PHOSPHATE BIOAVAILABILITY IN FOOD:
WHAT SHOULD WE BE TEACHING OUR PATIENTS?

Lisa Gutekunst MSEd, RD, CSR, CDN
Conflict of Interest

- I am an employee of DaVita, Inc.
- I am a consultant for Keryx Biopharmaceuticals.
Objectives

- Review the bioavailability of phosphorus in animal and plant-based foods
- Discuss factors that can change the bioavailability of phosphorus in animal and plant-based foods
- Show how these factors affect your patient population
Forms of Phosphorus
Sources of Dietary Phosphate

- **Animal Sources**
  - Organic phosphates in intracellular compartments → easily hydrolyzed → readily absorbed

- **Plant Sources**
  - Mostly in storage form of phytic acid or phytate. Not well absorbed

- **Phosphate Salts**
  - Phosphate additives → up to 100% absorbed

Bioavailability in Animal and Plant based foods
Differences among Total and In Vitro Digestible Phosphorus Content of Meat and Milk Products

Heini Karp, MSc,* Päivi Ekholm, PhD,† Virpi Kemi, PhD,* Tero Hirvonen, PhD,‡ and Christel Lamberg-Allardt, PhD*

**Objective:** Meat and milk products are important sources of dietary phosphorus (P) and protein. The use of P additives is common both in processed cheese and meat products. Measurement of in vitro digestible phosphorus (DP) content of foods may reflect absorbability of P. The objective of this study was to measure both total phosphorus (TP) and DP contents of selected meat and milk products and to compare amounts of TP and DP and the proportion of DP to TP among different foods.

**Methods:** TP and DP contents of 21 meat and milk products were measured by inductively coupled plasma optical emission spectrometry (ICP-OES). In DP analysis, samples were digested enzymatically, in principle, in the same way as in the alimentary canal before the analyses. The most popular national brands of meat and milk products were chosen for analysis.

**Results:** The highest TP and DP contents were found in processed and hard cheeses; the lowest, in milk and cottage cheese. TP and DP contents in sausages and cold cuts were lower than those in cheeses. Chicken, pork, beef, and rainbow trout contained similar amounts of TP, but slightly more variation was found in their DP contents.

**Conclusions:** Foods containing P additives have a high content of DP. Our study confirms that cottage cheese and unenhanced meats are better choices than processed or hard cheeses, sausages, and cold cuts for chronic kidney disease patients, based on their lower P-to-protein ratios and sodium contents. The results support previous findings of better P absorbability in foods of animal origin than in, for example, legumes.

