SODIUM AND POTASSIUM BALANCES, WHEN USED AS CITRATES IN ACIDOTIC AND RACHITIC CONDITIONS IN RATS.*

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In the two preceding papers (1), (2) from this laboratory, we reported on the utilization of calcium lactate in diets which were alkalized with sodium citrate and with sodium and potassium citrates, using both mature rats in a state of mineral drain, and young rats recovering from experimental rickets. In both cases it was clearly shown that alkalization with citrates had a favorable influence on the alkaline reserve, with respect to calcium, phosphorus and magnesium.

Incidentally we have determined the sodium and potassium balances on those experiments and these are here reported. For the sake of reference and clarity the other base balances are included in the tables. Of course these experiments were not especially designed to establish any particular points in connection with sodium and potassium metabolism, but they have, nevertheless, a certain interest because it is important to know what advantages or disadvantages might result from the use of alkaline citrates in such moderate quantities, and in such proportions as they are frequently employed therapeutically. In almost all nutrition experiments relating to the Na:K ratio as, for example, Richards, Godden and Husband (3), there is the tendency to use very large quantities of potassium as citrate, or chloride, so that the quantities are entirely out of line with therapeutic dosage. Nevertheless one draws the conclusion that potassium in excess has a somewhat detrimental effect on the easy adjustment of the tissues to an increased alkalinity, especially of calcium. Also phosphorus balance is not favorably influenced by excessive potassium.

As stated above, these experiments were not arranged for definite conclusions with respect to sodium and potassium yet they permit a few general observations which will probably be found correct in more elaborate tests. The summative effects of balanced alkaline solutions in metabolic experiments are, of course, the combined result of a very large number of variables, so many in fact that the practical conclusion as to the best ratios to use in practice will be decided by teleological rather than laboratory methods. Yet laboratory results have a certain confirmatory value on conclusions thus obtained. In the work of Ringer, Macallum, Clarke and others on the effects of electrolytes on tissues, laboratory results are largely confirmatory of such practical conclusions.

EXPERIMENTAL.

(1) Comparison of the retentions obtained using (a) sodium citrate plus calcium lactate, and (b) sodium and potassium citrate and calcium lactate on highly acidotic (potassium depleted) mature rats.

Since the work on mature rats reported in the first paper had been completed before we decided to determine the sodium and potassium balances, it was in part repeated in order that this added data might be secured. The rats were treated in all respects as previously described, save that sodium was substituted for potassium (3), mol for mol, in the salt mixture in the basal diet, and lactose added to compensate for the resulting decrease in weight.

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TABLE I.—FORE PERIOD—SIX DAYS.

Rat No.	Food eaten. Gm.	Na intake. Mg.	Na output. Mg.	Na balance. Mg.	K intake. Mg.	K output. Mg.	K balance. Mg.	Ca intake. Mg.	Ca output. Mg.	Ca balance. Mg.	P intake. Mg.	P output. Mg.	P balance. Mg.	Mg intake. Mg.	Mg output. Mg.	Mg balance. Mg.	Acidity. Cc. 0.1 N Acid.
47	73	198	284	− 86	37	65	− 27	8	58	−50	214	218	− 4	25.5	23.9	+1.6	+135
5	73	197	258	− 61	37	129	− 92	8	32	−24	214	199	+15	25.5	24.8	+0.7	+135
157	66	179	275	− 96	34	52	− 20	7	64	−57	195	205	−10	23.1	24.0	−0.9	+122
6	69	187	210	− 23	35	129	− 93	8	46	−38	204	220	−16	24.1	24.3	−0.2	+128
16	45	122	173	− 51	23	56	− 33	5	50	−45	133	171	−38	15.7	18.6	−2.9	+ 83
92	34	92	116	− 24	17	79	− 61	4	47	−43	100	120	−20	11.9	15.1	−3.2	+ 63
							Experimental	Period—Six	Days.								
47[1]	63	873	695	+178	26	43	− 17	31	43	−13	166	170	− 4	18.9	17.6	+1.3	−201
5[2]	67	369	279	+ 88	891	750	+141	31	9	+22	179	153	+26	20.1	15.1	+4.9	−217
157[1]	55	753	606	+148	23	55	− 33	30	37	− 7	145	152	− 7	16.5	14.7	+1.8	−179
6[2]	56	308	233	+ 65	745	652	+ 93	30	11	+19	149	144	+ 5	18.8	14.9	+3.9	−182
16[1]	46	630	601	+ 29	14	37	− 23	29	31	− 2	121	126	− 5	13.8	13.8	−0.0	−149
92[2]	35	193	156	+ 37	466	427	+ 39	28	44	−16	93	114	−21	10.5	11.0	−0.5	−113

[1] Received high sodium citrate plus calcium lactate.
[2] Received mixture of sodium and potassium citrates, plus calcium lactate.

