Managing Phosphate: From Plate to Prescription

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Managing Phosphate: From Plate to Prescription

- Old School vs. New Rules: The evolution of low phosphate diets

- Phosphate Binders: From basics to best practice

Old School vs. New Rules: The evolution of low phosphate diets

Historical Context – The Old Dietary Approach

- Focussed on blanket food restrictions based on phosphate content (e.g. cheese, milk, yoghurts, nuts)
- Limited patient education on phosphate types or absorption rates
- Often led to nutritional deficiencies and reduced quality of life

Modern Strategies

- More focus on phosphate source and absorption
- Use of food labelling to track phosphate additives
- Emphasis on patient education and individualised plans
  - More balanced diet approaches

"It's not just low phosphate—it's smart phosphate"

Sources of phosphorus

Where is it found?

Food sources
Non-food sources

Food sources

- Organic
    - Within food naturally

- Inorganic

- Added to food

Organic phosphorus

- Animal foods
  - Meat, poultry, fish, dairy products, eggs
  - High protein = high phosphate

- Plant foods
  - Beans, peas, cereals, and nuts
  - Mainly in the form of phytate

Phosphorus : protein ratio

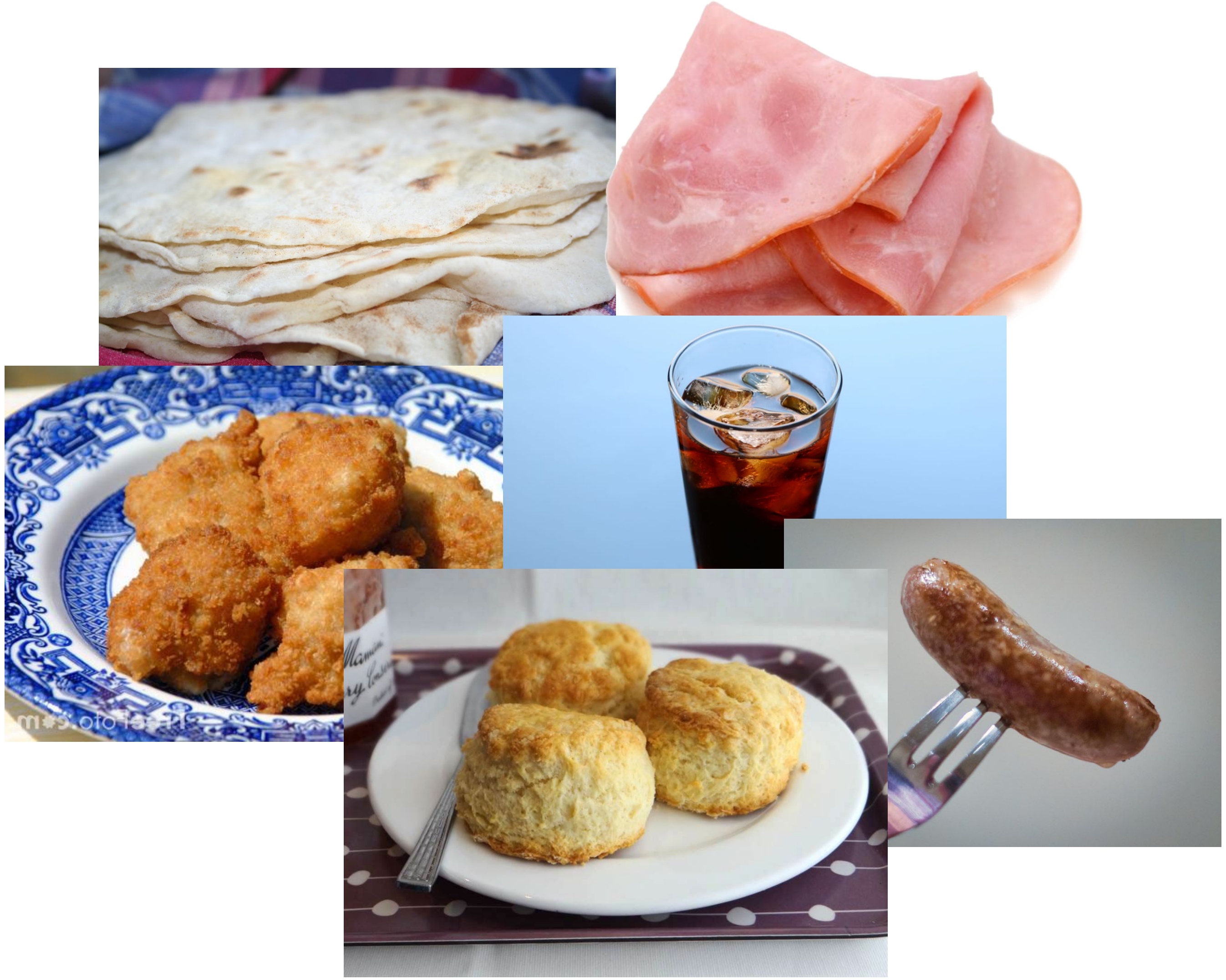
Protein source	***Phosphorus in mg / g protein***
Meat	8mg / g protein
Fish	10mg / g protein
Pulses	15mg / g protein
Eggs	16mg / g protein
Shellfish	17mg / g protein
Offal	18mg / g protein
Cheese	19mg / g protein
Tinned fish	20mg / g protein
Milk	25mg / g protein
Nuts	25mg / g protein
Yogurt	28mg / g protein
Mixed diet	***Average 12-14mg / g protein***

