Acta Alimentaria 55 (2026) 3, 422–434
DOI: 10.1556/066.2026.00226

Calcium citrate malate for calcium fortification and food supplements: A narrative review from a formulation perspective

V. Vičič[1,2*]

[1] Chair of Biomedicine in Healthcare, Faculty of Health Sciences, University of Ljubljana, Zdravstvena pot 5, 1000 Ljubljana, Slovenia

[2] Chair of Public Health, Faculty of Medicine, University of Ljubljana, Zaloška cesta 4, 1000 Ljubljana, Slovenia

REVIEW PAPER

Received: June 11, 2026 • Accepted: July 31, 2026
Published online: September 2, 2026
© 2026 The Author(s)

ABSTRACT

Different calcium salts often present a trade-off between high calcium content, bioavailability, solubility, and sensory properties, which limits their application. The settling of calcium is a significant problem in plant beverages; the calcium content in an unshaken beverage is often significantly lower than the labelled amount. Calcium citrate malate is a metastable calcium salt that was authorised for use in food in the EU in 2009. The calcium content of calcium citrate malate (24%) is significantly higher than that of other highly soluble calcium salts, such as calcium lactate (13%) or calcium gluconate (9%). It provides sufficient aqueous solubility for many beverage fortification and effervescent food supplement applications, enabling the dissolution of 500 mg of elemental calcium (contained in 2.1 g of calcium citrate malate) in 200 mL of water. To address the limited availability and high cost of commercial calcium citrate malate (CCM), a formulation for preparing a dry precursor that forms CCM upon reaction with water is provided.

KEYWORDS

calcium supplementation, calcium citrate malate, food fortification, beverage, supplements

* Corresponding author. Tel.: +386 1 300 11 33, E-mail: vid.vicic@zf.uni-lj.si

Unauthenticated | Downloaded 10/26/26 07:20 AM UTC

1. INTRODUCTION

Different calcium salts often present a trade-off between high calcium content, aqueous solubility, bioavailability, and sensory properties, which limits their application in various food and food supplement matrices. This narrative review provides an overview of calcium salts and compares them with calcium citrate malate (CCM), an underutilised calcium source with the potential to address some limitations in beverage fortification and effervescent food supplements. One of the limitations of CCM use is the limited availability and high cost of the commercial ingredient. Therefore, we also provide technical information on how to prepare a dry precursor that forms CCM upon reaction with water.

Literature was identified through searches of PubMed, Scopus, Google Scholar, and Google Patents, supplemented by regulatory opinions and technical handbooks. Searches covered the period up to July 2026, with no lower date limit. Preference was given to peer-reviewed publications. Patents and technical documents were included where peer-reviewed evidence was limited, particularly for formulation and technological aspects. No formal systematic review protocol or predefined inclusion or exclusion criteria were applied.

2. CALCIUM HOMEOSTASIS AND ABSORPTION

About 99% of calcium is found in the skeleton and teeth in the form of hydroxyapatite, where it provides rigidity and strength. The remaining calcium is involved in various metabolic processes, such as vascular and muscle contraction, nerve signal transmission, membrane transport, enzyme activation, and hormone regulation. Bone tissue also serves as a reservoir of calcium (Institute of Medicine, 2011).

Calcium homeostasis and absorption are tightly regulated by parathyroid hormone (PTH), $1,25(OH)_2D_3$, and calcitonin, with circulating ionised calcium (iCa^{2+}) acting as a feedback signal (Jeon, 2008). In the stomach, inorganic calcium salts (e.g. calcium carbonate) are first ionised and solubilised by hydrochloric acid. Recker (1985) found that achlorhydria significantly impairs calcium carbonate absorption under fasting conditions, but absorption was similar to that of healthy subjects when calcium carbonate was taken with a normal breakfast (Recker, 1985). Similarly, calcium absorption from food was not impaired in patients taking proton pump inhibitors (Hansen et al., 2010).

