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Sodium, Potassium and Chloride Utilizations Affected by White Corn Bread, Yellow Corn Bread, and Whole Wheat Bread Diets in Humans*

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ABSTRACT

Sodium restricted diets are known to lower blood pressure in salt sensitive, hypertensive patients. Thare is increasing evidence that potassium plays an important role as a protective factor in the regulation of blood pressure. The objective of the current study was to measure parameters of sodium, potassium, and chloride utilization as affected by feeding of substantial quantities of bread made from whole ground white corn meal, whole ground yellow corn meal, and whole ground wheat flour. The breads provided 40 percent of a caloric content of the constant, measured laboratory diet. The 28-day study was divided into an introductory period of 7-days and three experimental periods of 7-days each. Order of assignment to specific treatments for 12 healthy subjects were according to a complete randomized block design. Yellow corn bread diets resulted in the highest potassium retention (243 mg/day) and the lowest urinary sodium and potassium ratio (1.53 ± 0.26) numerically in comparison to the other test breads. The excretions of sodium and chloride were higher during controlled feeding periods than during the self-selected diet period ($p < 0.05$). This indicates a response to the higher intake of these electrolytes from the experimental diets than from self-selected diets. There was no significant difference in the effect of white corn bread, yellow corn bread, or whole wheat bread diet on electrolyte status in humans. However, the yellow corn bread diet resulted in a somewhat more favorable urinary sodium to potassium ratio than that from white corn bread or whole wheat bread diet.

KEY WORDS: sodium and potassium ratio, blood pressure, hypertension, human.

INTRODUCTION

High arterial blood pressure (hypertension) is the most common chronic disease in the United States and probably in other acculturated societies throughout the world as well.[1)2)] The results of high arterial blood pressure are disabilities or death due to stroke, heart failure or kidney failure.[3)4)] Clearly, the problem is immense and important. Fortunately, the results of high blood pressure can to a large extent be avoided by proper treatment and dietary sodium, potassium, and chloride may well have a role in this treatment.[5-11)]

Haddy suggest that sodium restriction may lower blood pressure in some individuals although the exact degree of restriction required has not been determined.[12)] The relationship between salt and hypertension remains weak and inconsistent. Approximately 50 percent of hypertensive persons are believed to be sodium sensitive and may respond positively to sodium restriction.[12)13)]

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Many investigators have found that dietary K supplementation lowers blood pressure in established hypertension, though this is controversial.[14-19)] However, considerable data indicates that in patients with salt-induced hypertension, the elevation of blood pressure is dependent not on the amount of sodium ingested per se but rather on the resulting sodium-potassium ratio.[20-26)]

Of particular interest is the role played by chloride, a basic component of salt, in the development of hypertension. Julian *et al.* reported that an increase in blood pressure was found in rats on a sodium chloride regimen but not in those fed sodium bicarbonate, implicating chloride rather than sodium in the development of hypertension.[27)]

These three minerals are considered together because they are all electrolytes that play a vital role in maintaining osmotic pressure in the extracellular and intracellular fluids and in maintaining acid-base balance.[28)29)] It had been suggested that sodium -dependent hypertension might be better be considered sodium chloride dependent and blood pressure tends to be related to the urinary Na-K ratio.[30-33)] Further research is needed to determine the role of sodium, potassium, and chloride in the development and management of hypertension. Carotenoids, yellow pigments found in plant tissues are of current research interest because of their possible protective effects against the occurrence or the development of certain types of cancer. Yellow corn, unlike white corn or other major cereals is a rich source of carotenoids. In Nebraska, little if any white corn is grown. There has been very little information is available on sodium, potassium and chloride utilization from yellow corn in humans.

The objective of the current study was to measure parameters of sodium, potassium, and chloride utilization as affected by fuman consumption substantial quantities of bread made of whole ground yellow corn meal, whole ground white corn meal, or whole ground wheat flour.