Kalantar-Zadeh et al (2010)

Barril-Cuadrado et al (2013)

Boaz and Smetana (1996)

Inorganic phosphorus



- Additives and preservatives
  - Bakery goods, drinks, processed meat, poultry and fish products, processed cheese, fast foods, other processed foods
  - Ingredients list
    - E numbers
    - ‘phosph’

E number	Name of additive	Products
E338	Phosphoric acid	Non-alcoholic flavoured drinks, sterilised and UHT milk, candied fruits, fruit preparations, beer, processed meats, sweets, cakes and chocolate
E339	Sodium phosphate	Partly dehydrated milk, dried milk powder pasteurised, sterilised and UHT cream, whipped cream and vegetable fat analogues, unripened cheeses, canned soup, breaded chicken and fish
E340	Potassium phosphate	Processed cheese, meat products, sports drinks, table waters, vegetable protein drinks, powdered milk, desiccated coconut
E341	Calcium phosphate	Beverage whiteners, edible ices, desserts, milk desserts, powdered milk, dry powder for dessert mixes, self-raising flour, instant pasta, sauces
E343	Magnesium phosphate	Bakery products, flour, liquid egg, salt substitutes, prepared mustard
E450	Diphosphate	Bakery products, meat products, processed cheese, sauces, soups and broths, instant tea and instant herbal infusions, edible ices, dried powdered food, milk-based drinks, baking powder
E451	Triphosphate	Meat products, fish and seafood products, processed cheese, beverage whiteners, edible ices, icing sugar, flavoured syrups for ice creams or milkshakes
E452	Polyphosphate	Meat products, frozen fish and seafood, processed cheese, sauces (especially cheese based), beverage whiteners, edible ices, icing sugar, sugar confectionary, dried powdered foods, milk based drinks, noodles, batters, processed potato products

BDA RNG (2018) Phosphorus in Foods: Considerations in Chronic Kidney Disease

Low additive diet v additive enhanced diet

Low additive =
'no preservatives added', 'organic', 'baked fresh', 'no processing'

v

Additive enhanced =
'enhanced' additives identified on packaging

- 4-day menu
- Identical energy and nutrient content
- Estimated nutrient contents
- Measured nutrient contents

Carrigan et al (2014)

Results

Variable	Low-Additive Diet		Additive-Enhanced Diet	
	Estimated Values *	Measured Values	Estimated Values *	Measured Values
Calories (kJ/day)	1932 ± 171	2294 ± 258	1910 ± 195	2278 ± 323
% fat	24 ± 2	24 ± 2	28 ± 0.1	28 ± 5
% protein	16 ± 3	17 ± 3	16 ± 1	16 ± 4
% carbohydrates	62 ± 1	59 ± 2	58 ± 2	56 ± 9
Calcium (mg/day)	656 ± 166	732 ± 232	654 ± 169	677 ± 178
Phosphorus (mg/day)	924 ± 82	1070 ± 58§	1426 ± 275	1677 ± 167†
Sodium (mg/day)	2271 ± 620	2068 ± 633	3727 ± 731	3396 ± 651††
Potassium (mg/day)	2785 ± 946	3252 ± 758	2919 ± 775	3152 ± 580

