Jungbunzlauer

From nature to ingredients®

facts

Mineral fortification in dairy alternatives

Introduction

Dairy products are considered healthy because they provide the body with minerals and vitamins. Fermented milk products such as yoghurt are excellent sources of protein, calcium, phosphorus, riboflavin, thiamine, vitamin B12, folate, niacin, magnesium and zinc. They also have a positive image because the probiotics they contain have a beneficial effect on the immune system, as demonstrated by various studies.[1]

Nevertheless, an increasing number of people cannot or do not want to consume milk products. The reasons range from ecological and animal welfare concerns, to health aspects such as cow's milk allergies, lactose intolerance, concerns around calorie intake and preventing high cholesterol.[2,3] Plant-based alternatives are therefore becoming increasingly important, and producers are facing the challenge of developing products that are as close as possible to cow's milk in terms of taste, appearance, stability and nutritional value.

Plant-based milk alternatives and yoghurts

Plant-based milk alternatives are liquids that consist of plant proteins homogenised in water, often together with emulsifiers, stabilisers, oil, sugar, salt and flavours to imitate the appearance and consistency of cow's milk.[2] Soy is still the most commonly used source of protein for plant-based drinks and yoghurts, followed by coconut, almonds and oats. In recent years, a large number of new plant-based sources of protein have entered the market, such as nuts (cashews, hazelnuts and walnuts), rice, peas, lupine and hemp. These sources of protein differ widely in terms of nutritional value, mineral profile and amino acid profile – as well as in terms of taste.

Indeed, some plant-based raw materials give rise to unpleasant taste profiles (e.g. bitter, green or beany notes), and therefore present a major challenge for manufacturers looking to produce a pleasant-tasting product.

Plant-based yoghurts can be produced in the same way as traditional yoghurts, employing fermentation with lactic acid-producing bacteria such as *Bifidobacterium* and *Lactobacillus*.[3] It may also be necessary to add sugars for the fermentation process, depending on the raw material used. The advantage of this process is that non-dairy yoghurts also contain living cultures. However, they still lack the vitamins and the minerals, especially calcium, found in cow's milk-based products.[4]

Mineral fortification and health claims

While calcium enrichment of soy drink has become relatively common, enrichment with other minerals and vitamins is still rare. Added minerals in plant-based yoghurts are also uncommon, even though fortification offers an additional opportunity for promoting health benefits. Minerals such as calcium, magnesium, potassium and zinc in particular allow many health claims besides bone health, addressing topics such as immunity, muscle function or energy (in line with the rules on health claims under Regulation (EC) No 1924/2006).

Solubility and bioavailability of different mineral salts

The addition of minerals to complex food matrices is often challenging and the right choice of mineral salts is crucial to success. Mineral salts can be broadly divided into soluble and insoluble salts. Whereas soluble salts have an influence on pH and taste, insoluble salts can lead to a sandy mouthfeel and sedimentation.

Table 1: **Overview of common mineral salts approved for fortification in Europe.**[5]
Organic salts are marked in bold, and salts offered by Jungbunzlauer are marked in blue.

Mineral source	Mineral content	Solubility	Taste
Calcium Carbonate	40%	Insoluble	Soapy, lemony
Tricalcium Phosphate	39%	Insoluble	Sandy, bland
Calcium Chloride * 2 H_2O	27%	745 g/l	Salty, bitter
Calcium Lactate * 5 H_2O	14%	90 g/l	Bitter at high concentrations
Calcium Lactate Gluconate	13%	400 g/l	Slightly bitter at high concentrations
Tricalcium Citrate * 4 H_2O	21%	1 g/l	Neutral
Magnesium Carbonate basic * 5 H_2O	24%	4 g/l	Earthy
Trimagnesium Phosphate * 5 H_2O	21%	Insoluble	Neutral
Magnesium Sulfate * 7 H_2O	10%	710 g/l	Saline, bitter
Magnesium Lactate * 2 H_2O	10%	84 g/l	Neutral
Trimagnesium Citrate * 9 H_2O	12%	16 g/l	Neutral
Trimagnesium Citrate Anhydrous	16%	200 g/l	Neutral, slightly buttery

Mineral salts can also be divided into organic and inorganic salts. Organic mineral salts are salts of naturally occurring acids, such as citric acid or lactic acid. They usually have a more neutral taste than inorganic mineral salts. In addition, various studies indicate that organic mineral salts have higher bioavailability than inorganic ones.[6–8] Jungbunzlauer offers a wide range of organic mineral salts in different granulation grades. These are suitable for fortification of various food matrices and are well established in the dairy industry.