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<table>
<thead>
<tr>
<th>Product</th>
<th>Total P (mg)/100 g</th>
<th>Digestible P (mg)/100 g</th>
<th>Protein (g)/100 g</th>
<th>Total P:Pro (mg/g)</th>
<th>Digestible P:Pro (mg/g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Milk, 1.5% fat</td>
<td>106</td>
<td>85</td>
<td>3.2</td>
<td>33.8</td>
<td>26.6</td>
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<tr>
<td>Simmed Milk</td>
<td>122</td>
<td>75</td>
<td>3.3</td>
<td>36.9</td>
<td>22.7</td>
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<tr>
<td>Processed cheese, 5% fat</td>
<td>574</td>
<td>589</td>
<td>23</td>
<td>24.9</td>
<td>25.6</td>
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<tr>
<td>Processed cheese, 12% fat</td>
<td>647</td>
<td>720</td>
<td>24</td>
<td>27.0</td>
<td>30.0</td>
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<tr>
<td>Processed cheese, 23% fat</td>
<td>584</td>
<td>576</td>
<td>21</td>
<td>27.8</td>
<td>27.4</td>
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<tr>
<td>Cheese spread, 9% fat</td>
<td>892</td>
<td>794</td>
<td>18</td>
<td>49.6</td>
<td>44.1</td>
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<tr>
<td>Cheese spread, 22% fat</td>
<td>755</td>
<td>772</td>
<td>19</td>
<td>39.7</td>
<td>40.6</td>
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<tr>
<td>Hard cheeses pool, 5-17% fat</td>
<td>638</td>
<td>484</td>
<td>30.3</td>
<td>21.1</td>
<td>16.0</td>
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<tr>
<td>Hard cheeses pool, 24-29% fat</td>
<td>529</td>
<td>282</td>
<td>26.5</td>
<td>20.0</td>
<td>10.6</td>
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<tr>
<td><strong>Cottage Cheese</strong></td>
<td><strong>164</strong></td>
<td><strong>71</strong></td>
<td><strong>13.8</strong></td>
<td><strong>10.6</strong></td>
<td><strong>5.1</strong></td>
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<tr>
<td>Processed sausage, 18% fat</td>
<td>210</td>
<td>224</td>
<td>9</td>
<td>23.3</td>
<td>24.9</td>
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<tr>
<td>Processed sausage, 10% fat</td>
<td>541</td>
<td>242</td>
<td>10</td>
<td>24.1</td>
<td>24.2</td>
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<tr>
<td>Frankfurter pool, 20% fat</td>
<td>175</td>
<td>144</td>
<td>9.2</td>
<td>19.0</td>
<td>15.7</td>
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<tr>
<td>Frankfurter pool, 13% fat</td>
<td>186</td>
<td>130</td>
<td>10</td>
<td>18.6</td>
<td>13.0</td>
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<tr>
<td>Sausage, dry, salami type</td>
<td>244</td>
<td>171</td>
<td>21.5</td>
<td>11.4</td>
<td>7.9</td>
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<tr>
<td>Sausage cold cuts</td>
<td>184</td>
<td>164</td>
<td>10.7</td>
<td>17.2</td>
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<tr>
<td>Boiled ham</td>
<td>279</td>
<td>255</td>
<td>17.9</td>
<td>15.6</td>
<td>14.3</td>
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<tr>
<td><strong>Raw pork steak</strong></td>
<td><strong>212</strong></td>
<td><strong>161</strong></td>
<td><strong>21</strong></td>
<td><strong>10.1</strong></td>
<td><strong>7.7</strong></td>
</tr>
<tr>
<td><strong>Raw chicken fillet</strong></td>
<td><strong>229</strong></td>
<td><strong>191</strong></td>
<td><strong>23</strong></td>
<td><strong>10.0</strong></td>
<td><strong>8.3</strong></td>
</tr>
<tr>
<td><strong>Raw beef</strong></td>
<td><strong>199</strong></td>
<td><strong>147</strong></td>
<td><strong>22</strong></td>
<td><strong>9.1</strong></td>
<td><strong>6.7</strong></td>
</tr>
<tr>
<td><strong>Raw rainbow trout fillet</strong></td>
<td><strong>232</strong></td>
<td><strong>207</strong></td>
<td><strong>16.8</strong></td>
<td><strong>13.8</strong></td>
<td><strong>12.3</strong></td>
</tr>
</tbody>
</table>
Differences Among Total and In Vitro Digestible Phosphorus Content of Plant Foods and Beverages

Heini Karp, MSc,* Päivi Ekholm, PhD,† Virpi Kemi, PhD,∗ Suvi Itkonen, MSc,∗ Tero Hirvonen, PhD,‡ Silja Närkki, MS,† and Christel Lamberg-Allardt, PhD∗

Objective: Among plant foods, grain products, legumes, and seeds are important sources of phosphorus (P). Current data on P content and absorbability of P from these foods are lacking. Measurement of in vitro digestible P (DP) content of foods may reflect absorbability of P. The objective of this study was to measure both total phosphorus (TP) and DP contents of selected foods and to compare the amounts of TP and DP and the proportion of DP to TP among different foods.

Methods: TP and DP content of 21 foods and drinks of plant origin were measured by inductively coupled plasma optical emission spectrometry. In DP analysis, samples were digested enzymatically in principle in the same way as in the alimentary canal before P analyses. The most popular national brands were chosen for analysis.

