EFFECTS OF ACTIVATED CARBON ON GROWTH, RUMINAL CHARACTERISTICS, BLOOD PROFILES AND FEED DIGESTIBILITY IN SHEEP

E. P. Garillo, R. Pradhan and H. Tobioka[1]

School of Agriculture, Kyushu Tokai University Kumamoto 869-14, Japan

Summary

This study was carried out to investigate the effects of activated carbon (AC) on growth, ruminal charateristics, blood profiles and feed digestibility in sheep, using roughage-based or concentrate-based diets. Twelve Suffolk breed of sheep of similar age and weight were distributed into 4 groups in a 2 × 2 factorial design. Two groups were fed a roughage-based diet with (R + AC) and without AC (R − AC), while the other two were fed a concentrate-based diet with (C + AC) and without AC (C − AC), respectively. The addition of 0.3% AC was based on dry matter of feed offered to animals. The incorporation of AC in roughage and concentrate based diets had no marked effects on feed intake, daily gain and feed conversion of the animals within experimental diets. The results obtained might be due to the low level of AC added in the diet. The animal on both concentrate-based diets were higher than the roughage-based diets in terms of daily gain and feed conversion ratio. However, it was observed that the animals provided with AC in the concentrate-based diet did not suffer from diarrhea and easily adjusted to high concentrate feeding. Further, the pH value for all diets before feeding was noted to be similar. After feeding, however, pH was shown to be higher in R + AC ($p < 0.05$) than in C + AC diet. Rumen protozoa number was decreased after feeding for both + AC diets, but in C − AC diet it was higher than in the roughage-based diets. For ammonia-nitrogen, C − AC was found to be higher than C + AC diet and the roughage-based diets before feeding. Total volatile fatty acid concentration, propionate and valerate molar ratios for both diets and time of collection were not affected. However, acetate, butyrate and valerate molar ratios were observed to be affected by diets and time of collections. The diets with AC increased ($p < 0.05$) before feeding for acetate molar ratio, but not different within diet, however, the roughage diets were found to be higher ($p < 0.05$) in acetate than the concentrate diet. In the blood parameters, the glutamic pyruvic transaminase (GPT), red and white blood cell (RBC, WBC) counts and packed cell volume (PCV) did not differ within and among the diets. Likewise, the WBC differential count in both diets with either − AC or + AC were similar in trend. However, lymphocyte count was noted to be increased in R + AC than the R − AC diet. The addition of AC in both diets did not affect nutrient digestibilities within diets.

(**Key Words** : Activated Carbon, Growth, Ruminal Characteristics, Blood Profiles, Digestibility)

Introduction

In general, feed additives are classified into three categories, namely : the agents relating to production efficiency of livestock, the chemicals that prevent diseases and the agents that preserve feed quality (Japan Veterinary Society, 1986). These groups have their own advantages and disadvantages in livestock feeding. However, feed additives can be sub-classified as therapeutic or prophylactic, growth promoters, simple chemical additives, palatability enhancers and non-nutritional additives (Wilson and Brigstocke, 1981). The feed additive, activated carbon (AC) which was used in this study can be classified either as a non-nutritive or simple chemical additive which has the capacity to adsorb inorganic and organic substances and colloidal particles. It is a black, solid nonlustrous residue produced by charring coconut shell and activated by heating in steam. AC is generally used for clarifying, deodorizing, decolorizing and filtering in liquid or solid preparation. It also serves as an antidote, an internal adsorptive agent in diarrhea and as a treatment for external foul wounds (The Merck Index, 1976).

The addition of AC in high concentrate diets for

[1]Address reprint requests to Prof. H. Tobioka, Department of Animal Science, School of Agriculture, Kyushu Tokai University Kumamoto 869-14, Japan.