Calcium is important for healthy bones

Calcium is one of the most important modifiable dietary factors for normal bone development and maintaining bone mass in old age. About 99% of the calcium contained in the human body is stored in the bones in the form of calcium hydroxyapatite. The amount of calcium present influences peak bone mass.[9] Multiple studies have shown that insufficient calcium intake is associated with an increased risk of osteoporosis and related fractures.[9–11] As well as calcium, other minerals such as magnesium, zinc and vitamin D are crucial for healthy bones.[6] However, there are still many people whose calcium intake is inadequate. The USDA Advisory Committee's 2020 scientific report states that 44% of Americans are at risk of calcium inadequacy.[12]

Dairy products are the most important source of calcium in our diet and provide 52–65% of daily calcium requirements.[10,13] Milk contains 120 mg calcium per 100 ml, whereas most plant-based alternatives contain significantly less. Soy drinks, for instance, contains only 25 mg calcium per 100 ml and coconut drink contains 0 mg per 100 ml.[14,15] Other minerals, such as magnesium and zinc, are only present in small quantities in many dairy alternatives. People who do not consume milk-based products typically have a lower intake of these minerals and are therefore at a higher risk of inadequacy.[11] Enrichment of milk alternatives can therefore make an important contribution to a healthy diet.

Challenges in the production of fortified dairy alternatives

When enriching milk alternatives, it's very important to consider the various properties of the mineral salts in question. Soluble calcium salts in particular, such as calcium lactate or calcium chloride, can lead to interactions with proteins due to the high concentration of free calcium ions. This can affect the pH value and stability of the product when it is heat treated. Insoluble inorganic salts such as calcium carbonate or calcium phosphate do not have this problem, but can precipitate or cause a sandy mouthfeel. Tricalcium citrate is a good compromise. It has a solubility of approx. 1 g/l and exhibits inverse solubility: solubility decreases as temperature increases, so only a very low concentration of free calcium ions is present during the heat treatment process.[16] Jungbunzlauer offers tricalcium citrate in a micronised grade (M1098: min. 98% < 10 µm). Due to the very fine particle size, sedimentation is less pronounced and the product offers a pleasant mouthfeel, since the particles are too small to be detected on the tongue.

Magnesium salts are less common in fortifying dairy alternatives. During processing, their behaviour is similar to that of calcium salts, but less mineral salt is required because the recommended daily intake for magnesium is lower than for calcium.[5] As a result, magnesium salts have less severe negative impacts on the product than calcium salts. Among the neutral-tasting magnesium salts, trimagnesium citrate offers the highest mineral content, but the insoluble inorganic salt magnesium phosphate has been used more often because of its neutral taste and low price. However, consumers are becoming increasingly sceptical about phosphate-containing ingredients. Various studies have indicated that excessive consumption of phosphates from food additives can be associated with health risks. The EFSA therefore called for an upper limit on phosphate levels in a new risk assessment in 2019.[17]

Fortifying with minerals, masking unpleasant flavours

Unpleasant off-tastes can be a problem, especially with plant-based products: plant proteins can have a beany, green or bitter taste, making the product less attractive for the consumer.

Previous trials have shown that mineral salts of organic acids – such as citrate or gluconate salts of magnesium, sodium or potassium – can mask bitterness and other unpleasant flavours.[18] Fortification with mineral salts can therefore improve not only the mineral content but also the taste of milk alternatives. The effect of each mineral salt on the flavour can vary depending on the matrix and the source of plant protein used: the mineral salt with the largest impact on off-notes in the flavour of one product may have much less effect in another.

Before examining the taste-masking properties of mineral salts, it is essential to identify the dominant taste characteristics of the various plant materials. To cover as wide a range of off-notes as possible, a soy drink and a walnut drink were selected as basis drinks to which mineral salts were added.

