats, consisting of 6 West African Dwarf (*Fouta Djallon*), (10.19 to 15.45 kg), and 6 Red Sokoto (*Maradi*), (9.09 to 14.09 kg), were used throughout the experiment (3 trials). The 12 goats were maintained on basal forage (*Cynodon nlemfuensis*) in Trial 1 but in Trial 2, they were divided into two groups with two animals per sub-group. Animals in a sub-group were maintained on basal forage plus 25, 50 or 75% fresh citrus pulp. In Trial 3, six West African Dwarfs were maintained on similar levels as in Trial 2 but using dried citrus pulp.

The results showed that protein content of citrus pulp was low (6%) with high crude fibre value of 15%, high moisture content (84%), and high nitrogen-free extractive (NFE) value (57%). Dry matter (DM) intakes of basal forage ration were higher than those of mixtures of basal forage and fresh citrus pulp ($P < 0.01$) due probably to high moisture content of the pulp, because the DM intakes of dried pulp mixtures were higher than those of basal rations ($P < 0.01$). The rations with 50% fresh or dried pulp was consumed more than the other mixture. Fresh pulp significantly depressed nutrient digestibilities at all levels of supplementation relative to basal forage ($P < 0.05$), while those of dried samples were about the same with the values for the basal ration. Red Sokoto and West African dwarf goats retained 39.29 and 41.34g N/100g N consumed respectively when fed on forage only, but 11.43 and 17.03, 14.11 and -14.22, -2.48 and 15.23g N/100g N consumed respectively when fed on grass/fresh citrus mixtures. The corresponding N retention for West African dwarf goats were 38.51, 31.86 and 40.01g N/100g N when fed the forage dried citrus mixtures. The digestible energy (DE) and metabolizable energy (ME) intakes for these animals were optimal at the 25 and 50% citrus supplementation. There was highly significant correlation between ME intake and liveweight changes throughout the experiment ($P < 0.01$). Animals fed on forage fresh pulp mixtures lost weights ($-0.59 < 0.01$ kg/animal/week) in Trial 2, while those on forage-dried citrus mixtures gained weights ($0.05 < 0.03$ kg/animal/week) in Trial 3.

INTRODUCTION

ALTHOUGH dried citrus pulp was first introduced as a supplement to dairy cattle feeds in Florida, USA, in 1932

(Becker and Dixanold, 1951), its use in animal feeds has since increased with increase in citrus canning industries. Citrus seed oil is of higher nutritive value than the carbohydrate portion of dried pulp, while hulls alone are of very poor feeding values (Becker and Dixanold, 1951). Thus, citrus pulp containing seeds has a slightly higher nutritive value than the by-product without seeds and, as has been pointed out by these authors, should be regarded as a carbohydrate feed, fairly high in energy, although it might be high in calcium (Ca) depending on the method of processing but largely low in phosphorus (P). They further observed that even though fresh pulp contained about 85% moisture, its dry matter (DM) was similar in composition to that of corresponding dried samples except the volatile essential oils of the peel which had not evaporated in the fresh sample.

Several attempts have been made to carry out nutritive evaluations of fresh and dried citrus pulp samples using cattle (Becker and Dixanold, 1951; Keener, Colovos and Eckberg, 1957; Ammerman, Van Wallengham, Palmer, Carpenter, Hartges and Arrington, 1963) and sheep (Ammerman, Hendrickson, Hall, Easley and Loggins, 1965; Sanchez-Vizcaino-Fernandez, 1970; Bhattacharya and Harb, 1973; Devendra, 1973).