Received December 23, 1993
Accepted September 26, 1994

ruminants has been tried by some beef cattle operators in Japan, expecting to improve the performance of their animals based on feed efficiency, carcass characteristics and to have low morbidity/mortality rate in high concentrate feeding. The feeding scheme with a high concentrate has been practiced to obtain a quality carcass with better marbling quality. However, the adaptation to this scheme have brought some diseases and clinical disorders (Motoi, 1988). Nevertheless, the use of some feed additives proved to have some residues in the liver and meat after slaugthering (Honikel, et al. 1978).

A dearth of scientific investigations have worked along the use of AC. Preliminary experiments conducted by Tobioka et al. (1991) on the effects of AC on growth of golden hamsters increased the feed intake which resulted in high growth of the animals. They also noted increased ruminal pH of the forestomach and cecum, and increased protozoa count in forestomach by the addition of 0.3% AC. These results would suggest that AC might affect the ruminal characteristics since the forestomach of hamsters is similar in function to the rumen of ruminants (Manda, 1979) and AC might help to solve the aforementioned problems on concentrate-based feeding.

In the present study, using roughage-based or concentrate-based diets, the effects of AC in mature sheep were investigated.

Materials and Methods

A baled Bermuda grass hay and formula feed (Kumamoto Livestock Coop. Special, DE 3.2Mcal/kgDM, DCP 13.0%) were used as the experimental diets. The ratio of roughage to concentrate was 80 to 20 in the roughage-based diet (roughage diet) and 20 to 80 in the concentrate-based diet (concentrate diet). The formula feed composed of barley, corn, milo, soy bean meal, bran and mineral mixtures. Twelve healthy female suffolk sheep of similar age (12-13 months) and weight (38 kg in average) were used for 6-week experimental period. The animals were equally divided and distributed into four groups with 3 animals each. The concentrate diet was offered to 2 groups and the roughage diet to the other 2 groups. The AC was given to one of the groups on concentrate and roughage diets. The AC was incorporated at a rate of 0.3% of the dry matter feed offered equivalent to 2.8% of the animal body weight. The AC was mixed with the concentrate diet just before feeding. Feeds were offered twice a day at 08:30 in the morning and 04:00 in the afternoon. Weekly intake for both the roughage and concentrate were recorded. Dry matter requirements of the experimental animals were determined weekly by measuring their body weight. The animals were housed in an individual metabolic cages provided with a feeding and drinking trough. The room temperature was maintained at about 20-25 ℃ throughout the study. The animals were dewormed, injected with vitamin AD_3E and administered anti-filariasis drug. An adjustment period of two weeks was initiated in order for the animals to adjust to the experimental diets.

Pooled feed samples for analysis were taken from every batch of feeds offered during the entire duration of the study. For the chemical analysis of the diets, pooled samples were oven dried at 55 ℃ for about 48-72 hours and then ground through a 1 mm mesh screen by using a Willey grinder.

Rumen and blood samples were taken at the 6th week of the experimental period. Rumen fluid was taken just before feeding at 08:30 in the morning and 4 hours later. A specially designed plastic catheter (Denka Pharmacy Co., Ltd., Tokyo, Japan) was used in collecting rumen liqour through the mouth. Blood samples were taken from the jugular vein by use of sterelized needles and air-vacuumed tubes. Blood samples were centrifuged at 2000 × g for 15 minutes and serum was isolated, then refrigerated for later analysis.

Pooled fecal samples for digestibility analysis were collected for three consecutive days during the last 3 remaining days in the 6th week of feeding period. Samples were oven dried at 55 ℃ for about 48-72 hours and then ground through a 1 mm mesh screen by using a Willey grinder.

Proximate analysis of the feeds was performed by the AOAC (1984) standard procedures. The components measured were dry matter (DM), crude protein (CP), crude ash, acid detergent fiber and neutral detergent fiber (NDF). The gross energy was determined using an automatic bomb calorimeter (CA-3P. Shimadzu Corp., Kyoto, Japan).

A glass electrode pH meter (L-7 LC, Horiba Ltd., Kyoto, Japan) was used for determining the pH of ruminal fluid. Ammonia nitrogen (N) was analyzed by the micro-diffusion technique of Conway (1957). The protozoa number was evaluated using the Fuchs Rosenthal deep 0.2 mm haematometer, following the procedures described by Ogimoto and Imai (1981).

