Relative intake, eating pattern, nutrient digestibility, nitrogen metabolism, fermentation pattern and growth performance of lambs fed organically and inorganically produced cowpea hay-barley grain diets

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Abstract

In a feeding experiment, 2 groups of 6 male lambs (13.1 ± 0.52 kg) were offered cowpea hay *ad lib* and barley grain grown under inorganic and organic management and feed intake and liveweight change were measured. After 60 days, a digestion trial was conducted to assess the dietary effects on nutrient digestibility and N metabolism. After 195 days, rumen liquor and blood samples were collected for determination of rumen metabolites, microbial activity and blood parameters. Dry matter intake was similar in lambs in both groups, while nutrient digestibility was 2–2.5 units higher in lambs fed the organic diet ($P>0.05$). Eating pattern and rate of feed intake were comparable in both groups. Lower urinary nitrogen concentration in the organic group resulted in higher N retention in this group. At 4 h post feeding, total volatile fatty acid and total N concentrations were higher ($P<0.05$) in rumen liquor from the organic group than the inorganic group. Blood metabolites of lambs were comparable in lambs of both dietary groups. Total bacterial count, total protozoa and entodiniomorph counts were higher ($P<0.05$) in the organic group. Growth rates were comparable in both groups, while wool yield was slightly higher in the organic group ($P>0.05$). Results indicate that lambs fed a diet based on organically produced cowpea hay and barley grain should perform at a similar level to those fed on a conventional diet produced with inorganic fertilisers.

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Introduction

Prior to the 19th century, most foods in the world were organically produced using organic manure and animal power (White 1970). Soil fertility was maintained through a combination of crop rotation and application of organic manure. It has been suggested (Vogtmann *et al*. 1993; Worthington 2001) that organically produced crops have better nutritive value and taste and are healthier than inorganically grown crops, as they have less accumulation of nitrate and better mineral and vitamin contents. Positive and negative effects of organic (manure) and inorganic (chemical) fertilisers on nutritional value, sensory quality of produce and animal productivity have been reviewed (Bourn and Prescott 2002). The ultimate test of the nutritional value of any food or fodder depends on its ability to support health, growth and reproduction. Studies have been carried out on the relative response of organically and inorganically produced feeds and fodder mostly in monogastrics and sporadically with ruminants (Vogtmann 1988; Reksen *et al*. 1999). The aim of the present study was to assess the impact of added nutrients from an organically produced diet on rumen function, its environment and lamb performance. Both organically and inorganically grown cowpea (*Vigna unguiculata*) hay and barley (*Hordeum vulgare*) grain (energy source) diets were evaluated in terms of intake, eating pattern, nutrient utilisation, fermentation pattern, microbial activity and lamb growth.

Materials and methods

Forage and feeds

Cowpea (cv. EC4216) fodder and barley grain (cv. RD 2506) crops were grown under organic and inorganic fertiliser management and other agronomic practices in Kharif and Rabi seasons in one hectare fields with organic and inorganic backgrounds for the preceding 5–6 years of crop production. Available N, P and K were 195 kg, 12.0 kg and 225 kg per hectare in these fields. Organic carbon, pH and EC of the soil were 0.64 %, 7.50 and 0.04 dS/m, respectively. Farmyard manure (N 0.41, P 0.3 and K 0.43%) was applied to organically grown cowpea and barley grain crops to meet their N, P and K requirements (20, 60 and 40; and 80, 40 and 40 kg, respectively) at the time of field preparation. For inorganically grown crops, urea, diammonium phosphate and muriate of potash were applied at the time of sowing and a half dose of N 40 days later to the barley crop to meet their N, P and K requirements. The cowpea was harvested at full bloom to pod initiation stage, chaffed and conserved as hay, while the barley grain was harvested when mature. Crude protein and organic matter concentrations were comparable in organically and inorganically grown cowpea hay and barley grains (Table 1). NDF, ADF and cellulose concentrations were 2 to 3.5 units higher in inorganically produced cowpea hay.