EXPERIMENTAL PROCEDURE

1. Experimental plan

The 28-day study was divided into an introductory period of 7 days and three experimental periods of 7-days each. During the pre-period subjects ate self-selected and self-recorded diets. Subjects ate a constant, laboratory controlled diet during the 21-day experimental period composed of the same foods each day except that during one experimental period, 40% of the calories was provided by whole wheat bread. The experimental plan of the study is shown in Table 1.

During the other two experimental periods, 40% of the calories was provided by whole ground yellow corn bread and by white corn bread. The diet randomization of the study is given in Table 2. Other foods included orange juice, milk, vegetable-beef soup, peach-strawberry gelatin, beef ravioli, green beans, apple sauce, jelly, butter and soft drinks. Adequacy of intake of all nutrients were assured by use of vitamin and mineral supplements. All subjects received all experimental treatments. Order of assignment to specific treatments for individual subjects were according to a complete randomized block design. All food was prepared and all meals were eateu under supervision in the special diet laboratory of the Department of Human Nutrition and Food Service Management.

2. Subject information

Twelve adult subjects participated in the study. All subjects were healthy as determined by physical examination and medical records at the University of Nebraska Student Health Center in Lincoln. All subjects signed informed consent forms before participating. The subjects maintained their normal daily activities during the study except for eating controlled diet or recording all food eaten, making complete excreta collections, and giving blood samples.

Table 1. Experimental Plan of white corn bread, yellow corn bread, and whole wheat bread diets

Period[1]	Days	Diet type	Bread type[3]
Pre-period	7	Self-selected	–
Expt.1	7	Lab-controlled[2]	Whole wheat
Expt.2	7	Lab-controlled[2]	Yellow corn
Expt.3	7	Lab-controlled[2]	White corn

1) See Table 2 for diet randomization
2) See Table 3 for menu
3) See Table 4 for bread recipe

Table 2. Diet Randomization of white corn bread, yellow corn bread, and whole wheat bread diets

Subject	Diet fed during period			
	Pre-period	I	II	III
3535	Self-selected	WC	YC	WW
3536	〃	YC	WW	WC
3537	〃	WW	WC	YC
3538	〃	WC	WW	YC
3539	〃	YC	WC	WW
3540	〃	WW	YC	WC
3541	〃	YC	WW	WC
3542	〃	WW	WC	YC
3543	〃	WC	YC	WW
3544	〃	WW	YC	WC
3545	〃	YC	WC	WW
3546	〃	WC	WW	YC

WC: white corn bread diet YC: yellow corn bread diet
WW: whole wheat bread diet

3. Laboratory analysis

Urine composites for each individual were composited by time for each 24-hour day, measured by volume, mixed and sampled for analyses. Fecal collections for each individual were composited to be representative of the food eaten during each 7-day experimental period by use of fecal dye and bead markers given at the first and last meals of each study period. These were mixed, weighed and sampled for analyses. Fasting blood samples were drawn by phlebotomists from the UNL Division of Health Services on the first day of the study and the morning following the last day of each study period. Post-prandial blood samples were drawn 2–3 hours after breakfast on the last day of each period. Blood samples were analyzed for a wide range of components using STAT-26. However, results of the blood analysis were not included in this part of the project.

Dry fecal weights were used to estimate accuracy and completion of fecal collections on a period basis. Fecal samples were ashed, then digested with nitric acid before being diluted for analysis. Neutral detergent fiber excretion was used to assess completeness of fecal collections. Urine samples were also diluted accordingly before analysis. Creatine excretion (Folin method) was used to assess completeness of urine collections.

Urine and fecal samples were analyzed for sodium and potassium content by the Varian Techtron 1275 series Atomic Absorption Spectrophotometer Model 1150. Chloride content of samples was determined by the method of Schales and Schales (1983).

Statistical analysis of data were completed by using the Statistical Analysis System (SAS). The Analysis of Variance was performed to detect variation as a result of dietary treatment. Difference among mean values were interpreted by Orthogonal Contrast, Least Square Means and Duncan's Multiple Range test.

RESULTS AND DISCUSSION

Mean sodium, potassium and chloride intake, urinary and fecal excretion, and electrolyte balances for subjects are given in Table 6 through 9. The food items and their amounts in the laboratory-controlled diets are shown in Table 3. The bread recipe of the study is given in Table 4.