A gas liquid chromatograph instrument (GC-7AG, Shimadzu Corp., Kyoto, Japan) was used to determine volatile fattly acids (VFA) of the rumen fluid principally following the analytical procedures described by Tobioka and Kato (1986). Briefly, rumen samples were treated with mercuric chloride and 5 ml of rumen fluid was made up to the total volume of 10 ml by adding acetone-phosphoric acid (2.0%) solution. The samples were frozen

overnight and were kept at room temperature for about 10-15 minutes before centrifugation at 2000 × g for 15 minutes. After centrifugation, 4 ml of the supernatant was mixed with 1 ml internal standard of phenol solution (0.4%).

The enzyme activity, glutamic pyruvic transaminase (GPT) was analyzed following the modified procedure of Reitman & Frankel as described by Nakamura et al. (1981). An Erma improved Neubauer deep 0.1 mm haematometer was used to determine the red and white blood cell (RBC, WBC) counts. The WBC differential count test was performed using a hemacolor rapid blood smear staining set for microscopy (Diagnostic Merck Co., Darmstadt, Germany). Packed cell volume (PCV) value was analyzed by micro hematocrit method.

The feed digestibility was analyzed through the natural marker method, using acid insoluble ash (AIA). The analytical procedure of AIA was based on the method described by Van Keulen and Young (1977), but slight modification was made in our Laboratory. All analyses were replicated three times.

All pertinent data were recorded and analyzed using 2 × 2 factorial design in Complete Randomized Design (CRD).Comparison among means were done using Tukey's t-Test procedure by Steel and Torrie (1980).

TABLE 1. CHEMICAL COMPOSITION OF THE EXPERIMENTAL DIETS

	DM %	g / 100 g DM				GE(cal /gDM)
		CP	Ash	ADF	NDF	
Bermuda grass hay	91.09	7.84	7.88	32.96	74.08	4,050
Formula feed	88.82	16.32	6.24	6.76	23.00	4,091
Activated carbon	96.46	0.72	36.92	–	–	–

Dry matter, crude protein, crude ash, acid detergent fiber, neutral detergent fiber and gross energy are represented by DM, CP, Ash, ADF, NDF and GE, respectively.

Results and Discussion

Table 1 presents the chemical composition of the pooled experimental diets. The baled imported Bermuda grass hay had a low CP content, 7.84% and high NDF of 74.08%. The formula feed had CP and NDF values of 16.32% and 23.0%, respectively.

The effect of AC on body weight, feed intake, feed conversion and daily gain of the animals are presented in table 2. As expected due to type of feed offered, the differences among diets have shown to be higher ($p < 0.05$) and improved in concentrate diets both in daily gain and feed conversion ratio. The AC had no marked effects on daily gain, feed intake or feed conversion of the animals, as compared to the corresponding treatments without AC. The no improvement observed on growth and feed conversion might be due to the low level of AC added in the diets. Results obtained were quite different from the previous experiment of Tobioka et al. (1994) in growing cattle where a marked increase in daily gain and feed conversion were observed for the animals fed concentrate diet with 0.3% or 0.5% AC. The AC has a similar physical characteristics to buffering substances and bentonite in terms of buffering (Garillo et al., 1994) and adsorbance capacity, respectively. Low levels of buffers commonly do not affect feed intake (Dunn et al., 1979; Kilmer et al., 1980), however, 2-6% sodium bicarbonate improved feed intake and weight gain of feedlot cattle (Nicholson et al., 1963). On the other hand, the feeding of 2% bentonite, 4% bentonite or 2% sodium bicarbonate

TABLE 2. GROWTH PARAMETERS OF THE EXPERIMENTAL ANIMALS

	IBW	FBW	DG	FI	FCR
R −AC	38.33	44.06	0.14^{ab}	1.22	9.31^{ab}
R +AC	39.06	43.63	0.11^{a}	1.16	11.16^{b}
C −AC	37.13	48.60	0.28^{c}	1.25	4.54^{a}
C +AC	38.33	47.16	0.21^{bc}	1.23	5.89^{a}
SEM	1.48	2.07	0.02	0.07	1.10
Main effects					
Diet			**	*	**
AC					
diet × AC					

Figures with different superscipts in a column differ significantly ($p < 0.05$).