Screening for off-notes

The first step involved a benchmark soy drink (consisting of only water and 9% soy) and a self-prepared walnut drink (5% nut content; for recipe see table 2) being screened by an internal sensory panel. These screenings were carried out in form of a CATA ('check all that apply') test. CATA is a rapid descriptive method in which the panellists are given a list of attributes and are asked to determine which attributes, as perceived by the panellists, are most relevant to the samples. Quantitative results were then produced by counting the frequency of each attribute for each sample. The aim of these sessions was to find the most relevant attribute for subsequent discrimination tests.

The panellists identified the beany notes in the soy drink and the bitter notes in the walnut drink as the most dominant off-notes. Following these screenings, paired comparison tests were carried out to analyse the soy drink and the walnut drink, focusing on the two attributes identified by the panellists. As well as the paired comparison test, the panellists were asked to identify their preference and to comment on their impression of the taste. This additional information did not form part of a representative consumer test.

Minerals for masking unpleasant flavours in milk alternatives

Experimental setup

For each comparison test of the soy drink, the panellists were given a plain soy drink sample and a sample containing 0.15% added mineral salt (sodium gluconate, trimagnesium citrate, tripotassium citrate, calcium lactate gluconate or potassium lactate). The panellists were asked to identify which sample they perceived as more beany.

The same test setup was also used to evaluate the taste-masking properties of mineral salts in walnut drinks. Here, the panellists were asked to identify which sample they perceived as more bitter.

The test was carried out as a blind experiment; all samples were randomised and identified only by three-digit codes.

The soy drink was commercially available and was used both with and without added mineral salts. The walnut test matrix was prepared and fortified with one of the mineral salts afterwards.

Table 2: Recipe for walnut drink

Ingredient	Company	%
Walnut Paste	Fruisec	5.000
Water		92.250
Lecithin Sternphil S DH50	Sternchemie	0.100
Xanthan Gum FN	**Jungbunzlauer**	**0.025**
Guar Gum	TicGums	0.025
Sugar		2.500
Salt		0.100
SUM		100

The first step in preparing the walnut drink involved mixing the stabilisers with a quarter of the required amount of water. Another quarter of the water was heated to 60° C and mixed with lecithin. Both solutions were stirred thoroughly for 30 minutes. The walnut paste was meanwhile soaked at 60° C in the rest of the water.
This mixture was then transferred to a Becomix® and reheated to 60° C. The lecithin solution was homogenised, and then the lecithin solution and the stabiliser solution were stirred into the walnut-water mixture. The resulting mixture was homogenised at 60° C and then had its pH adjusted to 7.0. Finally, the product was pasteurised.

Soy drink results

The addition of 0.15% sodium gluconate, trimagnesium citrate or tripotassium citrate significantly reduced the beany off-note in the soy drink ($n = 20$, $\alpha = 0.05$).

The samples containing sodium gluconate and trimagnesium citrate were preferred over the plain soy drink.

Table 3: Sensory evaluation of soy drink – comments by panellists

Soy drink before addition of minerals	Mineral salt (0.15%)	Soy drink after addition of minerals
Beany, watery and astringent	Sodium Gluconate	More balanced, more neutral
	Trimagnesium Citrate	More creamy, more milky
	Tripotassium Citrate	Fuller mouthfeel, more milky

Walnut drink results

The addition of 0.15% sodium gluconate, trimagnesium citrate, calcium lactate gluconate and potassium lactate significantly reduced the bitter off-note of the walnut drink ($n = 20$, $\alpha = 0.05$).

The panellists also preferred these samples over the plain walnut drink.

Table 4: Sensory evaluation of walnut drink – comments by panellists

Walnut drink before addition of minerals	Mineral salt (0.15%)	Walnut drink after addition of minerals
Watery, very bitter	Sodium Gluconate	Sweeter, more creamy
	Trimagnesium Citrate	Sweeter, creamier, more balanced
	Calcium Lactate Gluconate	Sweeter, more balanced
	Potassium Lactate	Fuller mouthfeel, creamier

Conclusion

The sensory tests conducted showed that minerals are not only valuable for mineral fortification of milk substitutes but may also be suitable for masking undesired off-tastes. The results also indicated how crucial the selection of the right mineral salt is for masking specific off-notes.