The accuracy of estimating electrolyte leve's in human subjects is dependent on several variables: the accuracy of the experimental analytical methods, the skill of the individual performing the analysis, the completeness of urine and fecal collections and the accuracy of processing excreted matter into period lots. Elimination of these possibilities of error is in part dependent on care taken by the researcher in analysis and processing, and on the care taken by the subject in making collections. To minimize inaccuracies on the researcher's part, all samples were run in duplicate. To correct for inaccuracies on the subject's part, mean creatinine levels in urine and total dry fecal weights for each subject were used to correct for differences in urine and fecal collections. The individual mean creatinine values of the study are shown in Table 5.

Mean sodium intake, corrected urinary and fecal sodium losses and sodium balances of subjects feeding on white corn bread, yellow corn bread, and whole wheat bread are given in Table 6. As shown in Table 6, sodium intake was found to be lower when subjects received the white corn bread diet than when yellow corn bread or whole wheat bread were used (5133 ± 467 in the white corn bread diet, 5137 ± 550 in the yellow corn bread diet and 5279 ± 409 mg/day in the whole wheat bread diet, respectively). Mean sodium dietary intake did not differ significantly among the white corn bread diet, the yellow corn bread diet, and the whole wheat bread diet.

Urinary sodium excretion was significantly lower during self-selected diet than during the experimental period

Table 3. Menu of the laboratory-controlled diets

Food item	Amount[1)]
Breakfast:	
Bread[2)]	2 slices
Milk	227 g
Orange juices	170 g
Butter	12.1 g
Jelly	19 g
Lunch:	
Bread[2)]	2 slices
Vegetable-beef soup	270 g
Jelly	19 g
Butter	12.1 g
Milk	227 g
Peach-strawberry gelatin	142 g
Dinner:	
Bread[2)]	2 slices
Milk	227 g
Jelly	19 g
Beef ravioli	259 g
Green beans	227 g
Apple sauce	152 g

1) Amount of these items varies in intake with subjects
2) Bread type varied among periods

Table 4. Bread recipe of the laboratory-controlled diets

Amount	Ingredient	Method
30.5 oz.	Cornmeal (White or yellow)[1)]	Combine dry ingredients in mixer bowl.
10.5 oz.	Unenriched flour[2)]	
6 oz.	Sugar	
1 oz.	Salt	
2 oz.	Baking powder	
5 oz.	Eggs, beaten	Combine eggs, milk and fat.
1 qt.	Milk	Add to dry ingredients
6 oz.	Fat, melted, cooled	Mix (low speed) only until ingredients are moistened. Spread into greased baking pan.

1) For whole wheat bread-1 lb 4 oz. whole wheat and 1 lb 5 oz. flour
2) White and yellow corn meal and whole wheat purchased from Brownville Mills, Brownville, Nebraska 68321

Table 5. Individual urinary creatinine values (corrected value)[1)]

Subject	Pre-period	Experimental period		
		I	II	III
3535	0.91	1.08	1.00	1.02
3536	0.98	1.17	0.90	1.16
3537	0.96	0.93	0.74	1.00
3538	0.99	0.99	1.01	1.01
3539	1.13	0.97	0.83	1.13
3540	0.95	0.99	1.10	0.99
3541	0.94	1.04	0.99	1.07
3542	0.90	1.01	0.96	1.15
3543	0.98	0.98	1.02	1.02
3544	1.09	0.93	0.89	1.12
3545	1.04	0.98	0.94	1.04
3546	0.98	1.01	0.92	1.11

1) Average/period

Table 6. Sodium utilization as affected by white corn bread diet, yellow corn bread diet, and whole wheat bread diet (mg/day)[1)]

Treatment	Intake	Urinary loss[2)]	Fecal loss[3)]	Balance
Self selected diet	*[4)]	3333 ± 1173[5),b]	42 ± 33[a]	*
White corn bread	5134 ± 467[a]	4718 ± 1164[a]	72 ± 75[a]	343 ± 838[a]
Yellow corn bread	5137 ± 550[a]	4651 ± 1149[a]	59 ± 55[a]	424 ± 700[a]
Whole wheat bread	5279 ± 409[a]	4789 ± 1201[a]	73 ± 68[a]	434 ± 871[a]

1) Values with same letter in the same column are not significantly different from one another ($p < 0.05$)
2) Urinary excretions of sodium were corrected to the mean urinary creatinine values of each individual
3) Fecal excretions of sodium were corrected to the mean fecal dry weights of each individual
4) Subjects consumed self-selected diet: pre-period 5) Mean ± S.D.