Roughage-based diet with and without AC, concentrate-based diet with and without AC, initial body weight, final body weight, daily gain, feed intake and feed conversion ratio are represented by R −AC, R +AC, C −AC, C +AC, IBW, FBW, DG, FI and FCR, respectively.

Level of significance : * $p < 0.05$, ** $p < 0.01$.

was only beneficial to lambs during the initial 21 days of a high-concentrate feeding regime as evidenced by improved (nonsignificant) daily gain and feed conversion (Huntington et al., 1977). Other possible reason for the lower growth performance of animals provided AC diets might be due to the lower DM intake in terms of rate to body weight on the diets with AC than those of diets without AC. The factors associated with the effects of AC should be elucidated.

The effect of AC on ruminal characteristics, i. e. pH, ammonia-N, protozoa count and VFA are summarized in tables 3a and 3b. The pH values obtained for animals fed AC diets before feeding seem to be slightly lower and higher than those in roughage or concentrate diets without AC, respectively. Slight difference of ruminal pH between AC diets before feeding might suggest that AC has a prolonged buffering effect or adsorbance capacity due to its enormous surface area. This agreed to some extent with the results obtained by Ha et al.(1985) who revealed that feeding buffers generally increased ruminal pH. However, 4 hours after feeding, pH declined in the concentrate diets and was noted to be higher ($p < 0.05$) in the R +AC than in the C +AC which could be accounted for the compositon of the diet. This trend was attributed mainly to the quantity of available carbohydrates in the diets. It can be described that there were inconsistencies on the effect of AC in pH within diets and time of collection. However, Tobioka et al. (1991) revealed that the pH of the forestomach and the cecum were slightly increased 4 hours after feeding AC diets in 35 days old hamsters. Further, Garillo et al. (1994) noted that the ruminal pH tended to increase slightly in the 0.3% and 0.6% AC diets 4 hours after feeding in mature goats. Bunn and Matrone (1968) also reported that addition of buffers to purified and semipurified high concentrate diets elevated ruminal pH.

The levels of ruminal ammonia-N concentration for C −AC and C +AC diets were higher than those for roughage diets, while they were very similar within the diets for each period. The C +AC before feeding was noted to be lower ($p < 0.05$) in value than C −AC diet. A similar tendency was observed by Garillo et al. (1994) in mature goats where the ruminal ammonia-N tended to be lower in 0.6% AC diet than in reference diet before and after feeding.

The total number of rumen protozoa was observed to be insignificantly different among the diets before feeding, however, protozoa number tended to increase in +AC diet. After feeding, C −AC was found to be higher in protozoa number as compared to the roughage diets. However, in C +AC diet the protozoa number was noted to decrease after feeding. Tobioka et al. (1991) revealed that the protozoa count in cecum of golden hamsters fed on concentrate diet with AC was lower than that of the reference group. The effect of AC on protozoa is somewhat inconsistent due to type of diets and animal species.

TABLE 3a. EFFECTS OF AC ON RUMINAL CHARACTERISTICS

Dite	Time	pH	NH_3-N (mg / 100ml)	Protozoa (10^4 / ml)
R − AC	BF	6.96	10.33^{ab}	31.25
R + AC	BF	6.74	9.94^{a}	45.42
C − AC	BF	6.50	38.05^{c}	121.61
C + AC	BF	6.64	23.62^{b}	142.60
SEM		0.14	2.90	37.03
Main effects				
Diet			*	**
AC			*	
Diet × AC			*	
R − AC	AF	6.69^{ab}	15.20	31.15
R + AC	AF	6.74^{b}	14.49	31.30
C − AC	AF	6.08^{ab}	21.77	126.46
C + AC	AF	6.05^{a}	22.37	90.10
SEM		0.15	1.81	18.97
Main effects				
Diet		**	**	**
AC				
Diet × AC				

Figures with different superscripts in a column within period differ significantly ($p < 0.05$).
BF = Before feeding AF = After feeding.
Level of significance : * $p < 0.05$, ** $p < 0.01$.