In view of the numerical abundance of goats compared with other ruminants in Nigeria and lack of information on the utilization of by-products of canning industry by goats, attempts were made to carry out nutritive evaluation of fresh and dried citrus wastes obtained from Lafia Canning factory using two breeds of West African goats. Attempts were also made to assess the optimal level of replacing forage DM with that of the by-product so as to provide

TABLE 3
Dry Matter intake and Digestibility Coefficients of rations fed to Red Sokoto Goats (Maradi) in trials I and II

Characteristics	Treatments						
	1	2	3	4	5	6	7
Dry Matter Intake (g/day/W.734 kg)	98.77 ± 2.27	40.95 ± 0	41.60 ± 9.96	41.95 ± 3.22	79.12 ± 0	75.74 ± 1.08	83.53 ± 3.31
Dry Matter	80.53 ± 5.14	75.50 ± 0	64.28 ± 14.84	67.61 ± 11.54			
Digestibility (%)							
Crude Protein	85.58 ± 2.12	53.09 ± 0	53.12 ± 2.91	58.07 ± 3.15	75.97 ± 0	80.86 ± 1.65	85.35 ± 0.86
Digestibility (%)							
Crude Fibre	83.82 ± 3.29	79.60 ± 0	55.52 ± 12.14	55.67 ± 17.20	83.16 ± 0	78.17 ± 0.98	83.90 ± 4.70
Digestibility (%)							
Ether Extract	75.16 ± 8.05	25.67 ± 0	33.84 ± 5.63	32.45 ± 18.27	61.00 ± 0	68.05 ± 2.35	72.36 ± 15.85
Digestibility (%)							
N—free Extract	69.95 ± 13.98	67.66 ± 0	60.95 ± 18.09	64.37 ± 14.95	67.41 ± 0	57.68 ± 9.60	76.02 ± 15.11
Digestibility (%)							

1 = Grass fed in Trial I

2 = Grass + 25% of fresh citrus pulp fed in Trial II

3 = Grass + 50% of fresh citrus pulp fed in Trial II

4 = Grass + 75% of fresh citrus pulp fed in Trial II

5 = Digestibility of true fresh citrus pulp in Treatment 2

6 = Digestibility of true fresh citrus pulp in Treatment 3

7 = Digestibility of true fresh citrus pulp in Treatment 4

TABLE 4
Dry Matter Intake and Digestibility Coefficient of rations fed to West African Dwarf Goats (Fouta Djallon) in Trials I and II

Characteristics	Treatments						
	1	2	3	4	5	6	7
Dry Matter Intake (g/day/W.734kg)	107.47±15.88	54.71± 8.48	58.27± 9.23	36.09± 7.67	—	—	—
Dry Matter	85.81±23. 8	75.35±10.32	64.02±11.46	55.97±73. 9	82.64± 0.21	83.36± 3.41	83.36± 2.22
Digestibility (%)							
Crude Protein	87.97± 2.67	39.65± 8.63	32.13±15.01	59.83±10.54	75.96± 0.83	82.29± 0.44	86.80± 3.23
Digestibility (%)							
Crude Fibre	88.21± 1.62	73.76± 8.21	55.12±15.80	42.47± 2.31	86.83± 0.98	84.27± 3.72	83.80± 0.74
Digestibility (%)							
Ether Extract	72.60±16.52	52.73±38.28	31.78± 1.24	32.92± 6.82	72.14±13.71	82.01± 1.69	50.47± 2.95
Digestibility (%)							
N-free Extract	80.00±13.45	72.68± 4.38	77.28±22.50	56.62± 6.05	79.44± 0.14	89.03± 2.79	86.35± 8.01
Digestibility (%)							

- 1 = Grass fed in Trial I
 2 = Grass + 25% fresh citrus pulp fed in Trial II
 3 = Grass + 50% fresh citrus pulp fed in Trial II
 4 = Grass + 75% fresh citrus pulp fed in Trial II
 5 = Digestibility of true fresh citrus pulp in Treatment 2
 6 = Digestibility of true fresh citrus pulp in Treatment 3
 7 = Digestibility of true fresh citrus pulp in Treatment 4

TABLE 5

Dry Matter Intake and Digestibility Coefficient of rations fed to West African Dwarf Goats (Fouta Djallon) in Trial III

