Demineralization of a Wide Variety of Foods for the Renal Patient

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Objective: To develop the (1) simplest, most efficacious, mineral (phosphorous, potassium, and sodium) reduction procedures applicable to a total dietary selection of foods that will (2) preserve postprocessing food taste and texture expectations.

Design: Preprocessing and postprocessing mineral analysis of more than 245 individual samples.

Setting: Analysis of mineral content performed at certified food laboratory in Omaha, NE.

Participants: Renal and control volunteers participated as postprocessing test consumers.

Intervention: Food materials were subjected to aqueous mineral extraction involving variations in (1) pretreatment handling, (2) aqueous temperatures, and time depending on cell type and initial state (raw, canned, dried). Measurements of remaining mineral concentrations of phosphorous, potassium, and sodium were performed on samples drawn at various time points.

Main outcome measure: Determination of remaining postprocessing concentrations of target minerals and calculation of the maximum mineral reduction achieved with each food type.

Results: The phosphorous reduction range for vegetables, legumes, meats, flours, and cheddar cheese was 51% ± 33%, 48% ± 25%, 38.5% ± 22.5%, 70.5% ± 13.5%, and 19%, respectively; for potassium, the reduction range for vegetables, legumes, meats, flours, cheddar cheese, and fruit was 59% ± 40%, 78.5% ± 20.5%, 57% ± 41%, 94% ± 3%, 99%, and 43% ± 16%, respectively; for sodium, the reduction range for vegetables, meats, and cheddar cheese was 83.5% ± 14.5%, 67.5% ± 27.5%, and 97%, respectively.

Conclusion: Consuming a total dietary selection of demineralized foods is expected to have a significant positive impact on the renal patient's problematic hematologic mineral values and nutritional profile. Reducing food mineral load will make restricted foods permissible once again.

PRESENTLY, more than a quarter of a million people in the United States are undergoing long-term dialysis because of end-stage renal disease (ESRD).[1] Despite pre-ESRD treatment options, and advanced in transplant technology, the number of those requiring dialysis to sustain life increases annually by more than 7.8%.[2] For many with ESRD, lifelong dialysis will be the only option.[3]

Two of the life-sustaining functions kidneys must perform are the elimination of nitrogenous wastes, and regulation of physiologic mineral levels.[4-6] Phosphorous, potassium, and sodium are 3 of the most problematic minerals to regulate when function is severely compromised.[7,8] As kidney failure escalates, mineral concentrations rise sharply, increasing the potential for hypertension, disrupting electrolyte balance, causing structural integrity of bones to weaken, accelerating nitrogenous buildup, and promoting fluid overload and cardiac congestion. Ironically, a heretofore healthy diet, one rich in essential meat protein, mineral-rich fruits, vegetables, legumes, and dairy products, can rapidly push the physiologic potassium concentration in those with ESRD to dangerously toxic levels. To slow this toxic buildup, a regime of severe dietary restrictions, including total avoidance of numerous mineral-rich foods, is imposed.[9,10] These restrictions are responsible for the majority of compliance problems with patients who are suddenly thrust into totally new eating habits. Unfortunately, after lifelong individualized eating patterns, many peo-

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Planning, design, setup, and sample preprocessing were performed at Royal Knight Inc, 2015 41st St NW, Ste G33, Rochester, MN 55901. Food sample mineral analysis and computations were conducted at Midwest Laboratories, Inc, 13611 "B" St, Omaha, NE.

