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Factors Influencing Excretory Patterns of Cesium-134, Potassium-42 and Rubidium-86 in Rats.* (22961)

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MacLeod and Snell(1) reported that cesium, potassium, and rubidium behaved similarly in nutrition of lactic acid bacteria. These elements are known to enter the solute complex, participating in ion antagonism, osmosis, permeability regulation, maintenance of colloidal state and similar physiological phenomena(2). Mraz *et al.*(3) observed an increase in excretion of cesium-134 by the rat when dietary potassium was increased. Hamilton(4) reported that cesium excretion was distributed equally between feces and urine. Hood and Comar(5) found that the rat excreted 12 times more cesium-134 in urine than in feces. Mraz and Patrick(6) reported that supplementation of a simplified (casein-corn starch) rat diet with natural feedstuffs decreased the ratio of urinary to fecal excretion of cesium-134 and potassium-42.

This study was initiated to ascertain the factors responsible for these changes in excretory patterns of cesium-134 and potassium-42. Rubidium-86 was also used because of its biological and chemical similarity to cesium and potassium.

Methods and materials. The basal diet employed was the simplified rat diet used by Mraz and Patrick(6). Vermiculite, alfalfa, beet pulp, bentonite, or Amberlite IRC-50 (cation exchange resin) were incorporated at 10% of the diet substituting for an equivalent amount of corn starch in the basal diet. Two potassium-deficient diets were formulated, one from the basal and the other from the 10% vermiculite diet. Four weanling albino rats (Rockland strain) were used per diet in each experiment. All rats were fed their respective diets for 7 days before subcutaneous administration of 0.5 ml of the radioisotope dosing solutions. This period was considered of sufficient length to permit the rat to adjust to the new diet. Five microcuries (μc) of cesium-134 or 20 μc of rubidium-86 were administered to each rat in the cesium and rubidium studies and a 72-hour balance trial made. The short half-life of potassium-42, 12.5 hours as compared to 2.3 years for cesium-134 and 18.6 days for rubidium-86, necessitated the use of 100 μc of the nuclide and only a 48-hour balance trial. All nuclides were administered in the chloride form. Cesium-134 was used at tracer levels, while potassium-42 and rubidium-86 dosages contained 0.38 mg potassium and 0.063 mg rubidium, respectively. *Feces and urine* samples were collected every 24 hours after administration of the nuclides. Excreta were digested with nitric acid and aliquots counted in scintillation well-type counter. In the interest of ease of recording and reading, fecal, urinary, and total excretory data have

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TABLE I. Influence of Some Organic and Inorganic Materials on Excretory Pattern of Cesium-134 in Rats.

Treatment	Excretion* Urinary	Fecal	Total	Ratio of urinary /fecal Cs-134
Basal + K	24.9	1.0	25.9	24.9
" – K	4.4	0.3	4.7	14.2
Vermiculite + K	13.6	25.5	39.1	0.5
" – K	4.3	22.1	26.4	0.2
Alfalfa + K	24.7	2.5	27.2	9.8
Beet pulp + K	21.7	6.2	27.9	3.5
Bentonite + K	14.8	15.4	30.2	1.0
Amberlite IRC-50 + K	22.2	3.2	25.4	7.0
L.S.D.†	8.2	1.4	7.5	

* Expressed as % of subcut. admin. dose/rat.
† Least significant difference between means at 5% level of confidence.

been reported utilizing a maximum of 3 significant figures and are not indicative of sensitivity of the experiments. The ratios were obtained from urinary and fecal excretory data containing 3 significant figures and therefore may differ slightly from the ratios which would be obtained from data reported in the Tables. The 5% level of confidence was the criterion for reporting significance in *in vivo* studies and the 1% level in *in vitro* studies. *In vitro* studies were performed in 125 ml Erlenmeyer flasks. Two flasks were used with 0.5 g of each material (air dried and passed through a sieve, 40 meshes/inch) and 2 were left as blanks to ascertain the influence of adsorption on glass. Twenty-five ml of solutions containing 1 ml of radionuclide dosing solution in 499 ml of distilled water or of 0.1 N solutions of either potassium chloride, hydrochloric acid or sodium chloride were placed in each flask. Standards were removed at this time. The flasks were stoppered and shaken 5 times during the first 3 hours and then permitted to stand for an additional 21 hours. Two aliquots of supernatant solution were then removed from each flask and counted against the standards. In all trials it is believed that results obtained from distilled water solutions of nuclides with bentonite would have been lower if some of the bentonite had not been colloidally suspended.