Characteristics	Treatments					
	1	2	3	4	5	6
Dry Matter Intake (g/day/W.734kg)	98.88 ± 6.68	101.92 ± 14.71	71.16 ± 3.57	84.94 ± 2.23	85.32 ± 2.86	87.40 ± 1.70
Dry Matter Digestibility (%)	85.15 ± 6.29	79.80 ± 6.29	83.78 ± 3.34			
Crude Protein Digestibility (%)	81.11 ± 12.15	72.18 ± 0.91	75.32 ± 5.02	88.38 ± 2.74	86.71 ± 1.68	89.27 ± 3.07
Crude Fibre Digestibility (%)	83.61 ± 0.78	81.71 ± 2.07	81.44 ± 2.68	88.46 ± 0.68	87.00 ± 2.47	87.87 ± 1.55
Ether Extract Digestibility (%)	58.97 ± 6.05	84.42 ± 6.01	78.12 ± 10.59	75.80 ± 6.04	87.10 ± 2.31	53.61 ± 3.58
N-free Extract Digestibility (%)	89.38 ± 3.33	87.24 ± 0.85	85.12 ± 3.26	72.79 ± 15.54	79.96 ± 12.45	89.25 ± 7.53
1 = Grass + 25% dried citrus pulp						
2 = Grass + 50% dried citrus pulp						
3 = Grass + 75% dried citrus pulp						
4 = Digestibility of true dried citrus pulp in Treatment 1						
5 = Digestibility of true dried citrus pulp in Treatment 2						
6 = Digestibility of true citrus pulp in Treatment 3						

DM intake and digestibility

DM intakes and digestibility values for fresh and dried citrus pulp-grass mixtures and grass alone are shown in Tables 3, 4 and 5. DM intakes of basal forage were very much higher than those of the mixtures ($P < 0.01$), but within the mixtures there were no significant differences ($P > 0.05$). The decrease in the DM intakes of the mixtures was due to high moisture content because the DM intakes for grass-dried citrus pulp mixtures in Trial III were higher than those of the fresh mixtures, and about the same with those of grass alone, 98.88 ± 6.68 , 101.92 ± 14.71 , 71.15 ± 3.57 and 107.47 ± 5.88 g/day/ $W_{kg}^{0.734}$ for 25, 50, 75% dried citrus pulp and grass alone fed to West African dwarf goats respectively. DM intakes of grass-citrus pulp mixtures were generally higher at 50% than at any other level of supplementation. Supplementing basal forage with citrus pulp tended to depress the corresponding digestibility values ($P < 0.01$), although there were no breed differences ($P > 0.05$). The DM digestibilities for

grass-fresh citrus pulp mixtures fed to Red Sokoto and West African dwarf goats were 75.50 ± 0.0 and 75.35 ± 10.32 at 25%; 64.28 ± 14.84 and 64.02 ± 11.46 at 50%; 67.61 ± 11.54 and 55.97 ± 7.39 at 75% supplementations respectively. The corresponding values for the citrus pulp alone were 79.12 ± 0.0 and 82.64 ± 0.21 , 75.74 ± 1.08 and 83.59 ± 3.41 , 83.53 ± 3.13 and 83.36 ± 2.22 at 25, 50 and 75% supplementations respectively. There were indications that DM digestibilities of fresh citrus pulp alone were much higher than the corresponding values of the mixtures ($P < 0.01$) assuming that there were no associative effects between basal and supplementary diets. Digestibility values for CP, Crude fibre (CF), EE and NFE followed almost the same pattern as that of the DM. There were general tendencies for digestibility values to increase with the levels of citrus pulp supplementation.

The low digestibility values obtained for CP and DM with grass-fresh citrus pulp mixtures in Trial II might have been responsible for the low DM intake and is in general agreement with the findings of

TABLE 6

Nitrogen utilization of mixtures of fresh or dried citrus pulp and *C.nlemfuensis* fed to goats in Trials I, II and III.