The chemical form of calcium salts appears to have a relatively minor influence on calcium bioavailability compared with other factors. Apparent differences in bioavailability may partly reflect the methods used to assess absorption. Stable isotope tracer studies, which directly measure true intestinal calcium absorption, have shown that calcium carbonate and calcium citrate exhibit comparable absorption when administered with food at equivalent elemental calcium doses (Heaney et al., 1999; Heaney, 2001). In contrast, studies using indirect biomarkers of calcium bioavailability, including the serum calcium response, urinary calcium excretion, and PTH suppression, reported greater bioavailability of calcium citrate than calcium carbonate (Sakhaee et al., 1999; Heller et al., 2000). Additionally, product formulation (e.g., coating, granulation, tablet hardness, and excipients) of tested products can substantially affect calcium bioavailability (Heaney, 2001).

Unauthenticated | Downloaded 10/26/26 07:20 AM UTC

Calcium is absorbed in the intestine via two complementary mechanisms: a $1,25(OH)_2D_3$-regulated transcellular active transport pathway, which predominates at low luminal concentrations, and an unregulated paracellular passive pathway, which becomes the principal route when luminal calcium is high (Bronner, 2003). Fractional calcium absorption decreases with increasing calcium intake, declining from 64.0% at a dose of 15 mg to 28.6% at a dose of 500 mg as part of the meal (Heaney et al., 1990b). Calcium is generally absorbed more efficiently with meals than in the fasting state, likely because delayed gastric emptying prolongs calcium solubilisation and intestinal residence time, whereas oxalate and phytate reduce absorption by forming insoluble complexes (Shkembi and Huppertz, 2021).

Calcium homeostasis is primarily regulated by parathyroid hormone (PTH). Hypocalcaemia stimulates PTH secretion, which upregulates renal 1α-hydroxylase, increasing the conversion of 25-hydroxyvitamin D to the active metabolite 1,25-dihydroxyvitamin D. This enhances intestinal calcium absorption *via* the $1,25(OH)_2D_3$-regulated transcellular active transport pathway (Goltzman et al., 2018). A linear relationship has been observed between true net calcium absorption and 1,25-dihydroxyvitamin D (Sheikh et al., 1988). In vitamin D deficiency, active intestinal calcium absorption is decreased, whereas passive paracellular absorption remains largely unaffected (Lips, 2012). Similarly, the decline in oestrogen levels after menopause reduces circulating 1,25-dihydroxyvitamin D concentrations, leading to decreased intestinal calcium absorption and increased bone loss (Gallagher et al., 1980). Prolonged hypocalcaemia and elevated parathyroid hormone (PTH) concentrations increase bone resorption and may contribute to bone loss (Goltzman et al., 2018). The intestine also adapts to habitual calcium intake by regulating active calcium transport. Individuals consuming low-calcium diets exhibit higher fractional calcium absorption, whereas high calcium intake reduces absorption efficiency (Heaney et al., 1989).

Calcium absorption in the colon accounts for <10% of total calcium absorption (Bronner and Pansu, 1999), but this proportion increases if there is malabsorption in the small intestine, for example after intestinal resection (Hylander et al., 1990). It can also be increased by colon acidification achieved through fermentation of indigestible carbohydrates such as lactulose (Van den Heuvel et al., 1999; Vičič et al., 2024) and some fermentable dietary fibre such as inulin (Abrams et al., 2005; Whisner et al., 2016; Nath et al., 2017). This approach could be used in food supplements, fortified foods, and calcium-containing medicines to improve absorption. Not all dietary fibre has this effect. A study on psyllium and cellulose added to a test meal reported no significant effect on calcium absorption in humans (Heaney and Weaver, 1995). Studies in rats fed diets containing high concentrations (5–10% of the diet) of psyllium or wheat bran, which are not expected in humans, reported reduced calcium absorption (Luccia and Kunkel, 2002).

In conclusion, assessment of calcium bioavailability in humans is inherently complex because absorption is influenced by multiple factors. Differences in calcium absorption among calcium salts appear to be relatively minor in healthy humans (Heaney, 2001). Therefore, the choice of calcium source should be primarily guided by the technological requirements of the intended application, while also considering nutritional, clinical, and economic factors.

3. RECOMMENDED AND ACTUAL CALCIUM INTAKE

The D-A-C-H recommended calcium intake for adults is 1,000 mg, the same amount is recommended for pregnant and lactating women (German Nutrition Society, 2013). IOM recommendations differ only slightly (Institute of Medicine, 2011).