TABLE II.—DATA FOR SEVEN-DAY PERIODS.

Food eaten. Gm.	Na intake. Mg.	Na output. Mg.	Na balance. Mg.	K intake. Mg.	K output. Mg.	K balance. Mg.	Ca intake. Mg.	Ca output. Mg.	Ca balance. Mg.	P intake. Mg.	P output. Mg.	P balance. Mg.	Mg intake. Mg.	Mg output. Mg.	Mg balance. Mg.	Acidity. Cc. 0.1 N Acid.	Na/K.
78[3]	0.348	0.366	− 18	208	140	+68	226	148	+ 78	242	153	+ 89	93.6	84.8	+ 8.8	+138	1.67
72[1]	1.143	1.042	+101	192	113	+79	225	127	+ 98	223	131	+ 92	86.4	67.3	+19.1	−229	5.95
75[1]	1.156	1.060	+ 96	200	137	+63	226	97	+129	233	145	+ 88	90.0	57.4	+32.6	−224	5.80
67[2]	551	554	− 3	413	391	+22	224	149	+ 75	300	226	+ 74	94.8	76.4	+18.4	+ 17	1.34
69[2]	561	560	+ 1	418	401	+17	224	143	+ 81	306	231	+ 75	97.8	74.5	+23.3	+ 14	1.34
66[2]	547	565	− 18	410	422	−12	224	139	+ 85	296	206	+ 90	93.8	67.3	+26.5	+ 19	1.33
81[3]	344	381	− 37	218	161	+57	332	229	+103	235	150	+ 85	94.0	99.6	− 5.6	+143	1.58
81[3]	344	366	− 22	218	158	+60	332	214	+118	235	158	+ 77	94.0	93.5	+ 0.5	+143	1.58
81[1]	1.166	1.145	+ 21	218	157	+61	332	177	+155	235	121	+114	94.0	73.8	+20.2	−214	5.35
79[1]	1.158	1.085	+ 73	212	160	+52	332	181	+151	229	117	+112	91.7	76.9	+14.8	−217	5.45
82[2]	729	698	+ 31	574	517	+57	332	210	+122	379	278	+101	118	88.8	+29.2	− 48	1.27
80[2]	721	742	− 21	568	534	+34	331	192	+139	373	277	+ 95	116	89.5	+26.5	− 51	1.27
71[3]	683	626	+ 57	544	513	+31	330	192	+138	347	261	+ 86	105	79.5	+25.5	− 67	1.26

[1] Alkalized with sodium citrate alone. [2] Alkalized with sodium and potassium citrates. [3] Basal diet alone.

TABLE III.—DATA FOR SEVEN-DAY PERIODS.

Food eaten. Gm.	Na intake. Mg.	Na output. Mg.	Na balance. Mg.	K intake. Mg.	K output. Mg.	K balance. Mg.	Ca intake. Mg.	Ca output. Mg.	Ca balance. Mg.	P intake. Mg.	P output. Mg.	P balance. Mg.	Mg intake. Mg.	Mg output. Mg.	Mg balance. Mg.	Na/K intake. Mg.	Total acidity Cc. 0.1 N Acid.
73[1]	153	85	+68	235	108	+127	361	137	+224	190	72	+118	19.7	9.0	+10.7	0.65	+135
92[1]	192	141	+51	296	218	+ 78	455	219	+236	239	130	+109	24.8	28.2	− 3.4	0.65	+168
94[1]	197	131	+66	303	214	+ 89	464	175	+289	245	150	+ 95	25.4	27.2	− 1.8	0.65	+172
92[1]	192	128	+64	296	208	+ 88	455	205	+250	239	88	+141	24.8	18.5	+ 6.3	0.65	+168
62[2]	385	322	+63	200	170	+ 30	306	81	+225	162	68	+ 94	16.8	15.0	+ 1.8	1.92	± 0
92[2]	572	525	+47	296	225	+ 71	455	97	+358	239	134	+105	24.8	6.7	+18.1	1.93	± 0
92[2]	572	517	+55	296	210	+ 86	455	111	+344	239	94	+145	24.8	17.0	+ 7.8	1.93	± 0
92[3]	385	310	+75	613	473	+143	452	148	+304	242	93	+149	24.8	28.8	− 4.0	0.63	± 0
92[3]	385	308	+77	613	507	+106	452	162	+290	242	109	+133	24.8	27.6	− 2.8	0.63	± 0
72[3]	301	258	+43	480	428	+ 52	354	95	+259	191	77	+114	19.4	15.8	+ 3.6	0.63	± 0

[1] Basal diet. [2] Sodium citrate alone. [3] Sodium and potassium citrate.