Animal and feeds	% Citrus fed	N intake (g/day)	N in faeces (g/day)	N in urine (g/day)	N-balance (g/day)	N-balance (g/day/ $W^{0.74}$ kg)	N-retention %
Red Sokoto goats given fresh citrus pulp and <i>C.nlemfuensis</i> (Trials I and II)	0	622.61	271.29	106.71	244.61	40.03	39.29
	25	189.53	93.32	74.55	21.66	4.04	11.43
	50	228.32	137.40	58.72	32.21	5.17	14.11
	75	249.32	215.30	40.22	-6.19	-1.03	-2.48
West African dwarf goats given fresh citrus pulp and <i>C.nlemfuensis</i> (Trials I and II)	0	660.48	351.48	35.97	273.03	44.83	41.34
	25	301.96	234.56	15.99	51.41	8.61	17.03
	50	301.18	285.90	58.12	-42.84	-7.18	-14.22
	75	212.80	161.22	19.16	32.42	5.43	15.23
West African dwarf goats given dried citrus pulp and <i>C.nlemfuensis</i> (Trial I)	25	650.88	314.70	85.52	250.66	41.78	38.51
	50	746.27	396.71	111.77	237.79	39.63	31.86
	75	481.68	271.11	17.86	192.71	32.12	40.01

Conrad, Pratt and Hibbs (1964). The higher CP digestibility values for grass-dried citrus pulp mixtures and for the pulp alone in Trial III resulted in the corresponding higher DM intake than for the fresh pulp mixtures.

N. retention

Utilization values of N contents of grass, grass-citrus pulp mixtures are shown in Table 6. Red Sokoto and West African dwarf goats maintained on grass alone retained 39.29 and 41.34 g/100g CP/day respectively. The corresponding values in Trial II were 11.43 and 17.03, 14.11 and -14.22, -2.48 and 15.23 g/100g CP/day respectively, at 25, 50 and 75% supplementation. West African dwarf goats fed on grass-dried citrus pulp mixtures retained daily in Trial III 38.51, 31.86 and 40.01/100g CP at 25, 50 and 75% supplementation respectively. The mean

differences between these values and those in Trial I were not significant ($P > 0.05$) but were much higher than the corresponding values in Trial II ($P < 0.01$). The N balance values followed almost the same pattern as the percentage N retention but was emphasizing the fact that N utilization was optimal between 25 and 50% citrus supplementation. There were no breed differences in the utilization of the N contents of grass and grass-citrus pulp mixtures ($P < 0.05$).

Energy digestion and utilization

Energy digestibility, digestible energy (DE) intake, metabolizable energy (ME) values and total digestible nutrients (TDN) are shown in Table 7. Energy digestibility followed almost the same pattern as that of DM, DE and ME intakes, and TDN in Trial I were 163.37 ± 12.73 , 155.88 ± 7.79 KJ/100g DM/day/W_{kg}^{0.734} and $65.11 \pm$

TABLE 7

Energy utilization of mixtures of fresh or dried citrus pulp and *C.nlemfuensis* fed to goats in Trials I, II and III

Animal and feeds	% Citrus fed	TDN (kg)	GE	Faecal GE (KJ/day)	Urinary GE (KJ/day)	DE		KJ/100g DM/day/Wkg 0.734	ME KJ/100 KJ
			intake (KJ/DAY/0.734 Wkg 0.734)			KJ/100g DM/day/Wkg 0.734	KJ/100 KJ		
Red Sokoto goats given fresh citrus pulp and <i>C.nlemfuensis</i> (Trials I and II)	0	65.11	1170.96	1180.98	240	163.37	83.42	155.88	79.93
	25	58.62	624.37	912.87	90.30	206.64	72.78	199.05	70.80
	50	44.45	629.23	1176.90	512.65	189.89	72.15	145.11	58.31
	75	47.80	744.99	1566.77	146.37	191.36	66.73	181.65	63.41
West African dwarf goats given fresh citrus pulp and <i>C.nlemfuensis</i> (Trials I and II)	0	73.38	1268.37	104.12	109.12	162.66	88.78	160.23	87.45
	25	60.80	828.18	1632.52	52.15	188.08	66.78	170.90	61.05
	50	46.03	981.84	2087.03	491.23	202.08	64.93	158.53	56.57
	75	42.35	647.17	1383.36	86.27	181.88	66.03	177.80	65.08
West African dwarf goats given dried citrus pulp and <i>C.nlemfuensis</i> (Trial III)	25	74.15	2055.94	1864.63	313.86	313.20	83.65	300.92	80.34
	20	74.23	2302.96	2353.81	778.89	312.19	83.16	290.85	77.55
	75	71.57	1477.64	2301.73	290.85	267.26	83.93	257.02	80.91