607 ± 125mg more P in additive-enhanced diet (measured) ($p<0.001$)
Measured v estimated - no statistically significant differences

Non-food sources

Medication

Ranked by frequency	Medication	Phosphate content/tab (mg)	Median dose (# of tablets per day)	Phosphate contribution by median daily dose (mg)
1	Amlodipine	3.8 – 116.6 dibasic calcium phosphate	1	3.3 – 112
2	Lisinopril	3.6 – 121 dibasic calcium phosphate	1	3.1 – 116.2
3	Clonidine	1.4 – 3.5 dibasic calcium phosphate	2	2.4 – 6.72
4	Acetaminophen	0	4	0
5	Omeprazole	175 – 200 disodium hydrogen phosphate	1	175 – 200
6	Nifedipine	40 dibasic calcium phosphate	1	40
7	Pantoprazole	175 – 200 calcium glycerophosphate	1	175 – 200
8	Tramadol	62 dibasic calcium phosphate	3	160 – 178

(Sawin et al, 2019)

Supplements

- dietary
- herbal
- nutritional


SO
WHAT?

Bioavailability of phosphorus

What proportion of the phosphorus is absorbed?

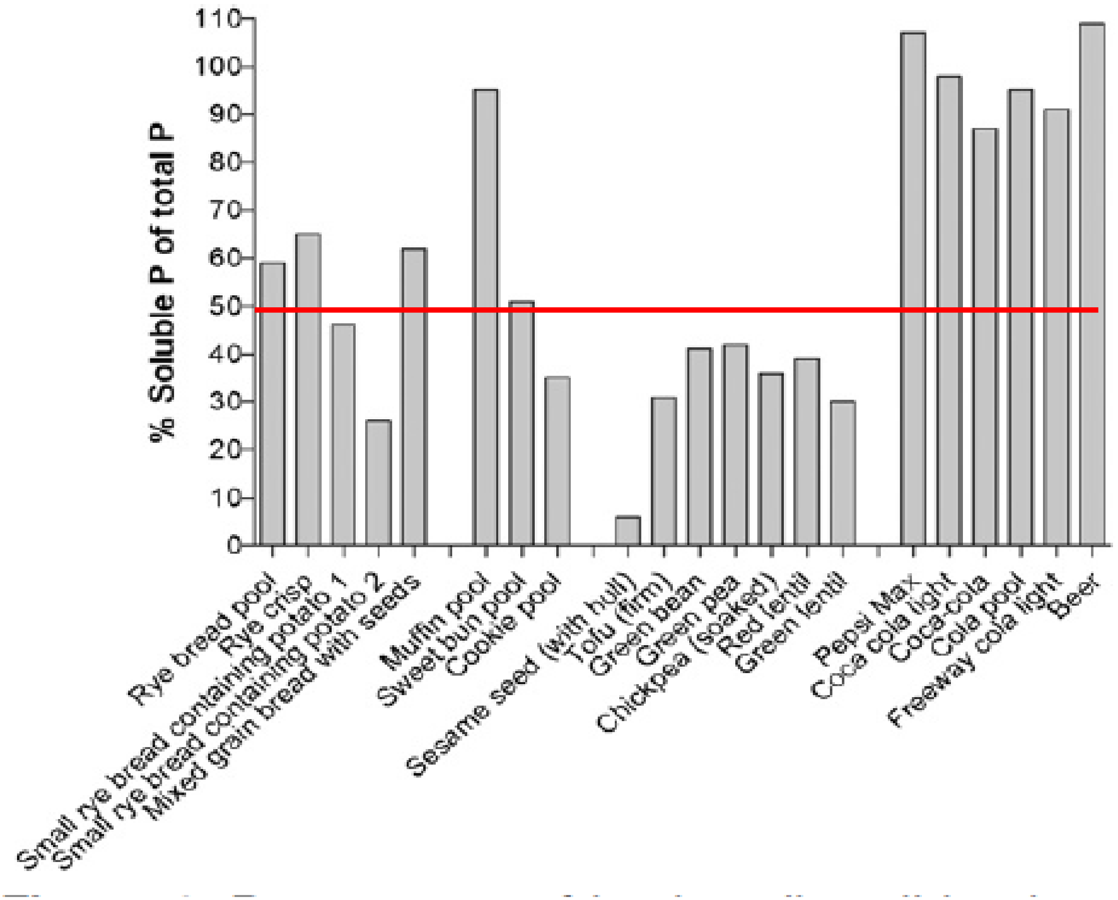
Bioavailability

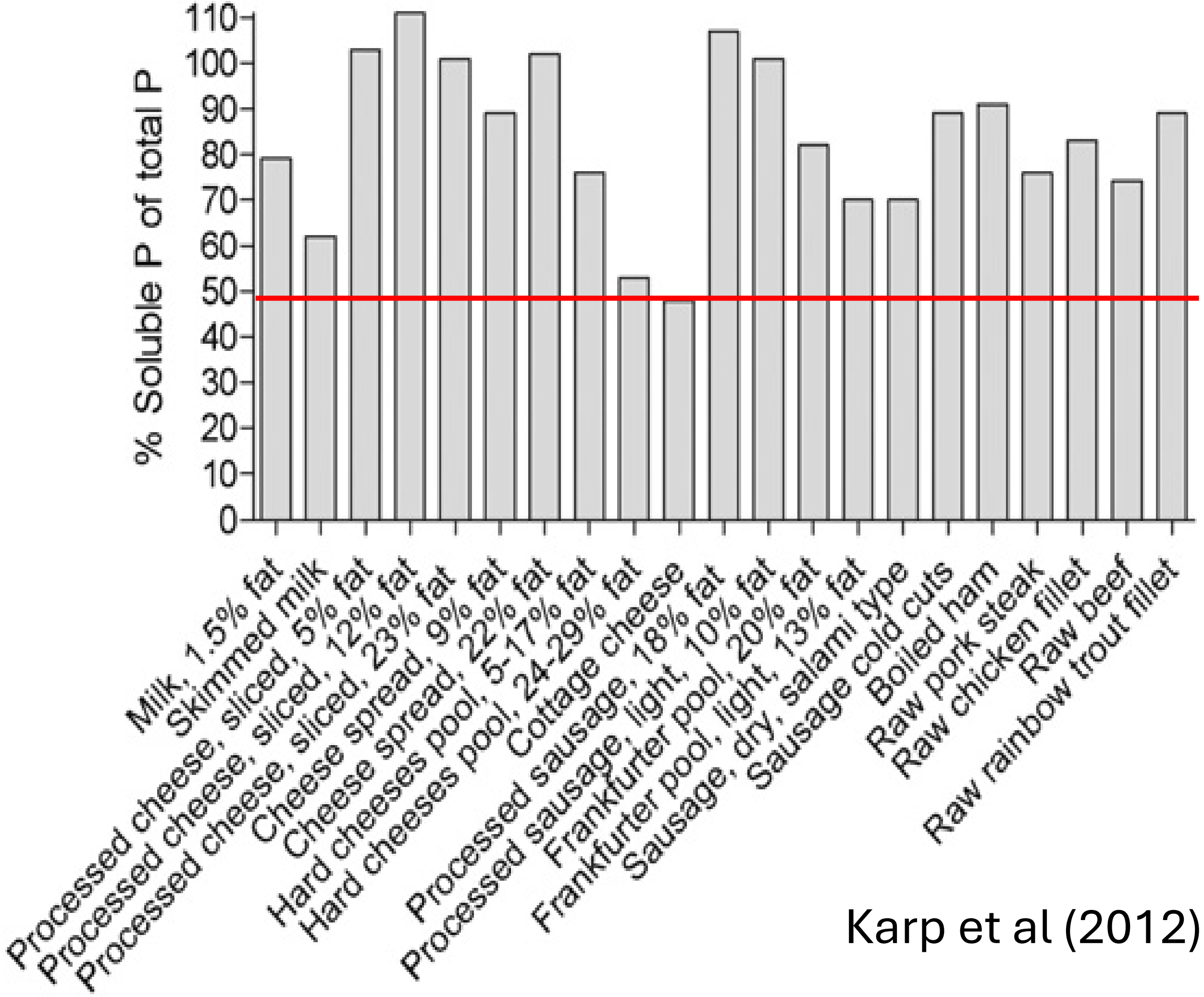
The proportion of phosphate taken up systematically by the body