Animals, feeding and digestion/metabolism trial

Twelve male lambs (Local x Corridale) were randomly distributed into 2 groups of 6 animals with mean body weight of 13.12 ± 0.795 and 13.12 ± 0.748 kg, respectively, and were housed individually and offered inorganically and organically grown cowpea hay *ad lib* and crushed barley grain in 62.8: 37.2 and 62.4: 37.6 proportions, respectively, supplemented with common salt to meet their nutritional requirements (Ranjhan 1998) at 09.00–10.00 h daily and additional cowpea hay was fed at 15.00–15.30 h. The lambs were maintained on these diets from October 10, 2006 to April 30, 2007 (202 days). Water was offered twice daily at 11.30 h and 16.00 h.

After 60 days of feeding, a digestibility trial of 7 days was conducted. Lambs were housed in metabolism cages with provision for collecting faeces and urine separately and a 2-day adaptation period was allowed. Faeces and urine of individual animals were then collected daily and pooled in iron trays and plastic canes, respectively. Representative samples of faeces for DM (1/10 aliquot) and N (1/50 aliquot preserved in 20% H_2SO_4) estimation were collected from individual animals during the trial. Samples of feed offered (cowpea hay and barley grain) and refusals were also collected daily and representative samples were kept for DM estimation. Dried samples of faeces, feed offered and refusals were ground through a 2 mm sieve using an electrically operated grinding mill. Ground samples were stored in plastic containers and used for further chemical and biochemical estimations. After the metabolism trial, eating patterns of lambs fed the mixed diets were recorded for 3 consecutive days by measuring the amounts of feed consumed during different periods (1, 1–3, 3–5, 5–7 and 7–17 h) of feeding. Lambs were weighed monthly on 2 consecutive days using electronic platform scales. Growth rate during the study period was calculated.

Rumen liquor and blood collection

At the termination of the experimental feeding, rumen liquor was sampled from individual animals using stomach tubes before feeding (0 h) and 4 h post feeding. About 100 ml of a representative sample was drawn from each lamb from

Table 1. Chemical composition of cowpea hay and barley grain produced organically and inorganically.

Constituents	Organic		Inorganic	
Nutrients	Cowpea hay	Barley grain	Cowpea hay	Barley grain
Crude protein (%)	13.6	11.6	14.0	11.9
Organic matter (%)	85.2	93.9	87.9	92.4
Neutral detergent fibre (%)	56.4	36.4	60.2	36.4
Acid detergent fibre (%)	40.3	14.9	43.5	17.3
Cellulose (%)	32.0	7.3	34.6	7.9
Hemicellulose (%)	16.0	21.5	16.7	19.1
Lignin (%)	8.23	1.43	8.91	2.03
Gross energy (kcal/g)	4.3	4.2	4.3	4.5

all parts of the rumen. Rumen pH was measured immediately after collection using a digital pH meter (Systronic pH system 361). Rumen liquor samples were strained through a double layer of muslin cloth. About 80 ml of rumen liquor was preserved with a few drops of saturated mercuric chloride and frozen in labelled polypropylene bottles for estimation of metabolites. The remainder of the rumen liquor was preserved with 10% formalin in polypropylene bottles for microscopic counts.

Blood samples were collected from the jugular veins in air-tight vacutoner tubes using dehydrated EDTA from individual lambs prior to feeding and frozen for blood biochemical analysis.

Analytical techniques and statistical analysis

The DM, ash and CP of feeds offered, refusals and faeces were estimated as per AOAC (1990) and fibre fractions (NDF, ADF, lignin and cellulose) by the method of van Soest *et al.* (1991). Gross energy (GE) concentrations of cowpea hay and barley grain were estimated using a bomb calorimeter (Toshniwal Brothers CLOI/M2). DM digestibility values were used to estimate digestible energy (DE) of diets using the regression equation reported by Fonnesbeck *et al.* (1984). The DE values were converted to ME using the formula reported by Khalil *et al*. (1986).

Total volatile fatty acids (TVFA), total N and ammonia N of rumen liquor were determined following the methods of Briggs *et al*. (1957), McKenzie and Wallace (1954) and Conway (1957), respectively. Blood samples (plasma) were analysed for glucose (Folin and Wu method), protein (MacIntosh and Styke 1927) and urea N concentrations (Rahmatullah and Boyde 1980) as described by Sastry *et al.* (1999). The method described by Moir (1951) was followed for counting the total protozoa in formalised rumen liquor, while holotrichs and entodiniomorphs were identified by the method of Ogimoto and Imai (1981). The data were analysed statistically (SPPS 13.0) in one-way ANOVA using the General Linear Model as per Snedecor and Cochran (1968).