Results: The highest amount of TP (667 mg/100 g) was found in sesame seeds with hull, which also had the lowest percentage of DP (6%) to TP. Instead, in cola drinks and beer, the percentage of DP to TP was 87 to 100% (13 to 22 mg/100 g). In cereal products, the highest TP content (216 mg/100 g) and DP proportion (100%) were present in industrial muffins, which contain sodium phosphate as a leavening agent. Legumes contained an average DP content of 83 mg/100 g (38% of TP).

Conclusion: Absorbability of P may differ substantially among different plant foods. Despite high TP content, legumes may be a relatively poor P source. In foods containing phosphate additives, the proportion of DP is high, which supports previous conclusions of the effective absorbability of P from P additives.

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## Total and in vitro Digestible P, Protein, P:Pro Ratios

<table>
<thead>
<tr>
<th>Product</th>
<th>Total P (mg)/100 g</th>
<th>Digestible P (mg)/100 g</th>
<th>Protein (g)/100 g</th>
<th>Total P:Pro (mg/g)</th>
<th>Digestible P:Pro (mg/g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rye bread pool</td>
<td>208</td>
<td>123</td>
<td>8.2</td>
<td>25.4</td>
<td>15.0</td>
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<tr>
<td>Rye crisp</td>
<td>291</td>
<td>191</td>
<td>10.1</td>
<td>28.8</td>
<td>18.9</td>
</tr>
<tr>
<td>Small rye bread containing potato 1</td>
<td>192</td>
<td>89</td>
<td>8.2</td>
<td>23.5</td>
<td>10.9</td>
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<tr>
<td>Small rye bread containing potato 2</td>
<td>206</td>
<td>54</td>
<td>10</td>
<td>20.6</td>
<td>5.4</td>
</tr>
<tr>
<td>Mixed grain bread with seeds</td>
<td>189</td>
<td>116</td>
<td>9.7</td>
<td>19.5</td>
<td>12.0</td>
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<tr>
<td>Muffin pool</td>
<td>212</td>
<td>201</td>
<td>6.6</td>
<td>32.1</td>
<td>30.5</td>
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<tr>
<td>Sweet bun pool</td>
<td>116</td>
<td>60</td>
<td>7.7</td>
<td>15.1</td>
<td>7.8</td>
</tr>
<tr>
<td>Cookie pool</td>
<td>125</td>
<td>43</td>
<td>6.1</td>
<td>20.5</td>
<td>7.0</td>
</tr>
<tr>
<td>Sesame seed (with hull)</td>
<td>667</td>
<td>42</td>
<td>26.9</td>
<td>24.8</td>
<td>1.6</td>
</tr>
<tr>
<td>Tofu (firm)</td>
<td>164</td>
<td>51</td>
<td>16.5</td>
<td>9.9</td>
<td>3.1</td>
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<tr>
<td>Green bean</td>
<td>57</td>
<td>24</td>
<td>1.9</td>
<td>30.2</td>
<td>12.4</td>
</tr>
<tr>
<td>Green pea (frozen)</td>
<td>118</td>
<td>50</td>
<td>5.1</td>
<td>23.1</td>
<td>9.7</td>
</tr>
<tr>
<td>Chickpea (soaked)</td>
<td>149</td>
<td>53</td>
<td>8.4</td>
<td>17.7</td>
<td>6.3</td>
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<tr>
<td>Red Lentil</td>
<td>432</td>
<td>167</td>
<td>23.8</td>
<td>18.2</td>
<td>7.0</td>
</tr>
<tr>
<td>Green lentil</td>
<td>400</td>
<td>120</td>
<td>24.4</td>
<td>16.4</td>
<td>4.9</td>
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<tr>
<td>Pepsi Max</td>
<td>14</td>
<td>15</td>
<td>0</td>
<td>n/a</td>
<td>n/a</td>
</tr>
<tr>
<td>Coca-Cola light</td>
<td>13</td>
<td>13</td>
<td>0</td>
<td>n/a</td>
<td>n/a</td>
</tr>
<tr>
<td>Coca-Cola</td>
<td>19</td>
<td>16</td>
<td>0</td>
<td>n/a</td>
<td>n/a</td>
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<tr>
<td>Cola pool</td>
<td>17</td>
<td>16</td>
<td>0</td>
<td>n/a</td>
<td>n/a</td>
</tr>
<tr>
<td>Freeway cola light</td>
<td>11</td>
<td>10</td>
<td>0</td>
<td>n/a</td>
<td>n/a</td>
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<tr>
<td>Beer</td>
<td>21</td>
<td>22</td>
<td>0.4</td>
<td>52.5</td>
<td>55.0</td>
</tr>
</tbody>
</table>
Factors Affecting Bioavailability
Effect of Boiling on Dietary Phosphate