Unauthenticated | Downloaded 10/26/26 07:20 AM UTC

Global data on calcium intake in adults reveal substantial variability between countries: average intake across 74 countries ranged from 175 to 1,233 mg day^{-1}. The authors also highlight the severe lack of nationally representative data; for half of the world's countries, no data were available. Considering only nationally representative studies, mean calcium intake in Europe ranged from 673 mg (Hungary) to 1,080 mg (Ireland) (Balk et al., 2017).

In practice, calcium is most often supplemented in postmenopausal women receiving osteoporosis treatment (Reymondier et al., 2013). However, adequate calcium intake is particularly important in children and young adults as peak bone mass is achieved at around 20 years of age and is influenced by lifestyle and nutrition (Weaver et al., 2016). There are also indications that calcium supplementation during pregnancy can reduce the risk of decayed, missing, or filled teeth in their 12-year-old offspring (Bergel et al., 2010).

The European Food Safety Authority (EFSA) has set a Tolerable Upper Intake Level (UL) for calcium at 2,500 mg per day for adults, applicable to total intake from both diet and food supplements (European Food Safety Authority, 2012).

4. TECHNOLOGICAL PROPERTIES OF DIFFERENT CALCIUM SALTS

Technological properties, including aqueous solubility, calcium content, sensory characteristics, bioavailability, and cost, must be considered when selecting a calcium source for food fortification or use in food supplements. These characteristics are summarised in Table 1.

4.1. Aqueous solubility of calcium salts

The aqueous solubility of calcium is crucial in beverage applications. Data on the aqueous solubility of calcium in water are provided in Table 1. Aqueous solubility increases substantially in acidic solutions (Goss et al., 2007). Beverages with a pH near neutral can be more problematic. In bovine milk, calcium phosphate is bound to casein micelles, which is crucial in preventing mammary gland calcification (Holt, 1997). Calcium content in unshaken bovine milk is less than 6% lower than in well-mixed samples (Smith et al., 2022). However, this is not the case when calcium is added to plant beverages. Heaney and Rafferty (2006) demonstrated that the labelled calcium content of fortified soy beverages does not reflect the amount of calcium actually consumed. In unshaken samples, measurable calcium averaged only 31% of the declared value, increasing to a mean of 59% after shaking. Significant inter-product variability was observed: two products reached calcium levels consistent with label claims when shaken, whereas one product failed to exceed 20% of the labelled calcium content even after agitation (Heaney and Rafferty, 2006). Consistent with these findings, Smith et al. (2022) reported that calcium content in unshaken coconut plant-based beverages (PBB) deviated by no more than 6% from well-mixed samples. In contrast, unshaken almond and soy beverages exhibited 14 and 18% lower calcium contents, respectively, while unshaken rice and oat beverages contained 96 and 97% less calcium than their well-mixed counterparts, indicating extreme sedimentation of added calcium salts (Smith et al., 2022).

Unauthenticated | Downloaded 10/26/26 07:20 AM UTC

Table 1. Aqueous solubility and required dose of selected calcium salts for 1,000 mg of elemental calcium

Calcium salt	Aqueous solubility in H_2O (g L^{-1})	Calcium concentration (%)*	Required mass for 1,000 mg of elemental calcium (g)	Key considerations
Calcium carbonate	<0.005 (20–22 °C) (Goss et al., 2007)	40.0	2.50	Low cost (Keller et al., 2002), high calcium concentration, good bioavailability when taken with meals (Recker, 1985). Low aqueous solubility
Tricalcium phosphate	0.020 (21 °C) (Kressel, 2010)	38.8	2.58	Significant source of phosphorus. Low aqueous solubility
Calcium chloride	745.0 (20 °C) (Tordoff, 1996)	36.1	2.77	Used as food additive (firming agent for tofu and other foods). Bitter and salty taste
Calcium citrate (CC)	0.96 (23 °C) (Haynes, 2016)	21.4	4.65	Low aqueous solubility
Calcium citrate malate (CCM, 6:2:3)	11.0 (25 °C) (Fox et al., 1993; European Food Safety Authority, 2007)	24.0	4.17	Sufficient aqueous solubility allows incorporation into beverages
Calcium lactate	64.1 (24 °C) (Kubantseva et al., 2004)	13.0	7.69	High aqueous solubility, low calcium concentration
Calcium gluconate	30 (21 °C) (Kressel, 2010)	9.0	11.11	High aqueous solubility, low calcium concentration
Calcium lactate gluconate	400.0 (20 °C) (Gerstner, 2002)	13.0	7.69	High aqueous solubility, low calcium concentration
Calcium lactate citrate	98.0 (21 °C) (Kressel, 2010)	16.2	6.17	High aqueous solubility
Calcium lactate malate	115.0 (21 °C) (Kressel, 2010)	18.1	5.52	High aqueous solubility