Results. In the cesium-134 experiment, Table I, a significant reduction in urinary and total cesium-134 excretion and in the ratio of urinary to fecal cesium-134 was noted in rats fed potassium-deficient basal diet when compared to those fed potassium-adequate basal diet. Potassium deficiency in the 10% vermiculite diet induced significant decreases in urinary, fecal and total excretion of cesium-134, when compared to the potassium-adequate vermiculite diet. The excretory ratio was also reduced. Total excretion of cesium-134 on potassium-deficient diet containing vermiculite was approximately equal to that obtained on potassium-adequate basal diet. Rats fed diets containing alfalfa, Amberlite IRC-50, beet pulp, bentonite, or vermiculite had lower excretory ratios and significantly higher fecal cesium-134 excretion than those fed the basal diet. Both bentonite and vermiculite significantly decreased urinary excretion of cesium-134. The *in vitro* studies with cesium-134, Table II, indicated that vermiculite, alfalfa, beet pulp, and bentonite preferentially removed cesium-134 ions from solutions containing potassium, hydrogen, or sodium ions. Amberlite IRC-50, however, appeared to adsorb ions at random. In the presence of other ions, the order of adsorption by materials was vermiculite > bentonite > beet pulp, which was the same as their order in the *in vivo* studies in Table I.

In the potassium-42 experiment, Table III, a significant reduction in urinary and total potassium-42 excretion, was found in rats fed potassium-deficient diets when compared to those fed potassium-adequate diets. No significant difference in urinary or fecal excre-

TABLE II. Cesium-134 Remaining in Solution Expressed as % of Standard Solutions.

Treatment	Cesium-134 diluent .1 N KCl	.1 N HCl	.1 N NaCl	H_2O
None	100	99	96	34
Vermiculite	36	16	6	3
Alfalfa	94	91	82	88
Beet pulp	85	67	49	40
Bentonite	31	31	22	44*
Amberlite IRC-50	98	98	95	10

Least significant difference between means at 1% level of confidence is 2%.
* Supernatant contained suspended particles.

TABLE III. Influence of Some Organic and Inorganic Materials on Excretory Pattern of Potassium-42 in Rats.

Treatment	Excretion* Urinary	Fecal	Total	Ratio of urinary /fecal K-42
Basal + K	15.5	.5	16.1	29.1
" − K	.6	.3	.9	1.9
Vermiculite + K	13.9	1.5	15.4	9.4
" − K	1.1	.6	1.7	1.8
Alfalfa + K	23.6	1.2	24.8	20.5
Beet pulp + K	12.2	2.3	14.5	5.4
Bentonite + K	8.4	3.4	11.8	2.4
Amberlite IRC-50 + K	10.3	5.1	15.3	2.0
L.S.D.†	4.6	1.8	4.3	

* Expressed as % of admin. dose/rat.
† Least significant difference between means at 5% level of confidence.

tion of potassium-42 was observed between rats fed the vermiculite diets and those fed basal diets with comparable potassium levels. The excretory ratios between these two diets containing adequate potassium differed by a factor of three, with vermiculite having the lower ratio. Alfalfa significantly increased urinary and total potassium-42 excretion, but had no significant effect on fecal potassium or on excretory ratio when compared to basal diet. Beet pulp, bentonite, and Amberlite IRC-50 significantly increased fecal potassium-42 excretion and considerably decreased the excretory ratio over that found on basal diet. Bentonite and Amberlite IRC-50 significantly decreased urinary potassium-42 excretion. In the *in vitro* studies with potassium-42, Table IV, bentonite had an affinity for potassium even in 0.1 N solutions of hydrochloric acid or sodium chloride. Vermiculite exhibited some preference for potassium

TABLE IV. Potassium-42 Remaining in Solution Expressed as % of Standard Solutions.

Treatment	Potassium-42 diluent .1 N KCl	.1 N HCl	.1 N NaCl	H_2O
None	98	101	101	93
Vermiculite	98	97	86	37
Alfalfa	96	100	100	95
Beet pulp	95	101	95	75
Bentonite	91	85	80	58*
Amberlite IRC-50	99	100	99	17

Least significant difference between means at 1% level of confidence is 4.
* Supernatant contained suspended particles.

ions over sodium ions; however, appreciably more potassium-42 was removed when no other ions were present. Amberlite IRC-50 and beet pulp showed very little affinity for potassium-42 until no other ions were present.