Phosphate source	Bioavailability	Absorption
Animal derived	High	>50%
Plant derived	Low	<50%
Additives/ preservatives	Very high	>90%

Kalantar-Zadeh et al (2010)
Noori et al (2010)

% of in vitro digestible phosphorus to total phosphorus (reflecting absorbability)





Karp et al (2012)

Safety and Efficacy of Using Nuts to Improve Bowel Health in Hemodialysis Patients

- Daily consumption of 40g raw unsalted almonds with skin for four weeks
  - 8 g of protein, 3 g of fibre, 210 mg of phosphate and 318 mg of potassium

- The primary efficacy outcome was reduction in constipation
  - Significant improvement in constipation
- The primary safety outcome measures were change in predialysis serum potassium and phosphate levels.
  - No significant increase in serum potassium ($p=0.21$) or serum phosphate ($p=0.16$) after controlling for confounders.

Lambert et al (2020)

Vegetarian v meat dietary protein source Moe et al (2011)

- eGFR 25 to 40 ml/min) and normal serum phosphorus (no CKD-MBD meds)
- Grain/soy-based protein diet (vegetarian) v meat/dairy-based protein diet (meat)
  - 7 days, comparable for macronutrients and dietary phosphorus intake, 2 – 4 week washout then switched diet
- Blood and urine tests at baseline and during last day of the 7-day diet period

	Before Meat (casein) Diet	After Meat (casein) Diet	Before Vegetarian (grain) Diet	After Vegetarian (grain) Diet	*P* (paired *t* test)[a]
Average daily phosphorus intake (mg/day)		810 ± 27		795 ± 51	NS
Plasma phosphorus (mg/dl)	3.5 ± 0.6	3.7 ± 0.6	3.5 ± 0.6	3.2 ± 0.5	0.02
Plasma intact PTH (pg/ml)	58 ± 31	46 ± 29	58 ± 39	56 ± 30	0.002
Plasma FGF23 (pg/ml)	72 ± 39	101 ± 83	84 ± 65	61 ± 35	0.008
Plasma calcium (mg/dl)	9.2 ± 0.4	9.4 ± 0.7	9.3 ± 0.4	9.1 ± 0.3	NS
Urine 24-hour phosphorus excretion (mg/24 h)	836 ± 187	583 ± 216	778 ± 190	416 ± 233	0.07

The Impact of Protein Type on Phosphorus Intake, Serum Phosphate Concentrations, and Nutrition Status in Adults with Chronic Kidney Disease: A Critical Review

- Updated KDOQI (2020) suggested insufficient evidence to recommend animal protein over plant protein, however, historically limiting plant proteins was central to low phosphate diets.

- Review aimed to summarise evidence

- 16 articles included (7 intervention and 9 observational studies)

- General agreement that higher amounts of plant compared with animal-protein intake were not associated with either higher phosphorus intakes or serum concentrations.

- Limitations
  - Baseline serum phosphate levels not that high, ?flawed search strategy, ?publication bias, small sample sizes in intervention studies

Picard et al (2021)

Effect of Food Additives on Hyperphosphatemia Among Patients With End-stage Renal Disease. A Randomized Controlled Trial