*Typical values are presented as reported in the literature; differences in hydration state may affect elemental calcium content.

Unauthenticated | Downloaded 10/26/26 07:20 AM UTC

4.2. Calcium concentration of calcium salts

Calcium carbonate is usually a mined, finely milled mineral with the lowest cost (Keller et al., 2002) and a high elemental calcium content of 40% (Table 1). When consumed with food, it has good bioavailability (Recker, 1985), making it a preferred form for the fortification of wheat flour and baked products (Hackett et al., 1984; Romanchik-Cerpovicz and McKemie, 2007), where low aqueous solubility is not a technological limitation. In contrast, the high aqueous solubility of calcium gluconate and calcium lactate is advantageous for beverage applications; however, their low calcium content (9 and 13%, respectively) makes their use inefficient and economically unfavourable (Kubantseva et al., 2004; Kressel, 2010). Swallowable calcium tablets are predominantly based on calcium carbonate, as tablet size is inherently limited and large tablets significantly reduce adherence (Radhakrishnan et al., 2021). FDA adverse event reporting data indicate that most reported swallowing-related problems are associated with multivitamin products (72.9%) and calcium food supplements (17.3%) (Punzalan et al., 2019). However, given that multivitamins are the most commonly used food supplements, whereas calcium supplements rank only fourth among adults aged >60 years, calcium food supplements appear disproportionately problematic with respect to swallowing difficulties (Mishra et al., 2021). Because of its relatively low elemental calcium content (~21%), calcium citrate (CC) is rarely used in swallowable tablets. It is more commonly formulated as chewable products, where its low aqueous solubility can result in a gritty or chalky mouthfeel unless particle size is sufficiently reduced (Scheurer and McNamee, 1989). Calcium chloride (36% elemental calcium) has excellent aqueous solubility but its bitter and salty taste limits its application (Tordoff, 1996).

4.3. Calcium citrate malate

Calcium citrate malate (CCM) is a metastable complex of calcium, citrate, and malate (Fox et al., 1993). In 2007, EFSA conducted a review of the available evidence and concluded that CCM is a safe and bioavailable source of calcium for use in foods (European Food Safety Authority, 2007) and it was authorised for use in food in 2009 (European Commission, 2009). CCM provides a relatively high elemental calcium content (~24%) combined with adequate aqueous solubility; although its aqueous solubility is lower than that of some other calcium salts, it is sufficient for use in many calcium-fortified beverages (Fox et al., 1993; European Food Safety Authority, 2007) (Table 1). Sufficient aqueous solubility in practice is demonstrated by the following example: When a food supplement containing 2.3 g of calcium citrate (CC) (~500 mg of elemental calcium) is dissolved in 200 mL of water, the limited aqueous solubility of CC (0.96 g L^{-1}) results in only about 0.19 g of CC (41 mg of elemental calcium) remaining dissolved. The remaining 2.1 g of CC (459 mg of elemental calcium) forms a white, chalky sediment at the bottom. It is plausible that some users may discard the sediment, potentially reducing calcium intake, although this has not been investigated for calcium products. However, indirect evidence from one large therapeutic drug monitoring study compared plasma concentrations of the poorly soluble drug clozapine and its metabolite norclozapine in patients receiving crushed tablets or suspension (n = 846) versus intact tablets (n = 6,065). Although the median prescribed dose was higher in the crushed tablet/suspension group, the median plasma levels of both compounds were significantly lower. The authors attributed these findings to poorer adherence, sedimentation of the suspension before use, and incomplete dosage (Flanagan et al., 2022). In contrast, dissolving a supplement containing 2.1 g of calcium citrate malate (CCM) (~500 mg of

Unauthenticated | Downloaded 10/26/26 07:20 AM UTC

elemental calcium), which has a higher aqueous solubility (11.0 g L^{-1}), allows the majority of CCM to remain in solution (Table 1 and Fig. 1).