In the rubidium-86 experiment, Table V, a significant reduction in urinary, fecal, and total rubidium-86 excretion and in excretory ratios was observed in rats fed potassium-deficient diets when compared to those fed comparable potassium-adequate diets. Rats fed vermiculite diets excreted significantly more rubidium-86 in the feces than did those fed the basal diets, even though no difference in total excretion of rubidium-86 was observed between diets containing equivalent amounts of potassium. Significantly more rubidium-86 was excreted by rats fed diets containing alfalfa, bentonite, and Amberlite

TABLE V. Influence of Some Organic and Inorganic Materials on Excretory Pattern of Rubidium-86 in Rats.

Treatment	Excretion* Urinary	Fecal	Total	Ratio of urinary /fecal Rb-86
Basal + K	9.0	.9	9.9	10.0
" − K	1.5	.3	1.8	5.6
Vermiculite + K	5.8	4.0	9.8	1.5
" − K	.5	2.0	2.5	.3
Alfalfa + K	14.4	1.1	15.5	12.6
Beet pulp + K	9.4	2.0	11.4	4.8
Bentonite + K	5.4	9.5	14.9	.6
Amberlite IRC-50 + K	7.1	7.0	14.1	1.0
L.S.D.†	2.7	.6	1.8	

* Expressed as % of admin. dose/rat.
† Least significant difference between means at 5% level of confidence.

IRC-50 than those fed the basal diet. This increase with alfalfa occurred through urinary excretion, while with bentonite and Amberlite IRC-50 it occurred through fecal excretion. The order of fecal excretion of rubidium-86 was bentonite > Amberlite IRC-50 > vermiculite > beet pulp. As occurred with cesium-134, both bentonite and vermiculite significantly decreased urinary rubidium-86 excretion. The *in vitro* studies, Table VI, indicated that vermiculite and bentonite preferentially removed rubidium-86 from 0.1 N solutions of potassium chloride, hydrochloric acid or sodium chloride. Amberlite IRC-50

TABLE VI. Rubidium-86 Remaining in Solution Expressed as % of Standard Solutions.

	Rubidium-86 diluent			
Treatment	.1 N KCl	.1 N HCl	.1 N NaCl	H_2O
None	98	100	100	91
Vermiculite	90	80	53	13
Alfalfa	98	99	99	97
Beet pulp	95	97	93	76
Bentonite	76	68	53	49*
Amberlite IRC-50	96	99	97	14

Least significant difference between means at 1% level of confidence is 3.
* Supernatant contained suspended particles.

and beet pulp did not appreciably remove rubidium-86 from solution until no other ions were present.

Comparisons of *in vitro* data with that found *in vivo* show a comparable order as found in distilled water, if one allows for a lower value for bentonite (closely approximating vermiculite) which would probably occur if no colloidal suspension were present.

Since all radionuclides were subcutaneously administered, the changes in excretory pattern of cesium-134, potassium-42 and rubidium-86 exhibited by the rat appear to be due to certain materials in the gut preferentially adsorbing nuclide during passage of the nuclide from body fluids into gut. If no materials are present in the gut to adsorb or remove these nuclides, most nuclides pass back into the body fluids and are either passed out through the kidneys or are recycled through the body and eventually reach the gut again and the cycle continued. This is substantiated in part by the continued high fecal excretion occurring on some diets 48 and 72 hours after administration of nuclides to the rats.

Summary. These experiments demonstrated that absence of dietary potassium in basal or vermiculite diet decreased urinary and fecal excretion of cesium-134, potassium-42 or rubidium-86, as well as their excretory ratio within each diet, but the pattern between the 2 diets remained relatively the same. Vermiculite, alfalfa, beet pulp, bentonite, and Amberlite IRC-50 fed to rats had the property of influencing the excretory patterns of radionuclides used. The magnitude of influence these materials exerted upon urinary and fecal excretion of these radionuclides varied between nuclides. The results *in vitro* demonstrated that some of these materials exhibited an affinity for specific nuclides even though these materials were in minute quantities in 0.1 N solutions of potassium chloride, hydrochloric acid, or sodium chloride.

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