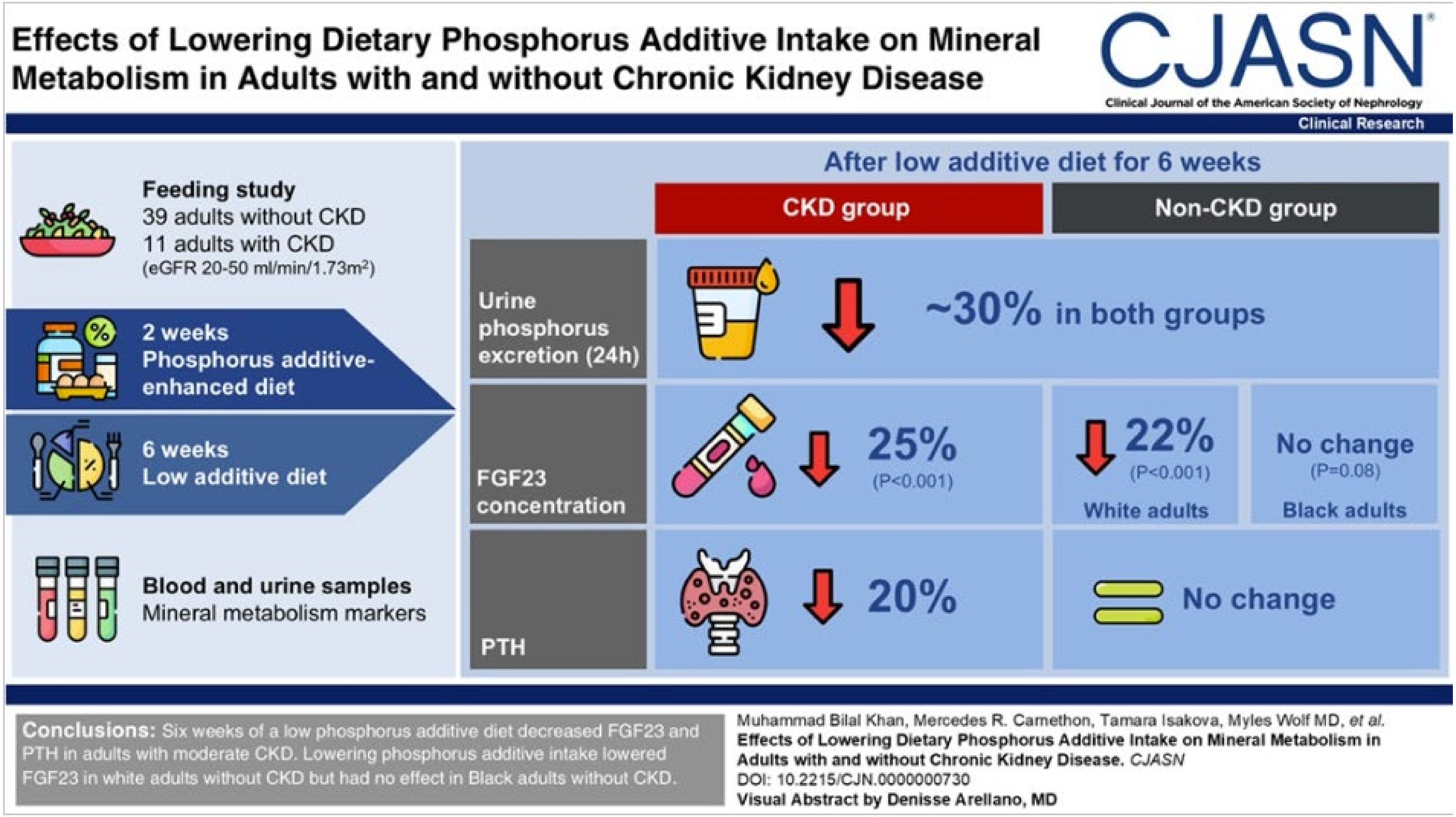
- 14 long-term dialysis facilities in US
- Serum phosphate >5.5mg/dl (1.78mmol/l)

- Intervention
  - 30 mins education about phosphate additives
  - Small magnifier with details of common phosphate additives on the case
  - Advised to avoid purchase of foods with additives and given info re: fast food menus
- Control
  - Usual care

- Main Outcome
  - Change in serum phosphorus level after 3 months

	Intervention (n=145)	Control (n=134)
Change in serum phosphate	-1.0mg/dl (-0.323mmol/l) p<0.001	-0.4mg/dl (-0.129mmol/l) p=0.02
-0.6mg/dl difference		p=0.03

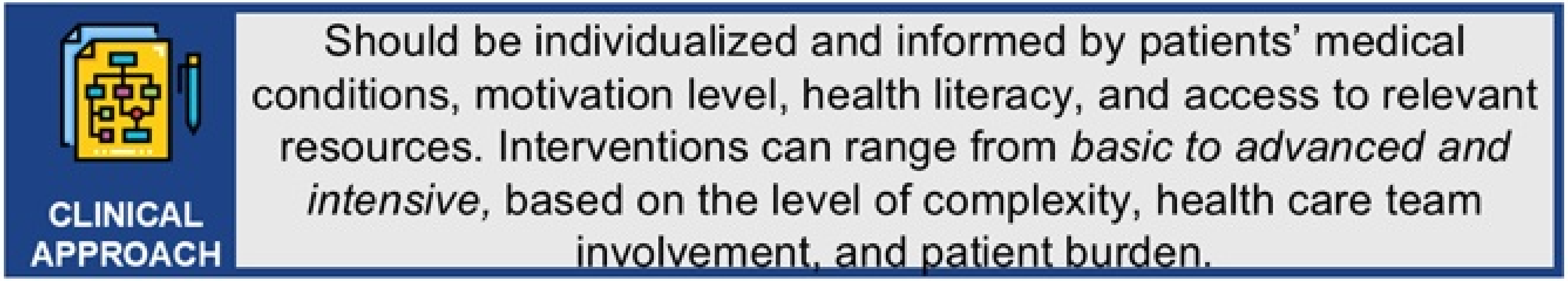
Sullivan et al (2009)