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ple find maintaining even a modicum of compliance with such food restrictions impossible.[11] Misinterpretation of dietary instructions, ESRD-influenced food preference shifts,[12] and noncompliance inevitably lead to nutritional deficit.[13-17]

To combat this nutritional dilemma, suitable mineral reduction procedures, applicable to an entire dietary range of foods, are needed. A few authors have attempted to address alternative food handling procedures aimed specifically at reducing the mineral content in vegetables, but demineralization of meats (red meat, fish, pork), legumes (fresh, canned, and dried), fruits, grains, and, cheese has never been addressed. To date, renal dietary information focuses primarily on avoidance or severely restricting a wide variety of mineral-laden foods to control mineral intake.[18,19] Authors who have addressed vegetable demineralization have either limited their study to one selection, or a few vegetables processed in only one way.[20-22] This limited information leaves numerous unanswered questions concerning pre– and post–food handling procedures for many unexplored nutritional selections. Rigid processing rules, and unpalatable or visually unappealing final product cause further noncompliance problems.

The objective of this study was to develop and validate the most efficient mineral (potassium, phosphorous, and sodium) reduction procedures, which (1) are easy to perform and hence consumer-friendly, (2) can be applied to a total dietary selection of meats, legumes, cereal grains, cheddar cheese, fruits, as well as numerous vegetable varieties, while (3) maintaining the highest level of taste and food texture expectations. These procedures are expected to effectively aid the renal patient in closing their gapping nutritional gap, by making previously restricted, or excluded, nutritious high-mineral foods permissible once again.

Methods

Food Selection Criteria

The decision to include a specific food in the study was based on 4 factors: (1) the selection had a substantial concentration of one or more target minerals (phosphorous, potassium, sodium), (2) there was a general consumer preference for that selection, (3) the characteristics of that selection would not prevent it from being processed (ie, excessive mucilage or buoyancy, oiliness, poor postprocessing structural integrity or taste (Table 1), as well as (4) availability of the selection (year-round as opposed to briefly seasonal). A total of 15 different vegetable varieties, 8 fruits, 5 legumes, 7 meats, 4 grains or flours, and 1 cheese, each with one or more of the target minerals in a significant concentration, and representing an average cross section of the produce found in an American diet, were purchased from a local retail outlet. Included in the selection of vegetables and legumes were fresh, canned, and dried samples. Average consumer preference was considered when making the decision to include a specific produce canned, as opposed to fresh. The treatment conditions, and total time each food variety would ultimately be subjected to demineralization, were determined in a prior mini-study (data unpublished) in which volunteer consumers tested numerous time point samples of each selected food variety for taste and texture acceptability.

Preparing for the "0" Time Point

All fresh fruits and vegetables were cleaned, rinsed, and allowed to drain. Old outer leaves or peels were removed before each selection was cut into slices of ¼-inch thickness (or less) using a kitchen slicer or knife. Grapefruit and tangerine sections were opened, the membrane was removed, and the slices were "flexed," exposing the juice pouches. Broccoli stems were cut into thin ¼-inch slices, and floret clusters were reduced to a size of 1" or less in diameter. A cabbage head was cut in half, and the base was crosscut before being shredded with a kitchen slicer (approximately ½- to ¼-inch wide, by 1 inch in length). The contents of each canned, or otherwise preprocessed selection, were emptied into a sieve and allowed to drain. Fresh and canned whole meats (excluding ground hamburger and tuna) were cut into strips of approximately ¼ inch in thickness. Cheddar cheese was purchased shredded. Dried grains, rice, potato flakes, legumes, hamburger, and tuna were sampled directly from their packages. A 50-g sample of each food material listed in Table 2 was weighed, packaged, and labeled as the "0" time point.