Results

Both groups of lambs ate the feed at similar rates, although there was a tendency for those on the inorganic diet to eat more rapidly initially. Dry matter intakes (DMIs, g/d and g/kg $W^{0.75}$) were not significantly different (P>0.05) in lambs fed inorganic (611.60 and 79.08) and organic (633.62 and 76.45) cowpea hay-barley grain diets (Table 2) as were CP, DCP and ME intakes. The DM, CP and NDF digestibilities of organic diets were 2–2.5 units higher than those of inorganic diets, but differences were not significant. Nitrogen intakes and faecal N losses were comparable in

Table 2. Nutrient intake and digestibility in lambs fed organically and inorganically produced cowpea hay-barley grain diets.

Attributes[1]	Inorganic	Organic	s.e. m	Significance
Intake				
DM (g/d)	612	637	32.6	NS
DM (g/kg $W^{0.75}$)	79.1	76. 5	2.77	NS
CP (g/d)	73.2	70.9		NS
CP (g/kg $W^{0.75}$)	9.47	8.80	0.237	NS
DCP (g/d)	48.4	48.4		
DCP (g/kg $W^{0.75}$)	6.27	6.05	0.109	NS
ME (kcal/d)	1454	1411	69.9	NS
ME (kcal/kg $W^{0.75}$)	187.7	174.7	5.24	NS
Digestibility (%)				
DM	61.2	63.6	1.04	NS
OM	65.1	67.4	1.01	NS
CP	66.3	69.1	1.40	NS
NDF	52.9	55.5	1.44	NS
ADF	50.9	52.9	1.37	NS
Cellulose	60.2	59.9	0.96	NS
Hemicellulose	54.2	54.7	0.71	NS

[1]DM = dry matter, DCP = digestible crude protein, ME = metabolisable energy, OM = organic matter, CP = crude protein, NDF = neutral detergent fibre, ADF = acid detergent fibre.

both groups. Urinary N loss was significantly (P<0.05) higher in lambs fed an inorganic (2.04 g/d) than in those on an organic diet (1.34 g/d; Table 3). This resulted in higher N retention for lambs on the organic diet than for those on the inorganic diet (6.38 *vs* 5.68 g/d), but again the difference was not significant. Nutritive values (DCP %, DE and ME Mcal/kg DM) were comparable (P>0.05) in both organic and inorganic diets.

Total weight gains of lambs during the study were similar for both groups (14.1 *vs* 13.9 kg; Table 4). While wool growth of the organic group exceeded that of the inorganic group (968 *vs* 926 g), the difference was not significant. The food conversion ratio (FCR), crude protein conversion ratio (CPCR) and metabolisable energy conversion ratio (MECR) were identical in lambs fed the organic and inorganic diets.

Rumen pH was significantly (P<0.05) lower in lambs on the organic diet than on the inorganic diet at both 0 and 4 h post feeding (Table 5). TVFA level in rumen liquor of the organic lambs was also higher (P<0.05) at 4 h post feeding than in the inorganic group (128.4 *vs* 92.9 meq/l) as was total-N concentration (99.4 *vs* 90.8 mg/100 ml). The concentrations of blood metabolites, namely plasma urea, plasma protein and blood glucose, were not affected by the type of diet.

Table 3. Nitrogen utilisation and nutritive value in lambs fed organically and inorganically produced cowpea hay-barley grain diets.

Attributes	Inorganic	Organic	s.e. m	Significance
N balance				
N intake (g/d)	11.70	11.34	0.517	NS
Faecal N (g/d)	3.97	3.60	0.306	NS
N absorbed (g/d)	7.73	7.73	0.256	NS
Urinary N (g/d)	2.04	1.34	0.179	*
N retained (g/d)	5.68	6.38	0.282	NS
N retention (% intake)	48.54	56.26	1.326	NS
Nutritive value[1]				
DCP (%)	7.97	8.56	0.266	NS
DE (Mcal/kg DM)	2.89	2.99	0.708	NS
ME (Mcal/kg DM)	2.37	2.45	0.036	NS

[1]DCP = digestible crude protein, DE = digestible energy, ME = metabolisable energy.