While 0.15% tripotassium citrate worked well for masking beany off-notes of the soy drink, calcium lactate gluconate and potassium lactate worked well for the bitter off-note of the walnut drink. Sodium gluconate and trimagnesium citrate masked both off-notes.

At a concentration of 0.15%, trimagnesium citrate fulfils a dual function: its addition allows the product to be claimed as a source of magnesium, and it also helps enhance the taste of the product by masking beany and bitter off-notes.

Mineral fortification in non-dairy yoghurt

As described above, specific minerals can be utilised as taste masking agents for undesired off-notes in soy and walnut drinks. While milk alternatives are often fortified so that their mineral content matches that of cow's milk, fortification of non-dairy yoghurt can go further. Yoghurt products are generally considered healthy and their set portion size allows them to be used as an important source of minerals. Therefore yoghurt fortification can be used to achieve "high in minerals" status – an especially interesting option for vegan yoghurts.

However, since non-dairy yoghurts are produced directly from milk alternatives, additional minerals could have a negative effect on the stability, texture and taste of plant-based yoghurts. The following trials therefore focused on the influence of minerals on taste and texture in a plant-based yoghurt matrix. Unlike the trials with non dairy drinks not only one mineral was added, these used a combination of trimagnesium citrate and tricalcium citrate at concentrations that allow a "high mineral content" claim. Because soy is still the most common basis for non-dairy yoghurt, the following trials were carried out using a soy-based matrix.

The US Food and Drug Administration (FDA) gives a daily recommended intake of 1300 mg calcium and 420 mg magnesium per day. A product can be labelled as "high in calcium/magnesium" if it provides a minimum of 20% of the daily value (DV) (FDA 21CFR). The reference amount customarily consumed (RACC) is set at 150 g per portion, as this is a typical amount for commercially available single-portion yoghurts.

In the EU, Regulation (EU) No 1169/2011 requires that 100 g of final product contains 30% of the Nutrient Reference Value (NRV) if the product is to be labelled as "high in calcium/magnesium". The NRV is set at 800 mg calcium and 375 mg magnesium per day.

Table 5: Overview of requirements for "high in calcium/magnesium" claims in EU and USA

Claim	EU Amount of mineral needed (mg per 100 g portion)	USA Amount of mineral needed (mg per 150 g portion)
High in calcium	240	260
High in magnesium	112.5	84

In the experimental setup, the quantities for a "high in calcium/magnesium" claim under US regulations were used. Besides visually analysing stability, the internal sensory panel also tested the influence of the added minerals on the flavour of the product.

Experimental setup

Apart from the raw materials and the use of starter cultures for dairy alternatives, dairy and non-dairy yoghurt are processed in exactly the same way.

Table 6: Recipe for soy yoghurt

Ingredient	Company	%
1 Soy drink		98.67
2 Pectin Amid CM 020	Herbstreith & Fox	0.10
3 Tricalcium Citrate M1098	**Jungbunzlauer**	0.83
4 Trimagnesium Citrate Anhydrous	**Jungbunzlauer**	0.37
3 Starter culture VEGE 053	Danisco	*
Total		100

*Dosage: 20 DCU/100 kg

To produce the test yoghurts, a soy drink (protein content approx. 5–7 g per 100 g) was added to 0.1% pectin and heated to 90° C for 5 minutes in a Thermomix®. Trimagnesium citrate and tricalcium citrate were then stirred in until evenly suspended. After cooling the mixtures to below 40° C, the yoghurts were inoculated with lactic acid bacteria. The yoghurts were then poured into sealable cups and placed in a warming chamber at 40° C until a final pH of 4.7 was achieved.

Table 7: Nutritional values of the test yoghurt (values are per 150 g yoghurt)

Yoghurt basis	Soy
Claim (USA)	High in calcium and magnesium
Energy (kcal)	45.000
Protein (g)	3.500
Carbohydrates (g)	2.100
of which sugar (g)	0.800
Fat (g)	2.100
Sodium (g)	0.016
Calcium (g)	0.260
Magnesium (g)	0.084

Sensory evaluation of mineral-fortified soy yoghurt

Triangle tests ($\alpha = 0.05$) were used to find out if the addition of large quantities of tricalcium citrate and trimagnesium citrate influences the overall taste of a fortified product compared to the non-fortified product.