Table 1. Food Selections That Process Poorly

Selection	Reason
Berry fruits (blackberries, blueberries, cherries, etc)	Fruit is "tender," tends to mash easily during cutting. Fruit size limits the ability to prepare properly.
Dried fruit (any variety)	Needs to be in a hydrated first. Difficulty in achieving adequate exposure of all surfaces to bath. Does not hydrate properly. Final product generally unacceptable.
Eggplant	Floats. Spongy texture makes it very difficult to keep submerged. Inadequate exposure to water bath.
Head lettuce (iceberg only)	Becomes "soggy." Final appearance and taste are unacceptable.
Mushrooms (raw only)	Floats. Spongy texture. Does not submerge properly.
Nut meats	Dried nutmeat does not process well. Poor demineralization. Unacceptable final product (taste/texture).
Okra (fresh only)	Thick mucilage prevents adequate processing. Does not demineralize properly.
Sunflower seeds	Dried seeds do not demineralize properly. Oily consistency prevents good aqueous interaction. Unacceptable final product (taste/texture).
Peanut butter	Oily consistency prevents good demineralization. Much of the oil is removed during processing leaving the final product with an uncharacteristically 'dry' texture within a couple of days after processing. Final product has a dry, hard unacceptable texture and taste.
Swiss cheese—sheets (only)	Requires a minimum of 2 hours to remove sufficient phosphorous, but demineralization for longer than 15 minutes renders the final product tasteless.
Watermelon	Excessively waterlogged. Tasteless final product.

Processing for the First Time Point

After the "0" time point sample had been drawn, all remaining food materials were rinsed briefly (30 seconds or less) under cold running water before proceeding. A quantity of each selection, sufficient to cover all experimental time points, was used. Each food was placed in a minimum of 2 L of water, at predetermined temperatures for predetermined times. Food materials from groups A, C, and E (Table 2) were placed in hot tap water (100-110°F), stirred vigorously for 15 to 20 seconds, and

Table 2. Dietary Selection Processing Groups

Group A	
Vegetables:	Asparagus, green beans (canned), broccoli, cabbage (red), carrots, corn, garlic, mushrooms and peas (both canned), potato (flake), summer squash, sweet potato, tomatoes (canned/fresh), winter squash
Meats:	Beef liver, beef strips, salmon (fresh)
Legumes:	Peanuts (cracked)
Fruits:	Apples, cantaloupe, kiwi, pineapple and tangerine (canned), grapefruit
Grains:	Whole wheat, soy flour, pancake mix
Group B	
Grain:	Rice (wild)
Legumes:	Great Northern and lima beans (canned), kidney beans, soybeans, soy grits
Group C	
Cheese:	Cheddar (shredded)
Meats:	Tuna (canned), hamburger (fresh)
Group D	
Meats:	Ham (canned-processed), hot dogs (processed-pork)
Group E	
Vegetables:	Sauerkraut (canned)
Group F	
Fruits:	Avocado, banana

allowed to stand for predetermined time periods. Samples of canned great Northern and lima beans (group B) were chopped or split at least once before being subjected to the same hot water bath temperature and conditions as materials in groups A, C, and E above. Samples of wild rice, soy beans, soy grits, and kidney beans (group B) were placed in boiling water, stirred vigorously for 15 to 20 seconds before the container was removed from the heat, and allowed to stand for 1 hour. Food materials from group D were each placed in boiling water baths, stirred continuously, and allowed to boil for 3 minutes. Samples from group F were placed in cold tap water, stirred gently for 5 to 10 seconds, and allowed to stand undisturbed.

At the conclusion of each respective treatment period, samples of each food item were removed from their respective water baths, allowed to drain in a sieve before being placed on a paper towel and patted dry. Fifty-gram samples of each were weighed, bagged, and labeled as the first time point. Excess food materials were returned to their respective water baths, with the exception of kidney beans and soybeans (group B), tuna (group C), and food material in group D. The contents of each water bath were then drained into sieves, the hot water was replaced with cold tap water (50-55°F), and food materials were returned to a cold water bath and allowed to continue to the second time points. Soybeans were ground in a meat grinder, returned to a boiling water bath, and stirred; the container was removed immediately from the heat; and the contents were allowed to stand until the end of the second time point. Kidney beans were chopped, at least one cut per bean, before being placed in a boiling water bath and processed in a like manner as soybeans.