The total VFA concentrations, propionate and isobutyrate molar ratios were not affected for both diets and time of collection. However, molar ratios of acetate, butyrate and valerate were noted to be affected by the diets and time of collection. The molar ratio of acetate in both roughage diets were found to be higher ($p < 0.05$) than those of the concentrate diets before feeding. However, after feeding roughage diets were found to be similar in acetate to that of C +AC diet, but R −AC was found to be higher ($p < 0.05$) than C −AC diet. A reversal trend was noted in butyrate molar rario to that of acetate where butyrate tended to decrease after feeding in concentrate diets. Although the trend for butyrate in C −AC diet was found to be higher ($p < 0.05$) than roughage diets before and after feeding, but not different

TABLE 3b. EFFECTS OF AC ON VFA CONCENTRATION

Diet	Time	Tot. VFA (mMole)	Molar ratio (%)						
			C2	C3	i - C4	n - C4	i - C5	n - C5	n - C6
R − AC	BF	80.86	72.31^{b}	14.56	1.22	8.73^{a}	1.47^{a}	0.84^{a}	0.83
R + AC	BF	81.05	73.34^{b}	15.32	1.05	8.51^{a}	1.51^{a}	0.89^{ab}	0.60
C − AC	BF	79.74	59.02^{a}	16.45	2.00	18.13^{b}	2.43^{b}	1.43^{c}	0.48
C + AC	BF	85.43	62.28^{a}	16.39	2.07	14.62^{ab}	2.50^{b}	1.19^{bc}	0.92
SEM		7.75	1.69	0.85	0.27	1.63	0.16	0.08	0.19
Main effects									
Diet			**			**	**	**	
AC									
Diet × AC									
R − AC	AF	94.88	74.01^{b}	13.75	0.97	9.21^{a}	1.02	0.81^{a}	0.21^{a}
R + AC	AF	89.81	69.21^{ab}	15.93	1.27	11.22^{a}	1.09	1.01^{a}	0.20^{a}
C − AC	AF	89.64	63.84^{a}	16.28	1.05	16.11^{b}	1.31	1.24^{ab}	0.18^{a}
C + AC	AF	89.05	65.41^{ab}	18.23	1.01	12.34^{ab}	1.38	1.36^{b}	0.39^{b}
SEM		6.43	1.75	2.17	0.23	0.82	0.12	0.10	0.03
Main effects									
Diet			**			**		**	*
AC									*
Diet × AC									**

Figures with different superscripts in a column within period differ significantly ($p < 0.05$)
Level of significance : * $p < 0.05$, ** $p < 0.01$)

from that of C + AC diet. The propionate molar ratio on AC diets seems to be increased after feeding than those of the diets without AC. Furthermore, C + AC diet was observed to be higher ($p < 0.05$) in caprorate than C − AC and roughage diets after feeding. Garillo et al. (1994) observed in mature goats that the concentrations of the total VFA and propionate molar ratio tended to be higher in 0.6% AC diet than in 0.3% AC and the reference diets only after feeding. With the increased tendency for propionate molar ratio 4 hours after feeding, it seems to suggest that AC has the effect similar to salinomycin and monensin as described by Tobioka et al. (1986) and Ushida et al. (1985), respectively where the addition of these antibiotics increased the molar proportion of ruminal propionate. Erdman et al. (1982) however, observed that total VFA were increased by the addition of magnesium oxide, while the addition of sodium bicarbonate and magnesium oxide increased rumen molar percentage of acetate and reduced propionate. Therefore AC was considered to have a different mode of action from buffering substances in respect to VFA production.