- Cupisti, et. al. JRN, Vol 16, No 1, 2006
- Total phosphate of beef and chicken after 10, 20, and 30 min boiling
- They also looked at protein content

<table>
<thead>
<tr>
<th>Cooking Time</th>
<th>Raw</th>
<th>10 min</th>
<th>20 min</th>
<th>30 min</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beef (mg P/g Protein)</td>
<td>9.8 ± 3.4</td>
<td>7.8 ± 3.4</td>
<td>4.8 ± 0.8</td>
<td>4.3 ± 0.4</td>
</tr>
<tr>
<td>Chicken (mg P/g Protein)</td>
<td>12.3 ± 0.7</td>
<td>10.6 ± 0.9</td>
<td>10.3 ± 1.2</td>
<td>9.5 ± 1.2</td>
</tr>
</tbody>
</table>
Review

Phytate in foods and significance for humans: Food sources, intake, processing, bioavailability, protective role and analysis

Ulrich Schlemmer¹, Wenche Frølich², Rafael M. Prieto³,⁴ and Felix Grases³,⁴

¹ Department of Physiology and Biochemistry of Nutrition, Max Rubner-Institut, Federal Research Institute of Nutrition and Food, Karlsruhe, Germany
² University of Stavanger, Norwegian School of Hotel Management, Jar, Norway
³ Laboratory of Renal Lithiasis Research, University Institute of Health Sciences Research (IUNICS), University of Balearic Islands Ctra, Palma de Mallorca
⁴ CIBER Fisiopatología Obesidad y Nutrición (CB06/03), Instituto de Salud Carlos III, Spain

The article gives an overview of phytic acid in food and of its significance for human nutrition. It summarises phytate sources in foods and discusses problems of phytic acid/phytate contents of food tables. Data on phytic acid intake are evaluated and daily phytic acid intake depending on food habits is assessed. Degradation of phytate during gastro-intestinal passage is summarised, the mechanism of phytate interacting with minerals and trace elements in the gastro-intestinal chyme described and the pathway of inositol phosphate hydrolysis in the gut presented. The present knowledge of phytate absorption is summarised and discussed. Effects of phytate on mineral and trace element bioavailability are reported and phytate degradation during processing and storage is described. Beneficial activities of dietary phytate such as its effects on calcification and kidney stone formation and on lowering blood glucose and lipids are reported. The antioxidative property of phytic acid and its potential anticancerogenic activities are briefly surveyed. Development of the analysis of phytic acid and other inositol phosphates is described, problems of inositol phosphate determination and detection discussed and the need for standardisation of phytic acid analysis in foods argued.

Keywords: Absorption / Antioxidant / Degradation / Inositol phosphates / Phytic acid

Received: March 7, 2009; revised: May 25, 2009; accepted: May 31, 2009
Phytate Facts

- Main storage of P for plants
- Considered an “anti-nutrient” because it binds to other nutrients in the GI tract preventing absorption
- Reduces digestibility of starches, proteins, and fats.

Sources
- Cereals: Bran and germ
- Legumes: Endosperm and cotyledon
- Oil seeds (sunflower, soy, sesame, linseed, rapeseed)
- Nuts
The phytate content of plants can vary depending on the type of plant, part of the plant, growing conditions and soil mineral content. The content ranges from 0.1% in rice to 1.8% in rice bran.

http://phytate.info/what-is-phytate
Overview

**INCREASES P AVAILABILITY**
- Long term vegetarianism
- Hot, humid storage
- Addition of phytase
- Bread making
- Fermentation
- Malting
- Germination-legumes

**NO CHANGE OR DECREASE IN AVAILABILITY**
- Western Diet
- Cool dry storage
- Boiling legumes
- Soaking
- Germination-grains
- Oats
Natural Bioavailability

- When the diet is rich in plant food phytases 37-66% of dietary phytate is degraded during digestion in the stomach and small intestine due to the presence of natural enzymes (phytase).

- Humans consuming Western style diets have minimal natural enzymes therefore degradation in the stomach and small intestine is very limited.
Effects of Food Processing

- To increase the bioavailability of phosphorus, phytate must be broken down

- Food processes include:
  - Boiling
  - Soaking
  - Malting
  - Germination
  - Fermentation
  - Addition of commercial or activation of natural phytases
Effects of Boiling

- **Overall, limited increase in phosphorus**
- Stable up to ~100°C (212°F)
- Preparing brown beans under normal household conditions (soak beans overnight, cooking at 110°C for 1.5 hrs), 25% of phytate is degraded.
- Preparing brown beans in industrial conditions (>140°C for 45 min), 30% of phytate is degraded. (degradation increases to 40% if cooked as long as 90 min)
Effects of Soaking and Malting

- **Soaking Grains**
  - Decrease P availability
  - Phytate is water soluble

- **Soaking Legumes**
  - No change in P availability
  - Phytate remains intact

- **Malting grains**
  - Increase P availability
  - almost 100% breakdown of phytate
Effects of Germination

- **Grains:**
  - Increases P availability. But not by a lot.
  - 16% in barley, 17% in oats, 30% in wheat and rye.

- **Legumes:**
  - Increases P availability
  - Pigeon peas (65.8%), chickpeas (64.1%), bean curd (40.6%), soy beans (38.9%), mung beans (37.2%).
  - **Quinoa:** 98% increase in P with soaking, germination, and fermentation.
Effects of Fermentation and Bread Making

- **Fermentation:**
  - Increase P availability
  - Decrease in pH of dough breaks down phytate. Natural phytases have more effect than yeast.

- **Bread making:**
  - Increase in P availability
  - Yeast: contributes to decrease in pH but not by much
  - Natural enzymes in flour contribute to break down of phytate
  - Sourdough fermentation breaks down phytate more effectively than yeast fermented breads
**Effects of the Enzyme Phytase**

- Phytase is naturally found in plant foods, microorganisms, and animal tissues.
  - Soaking, malting, germination, fermentation, and bread making, phytases of plant and microbial added to increase bioavailability of minerals.
  - Oat phytase is inactivated before storage as it is heated prevent rancidity (destroys the enzyme)

- When added to foods, commercial phytases increase in P availability
Conclusions
What this all means

- Phosphate additives are bad
  - Continue to educate patients to read labels and avoid these

- Animal based phosphate
  - Variability in absorption
  - Can include some dairy products
  - Boiling can reduce amount
What this all means

- Plant based phosphate
  - Phytate needs to be liberated for P availability
  - In the American diet, an increase in P availability usually seen in bread making and when eating malted grains and germinated seeds
  - In cultural diets, an increase in P availability can be seen in various food preparation methods.
  - When working with different cultures found in the US, it is important to have a clear understanding of not only the foods uses, but also the food preparation methods.

- More research is needed on various cooking methods on P availability and on the commercial production of foods effect on P availability.
They do that annually. LA isn't that bad

I hate this school

Like. If I had an opportunity to change schools, I would

Why? It's NO different at any other school. On a serious note, should I expect a call from the school today? Did the RA dog find anything in ur locker?

Yup i got caught with binders :/ will I get expelled?

I love you!