Processing for the Second and Subsequent Time Points

After the first time point sampling, all food materials, except kidney beans and soybeans, scheduled to undergo additional time point samplings, were placed in cold-water baths (same excess volume of water) for the remainder of the test period. Water changes were made at the end of each time point to be taken. Kidney beans and soybeans began their first cold water exposure after the second time point was taken.

Table 3. Mineral Content of Demineralized Cheese, Fruit, and Grain

	Milligrams of Potassium, Phosphorous, and Sodium per 100 g of Sample											
	0 Time			30 Min			1 Hr			Total % Reduction		
	K	P	Na	K	P	Na	K	P	Na	K	P	Na
Cheese												
Cheddar (shredded)	60	400	511	9	368	56	UD	325	14	>99	19	>97

	Milligrams of Potassium, Phosphorous, and Sodium per 100 g of Sample											
	0 Time			1 Hr			2 Hr			Total % Reduction		
	K	P	Na	K	P	Na	K	P	Na	K	P	Na
Fruits												
Apple	86	ND	ND	57	ND	ND	45	ND	ND	48	ND	ND
Avocado	197	ND	ND	178	ND	ND	116	ND	ND	41	ND	ND
Banana	351	ND	ND	223	ND	ND	188	ND	ND	46	ND	ND
Cantaloupe	229	ND	ND	133	ND	ND	111	ND	ND	51	ND	ND
Grapefruit	140	ND	ND	77	ND	ND	72	ND	ND	49	ND	ND
Kiwi	246	ND	ND	141	ND	ND	127	ND	ND	48	ND	ND
Pineapple (C)	125	ND	ND	58	ND	ND	50	ND	ND	>59	ND	ND
Tangerine (C)	215	ND	ND	180	ND	ND	157	ND	ND	27	ND	ND
	K	P	Na	K	P	Na	K	P	Na	K	P	Na
Grains (flour)												
Whole wheat	343	350	ND	73	165	ND	30	150	ND	91	57	ND
Soy	1705	533	ND	169	140	ND	42	90	ND	>97	84	ND
Pancake (mix)	125	577	ND	14	179	ND	5	230	ND	96	60	ND

Abbreviations: K, potassium; P, phosphorous; Na, sodium; C, canned; ND, not done; UD, below the limits of detection (less than 10 parts per million).

Table 4. Mineral Content of Demineralized Legumes, Raw and Processed Meats

	Milligrams of Potassium, Phosphorous, and Sodium per 100 g of Sample														
	0 Time			1 Hr			4 Hr			8 Hr			Total % Reduction		
	K	P	Na	K	P	Na	K	P	Na	K	P	Na	K	P	Na
Legumes															
Great Northern beans (C)	214	84	ND	38	51	ND	16	48	ND	2	48	ND	>99	43	ND
Kidney beans (D)	215	104	ND	95	98	ND	62	91	ND	22	80	ND	90	23	ND
Lima beans (C)	306	70	ND	84	51	ND	29	40	ND	6	39	ND	98	44	ND
Peanuts (D)	549	310	ND	364	257	ND	353	227	ND	229	216	ND	58	30	ND
Soybeans (D)	1010	367	ND	116	184	ND	66	160	ND	29	144	ND	97	61	ND

	0 Time			1 Hr			2 Hr			Total % Reduction		
	K	P	Na	K	P	Na	K	P	Na	K	P	Na
Soy grits (D)	2488	514	ND	160	158	ND	117	139	ND	>95	>73	ND

	Milligrams of Potassium, Phosphorous, and Sodium per 100 g of Sample														
	0 Time			30 Min			1 Hr			8 Hr			Total % Reduction		
	K	P	Na	K	P	Na	K	P	Na	K	P	Na	K	P	Na
Meats															
Beef liver	249	284	ND	ND	ND	ND	109	194	ND	19	125	ND	>92	56	ND
Beef strips	232	131	ND	ND	ND	ND	19	67	ND	4	61	ND	>98	53	ND
Hamburger	216	123	44	36	70	9	11	65	5	ND	ND	ND	95	47	89
Salmon (C)	259	158	26	ND	ND	ND	112	112	16	11	61	4	>95	61	>84

	Milligrams of Potassium, Phosphorous, and Sodium per 100 g of Sample											
	0 Time			30 Min			After Boiling			Total % Reduction		
	K	P	Na	K	P	Na	K	P	Na	K	P	Na
Processed meats												
Ham (C)	292	250	1104	ND	ND	ND	55	121	221	81	51	80
Hot dogs	155	222	1379	ND	ND	ND	88	187	840	43	16	39
Tuna (C)	136	92	219	5	51	9	ND	ND	ND	96	45	96

Abbreviations: K, potassium; P, phosphorous; Na, sodium; ND, not done; C, canned; D, dried.

Determinations of Phosphorus, Potassium, and Sodium

Processed samples were packaged, labeled, frozen, and shipped in a cooler with sufficient dry ice. To confirm the reproducibility of the demineralization results, sufficient additional materials for each food being tested were included in the shipment. Analysis of remaining phosphorous, potassium, and sodium content was conducted at Midwest Laboratories Inc in Omaha, NE, a multistate/United States Department of Agriculture certified food and industry testing facility, according to the procedure for inductivity coupled argon plasma spectrophotometry. Sample analysis was performed with check samples (peach leaf sample with a known mineral content) and a fresh blank's at every run. Duplication testing of samples was performed on every 10th sample (10% duplication), as well as checks for calibration errors. In addition, this author requested a recheck of randomly selected samples to verify test reproducibility. To be consistent with existing nutritional tables, all results are expressed as milligrams of remaining mineral per 100 g of sample.[2,3]

Results

Tables 3 through 5 summarize the demineralization results obtained for each selection. The phosphorous reduction range for vegetables, legumes, meats, flours, and cheddar cheese, was 51% ± 33%, 48% ± 25%, 38.5% ± 22.5%, 70.5% ± 13.5%, and 19%, respectively; for potassium, the reduction range for vegetables, legumes, meats, flours, cheddar cheese, and fruit was 59%

Table 5. Mineral Content of Demineralized Vegetables

	Milligrams of Potassium, Phosphorous, and Sodium per 100 g of Sample														
	0 Time			1 Hr			2 Hr			8 Hr			Total % Reduction		
	K	P	Na	K	P	Na	K	P	Na	K	P	Na	K	P	Na
Vegetables															
Asparagus	207	ND	ND	185	ND	ND	148	ND	ND	143	ND	ND	31	ND	ND
Green beans (C)	68	ND	262	13	ND	48	4	ND	9	UD	ND	4	>99	ND	>98
Broccoli	300	ND	ND	229	ND	ND	ND	ND	ND	185	ND	ND	>38	ND	ND
Cabbage (red)	219	ND	ND	76	ND	ND	ND	ND	ND	59	ND	ND	>73	ND	ND
Carrots	391	ND	ND	266	ND	ND	265	ND	ND	263	ND	ND	>32	ND	ND
Corn (C)	112	38	149	59	25	81	43	24	62	29	22	46	74	42	69
Garlic	479	ND	ND	286	ND	ND	ND	ND	ND	ND	ND	ND	>40	ND	ND
Mushrooms (C)	112	44	292	28	40	91	13	36	42	ND	ND	ND	88	18	>86
Peas (C)	105	84	286	33	71	113	13	66	41	3	62	14	97	26	95
Potato (D)	1047	124	ND	42	20	ND	16	20	ND	ND	ND	ND	98	84	ND
Summer squash	211	37	ND	141	28	ND	134	27	ND	ND	ND	ND	36	27	ND
Tomato (F)	208	ND	ND	194	ND	ND	136	ND	ND	75	ND	ND	64	ND	ND
Tomato (whole) (C)	212	ND	161	43	ND	54	37	ND	42	2	ND	4	99	ND	>98
Wild rice (D)	230	270	ND	72	142	ND	ND	ND	ND	44	115	ND	80	>57	ND
Winter squash	323	ND	ND	207	ND	ND	ND	ND	ND	193	ND	ND	40	ND	ND
Yam (sweet potato)	244	21	ND	233	20	ND	209	16	ND	198	11	ND	>19	48	ND

