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# ACID-BASE BALANCE AND ALKALINIZING FOODS

## Editorial

The impact of diet on the body's acid-base equilibrium has long been ignored because of its extremely effective blood buffering systems. However, more and more studies suggest that Western-style diets, rich in meats and processed foods, are globally acidic. This is unfavourable to the entire organism and especially in maintaining skeletal mineral balance. Among regularly consumed foods, only fruits and vegetables, despite their sometimes acidic flavour, have alkaline properties due to their organic potassium salts. Many other foods (meat, cold cuts, salted cheese) are acidifying, whereas milk or cereal products are relatively neutral in terms of acid-base balance.

These fundamental bases must no longer be ignored. Nutritional recommendations, especially for osteoporosis, must now be based on the role of nutritional associations - milk products of course, but associated with fruits and vegetables. In the case of copious meals with meat and salty foods, fruits and vegetables would be the best antidote to excess proteins and salt.

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# Impact of dietary alkalinization on skeleton : bone sparing effects of cations and anions from fruits and vegetables

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The nutritional prevention of bone disorders (ricketts, osteopenia and osteoporis) has long focused on the provision of calcium and related factors such as vitamine D. During the last decade, there was an increasing awareness that the western diet leads to profound alterations of the nutritional value of the diet: higher energy density in general with a lowered density of minerals (except sodium), vitamins and various other micronutriments. It is also well-recognized that modern dieting leads to an almost permanent situation of latent metabolic acidosis, resulting in mobilization of bone minerals (chiefly Ca) and of muscle amino acids for glutamine production, as well as renal disturbances. However, the above processes will be limited if foods provide alkalinizing compounds and there is a growing interest for the 'alkalinizing functionality' of foods which are sources of $KHCO^{3}$ precursors.

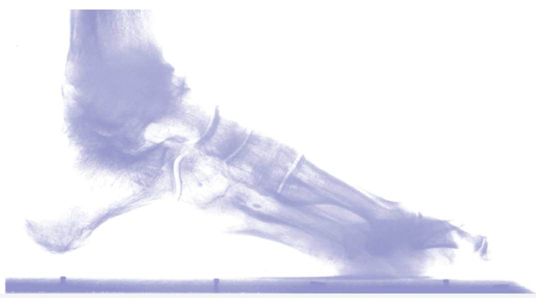
The alkalinizing functionality, an almost exclusive feature of fruits and vegetables, is based on their ionic composition: (i) a cationic profile in which potassium prevails, together with some magnesium and calcium; (ii) an anionic profile in which polycarboxylic anions prevail, especially citrate and malate; (iii) a relative paucity of inorganic anions such as Cl, $PO^{4}$ or $SO^{4}$.

With the exception of legumes and cereal products, most plant foods contain substantial amounts of organic anions, with levels varying from around 100 up to 4000 mg/100 g fresh weight for the richest products such as Citrus fruits. Generally, organic anion concentrations are consistently greater in fruits than in vegetables: a comparison of panels of fruits or of vegetables usually consumed indicates that average levels of (citrate + malate) will be around 1400 mg/100 g for fresh fruits and only 300 mg/100 g for fresh vegetables.

The potassium content of fruits is in the range of 100 to 400 mg/100 g fresh weight and that of vegetables is generally higher, exceeding 600 mg/100 g fresh weight in some cases. In fact, one of the most salient points distinguishing fruits from vegetables is the [K]/(organic anions) ratio (in mEq): this ratio is generally less than 0.5 for most fruits but is greater than 1 for vegetables (up to 2.3 for pumpkins). Basically, from the point of view of alkalinizing functionality, it appears that potassium may be limiting in fruits whereas the [K]/(organic) anions ratio is relatively well-balanced in vegetables.

The daily supply of organic anions is closely connected to intake of fruits and vegetables. Data in this domain are still scarce, but calculations using composition tables and food intake data suggest that organic anion intake may be in the range of 1-2 g/d in low plant food consumers, and around 3-4 g/d in well-diversified omnivores. It must be noted that these values are close to those observed for potassium, which reflects to a certain extent the fact that ingested organic anions are chiefly present as potassium salts in foods.

Epidemiological evidence of a favourable effect of fruit and vegetable consumption on bone status is relatively recent, and they used with different criteria (fractures incidence, bone mineral density or markers of bone cells activity) and populations (older people at risk of osteopenia/osteoporosis, younger people for bone peak mass). Nevertheless, a survey of the 1995-2007 epidemiological studies published in this domain (New et al 2004, updated to 2007) support the view that a substantial fruit and vegetable intake (in the '5-10/d' range) may exert a protective effect against the risk of bone alterations. Potassium has been identified as a protective factor in most of them and this likely reflects the alkalinizing functionality of fruits and vegetables due to organic anions in potassium salts. There is little doubt that the observed effects are multi-factorial and that some other compounds are also protective for bone in fruits and vegetables, such as vitamins C or K, as well as various phytonutrients (possibly through anti-oxidant or pseudo-hormonal effects). In turn, potassium may also have other protective effects, for example against cardio-vascular diseases (He & McGregor, 2003).