In a triangle test, panellists are given three samples, two of which are identical, and are asked to identify the third, non-identical sample. A significant difference between this sample and the other two samples would show that mineral fortification affects the flavour of the product. The panellists were also asked to comment on their decision and to choose their preferred yoghurt for each test set.

The test was carried out as a blind experiment; all samples were presented in a randomised order and identified only by three-digit codes.

Sensory results and conclusion
The sensory panel (n = 18) could not detect any difference between the fortified and the unfortified versions of the soy yoghurt.

It can therefore be concluded that the addition of mineral salts has no impact on the taste, texture, stability or appearance of the product.

The results demonstrate that a fortification with trimagnesium citrate and tricalcium citrate has no detectable effect on taste or texture for the consumer, even if large quantities of these minerals are used.

Cleaner label – replacing calcium phosphate

As mentioned above, mineral salts of phosphates are still commonly used, even though EFSA has issued new advice on phosphates.[17]

To further investigate whether phosphates could be replaced with clean label ingredients in non-dairy yoghurt, another soy yoghurt test was conducted. A soy yoghurt fortified with calcium phosphate was compared to a version fortified with tricalcium citrate in a triangle test.

Again, the panellists (n = 12) could not detect any difference between the two versions.

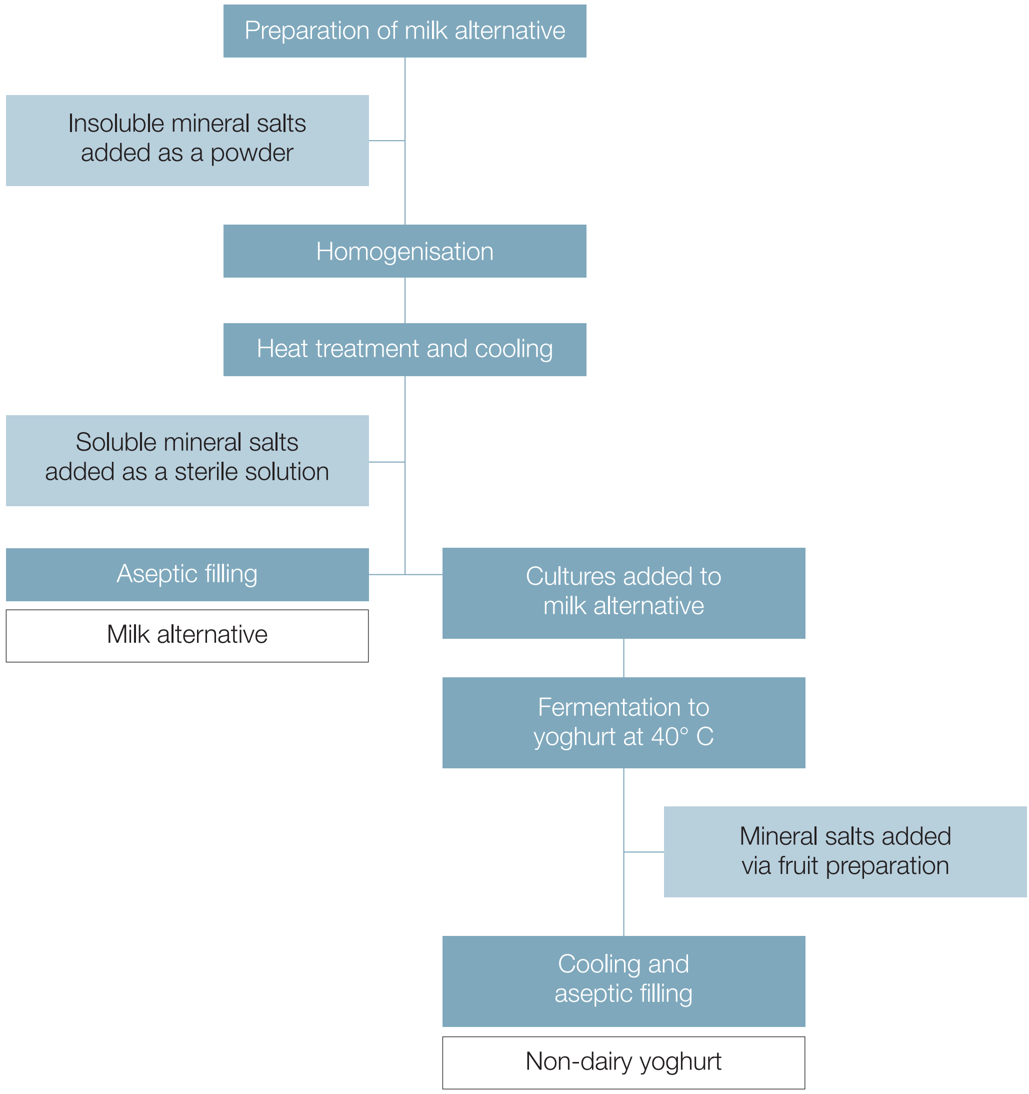
This indicates that cleaner labelling by switching from phosphates to label-friendly citrates can easily be achieved without any negative impact on the taste, texture, colour or appearance of the final product.

Both of these mineral salts have very low solubility and comparable reactivity. This means that citrates could be integrated into the production of non-dairy yoghurt without any change to the production process.

Incorporating mineral salts into the production process

As mentioned above, products containing dissolved cations such as calcium tend to be unstable during heat treatment. To avoid this, it is crucial that soluble mineral salts are added after the heating step. Since heat treatment is carried out to sterilise the product, the mineral salts must be added using a sterile method. There are various options:

- Mixing the minerals with water to produce a slurry or solution, followed by heat treatment before adding the minerals to the drink or yoghurt
- Adding the mineral salt solution using sterile filtration
- Adding the mineral salts to the fruit preparation, then sterilising this preparation before adding it to the yoghurt



Insoluble mineral salts present a lower risk of affecting product stability, so they can usually be added in micronised powder form before the heating step. Soluble mineral salts with low or moderate solubility can only be added in small quantities before heat treatment. The levels generally depend on the type of milk alternative in question, as the different plant proteins vary in their sensitivity to applied stress in form of heat, pH changes or shear forces.

Adding tricalcium citrate and trimagnesium citrate after the heating step to produce a high-magnesium/high-calcium soy yoghurt (in line with FDA standards) did not have any negative impact on the yoghurt's texture, stability or appearance.

The level of magnesium and calcium fortification required for a "high in calcium/magnesium" claim is higher under the EU standards than the US standards. Therefore, a test was also carried out to find out whether the stability and texture of non-dairy yoghurt can be maintained if even higher levels of mineral salts are added after the heating stage. Again, this experiment produced soy yoghurt with normal yoghurt-like stability and texture, demonstrating that high amounts of minerals can be incorporated into the yoghurt matrix after the heating step without any detectable loss of stability or texture.

Nowadays, various types of plant proteins are on the rise. Peas are a particularly common new ingredient for non-dairy yoghurts. The trials were therefore repeated using a pea-based yoghurt matrix instead of a soy-based one to find out whether stability can be maintained if a different plant protein is used. Provided that the yoghurt is processed as recommended, it was found that these versions did not demonstrate a lack of stability. However, the recommendations for the processing step must be followed meticulously.

Conclusion

The experiments described above show that mineral salts can be added to milk alternatives without any negative impact on texture or stability, and that this process can even be exploited to mask various undesired plant off-notes. Different plants proteins create varied undesired flavours, so selecting the right mineral salt plays an essential role in successfully masking such off-notes.

Some mineral salts (e.g. trimagnesium citrate) can even fulfil a dual function, enhancing flavours on the one hand and helping achieve fortification claims on the other.

Regarding non-dairy yoghurt and its complex texture, the experiments with soy yoghurt showed that mineral salts can be successfully added – even in large quantities – without having to compromise on taste, texture or stability of the final product.

References

[1] Hashemi Gahruie, H.; Eskandari, M. H.; Mesbahi, G. & Hanifpour, M. A. Scientific and technical aspects of yogurt fortification: A review. Food Sci. Hum. Wellness 4, 1–8 (2015).