In the experimental period, sodium citrate was added to the diet of half the rats at a level of 5 Gm. $Na_3C_6H_5O_7.2H_2O$ per 100 Gm. food, while the other half received 1.04 Gm. $Na_3C_6H_5O_72\ H_2O$ + 4.36 Gm. $K_3C_6H_5O_7.H_2O$ making the total alkalinity the same in each case. Four mg. calcium lactate per day was added in the usual manner. The Na and K analysis of the diets are:

	Basal diet.	Na citrate.	Na and K citrate.
Na	0.271%	1.37%	0.58%
K	0.051	0.041	1.33

Results are shown in Table I.

CONCLUSIONS.

(1) Addition of sodium and calcium does not conserve potassium, the balance of which is the same in both the fore and experimental periods.

(2) Addition of sodium and calcium favors calcium retention.

(3) Addition of sodium, potassium and calcium favored potassium retention, lowering to some extent sodium retention; perhaps by eliminating the necessity of sodium functioning for potassium as base.

(4) Addition of sodium, potassium and calcium favored calcium retention but too much potassium on low sodium is less favorable.

(5) We could not distinguish any difference between addition of Ca, K and Na and of Ca and Na alone on P retention. P retention has been shown to be increased if Ca level is raised (4).

(2) Alkali retentions of young rachitic rats when alkalized with varying amounts of sodium citrate.

The balances reported in this and the succeeding section were done on the same rats reported in the second paper of this series (2); consequently the methods and technique described there apply here also.

The control rats on the basal diet plus Ca lactate, but without any added alkali, were negative in Na, but gaining in K, Ca and P. When completely alkalized with sodium citrate, so that the ratio of total Na to K ingested was 5.9:1, Na and Ca balances were favored, while K and P were not affected. When only partially alkalized, so that the ratio of Na:K ingested was 1.3:1, the Na, K, Ca and P balances were all less favorable than with the Na citrate alone. It would appear that the increased alkalinity and the higher Na/K ration has a favorable tendency in salt balances. Data are given in Table II.

(3) Comparison of retentions obtained as in (2) but using a different basal diet.

The rats here reported are those shown in Table III in the preceding paper (2). This diet contained more calcium than given in Experiment 2, and its utilization is quite obviously favored where alkali was used. The increased retention of calcium in turn improves the phosphorus balances. But where the increased use of potassium has led to a greater potassium retention to meet the needs of the growing animal, the phosphorus balance continued improved while the calcium retention is materially lowered. With the exception of finding an increased retention of potassium, this experiment bears out the results of the others, in that a higher ratio of Na:K, within reason, appears to be more desirable.

SUMMARY.

1. Acidotic, depleted, mature and young rachitic rats have been treated with alkaline saline mixtures of sodium, potassium and calcium to study the more beneficial mixtures for retention of all bases.

2. Most favorable results require all the bases, but the ratios are not without an important bearing.

3. Assuming that the K, Ca, P and Mg requirements are met, the alkalization requires a considerable preponderance of sodium, our best results in this survey resulting from a mixture in which Na:K = 5.9:1. This is simply a suggestive value, indicating the nature of the proper balance. A ratio of Na to K of 33 to 1, as in Experiment 1, showed some tendencies to imbalance.

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PHYTOCHEMICAL NOTES.*†

No. 101. THE SEEDS OF MONARDA PUNCTATA.

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About two and three-quarter pounds of seeds were gathered at Lake Wisconsin and in the Pharmaceutical Garden. The heads were thrashed and the chaff removed with a fanning mill.

The moisture content, as determined by the xylene method[1] was found to be 3.6 p. c. (two determinations).

Ash content 2.6412 Gm. and 2.7580 Gm., respectively, when incinerated as directed[2] yielded the following amounts of

	I.		II.	
Water soluble ash	0.0101 Gm.	= 0.38 p. c.	0.0169 Gm.	= 0.61 p. c.
Acid soluble ash	0.1816 Gm.	= 6.87 p. c.	0.1836 Gm.	= 6.66 p. c.
Acid insoluble ash	0.0081 Gm.	= 0.3 p. c.	0.0076 Gm.	= 0.2 p. c.
	0.1998 Gm.	7.55 p. c.	0.2081 Gm.	7.47 p. c.

Extraction with Selective Solvents.—One hundred Gm. of seeds were finely pulverized and placed in a continuous extractor for extraction with petroleum ether, ether and alcohol. The extraction with hot alcohol, acetone and methyl alcohol was accomplished in a flask connected with a reflux condenser. The

* Scientific Section, A. PH. A., Portland meeting, 1928.
† From the laboratory of Edward Kremers.
[1] U. S. Dept. Agr., *Circ.* 134.
[2] Nellie Wakeman, "Plant Chem. for Pharm. Students," page 15.