Khan et al (2025)

ASN Kidney Health Guidance on Potassium and Phosphorus Food Additives

Journal of the American Society of Nephrology ():10.1681/ASN.0000000873, September 18, 2025. | ***DOI:*** 10.1681/ASN.0000000873



Biruete et al (2025)

Pilot Randomized Controlled Trial of a Standard Versus a Modified Low-Phosphorus Diet in Hemodialysis Patients

- 13 dialysis units in Ireland
- Inclusion
  - HD > 3 months, serum phosphate >5.0mg/dl (1.62mmol/l) preceding 3 months
- Exclusion
  - Hyperkalaemia in preceding month, parathyroidectomy, abnormal serum calcium
- Standard v modified low phosphorus diet

Outcome

- Impact on serum phosphate levels
- Self-reported tolerability, safety in respect to hyperkalemia, and the nutritional composition of the modified diet (specifically the phosphorus, the phytate bound phosphorus, and the fiber content of the modified diet)

Byrne et al (2020)

CONTROL

Standard diet
Aiming for 1-1.2g protein / kg ideal body weight (70% HBV)
Restricting dairy food intake (milk, cheese, yoghurt)
Avoidance of food high in phosphorus (wholegrains, nuts, pulses)
Avoidance of phosphorus additives

Re-educated regarding their diet and provided with the standard diet sheet

INTERVENTION

Modified low phosphorus diet
Inclusion of plant-based protein foods such as pulses, nuts, wholegrains with reduced phosphorus bioavailability due to phytate content. Substituted for HBV protein sources
Avoid overprescription of protein (and associated obligatory phosphorus) and include some focus on phosphorus : protein ratio.
Avoidance of phosphate additives from the European Union list of authorized phosphate additives in foods

Educated and provided with modified diet sheet, product samples of pulses and nuts, a recipe booklet, and a shopping card of phosphate additives

Results

- No significant difference in serum phosphate or serum potassium after 1 month
- Significantly more fibre and phytate bound phosphorus in modified diet group
- Other nutrient intakes were not significantly different
- Significantly increased bowel movements –reported by 34% in modified diet v 6% standard diet (p= 0.008)
- On the modified diet, 81% found it easy to include nuts, 44% to include pulses and 52% to include egg whites
- Wider food choice and greater fibre intake than the standard diet

Modern Strategies

- Focus on phosphate source and absorption, not just quantity
- Use of food labelling to track phosphate additives
- Emphasis on patient education and individualized plans

"It’s not just low phosphate—it’s smart phosphate"

Other factors affecting phosphorus intake

Other factors

- Phosphorus content can be reduced by: -
  - Boiling
  - Soaking
  - Dehulling of legumes
  - Consideration of particle size when cooking

Cupisti et al (2006)
Jones et al (2001)
De Abreu et al (2023)

- Increased bioavailability of phosphorus from phytate: -
  - Fermentation
  - Germination
  - Soaking
  - Pressure cooking

(NB. May have implications for more plant-based alternatives to meats, all containing phytate)

Byrne et al (2021)
Calvo & Uribarri (2021)

