Phosphorus in Food and Food Additives
Potential for Source Control?

Ralph Early
Harper Adams University
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Phosphorus and Crop Production

Cordell et al (2009) describe mankind’s dependence on Phosphorus as an addiction:

• P: essential to plant growth

• P: and element on the periodic table – cannot be substituted

• Sources: Manure; Guano; Human excreta; Phosphate rock

• World-wide demand for P predicted to grow by 50-100% by 2050

• Non-renewable resource: as with oil, peak P will be reached at some point
Phosphorus and Food

Phosphorus occurs in food as:

**Organic phosphorus**: naturally present due to the nature of food materials (DNA, phospholipids, calcium-phosphate, etc.)

**Inorganic phosphorus**: present due to the use of functional technical food additives
Inorganic Phosphates

- Phosphates are the salts of phosphoric acid
- Inorganic (mineral) phosphates are not considered natural or organic
- Clean label pressure from retailers to remove phosphates
- Environmental problems – fresh water eutrophication – need to replace phosphates
- Health problems – phosphates linked to kidney disease
- Food industry faces pressure to reduce use of, or replace phosphates as functional additives
Common food additives containing phosphorus

- Acid pyrophosphate
- Dicalcium phosphate
- Hexametaphosphate
- Monocalcium phosphate
- Phosphoric acid
- Pyrophosphate sodium
- Sodium aluminium phosphate
- Sodium phosphate
- Sodium tripolyphosphate
- Tricalcium phosphate

Note: Calvo and Uribarri (2013) record 50 commonly used phosphate-containing GRAS substances most of which are used in food manufacture
Functions of Phosphates in Food Systems

- Leavening
- Buffering pH
- Acidification
- Emulsification/creaming
- Stabilizing
- Water-holding capacity
- Chelating metals
- Antioxidant
- Flavour enhancer
- Texture modification/maintenance
- Decreasing cooking time
- Anti-caking
- Suspension/dispersion agent
- Maintain colour
Phosphorus in Manufactured Foods

- Bread and baked goods
- Canned soups
- Canned vegetables
- Carbonated beverages
- Cereals
- Condiments
- Evaporated milk
- Frozen vegetables
- Gravies and sauces
- Pet foods
- Prepared dry foods e.g. soups, sauces
- Prepared frozen foods
- Prepared RTE foods
- Processed cheeses
- Processed meats
- Shelf-stable juice drinks
- Snack foods
- Yogurt
### Phosphorus contributions from processed food additives in a typical daily diet (From Calvo and Uribarri (2013))

<table>
<thead>
<tr>
<th>Breakfast</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Blueberry pancakes, frozen</td>
<td>Sodium aluminium phosphate, monocalcium phosphate</td>
</tr>
<tr>
<td>Home-style syrup</td>
<td>Sodium hexametaphosphate, modified corn starch</td>
</tr>
<tr>
<td>Bacon (low sodium)</td>
<td>Sodium phosphate</td>
</tr>
<tr>
<td>Calcium-fortified orange juice</td>
<td>Calcium phosphate</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Lunch</th>
<th></th>
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</thead>
<tbody>
<tr>
<td>Grilled cheese sandwich</td>
<td>Sodium phosphate, calcium phosphate</td>
</tr>
<tr>
<td>Tomato soup</td>
<td>Monopotassium phosphate</td>
</tr>
<tr>
<td>Pringles potato chips, salt &amp; vinegar</td>
<td>Tricalcium phosphate</td>
</tr>
<tr>
<td>Cottage cheese and fruit</td>
<td>Calcium phosphate</td>
</tr>
<tr>
<td>Cola</td>
<td>Phosphoric acid</td>
</tr>
</tbody>
</table>
Dinner

Panko-breaded tilapia fillet, frozen  Food starch modified, sodium acid pyrophosphate
Oreida crispers French fries  Sodium acid pyrophosphate, disodium dihydrogen pyrophosphate
Birdseye broccoli and cheese sauce, frozen  Sodium phosphate, disodium phosphate
Garden salad with Hidden Valley ranch dressing  Phosphoric acid, disodium phosphate, modified food starch
Refrigerator buttermilk reduced-fat biscuits  Sodium acid pyrophosphate, sodium aluminium phosphate
Jello instant lemon pudding  Modified corn starch, disodium phosphate, tetrasodium pyrophosphate
Nabisco Ginger Snap cookies  Calcium phosphate
Diet coke  Phosphoric acid

Snack

Cheese Nachos (Tostitos brand salsa con queso)  Sodium phosphate, sodium hexametaphosphate
Diet coke  Phosphoric acid
Function of Phosphates in Meat Products

Different phosphates are used for different reasons:

- Increase pH to raise isoelectric point from 5.2-5.3 – opens muscle structure and increases water binding
- Helps to make some meat proteins more soluble, binding water and gelling on cooking
- Lower pH to improved meat colour in cured meat systems
- Emulsifies fat and reduces splattering in cooking e.g. bacon
Ingredients: British pork, salt, wheat dextrose, stabilisers diphosphates, triphosphates and polyphosphates, antioxidant sodium ascorbate, preservative sodium nitrite.