CCM is more soluble because its metastable form contains multiple hydration states and partially non-crystalline regions. These regions readily hydrate and behave like a pre-solubilised phase (European Food Safety Authority, 2007). Higher solubility of calcium salts by itself has only a limited effect on calcium bioavailability (Heaney et al., 1990a). Studies indicate that CCM is at least as bioavailable as conventional calcium sources, such as calcium carbonate and milk calcium (Martini and Wood, 2002), while some studies suggest that its absorption may be slightly greater than that of calcium carbonate (Smith et al., 1987; Miller et al., 1988).

The commercial availability of CCM remains limited and high prices limit its widespread use. According to EFSA, CCM can be a complex of calcium citrate and malate ligands, a mixture of calcium citrate with calcium malate, or a mixture of a calcium salt (e.g. calcium carbonate) with citric and malic acid (European Food Safety Authority, 2007). One patent presents preparation of calcium citrate malate (CCM) with a molar ratio of 6:2:3 (calcium:citrate:malate). Figure 2 presents a simplified scheme of the production and use of a dry precursor that forms

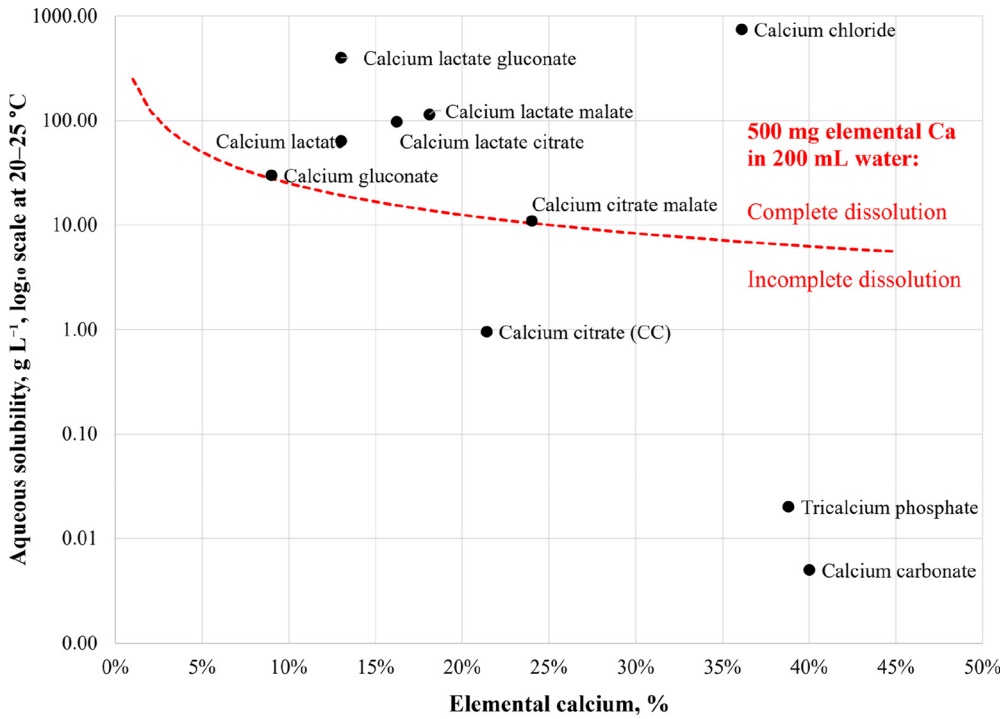

Fig. 1. Relationship between elemental calcium content and aqueous solubility of selected calcium salts. The red curve represents the minimum aqueous solubility required to dissolve the amount of calcium salt needed to provide 500 mg of elemental calcium in 200 mL of water (a common dosage). Calcium salts above the curve are expected to dissolve completely under these conditions. Actual solubility may vary with pH, temperature, and solution composition. Data compiled from the literature cited in Table 1

Unauthenticated | