Jungbunzlauer presents: The challenge of calcium fortification in beverages
The challenge of calcium fortification in beverages

Beverages enriched with calcium represent a significant part of the growing functional soft drinks segment in the USA, being the trendsetting market for supplementation with minerals, calcium-fortified lines reached a 20% share of the chilled orange juice products in 2001. This increasing demand drives mineral salt suppliers such as Jungbunzlauer to offer not only one product but rather a range of different calcium salts and granulations to be able to tune their industrial customers’ applications. This article discusses important nutritional, technological as well as economical aspects of calcium in beverages with a focus on the Jungbunzlauer products Tricalcium Citrate, Calcium Gluconate and the new product development Calcium Lactate Gluconate.

Calcium - A hot topic

Fighting osteoporosis and promoting calcium intake is a hot topic right now in Europe: At the International Osteoporosis Foundation conference on December 04, 2001, Health and Consumer Protection Commissioner David Byrne emphasised his intention to take action at EU level\(^1\). “Osteoporosis is a disease that is sadly overlooked, under-diagnosed and under-treated. This silent epidemic affects millions of Europeans, causing human suffering and taking a heavy economic toll”, David Byrne said. One in three women and one in eight men over the age of 50 are affected by an enhanced bone fragility and an increased fracture risk. During the conference, experts agreed to further increase efforts such as:

- optimising diagnostics and treatment
- promoting adequate intake of calcium and vitamin D in the diet.

Optimising calcium intake

Calcium is ke phinential in the human body, necessary for normal growth and development of the skeleton as well as for teeth, nerve, muscle and enzyme functions. As the body’s calcium absorption capabilities reduce with age, it is vital for the ageing to have a sufficient calcium intake. Calcium requirements vary throughout an individual’s life and for different population groups. However, it is generally evident that a significant proportion of the population in Western countries fails to achieve the recommended calcium intakes. Inadequate dietary habits are seen to be responsible for this situation, especially if consumption of fast food is dominating the daily menu. Various studies showed that a significant proportion of the population groups fails to achieve the calcium intakes in western countries\(^2\). This observation is seen as being one of the main factors causing osteoporosis\(^3\).

As a consequence, national authorities all over the world have recently reconsidered recommendations in order to take remedial measures against calcium deficiency and accordingly, to reduce the risk of osteoporosis. In this respect, the US National Institute of Health (NIH) has increased the amounts of optimal daily calcium intake and defined specific values for each population group\(^4\). For example, calcium intake should be 1000 mg/day for adults (25-65 years of age) and as much as 1500 mg/day for seniors (older than 65 years) or lactating women. Harmonisation of Recommended Daily Allowances (RDA) is under discussion also on EU level right now, presumably leading to levels comparable to current US recommendations.

There are several options to avoid calcium deficiency by increasing the daily calcium intake: A balanced diet with calcium-rich foods like milk, dairy products and certain vegetables (broccoli, Chinese cabbage, legumes) would be the best solution. However, this would require a profound change in dietary habits of western society. A further possibility consists in taking calcium supplement products. A more elegant option is consuming “regular” food fortified with calcium as an added value product.

Common calcium sources for beverage fortification

Table 1 (See next page) shows a typical range of calcium fortified beverages which have been seen in US and UK supermarkets recently. Practically every type of beverage such as mineral water, soy milk, energy drink, nectar or juice does have a fortified product line already. Looking at the ingredients list, it is evident that there is not “the” calcium source but rather a range of different possibilities used commercially:

- inorganic salts like calcium carbonate and calcium phosphate
- organic salts like tricalcium citrate, calcium lactate, calcium lactate gluconate and calcium gluconate.

The selection of the appropriate salt for a specific application is usually based on the consideration of a number of properties associated with the respective product such as solubility, calcium content, taste and bioavailability. Economic considerations are another important factor.

Solubility vs. calcium content

When fortifying beverages, solubility, dissolution characteristics and stability of ingredients in solution are a major issues. There are calcium salts with good solubility like calcium gluconate, calcium lactate, and calcium lactate gluconate but their drawback is a comparably low calcium content (Table 2 - see next page). Calcium salts with a high calcium content like calcium carbonate and calcium phosphate, on the other hand, are poorly soluble and for that reason not frequently used in beverages.

Tricalcium citrate offers a good combination: The commonly used tetrahydrate form shows a high calcium level (21%) and moderate solubility (0.9 g/L). Solubility is strongly influenced by the pH of the system since the solubility of calcium salts typically increases with decreasing pH. Tricalcium citrate shows improved solubility at pH-values below 4.5 as found in most beverages. Contrary to other salts, tricalcium citrate is more soluble at low temperatures which can be an advantage for cold food processing. To further increase the solubility and ease of dispersion, Jungbunzlauer has developed a particularly fine (micronized) tricalcium citrate grade. With this special granulation of min. 90% < 20 microns, it can be suspended in cloudy beverages and high concentrations of calcium (e.g. 1.5 g Ca/L) can be reached. Accordingly tricalcium citrate still is seen to be the main choice for fortified orange or grape juice.
Calcium lactate is provided as a pentahydrate, containing 13% of calcium. It shows good solubility properties and is therefore mainly used in clear beverages to achieve the necessary levels for nutritional claims on calcium. It is known that using calcium lactate in high concentrations may lead to adverse effects in certain applications. Due to the fact that with higher soluble salts, more free calcium ions are in solution and available for reaction than with lower soluble ones, complications in the form of calcium sediments can develop with time. This is the interesting properties: its solubility is not between the single components calcium lactate and calcium gluconate as one would expect, but it is synergistically enhanced to approx. 400 g/L water. This sums up to a calcium content of 45 to 50 g/L, depending on the ratio of the mixture. With this high calcium value in mind, it is not surprising that this salt is used when a high dissolution speed is required. It is also especially recommended for fortification of clear beverages. The reason for this phenomenon of extremely high solubility is interpreted as the ability of calcium lactate than tricalcium citrate to taste and mouthfeel

Generally, high levels of calcium, particularly insoluble forms like carbonates and phosphates, tend to produce a chalky mouthfeel and may promote astringency or bitter taste in the finished product. Calcium lactate may impart some bitter or malty notes at high concentrations. Calcium carbonate may come across as soapy or lemony. Calcium phosphate has a bland flavour, but imparts a gritty mouthfeel. Negative effects of calcium on taste can be masked with chelating agents (e.g. tripotassium citrate), and the use of stabilisers (e.g. carageenan) as well as with the addition of flavourings. Tricalcium citrate, calcium lactate gluconate and calcium gluconate are considered to be the most neutral calcium salts, as masking agents are not really necessary.

Since the particle size and solubility are linked with mouthfeel properties, Jungbunzlauer has developed micronized grades for tricalcium citrate combining excellent dispersion characteristics with a neutral taste profile in final applications.

Bioavailability

Any nutrient’s effectiveness depends on its bioavailability, which means how well the human body absorbs and utilises it. On average, only about 10 to 30% of calcium is absorbed from a mixed diet by healthy adults. Several different factors influence this level, among which the type of salt which provides the calcium.

Organic vs. inorganic salts. Various scientific studies have shown that organic calcium salts outperform inorganic calcium sources such as calcium carbonate and calcium phosphate with regard to their relative bioavailability. Accordingly, the US National Institute of Health recommended calcium citrate for supplementation, especially for older individuals where absorbability can be a limiting factor due to reduced gastric acid production. Recently, researchers at the University of Texas conducted a meta-analysis of calcium bioavailability, which evaluated studies on the bioavailability of two of the

<table>
<thead>
<tr>
<th>Product</th>
<th>Calcium source added</th>
<th>Serving size (ml)</th>
<th>Labelled Calcium content (mg/L)</th>
<th>Nutritional claim used on the product label</th>
</tr>
</thead>
<tbody>
<tr>
<td>Still mineral water</td>
<td>Calcium carbonate / chloride / sulphate</td>
<td>-</td>
<td>300</td>
<td>Source of calcium</td>
</tr>
<tr>
<td>Tropical nectar</td>
<td>Tricalcium citrate</td>
<td>200</td>
<td>500</td>
<td></td>
</tr>
<tr>
<td>Apricot nectar</td>
<td>Calcium lactate</td>
<td>162</td>
<td>417</td>
<td>With calcium</td>
</tr>
<tr>
<td>Wellness drink</td>
<td>Calcium lactate</td>
<td>-</td>
<td>?</td>
<td>With calcium</td>
</tr>
<tr>
<td>Soy milk</td>
<td>Calcium carbonate</td>
<td>250</td>
<td>1200</td>
<td>Added calcium</td>
</tr>
<tr>
<td>Apple juice</td>
<td>Calcium lactate</td>
<td>125</td>
<td>800</td>
<td>Calcium enriched</td>
</tr>
<tr>
<td>Fruit Juice</td>
<td>Calcium lactate gluconate</td>
<td>240</td>
<td>417</td>
<td>Fortified with calcium</td>
</tr>
<tr>
<td>Cranberry juice</td>
<td>Calcium lactate gluconate</td>
<td>240</td>
<td>417</td>
<td>Fortified with calcium</td>
</tr>
<tr>
<td>Grapefruit juice</td>
<td>Tricalcium citrate</td>
<td>240</td>
<td>1458</td>
<td>Plus calcium</td>
</tr>
<tr>
<td>Orange juice I</td>
<td>FruitCal™</td>
<td>240</td>
<td>1458</td>
<td>As much calcium as milk</td>
</tr>
<tr>
<td>Orange juice II</td>
<td>Tricalcium citrate</td>
<td>414</td>
<td>276</td>
<td>With added calcium</td>
</tr>
<tr>
<td>Beverage powder</td>
<td>Calcium gluconate</td>
<td>113</td>
<td>ca. 3550</td>
<td>Fast absorbing calcium</td>
</tr>
</tbody>
</table>