[2] Sethi, S.; Tyagi, S. K. & Anurag, R. K. Plant-based milk alternatives an emerging segment of functional beverages: a review. J. Food Sci. Technol. 53, 3408–3423 (2016).

[3] Ranadheera, C. S.; Vidanarachchi, J. K.; Rocha, R. S.; Cruz, A. G. & Ajlouni, S. Probiotic delivery through fermentation: Dairy vs. non-dairy beverages. Fermentation 3, 1–17 (2017).

[4] Chalupa-Krebzdak, S.; Long, C. J. & Bohrer, B. M. Nutrient density and nutritional value of milk and plant-based milk alternatives. Int. Dairy J. 87, 84–92 (2018).

[5] Gerhart, M. & Schottenheimer, M. Mineral fortification in dairy. Wellness Foods Eur. (2013).

[6] Domke, A.; Großklaus, R.; Niemann, B.; Przyrembel, H. & Richter, K. Verwendung von Mineralstoffen in Lebensmitteln. Bundesinstitut für Risikobewertung (2004).

[7] Harvey, J. A. et al. Superior Calcium Absorption from Calcium Citrate than Calcium Carbonate Using External Forearm Counting. J. Am. Coll. Nutr. 9, 583–587 (1990).

[8] Kappeler, D. et al. Higher bioavailability of magnesium citrate as compared to magnesium oxide shown by evaluation of urinary excretion and serum levels after single-dose administration in a randomized cross-over study. BMC Nutr. 3, 1–12 (2017).

[9] Zhu, K. & Prince, R. L. Calcium and bone. Clin. Biochem. 45, 936–942 (2012).

[10] Włodarek, D. et al. Calcium intake and osteoporosis: The influence of calcium intake from dairy products on hip bone mineral density and fracture incidence – A population-based study in women over 55 years of age. Public Health Nutr. 17, 383–389 (2014).

[11] Schumann, L.; Martin, H.-H. & Keller, M. Calcium, Milch und Knochengesundheit. Behauptungen und Fakten. Ernährung im Fokus 14, 326–331 (2014).

[12] USDA Advisory Committee. Scientific Report of the 2020 Dietary Guidelines Advisory Committee. (2020).

[13] Rene, R. Dairy products, yogurts, and bone health. Am. J. Clin. Nutr. 99, 1256S–1262S (2014).

[14] U.S. DEPARTMENT OF AGRICULTURE. Soy milk. FoodData Central https://fdc.nal.usda.gov/fdc-app.html#/food-details/781114/nutrients, accessed on 6th August 2020.

[15] U.S. DEPARTMENT OF AGRICULTURE. Coconut milk. FoodData Central https://fdc.nal.usda.gov/fdc-app.html#/food-details/572117/nutrients, accessed on 6th August 2020.

[16] Gerstner, G. Dairy products: the calcium challenge. Int. Food Ingredients 3, 45–48 (2002).

[17] Younes, M. et al. Re-evaluation of phosphoric acid-phosphates – di-, tri- and polyphosphates (E 338–341, E 343, E 450–452) as food additives and the safety of proposed extension of use. EFSA J. 17, 5674 (2019).

[18] Besler, L. & Gerstner, G. Formulating better tasting infant formula. Jungbunzlauer Fact Sheet (2015).

About Jungbunzlauer

Jungbunzlauer is one of the world's leading producers of biodegradable ingredients of natural origin. We enable our customers to manufacture healthier, safer, tastier and more sustainable products. Thanks to continuous investments, state-of-the-art manufacturing processes and comprehensive quality management, we are able to provide outstanding product quality.

Our mission "From nature to ingredients" commits us to protecting people and their environment.

The Authors

Dr. Sabrina Fischer – Junior Product Manager, Jungbunzlauer Ladenburg GmbH
sabrina.fischer@jungbunzlauer.com

Miriam Feja – Application Technology Assistant, Jungbunzlauer Ladenburg GmbH
miriam.feja@jungbunzlauer.com

Headquarters **Jungbunzlauer Suisse AG**
4002 Basel · Switzerland · Phone +41 61 295 51 00 · headquarters@jungbunzlauer.com · www.jungbunzlauer.com