7.12kg respectively for Red Sokoto goats and 162.66 ± 15.90 , 160.23 ± 17.47 KJ/100g DM/day/W^{0.734} kg and 73.38 ± 5.62 kg respectively for West African dwarf goats maintained on basal forage. There were no breed differences ($P > 0.05$). Although the DE and ME intakes for grass-fresh citrus pulp mixtures in Trial II were much higher than the values for basal forage ($P < 0.01$), the highest values were obtained for the dried citrus pulp mixtures, the optimal level of intake tending to be between 25 and 50% level of supplementation. Total digestible nutrient values were 74.15 ± 0.35 , 74.23 ± 0.40 and 71.57 ± 3.16 kg for dried citrus pulp mixtures at 25, 50 and 75% supplementation respectively, giving almost the same value as that of basal forage (73.38 ± 5.62 kg).

in Trial II indicated that the animals were breaking down their tissue proteins to meet their protein requirements. Thus, animals on these rations invariably lost weights. On the other hand, animals maintained on dried citrus pulp mixtures were generally on positive N balance and most of them gained weight. There was very little difference in the protein content of rations fed to these goats, which ranged from 5.3 to 7.5% (Tables 1 and 2) and was regarded as being generally low. Voluntary DM intake seemed to control total amount of protein and energy consumed. Recent studies by Akinsoyinu (1974) have shown that West African dwarf goats required daily 418 KJ ME/W^{0.734} kg for maintenance and 300 KJ ME/W^{0.734} kg reported in the present experiment even for the highest energy intake appeared

TABLE 8

Liveweight changes of West Africa dwarf goats fed on mixtures of fresh or dried citrus pulp and *C.nlemfuensis*

Feeds	Liveweights (kg)	Animal Number					
		102	113	117	151	169	174
Fresh citrus pulp and <i>C.nlemfuensis</i> in Trail II	Initial	15.45	13.18	14.09	11.36	10.91	12.27
	Final	12.18	10.00	12.73	8.64	8.64	10.91
	Changes (Total)	-3.27	-3.18	-1.36	-2.72	-2.27	-1.36
	Changes (per week)	-0.82	-0.80	-0.34	-0.68	-0.57	-0.34
Dried citrus pulp and <i>C.nlemfuensis</i> In Trial III	Initial	11.36	9.09	13.73	9.09	8.64	9.55
	Final	12.27	9.09	13.64	8.64	8.18	10.00
	Changes (Total)	0.91	0.00	0.91	-0.45	-0.45	0.45
	Changes (per week)	0.18	0.00	0.18	-0.09	-0.09	0.09

There was a very great tendency for ME intake to be very closely related to liveweight changes. As shown in Table 8, for instance, West African dwarf goats maintained on grass-fresh citrus pulp mixtures in Trial II gave a mean liveweight change of -0.59 ± 0.01 kg/animal/week, while those on dried citrus pulp mixtures in Trial III gained weekly 0.05 ± 0.03 kg. The negative N retention and balance values obtained for some of the rations

to be inadequate for maintenance, let alone for growth. This may account, in parts, for the tissue protein breakdown observed in the experiment. It was observed that urinary N output particularly in West African dwarf goats was very small and in some cases none at all throughout the collection period. This would indicate that such animals have probably initiated an emergency N conserving mechanism which is associated with increased recycling

of urea from ruminal blood vessel across the rumen wall to rumen as well as from saliva. Such urinary urea-N reduction by animals on low-N diets has been demonstrated by Schmidt-Nielsen and Osaki (1958), Houpt (1959), Coximano and Leng (1967) and Biddle and Evans (1970).

From all indications in the present experiment, the citrus waste products, although preferred by goats in dried form would still need to be supplemented with concentrates particularly carbohydrate concentrates before maximum utilization could be obtained from this by-product of citrus canning industry.

ACKNOWLEDGEMENT

The authors are grateful to University of Ibadan Senate Research Grant Sub-Committee for financial supports.

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