Table 2. Important characteristics of common calcium sources used in the food industry

<table>
<thead>
<tr>
<th>Product</th>
<th>Ca Solubility at 25°C (g/L)</th>
<th>Taste</th>
<th>Calcium Content</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calcium carbonate</td>
<td>Insoluble</td>
<td>Soapy, lemony</td>
<td>40%</td>
</tr>
<tr>
<td>Calcium phosphate</td>
<td>Insoluble</td>
<td>Sandy, bland</td>
<td>17 - 38%</td>
</tr>
<tr>
<td>Tricalcium citrate (4 H2O)</td>
<td>0.2</td>
<td>Neutral</td>
<td>21%</td>
</tr>
<tr>
<td>Calcium lactate (5 H2O)</td>
<td>9.3</td>
<td>Bland</td>
<td>13%</td>
</tr>
<tr>
<td>Calcium lactate gluconate</td>
<td>45 - 50</td>
<td>Neutral</td>
<td>10 - 13%</td>
</tr>
<tr>
<td>Calcium gluconate</td>
<td>3.5</td>
<td>Mild, neutral</td>
<td>9%</td>
</tr>
</tbody>
</table>
most common forms of calcium supplements, tricalcium citrate and calcium carbonate. Over 90% of the studies reviewed showed greater absorption of calcium from tricalcium citrate than calcium carbonate by an average of 22 to 27%.

Similarly, calcium phosphate has also been described in scientific studies to display lower bioavailability than tricalcium citrate. Absorption of calcium from soy milk fortified with tricalcium phosphate reached only 75% of the efficiency of calcium from cow milk. Furthermore, it is not considered to be an appropriate ingredient for calcium fortification due to the undesired characteristics of the phosphate anion. Intake of phosphate is reported to exceed adult RDAs practically 100% of the time. Therefore, further addition of phosphate to food should be avoided in order to gain a higher calcium-to-phosphorus ratio, which is considered to be favourable for sufficient calcium absorption.

Influence of solubility on bioavailability. Reviewing the various bioavailability studies which had been done on the common organic salts listed in Table 1, it is concluded that they show similar calcium absorption. This holds true even though there are significant solubility differences of organic calcium salts in plain water. Researchers agree that these differences have no significant effect on absorbability in an acidic environment such as in gastric acid in the human stomach as well as at neutral conditions in the intestine. Although for example tricalcium citrate displays only moderate solubility in water, it had been assessed as having the same solubility in artificial intestinal juice as the calcium lactate. Furthermore, studies with healthy male volunteers revealed that compared to calcium lactogluconate/carbonate and calcium phosphate, oral administration of tricalcium citrate induced the highest serum calcium and greatest reduction in parathyroid hormone, conditions most favourable for building bone mass or minimizing resorption.

Economic considerations vs. calcium content. Although inorganic calcium salts are more economic than organic ones due to their low price and high calcium content, they are not frequently used in beverages anymore. Comparing the mainly used organic sources on the other hand, they are all in the same price range, except for the premium mineral source calcium lactate gluconate. For this reason, their wide range of calcium contents (9 to 21%) has a considerable impact on the raw material cost when the price of calcium added is calculated for the product to be fortified.

Among the organic salts with high bioavailability and more neutral taste profiles, tricalcium citrate (21% calcium) clearly stands out as the most economic option for calcium addition and is the main choice for cloudy beverages. Calcium lactate has come at the same price but a lower calcium content (13%). Due to its good solubility, it is a good alternative for clear beverages, if the desired amount of calcium does not affect stability and taste of the beverage. For those critical applications, calcium lactate gluconate (available with up to 13% calcium) is worth the premium price to achieve high fortification levels, e.g. in clear soft drinks or concentrated pre-blends. Another possibility, having a calcium price which had been done on the common organic compounds. Journal of Japanese Society of Nutrition and Food Science 47(6), 447-451 (1994)

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