Table 7. Potassium utilization as affected by white corn bread diet, yellow corn bread diet and whole wheat bread diet (mg/day)[1)]

Treatment	Intake	Urinary loss[2)]	Fecal loss[3)]	Balance
Self selected diet	*[4)]	2769 ± 804[5),a]	431±195[a]	*
White corn bread	3569 ± 174[a]	2963 ± 655[a]	466 ± 191[a]	140 ± 717[a]
Yellow diet	3738 ± 283[a]	3037 ± 628[a]	481 ± 241[a]	243 ± 668[a]
Whole wheat bread	3632 ± 211[a]	2969 ± 695[a]	462 ± 68[a]	201 ± 748[a]

1) Values with same letter in the same column are not significantly different from one another ($p < 0.05$)
2) Urinary excretions of potassium were corrected to the mean urinary creatinine values of each individual
3) Fecal excretions of potassium were corrected to the mean fecal dry weights of each individual
4) Subjects consumed self-selected diet: pre-period 5) Mean ± S.D.

(3333 ± 1173 vs. 4718 ± 1164 in the white corn bread diet, 4650 ± 1149 in the yellow corn bread diet, and 4788 ± 1201 mg/day in the whole wheat bread diet, p < 0.0009). Urinary sodium excretion did not show a significantly greater decrease during the yellow corn bread diet than during the white corn bread diet or whole wheat bread diet (4650 ± 1149 in yellow corn bread diet, 4718 ± 1164 in white corn bread diet and 4788 ± 1201 mg/day in whole wheat bread diet, respectively). Fecal excretions were also lower during the yellow corn bread diet than during the white corn bread or whole wheat bread diet (58 ± 50 in yellow corn bread diet, 72 ± 75 in white corn bread diet and 72 ± 75 in white corn bread diet and 72 ± 68 mg/day in whole wheat bread diet). Although these differences were not significantly different, urinary and fecal sodium excretions were slightly lower during the yellow corn bread diet than during the white corn bread diet or whole wheat bread diet. During the pre-period diet in which subjects consumed self-selected diets, both urinary and fecal losses tended to be lower than when the experimental diets were eaten.

Numerically, the sodium balances can suggest a higher sodium retention during the whole wheat bread diet than during the white corn bread or yellow corn bread diets (434 ± 871 in whole wheat bread diet, 423 ± 700 in yellow corn bread diet and 343 ± 838 mg/day in white corn bread diet).

No statistically significant differences in effects of eating white corn breads, yellow corn breads, or whole wheat breads were demonstrated. However, a slight trend toward lower sodium excretion was found during the yellow corn bread diet period.

As shown in Table 7, potassium intake of subjects was numerically higher during the yellow corn bread diet than during the white corn bread diet or whole wheat bread diet (3737 ± 283 in yellow corn bread diet, 3632 ± 211 in whole wheat bread diet, 3568 ± 174 mg/day in white corn bread diet, respectively).

Urinary potassium excretions were numerically higher during the yellow corn bread diet than during the white corn bread diet or whole wheat bread diet (3036 ± 628 in yellow corn bread diet, 2968 ± 695 in whole wheat bread diet, 2962 ± 655 mg/day in white corn bread diet). Fecal potassium excretions were also numerically higher during the yellow corn bread diet than during the white corn bread diet or whole wheat bread diet (481 ± 241 in yellow corn bread diet, 466 ± 191 in white corn bread diet and 461 ± 222 mg/day in whole wheat bread diet).

Potassium balances were also positive among these all three experimental groups (139 ± 717 in white corn bread diet, 243 ± 668 in yellow corn bread diet, 201 ± 748 mg/day in whole wheat bread diet) and indicated that potassium retention tended to be higher during the yellow corn bread diet period.

Chloride utilization data is given in Table 8. Mean chloride intake was numerically lower during the yellow corn bread diet than during the whole wheat bread diet or white corn bread diet (214 ± 34 vs. 240 ± 22, 228 ± 24 Meq/day, respectively).

Mean urinary chloride excretions were significantly lower in the self-selected diet than during experimental periods (159 ± 44 in self-selected diet, 192 ± 43 in yellow co-

Table 8. Chloride utilization as affected by white corn bread diet, yellow corn bread diet and whole wheat bread diet (mEq/day)[1)]

Treatment	Intake	Urinary loss[2)]	Fecal loss[3)]	Balance
Self-selected diet	*[4)]	160 ± 44[5),b]	3.80 ± 1.05[b]	*
White corn bread	228 ± 207[ab]	207 ± 34[a]	4.68 ± 75[ab]	17 ± 19[a]
Yellow corn bread	215 ± 34[b]	193 ± 34[a]	4.54 ± 55[ab]	20 ± 27[a]
Whole wheat bread	240 ± 22[a]	20 ± 35[a]	5.16 ± 1.05[a]	16 ± 22[a]

1) Values with same letter in the same column are not significantly different from one another ($p < 0.05$)
2) Urinary excretions of chloride were corrected to the mean urinary creatinine values of each individual
3) Fecal excretions of chloride were corrected to the mean fecal dry weights of each individual
4) Subjects consumed self-selected diet: pre-period 5) Mean ± S.D.

Table 9. Sodium to potassium urinary excretion ratio as affected by white corn bread diet, yellow corn bread diet and whole wheat bread diet in humans[1)]

Treatment	Pre-period	White corn bread	Yellow corn bread	Whole wheat bread
Na/K ratio	1.26±0.43[2),a]	1.65±0.45[a]	1.53±0.26[a]	1.64±0.29[a]

1) Values with same letter in the same row are not significantly different from one another ($p < 0.05$) 2) Mean ± S.D.

rn bread diet, 207 ± 34 in white corn bread diet and 219 ± 35 Meq/day in whole wheat bread diet, respectively, $p < 0.001$). Urinary chloride excretion values in this study fell within the normal range of 170 to 250 Meq/day.

Mean fecal chloride excretions were significantly higher during the whole wheat bread diet than the self-selected diet (5.16 ± 1.05 vs. 3.79 ± 1.05 Meq/day, respectively, $p < 0.009$). Chloride is thought to be efficiently absorbed from the intestinal tract; hence, only very minute amounts would be expected to be found in the feces.

Positive chloride balances were observed among all experimental groups (16 ± 19 in the white corn bread diet, 20 ± 27 in the yellow corn bread diet, and 15 ± 22 Meq/day in the whole wheat bread diet). Yellow corn meal resulted in the highest chloride retention.

Urinary sodium to potassium ratios (Table 9) were also calculated. The yellow corn bread diet resulted in a numerically low urinary sodium to potassium ratio (1.26 ± 0.43 in self-selected diet, 1.65 ± 0.45 in white corn bread, 1.53 ± 0.26 in yellow corn bread, 1.64 ± 0.29 in whole wheat bread diet). Thus eating yellow corn bread should tend to decrease the risk of hypertension.

Yellow corn bread meal tended to depress both urinary and fecal losses of sodium in comparison to values achieved with white corn or whole wheat breads. Thus, the yellow corn meal diet resulted in increased sodium retention. Yellow corn bread meal tended to more greatly enhance both urinary and potassium losses than did the other test breads. Thus, yellow corn meal consumption resulted in decreased potassium retention and a decrease in urinary sodium and potassium ratios.

The higher excretion of sodium, potassium, and chloride during controlled feeding periods than during the self-selected diet period indicates a response to the higher intake of these electrolytes from the experimental diets than from self-selected diets.

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