	0 Time			15 Min Treatment			Total % Reduction		
	K	P	Na	K	P	Na	K	P	Na
Sauerkraut (C)	170	ND	ND	24	ND	ND	>85	ND	ND

Abbreviations: K, potassium; P, phosphorous; Na, sodium; ND, not done; C, canned; D, dried; F, fresh; UD, below the limits of detection (less than 10 parts per million).

± 40%, 78.5% ± 20.5%, 57% ± 41%, 94% ± 3%, 99%, and 43% ± 16%, respectively; for sodium, the reduction range for vegetables, meats, and cheddar cheese was 83.5% ± 14.5%, 67.5% ± 27.5%, and 97%, respectively. Participants rated processing instructions straightforward and "consumer friendly." The final product was judged satisfactory with regard to texture and visual appeal. Some considered taste slightly "bland." To effectively enhance favor, without increasing sodium, it was suggested that a mixture of sodium-free flavoring herbs, garlic, or onion powder be applied lightly to any demineralized dish. Care must be taken not to overseason the dish, or insatiable thirst may result. It is interesting to note that the test consumers felt positive word association significantly enhanced the likelihood that a procedure would be used. The word "demineralization" was rated positively, whereas words such as "leaching" or "dialyzing," used to describe aqueous mineral removal from foods, were considered to have a "somewhat negative" or "unappealing" connotation when used in food preparation instructions. A new consumer-friendly procedurally descriptive cookbook, entitled *Healthy Living With Demineralization,* focusing on total dietary demineralization, is currently under preparation (Fall of 2000), with its completion expected before the Summer of 2001.

Discussion

Most foods tested responded very well to demineralization. The largest mineral losses occurred primarily during the first, or first and second time points. As shown in Tables 3 through 5, by the end of the final processing period, most selections had 2 or more target mineral contents low enough for them to be reclassified as "low," as defined in either the mineral guidelines for renal patients,[24] or government labeling guidelines for sodium. Variability, in the degree and success of mineral removal across the food types tested, was expected because of: (1) cell density differences between the respective foods, (2) structural differences between animal and vegetable cells, and (3) permeability changes in cells exposed to canning conditions.

An example of how canning effects demineralization time can be seen in the results obtained for the fresh and canned tomatoes (Table 5). Initial potassium levels for fresh and canned tomatoes were 208 mg and 212 mg, respectively. Within the first treatment hour, potassium was reduced only 7% for fresh tomatoes, but 80% for canned. Although most foods do respond well to demineralization, this author discovered (in a prior mini-study—data unpublished) that some foods, which have certain mucilaginous characteristics, spongy texture, or oily qualities, are poor choices for demineralization. These foods are listed in Table 1.

Consuming a total dietary selection of demineralized foods is expected to have a significant positive impact on heretofore-problematic hematological mineral values. In a mini-study conducted in 1998-99 (data unpublished), control and renal volunteers, who were asked to consume an entire dietary range of only demineralized foods for 4 months, noted decreased blood serum values for these target minerals. It must be mentioned that the potential for certain water-soluble vitamin (ie, vitamin C, folate, vitamin B-6)[25] and iodine deficiencies exists if an individual consumes only demineralized foods over an extended period of time. Periodic monitoring and prescribing appropriate renal supplements, when warranted, should easily circumvent the problem.

By making previously restricted, or excluded, high mineral foods permissible once again, noncompliance issues are eliminated. Nutritional profiles will improve once the patient is able to reintegrate a broader dietary selection.

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