Data on tables 4a and 4b present the effects of AC on blood profiles of the animals. The incorporation of AC in both concentrate and roughage diets has shown no difference in GPT enzyme activity before and 4 hours after feeding. This blood profile information is necessary, since GPT is an indicator directly linked to physiological function of liver and Schafer and Wener (1974) recommended the use of GPT activity as part of a profile to organize prophylactic schemes on animals. Tobioka et al. (1991) reported that the GPT activity of hamsters fed with commercial formula feed plus AC was comparatively lower than those of the hamsters fed with commercial formula feed. However, Garillo et al. (1994) observed that GPT activity in goats fed with 0.3% AC diet was similar to that on reference diet before and after feeding. It was considered that the effect of AC on GPT is not consistent.

The RBC and WBC counts were not found to be different within and among the diets. However, Garillo et al. (1994) observed that the RBC count of mature goats offered 0.3% AC diet were slightly higher than that of the reference diet. The PCV of the animals for the concentrate diets with and without AC were noted to be very similar in values. Ha et al. (1985) revealed that high concentrate diets generally decreased the PCV values. The results obtained agreed with the report of Tobioka et al. (1991) on the PCV of golden hamsters fed with AC. They observed very similar values throughout the two

experimental periods. The WBC differential count was performed to ascertain the probable effects of AC on blood profile since no information was available at present. WBC differential count in the roughage diet with AC was found to be increased in lymphocyte count within the diets, but not significantly different. Other WBC types such as eosinophil, neutrophil and monocyte were found to be similar within the diets.

TABLE 4a. EFFECT OF AC ON BLOOD PROFILES

Diet	Time	GPT (R & FU)	RBC (10^6/mm^3)	WBC (10^3/mm^3)	PCV (%)
R − AC	BF	24.45	10.10	8.38	31.36
R + AC	BF	23.40	10.70	6.54	30.93
C − AC	BF	18.88	9.73	6.74	30.40
C + AC	BF	15.26	9.66	6.88	32.16
SEM		4.20	0.59	0.99	1.56
R − AC	AF	7.48	10.10	10.36	31.78
R + AC	AF	2.74	10.03	8.39	29.56
C − AC	AF	1.16	8.26	11.43	30.76
C + AC	AF	6.01	9.40	8.81	29.68
SEM		1.82	0.65	0.96	1.67
Main effects					
Diet					
AC				*	
Diet × AC					

Level of significance : * $p < 0.05$, ** $p < 0.01$.

TABLE 4b. EFFECT OF AC ON WBC DIFFERENTIAL COUNT (%)

Diet	Time	EOSI	NEUT	LYMP	MONO
R − AC	BF	0.62	22.88	76.15	0.42
R + AC	BF	0.67	25.16	73.67	0.50
C − AC	BF	4.87	26.99	68.64	0.52
C + AC	BF	1.33	26.91	71.22	0.66
SEM		1.88	2.82	3.43	0.27
R − AC	AF	0.42	35.74	63.59	0.25
R + AC	AF	0.41	18.15	81.14	0.34
C − AC	AF	7.25	28.67	68.50	1.25
C + AC	AF	1.83	24.55	73.03	0.00
SEM		0.90	4.33	4.36	0.20
Main effects					
Diet					
AC			*	*	
Diet × AC					

Level of significance : * $p < 0.05$, ** $p < 0.01$.

The effect of AC on nutrient digestibility of the diets are shown in table 5. It can be noted that the digestibility of chemical components within diets were very similar. It was expected that the NDF digestibility for roughage and concentrate diets were different, however, they were quite similar. The digestibility of concentrate diets were higher ($p < 0.05$) in terms of DM, OM and CP values than those of the roughage diets. The results obtained agreed with that of Ha et al. (1985), who reported that buffers did not affect nutrient digestibility. Nicholson et al. (1960) also observed little consistent effect of sodium bicarbonate on digestibility in high roughage diet.