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# Impact of dietary alkalinisation on kidney's acid excretion

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## *Acids in the body*

The acids in the human body are either ingested or metabolically produced. The kidneys, the lungs and the gut are responsible for the amount of acids in the body. In the gut, absorption of nutrients, including acids and bases, takes place. The lungs maintain the respiratory control of the body's acid-base status (ABS) by expiring volatile acids e.g. carbonic acid. The kidneys are the only organ that can excrete the strong, non-volatile acids e.g. sulphuric acid, hydrochloric acid, etc. In addition, the kidneys regenerate bicarbonate, the major blood buffer. Thus, the kidneys have the task of regulating ABS, which with the respiratory control, maintain the blood pH in a very narrow range 7.35-7.45.

## *Dietary acid & alkaline sources*

Fruits like oranges, apples etc. taste acidic due to organic acids they contain, such as citric acid or malic acid. Although these organic acids are acidic, they have no prolonged acidifying impact in the body because they are volatile and are usually fully metabolised and expired as carbon dioxide. Only those organic acids escaping renal reabsorption act metabolically acidic because they demand cationic bases for their excretion.

According to current knowledge, foods having an excess of inorganic anions (e.g. Cl,$SO^{4}$) over inorganic cations (Na, K, Mg) are acidic and those having an excess of cations over anions are alkaline. Inorganic cations are alkaline and inorganic anions are acidic. Proteins contain sulphur, which is a source of the strong dietary acid, sulphuric acid. Such acidic anions require corresponding alkaline cations (Na, K, Mg) to buffer them, both in metabolism and excretion. Fruits and vegetables (F&V), especially potatoes, leafy greens, herbs like parsley, dried fruits (dehydration concentrates the cations) like figs, raisins, contain alkaline cations (Na, K, Mg) usually as their organic salts in excess over the acidic, non-volatile anions (Cl,$SO^{4}$). As mentioned, the organic components are largely metabolised to carbon-dioxide and expired, and the cations alkalise. Thus, F&V are good sources of dietary alkalies.

## *Modern day diets*

Nutrient density of modern day F&V is lower than those produced in preagricultural times. General advice is to consume at least five portions of F&V daily. An increase in acid load through protein consumption can be compensated by adequate F&V consumption, as in preagricultural diets. The question is if modern day diets provide enough of these alkalies? Studies show that this is frequently not the case, leading to low-grade, latent acidosis, where the blood pH is more towards the lower end of the normal pH range. To conserve the cations in the body and maintain the body's more alkaline pH, the kidneys compensate by increasing ammonia production. Ammonia is an important component of the body's net acid excretion and buffers protons in the urine. In addition, bone stores of cations might be mobilised to make up the lack in dietary alkalies or to neutralise increases in dietary acids. Knowledge of the foods' acid (alkali) content would thus be useful.

## *Calculation of food acidity*

The potential renal acid load (PRAL) is a measure of food's acid load. An anion excess (e.g. $SO^{4}$ from protein degradation) over mineral cations (K, Na, Mg) would yield a high PRAL. This can be calculated from the amount of respective minerals in foods. The table shows the major food groups' average PRAL values.

**Average PRAL values /100g foodgroup**

| Foodgroup | PRAL (mEq) |
|---|---|
| Fruits & fruit juices | -3.1 |
| Vegetables | -2.8 |
| Herbs (e.g. basil, parsley, chives) | -8.2 |
| Beverages | |
| Alkali-rich & low phosphrous (e.g. wine, coffee) | -1.7 |
| Alkali-poor & low phosphorous (some beers, water poor in minerals) | 0 |
| Coca-cola | 0.4 |
| Milk | 0.9 |
| Fats & oils | 0 |
| Milk products with whey (e.g. yoghurt) | 1.3 |
| Grain products | |
| Bread | 3.5 |
| Flour | 7.0 |
| Noodles | 6.7 |
| Fish | 7.9 |
| Meat & meat products | 9.5 |
| Cheese | |
| Cheeses with lower protein content (<15 g protein) | 8.0 |
| Cheeses with higher protein content (>15 g protein) | 23.6 |

Recent studies show proteins increase bone strength in elderly and children. This is due to the anabolic effect of protein on bone. With adequate F&V consumption the protein negative effect of high PRALs is compensated. F&V ensure the availabilty of alkalies in the diet. PRAL tables help in making food choices, so that the kidney's renal regulation is facilitated.

# Fruits and vegetables as a marker for dietary alkali intake

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## *Why care about whether or not your diet is net acid or base forming?*

Present day diets in industrialized countries tend to be net acid forming, due to the high intake of grains and animal food products and the relatively low intake of fruits and vegetables. As we get older, the kidney's ability to excrete excess acid declines. This combination of high dietary acid intake and reduced renal acid excretion tends to lead to higher net acid balances as we age. This leads to a "trade-off", where to maintain electrical neutrality and buffer the excess acid, the body has to use endogenous buffers such as bone alkali, and may have to accept a slightly higher acid balance, such as a slightly lower blood pH. This in turn may be a factor in diseases of "old age", such as osteoporosis and age-related muscle wasting .

## *Estimating dietary net endogenous acid production (NEAP)*

Since determining renal acid excretion requires a special research laboratory to measure the various components, much interest has focused on developing methods of estimating the body's acid-base balance from dietary intake. These dietary acid loads can be estimated as the net endogenous acid production (NEAP) by various methods, but they all either estimate or measure the dietary components shown to be responsible for acid production: [sulfate (SO4), phosphate (PO4), and fixed organic acids such as hippuric acid; and those responsible for alkali production - potassium (K) salt of organic anions or "unmeasured anions" (UA), where K has been used as an estimate of dietary base intake.

## *Acid-producing and base-producing foods*

We used the U.S. Department of Agriculture nutrient database to calculate the net acid or base load for individual foods (ref 6). Since each food has a different composition, the various NEAP components can be assessed for each of them. We took 51 items from the USDA database which included 19 vegetables, 10 nut foods and 22 fruits (FV), and compared this to 24 items from the same database including 5 grains, 7 dairy products, 1 egg and 11 meat items (AP).

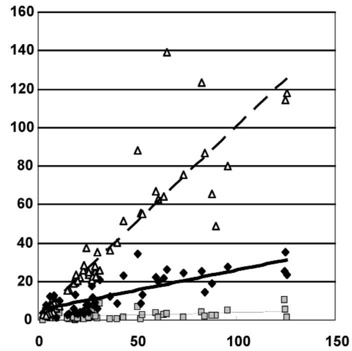
The following table demonstrates the mean and median values for potassium intake and the univariate correlations of dietary potassium with phosphate, sulphate, and the unmeasured anions in FV and AP foods. Figures 1a and 1b visually demonstrate these univariate correlations. All numbers are in milliequivalents (meq) per 1000kJ.

| FOOD ITEM | mean±SD | Median (range) | r | R2 | P value |
|---|---|---|---|---|---|
| FV | | | | | |
| K | 39.4±33.3 | 27.2 (17.8-59.6) | | | |
| PO4 | 13.2±9/1 | 11.6 (5.6-21.2) | 0.75 | 0.56 | <0.0001 |
| SO4 | 2.4±2.3 | 1.6 (0.9-3.3) | 0.38 | 0.14 | 0.007 |
| UA | 33.3±34.5 | 24.9 (18.1-57.3) | 0.89 | 0.80 | <0.0001 |
| AP | | | | | |
| K | 10.8±7.7 | 11.8 (4.6-16.8) | | | |
| PO4 | 19.8± 9.2 | 20.2 (14.2-23.2) | 0.74 | 0.54 | <0.0001 |
| SO4 | 10.4±6.5 | 7.4 (4.7-17.1) | 0.31 | 0.10 | 0.2 |
| UA | 1.3±8.2 | 0.4 (-1.1-2.9) | 0.19 | 0.04 | 0.4 |

Both the median and range of K content was much greater in the FV foods compared to the AP (p< 0.0001). Figure 1a demonstrates that as the K content of FV increases, the UA increase to a greater extent than the PO4 or SO4. By best subset analysis, UAs explained 83% of the variability in K intake (R2=0.83, p<0.0001), and PO4 (R2=0.84, p=0.03) and SO4 (R2=0.85, p=0.10) explained about an additional 1% each.

**Figure 1a.**
**Fruits, vegetables and nuts**

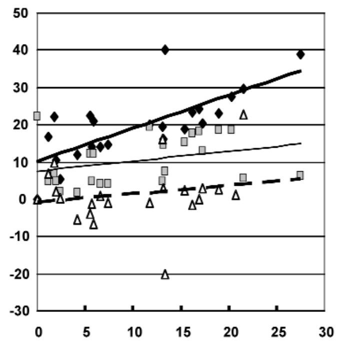
▪ H2SO4 meq/1000kJ
◆ p_meq/1000 kJ
△ unmeasured anions, meq/1000 kJ




Conversely, in animal foods (Fig 1b), the PO4 content was significantly higher than in the FV (p=0.006), the SO4 content was significantly higher than in the FV (p<0.0001) and the UA content was significantly lower in the AP group than the FV (p<0.001). By best subset analysis, PO4 content explained 44% of the variability in K intake (R2 =0.44, p=0.002), and SO4 (R2=0.56, p=0.01) and UAs (R2=0.66, p=0.03) explained another 12% each.

**Figure 1b.**
**Animal foods & grains**

▪ H2SO4 meq/1000kJ
◆ p_meq/1000 kJ
△ unmeasured anions, meq/1000 kJ




So, in as much as the K content correlates to the PO4 and SO4 content of foods, using only dietary K intake will tend to overestimate alkali intake. This is partially mediated by the average K content of animal foods, which tends to be significantly lower than in vegetable foods and therefore would contribute less to the total dietary K. However, as we have shown, in general fruits and vegetables are higher in alkali, and increased ingestion should help balance the high acid loads found in the diets most prevalent in industrialized countries which are made up of animal foods and grains. Whether or not eating a net base-producing diet will also improve some of the age-related, acidosis-related conditions mentioned previously, such as osteoporosis and muscle wasting, remains to be proven.

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