Ingredients: British beef, salt, wheat dextrose, brown sugar, stabilisers diphosphates, triphosphates and polyphosphates, antioxidant sodium ascorbate.
Ingredients: British port (75%), Bramley apples (3%), FORTIFIED WHEAT FLOUR, (wheat flour, calcium carbonate, iron, niacin, thiamin), dried apple (4%), honey, sea salt, salt, emulsifiers tetrasodium phosphate and disodium phosphate, preservatives sodium metabisulphite and sulphur dioxide, black pepper, yeast, dried parsley, nutmeg.
Function of Phosphates in Processed Cheeses

Phosphates are used in the manufacture of processed cheese often in combination with citrates – functions include:

- Phosphate/citrate blends used to make soft and hard processed cheeses e.g. for spreading, pizza toppings, catering cheese slices, etc.
- Adjust pH to 5.3 – 6.0 affecting the texture and flavour
- Fat emulsification and control of creaming
- Water binding and stabilisation of protein-water-fat interfaces
- Bacteriostatic & anti-microbial effects in processed cheeses
## Main Functions of Phosphates in Processed Cheeses

<table>
<thead>
<tr>
<th></th>
<th>Buffering Agent</th>
<th>Sequestering ion exchange</th>
<th>Emulsifying creaming reaction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Orthophosphates</td>
<td>XXX</td>
<td>X</td>
<td>0</td>
</tr>
<tr>
<td>Pyrophosphates</td>
<td>XX</td>
<td>XX</td>
<td>XXX</td>
</tr>
<tr>
<td>Polyphosphates</td>
<td>X</td>
<td>XXX</td>
<td>X</td>
</tr>
</tbody>
</table>

Ingredients: skimmed MILK (water, skimmed MILK powder), CHEESE, MILK fat, skimmed MILK powder, stabilisers (citric acid, sodium carbonate), MILK protein, whey powder, (from MILK), inulin, emulsifying salt (triphosphate).

Ingredients: skimmed MILK (water, skimmed MILK powder), CHEESE, skimmed MILK powder, MILK fat, inulin, modified starch, emulsifying salts (sodium phosphates, triphosphate, polyphosphate), whey powder (from MILK), calcium phosphate, acidity regulator (lactic acid).
Ingredients: skimmed milk (water and skimmed milk powder), cheese, butter, emulsifying salts: sodium polyphosphates, calcium phosphates, citric acid, sodium diphosphates, milk proteins.
# EU Cheese Production

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</thead>
<tbody>
<tr>
<td>All cheese</td>
<td>8,249</td>
<td>8,455</td>
<td>8,442</td>
<td>8,661</td>
<td>8,716</td>
<td>8,921</td>
<td>9,063</td>
<td>5,443</td>
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<tr>
<td>Processed cheese</td>
<td>626</td>
<td>624</td>
<td>620</td>
<td>605</td>
<td>656</td>
<td>638</td>
<td>615</td>
<td>n.a</td>
</tr>
</tbody>
</table>

Source: Clal (http://www.clal.it/en/?section=produzioni_cheese)

Note: Processes cheese production in some member states is confidential.

Assuming 1.5% phosphate use in processed cheese product this equates to 9,225 tonnes of phosphate in 2015.
Possible Alternatives to Phosphates

- Polysaccharides can bind water in some food systems and hold nearly as much as phosphates

- Carrageenan, guar gum, alginate, locust-bean gum, modified food starch, whey proteins, some fruit fibres can be used to bind water

- Collagen can also be used to bind water in some food systems

- Reported that rosemary, green tea, cherry powder extracts can be adhered to fibres or incorporated into protein ingredients to function as antioxidants or maintain colour

- Sodium gluconate offers potential in meat products but is only a partial replacement and more expensive

- Some cheese companies are using citrates to reduce/replace phosphates in some processed cheeses
Ingredients: Full Fat Soft CHEESE, Salt, Stabiliser (Locust Bean Gum), Acid (Citric Acid).

Ingredients: Medium Fat Soft CHEESE, Salt, Stabiliser (Locust Bean Gum, Carrageenan), Acid (Citric Acid).
Replacement of Phosphates in Food Manufacture

- No single ingredient yet has been found to replace all of the functions of phosphates
- Phosphates are difficult to replace when hard water is present
- Phosphates have superior buffering capacity which is difficult to emulate with other materials
- Phosphates are better at maintaining colour in meat products
- Phosphates are relatively inexpensive and are therefore attractive
- Use of materials such as whey proteins raises allergen issues
The Food Manufacturer’s Dilemma

If phosphorus replacement is not technically possible is it a matter of proceeding with business as usual and externalising the environmental costs?
What does the future hold?

- Food manufacturers voluntarily reducing use of, or replacing phosphate additives in food manufacture
- Food and environmental policy encouraging the voluntary reduction/replacement of phosphate additives in food manufacture
- **Food and environmental policy demanding the reduction/replacement of phosphate additives in food manufacture**
- Might some food products become environmentally unacceptable?
References