TABLE 5. EFFECT OF AC ON DIGESTIBILITY (%)

Diet	DM	OM	CP	ADF	NDF
R − AC	66.51^{a}	68.23^{a}	66.39^{a}	53.62^{c}	62.39
R + AC	64.39^{a}	66.12^{a}	63.11^{a}	52.67^{bc}	60.60
C − AC	78.42^{b}	80.27^{b}	77.23^{b}	43.83^{a}	60.83
C + AC	78.87^{b}	80.42^{b}	76.41^{b}	43.05^{a}	60.37
SEM	1.06	0.98	1.93	1.08	0.98
Main effects					
Diet	**	**	**	**	
AC					
Diet × AC					

Figures with different superscripts in a column differ significantly ($p < 0.05$).
Level of significance : * $p < 0.05$, ** $p < 0.01$.

The results of our investigation in sheep showed that the incorporation of AC at 0.3% level to the dry matter of feed offered to the animals had no marked effects on growth, ruminal characteristics, blood profiles and feed digestibility. The responses of animal to buffering materials including AC have been somewhat variable, and these inconsistencies may be associated with factors such as the rate of addition, the basal diets, levels of feed intake, differences among buffering sources and/or abilities, animal species and individual animal differences (Wheeler, 1979; Emery and Brown, 1961; and Miller et al., 1965; Tobioka et al., 1994; and Garillo et al., 1994). However, it was observed that animals fed on a high concentrate diet with AC did not suffer from diarrhea or bloat, and easily adjusted to high concentrate diet during the preliminary feeding period of 2 weeks.

It is recommended that further studies on AC with growing-fattening sheep involving high concentrate diets should be carried out in order to come up with better understanding of the AC effects in ruminants.

Literature Cited

Association of Official Analytical Chemists. 1984. Official Methods of Analysis. 14th ed. AOAC, Washington, D.C.

Bunn, C. R. and J. G. Matrone. 1968. Dietary factors affecting utilization of urea nitrogen by sheep in purified diets. J. Nutr. 95:122.

Conway, E. J. 1957. Microdiffusion analysis and volumetric error. 4th ed. London : Crosby, Lockwood and Sons, Ltd.

Dunn, B. H., R. J. Emerick and L. B. Embry. 1979. Sodium bentonite and sodium bicarbonate in high-concentrate diets for lambs and steers. J. Anim. Sci. 48:764-769.

Erdman, R. A., R. W. Hemken and L. S. Bull. 1982. Dietary sodium bicarbonate and magnesium oxide for early postpartum lactating dairy cows :Effects on production, acid-base metabolism and digestion. J. Dairy Sci. 65:712-731.

Emery, R. S. and L. D. Brown. 1961. Effect of feeding sodium and potassium bicarbonate on milk fat, rumen pH and volatile fattly acid production. J. Dairy Sci. 44:1899.

Garillo, E. P., R. Pradhan and H. Tobioka. 1994. Effects of activated charcoal on ruminal characteristics and blood profiles in mature goats. West Japan J. Anim. Sci. 37:85-89.

Ha, J. K., Y. H. Choi, In K. Han and C. Y. Yuk. 1985. Effect of $NaHCO_3$, MgO or combinations on ovine rumen fermentation. Proc. 3rd AAAP Seoul, Korea pp. 772-774.

Honikel, K. O., U. Schmidt, W. Woltersdorf and L. Leistner, 1978. Effect of storage and processing on tetracycline residues in meat and bones. J. Anim. Sci. 61:1222-1227.

Huntington, G. B., R. J. Emerick and L. B. Embry. 1977. Sodium bentonite or sodium bicarbonate as aids in feeding high concentrate diets to lambs. J. Anim. Sci. 45:804-811.

Japan Veterinary Society. 1986. In; Six Laws of Veterinary Matter and Animal Production. New Japan Law Publishers, Inc., Tokyo, Japan. p 495 (in Japanese)

Kilmer, L. H., L. D. Muller and P. J. Wangsness. 1980. Addition of sodium bicarbonate to rations of pre and postpartum dairy cows. J. Dairy Sci. 63:2026.