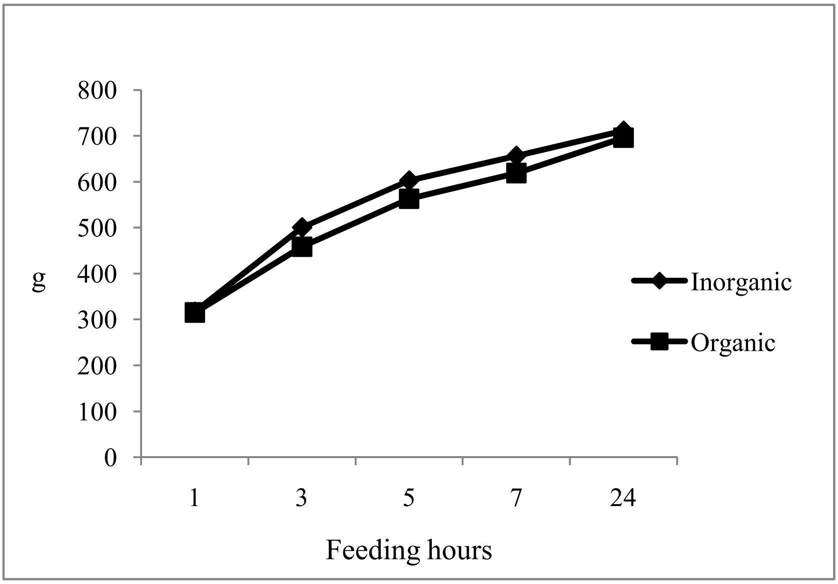

Figure 1. Cumulative daily feed consumption of lambs fed organically and inorganically produced cowpea hay-barley grain diets.

Table 4. Growth and wool production of lambs fed organically and inorganically produced cowpea hay-barley grain diets.

Attributes[1]	Inorganic	Organic	s.e. m	Significance
Initial weight (kg)	13.11	13.12	0.523	NS
Final weight (kg)	27.24	27.02	0.957	NS
Total gain (kg)	14.13	13.90	0.683	NS
Growth rate (g/d)	71.8	70.4	3.51	NS
FCR	8.50	8.97	0.593	NS
CPCR	1.04	1.03	0.063	NS
MECR	88.8	85.4	1.30	NS
Wool yield (g)	925.8	967.5	47.27	NS

[1]FCR (feed conversion ratio) = kg of DMI per kg weight gain; CPCR (crude protein conversion ratio) = kg of CP intake per kg weight gain; MECR (metabolisable energy conversion ratio) = M joules of ME intake per kg weight gain.

Table 5. Rumen fermentation and microbial activity in lambs fed organically and inorganically produced cowpea hay-barley grain diets.

Attributes[1]		Inorganic	Organic	s.e. m	Significance
Rumen metabolites					
pH	0 h	7.16	7.07	0.022	*[2]
	4 h	6.83	6.46	0.077	*
TVFA (meq/L)	0 h	68.26	73.48	1.862	NS
	4 h	92.92	128.42	9.592	*
Total-N (mg/100 ml)	0 h	73.17	79.63	2.359	NS
	4 h	90.77	99.37	2.114	*
NH_3-N (mg/100 ml)	0 h	21.29	14.73	1.436	NS
	4 h	32.48	37.33	2.186	NS
Blood parameters					
Plasma urea (mg/dl)		13.83	14.15	1.081	NS
Plasma protein (mg/dl)		10.27	9.84	0.391	NS
Glucose (mg/dl)		56.20	54.54	1.126	NS

[1]TVFA = total volatile fatty acids; total-N = total nitrogen; NH_3-N = ammonia nitrogen.

[2]Means within rows with an asterisk differ significantly at P<0.05.

Table 6. Microbial counts in rumen liquor of lambs fed organically and inorganically produced diets

Microbes	Inorganic	Organic	s.e. m	Significance
Total bacteria ($x10^{10}$/ml)	7.98	9.08	0.244	*[1]
Total protozoa ($x10^5$/ml)	4.43	5.21	0.149	*
Holotrichs ($x10^5$/ml)	1.04	1.18	0.059	NS
Entodiniomorphs ($x10^5$/ml)	3.41	4.01	0.101	*
Fungal count ($x10^5$/ml)	1.1	1.5	0.071	NS

[1]Means within rows with an asterisk differ significantly at P<0.05.