Phosphate Binders:
From basics to best practice

Summary of phosphate binders

Generic name	Trade name	Dosage	Elemental Ca per tablet	Instructions	Cost per tablet
Calcium carbonate	Adcal	1.5g	600mg	Chew	9p
Calcium carbonate	Calcichew	1.25g	500mg	Chew	9p
~~Calcium acetate~~	~~Phosex~~	~~1g~~	~~250mg~~	~~Swallow whole~~	
Calcium acetate	Renacet	475mg/950mg	120.25mg/ 240.5mg	Swallow whole	7p/10p
~~Calcium acetate /~~ magnesium carbonate	~~Osvaren~~	~~435mg/235mg~~	~~110mg~~	~~Swallow whole~~	
Sevelamer hydrochloride	Renagel	800mg	None	Swallow whole	15p
Sevelamer carbonate	Renvela	800mg / 2.4g sachet	None	Swallow whole / mix with water	
Lanthanum carbonate	Fosrenol	500, 750 & 1000mg / 750mg sachet	None	Chew / sprinkle on food	£1.38 / £2.03 / £2.15
Aluminium hydroxide	Alucaps	475mg	None	Swallow whole	
Sucroferric oxyhydroxide	Velphoro	500mg	None	Chew	£1.99

Which binder?

- Clinical
- Cost
- Preference

Relative phosphate binding coefficient (RPBC)

Phosphate binder	RPBC by g of compound listed in available product
Calcium carbonate (index value)	1.0
Calcium acetate	1.0
Magnesium carbonate (anhydrous weight, Magnebind)	1.7
"Heavy" magnesium carbonate (hydrated weight, OsvaRen)	1.3
Aluminum hydroxide	1.5
Aluminum carbonate	1.9
Sevelamer (carbonate or hydrochloride)	0.75
Lanthanum carbonate	2.0[a]

RPBC, relative phosphate-binding coefficient.

[a]Lanthanum carbonate tablet or wafer sizes are marketed as mg of elemental lanthanum. If based on mg of lanthanum carbonate the RPBC (relative to mg of $CaCO_3$ would be 1.2 instead of 2.0.

- Calcichew 1.25g tablet = 1.25
- Adcal 1.5g tablet = 1.5
- Renacet 950mg = 0.95
- Phosex 1g tablet = 1.0
- Sevelamer 800mg tablet = 0.6
- Lanthanum 750mg tablet = 0.9
- Sucroferric oxyhydroxide tablet 500mg = 1.6

(Daugirdas et al, 2011)

Phosphate-Binding Agents in Adults With CKD: A Network Meta-analysis of Randomized Trials (Palmer et al, 2016)

- All phosphate binders significantly lowered serum phosphorus levels compared to placebo.
- Iron lowered serum phosphorus levels to a greater extent than lanthanum, sevelamer, and calcium and was ranked as the best treatment.
- Lanthanum increased nausea compared with calcium and iron (ORs of 2.18 [95% CI, 1.00-4.74], and 4.07 [95% CI, 1.15-14.3])
- Sevelamer increased constipation compared with calcium, lanthanum, and iron (ORs of 2.12 [95% CI, 1.01-4.45], 3.04 [95% CI, 1.31-7.02], and 3.15 [95% CI, 1.73-5.75])
- Iron increased diarrhoea compared to calcium (OR, 3.30; 95% CI, 1.02-10.8), but differences between all other phosphate binders were not significant
- No drug increased abdominal pain

Phosphate binders for preventing and treating chronic kidney disease-mineral and bone disorder (CKD-MBD) (Review)

Cochrane Library

Cochrane Database of Systematic Reviews

Objectives

- To assess the benefits and harms of phosphate binders for people with CKD and whether phosphate binders have different effects compared with each other.

Selection criteria

- RCTs or quasi-RCTs of adults with CKD (any GFR)
- Studies that compared a phosphate binder to placebo, usual care, or a different phosphate binder with follow-up of at least eight weeks.

Key outcomes

- Death (all causes)
- Cardiovascular death
- Hypercalcaemia
- Nausea
- Constipation
- Serum phosphate
- Vascular calcification

Natale et al (2025)

Phosphate binders for preventing and treating chronic kidney disease-mineral and bone disorder (CKD-MBD) (Review)

- Sevelamer may lower death from any cause and incur less hypercalcaemia compared to calcium-based binders in people on dialysis. Lanthanum may also result in less hypercalcaemia compared to calcium.

- Sevelamer may increase the risk of constipation, while lanthanum may increase both the risk of nausea and constipation, but may slightly reduce serum phosphate in people with CKD compared to placebo/ usual care.

- No clinically important benefits of phosphate binders were identified for cardiovascular death or coronary artery calcium score compared to placebo/usual care.

- The evidence for the effects of other phosphate binders on key clinical outcomes in head-to-head comparisons was uncertain.

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