Manda, T. 1979. Nutrition and forage utilization charactersitics of golden hamsters. Proc. Soc. Anim. Nutr. Metabolism. 23:111-128. (in Japanese with English tables)

Miller, R. W., R. W. Hemken, D. R. Waldo, M. Okamoto and L. A. Moore. 1965. Effect of feeding buffers to dairy cows fed a high concentrate, low roughage ration. J. Dairy Sci. 48:1455.

Motoi, Y. 1988. Present status on animal disease due to low fiber intake. J. Japan Grassl. Sci. Popular version. 10:24-31 (in Japanese)

Nakamura, R., S. Yonemura and K. Sudoh. 1981. Clinical diagnosis of cattle. Nosangyosou Bunkakyokai. Tokyo, Japan. p 54-56. (in Japanese)

Nicholson, J. W. G., H. M. Cunningham and D. W. Friend. 1963. Effect of adding buffers to all concentrate rations on feedlot performance of steers, ration digestibility and intrarumen environment. J. Anim. Sci. 22:368.

Ogimoto, K. and S. Imai. 1981. Atlas of rumen microbiology. Japan Sci. Soc. Press. Tokyo, Japan. p158.

Okeke, G. C., J. G. Buchanan-Smith and W. L. Grovum. 1983. Effects of buffers on ruminal rate passage and degradation of soybean meal in steers. J. Anim. Sci. 56:1393-1399.

Preston, T. R., F. G. Whitelaw, N. A. Macleod and E. B. Charleson. 1962. The effect of sodium bicarbonate in all-concentrate diets for early-weaned calves. Anim. Prod. 4:299.

Steel, R. G. D. and J. H. Torrie. 1980. Principles and procedures of statistics. Second Ed., Mc Graw-Hill Book Co., N. Y.

The Merck Index. 1976. An encyclopedia of chemicals and drugs. 9th ed. Merck Co., Inc., Rahway, N. J., USA. p 230.

Tobioka, H. and E. P. Garillo. 1994. Growth performance of Japanese Brown cattle fed concentrate-based diets fortified with activated charcoal. West Japan J. Anim. Sci. 37:48-53.

Tobioka, H. and M. Kato. 1986. Methods of sample preparation for determination of volatile fatty acids in rumen fluid. Proc. Facul. Agric. Kyushu Tokai Univ. 5:77-82. (in Japanese with English summary)

Tobioka, H., M. Kikuchi and M. Kato. 1986. Effect of salinomycin on feed digestibility of growing heifers of Japanese Brown breed. Proc. Facul. Agric. Kyushu Tokai Univ. 7:33-36. (in Japanese with English summary and tables)

Tobioka, H., O. Tezuka and M. Kato. 1991. The effect of charcoal on chemical attributes in forestomach, cecum and blood of golden hamster. Proc. 3rd Int. Symp. Nutr. Herbivores. Penang, Malaysia. p 50.

Turner, H. A., R. J. Raleigh and D. C. Young. 1977. Effect of monensin on feed efficiency for maintaining gestating mature cows wintered on meadow hay. J.

Anim. Sci. 44:338-342.

Ushida, K., Miyazaki and K. Kawashima. 1985. Effect of *monensin on ruminal* VFA and gas production of sheep fed high concentrate diet. Japan. J. Zootech. Sci. 56:822-826.

Van Keulen, J. and B. A. Young, 1977. Evaluation of acid-insoluble ash as a natural marker in ruminant digestibility studies. J. Anim. Sci. 44:282-287.

Wheeler, W. E. 1979. Particle size of limestone in cattle rations influences gastrointestinal tract response. Feedstuffs. 51:31.

Wheeler, W. E. and C. H. Noller. 1976. Limestone buffers in complete mixed rations for dairy cattle. J. Dairy Sci. 59:1788.

Wilson, P. N. and T. D. A. Brigstocke. 1981. Improved feeding of cattle and sheep. Granada Publishing, London. pp. 124-134.

Wise, M. B., T. N. Blumer, E. R. Barrick and G. Matrone. 1961. Investigations on feeding of all-concentrate rations to beef cattle. J. Anim. Sci. 20:957.