Concentrations of total bacteria and protozoa were significantly (P<0.05) higher in rumen liquor of organic lambs than inorganic lambs (9.08 *vs* 7.98 x 10^{10}/ml; and 5.21 *vs* 4.43 x 10^5/ml, respectively) (Table 6). Similarly, entodiniomorph protozoa counts were significantly (P<0.05) higher in the organic than the inorganic group, while holotrichs and sporangia counts were similar on both diets.

Discussion

This study has shown that there was virtually no difference in growth or wool production of lambs fed on organically or inorganically produced cowpea hay-barley grain diets. As there were no significant differences in feed intake or digestibility of the diets, differences in performance could not be expected. The absence of intake differences on the organic and inorganic diets supports the findings of Bystrom *et al.* (2002) and Singh *et al*. (2008), who observed no significant difference (P>0.05) in feed intake of lactating cattle fed organically and inorganically produced diets. Similarly, Singh *et al*. (2009) had failed to observe differences in eating pattern and meal consumption with organic and inorganic diets in Tharparkar heifers.

While there were suggestions from the data that the organic diet might have been digested better than the inorganic one, differences were not significant. The lower rumen pH readings at 4 hours post feeding in the organic lambs were supported by the higher total volatile fatty acid levels and total-N at this time. Since total bacteria and total protozoa counts were superior in organic lambs, these indicators of higher or more rapid breakdown of the organic diet were not surprising. This pattern of lower pH and higher TVFA concentration in the organic group is in agreement with earlier observations (Raghuvansi *et al.* 2007). Despite greater urinary nitrogen excretion in the inorganic lambs, they were still able to produce liveweight gains and wool growth equivalent to those of the organic lambs. The higher N retention and lower urinary loss in Tharparkar cattle fed an organic diet reported earlier (Singh *et al*. 2009) are consistent with our present findings. The nutritive values (DCP, DE and ME concentrations) of organic and inorganic diets were comparable in both groups of lambs, which supports the results of Singh *et al*. (2006) with growing lambs.

Similarly, Arnon *et al.* (1947) failed to show significant differences in growth rates of guinea pigs fed grass from plots with histories of organic or inorganic manuring, and Singh *et al*. (2009) observed no effect of fertiliser type (organic *vs* inorganic) on growth rate in Tharparkar heifers. While Balfour (1975) suggested that organically grown feed may have some benefit for animal health and performance (more milk production in cows fed organic diet), Greaves and Scott (1959) and Miller and Dema (1958) showed no benefits on animal health and production from consumption of organically grown feed. However, Roesch *et al.* (2005) observed lower body weight of organic production cows than integrated production cows, though the reductions in body weight during dry and lactation periods were similar between systems. In one study, the effect of fertiliser (control *vs* manure *vs* chemical fertiliser) on nutritional value of wheat and millet in terms of chemical composition and livestock feeding was assessed by MacCarrison (1926). He recorded 10–15% more vitamin A in wheat and millet treated with manure than with chemical fertiliser along with better animal growth, but it was difficult to ascertain the reliability of these results owing to lack of statistics and unclear methodology. The similar FCR, CPCR and MECR in lambs fed the two diets are in agreement with the findings of earlier workers (Basra *et al.* 2003; Mahmoudzadeh *et al*. 2007).

Blood constituents serve as monitors of change in intake and metabolism of energy (Kunz *et al.* 1985; Reist *et al.* 2002) and protein (Clement *et al.* 1991). The concentrations of various blood metabolites were identical in lambs on both diets and were within the normal range (Mahanta *et al.* 1999; Singh *et al.* 2006; Raghuvansi *et al*. 2007), reflecting the similar energy and nutrient intakes in both organic and inorganic lambs. Similarly, Roesch *et al.* (2005) observed no difference in blood metabolites, except blood urea and IGF-I concentration, of dairy cows maintained on farms with organic production and conventional/integrated production.

Conclusions

This study has shown that an organically grown cowpea hay-barley grain diet will produce similar performance in lambs as an inorganically grown diet. While some differences between the diets in terms of rumen microflora and nitrogen retention were detected, this had no significant effect on the production parameters of liveweight gain and wool growth. This suggests that farmers can select their fertiliser strategies on the basis of cost and environmental issues with little concern for potential benefits of organic fertilisers for animal performance.

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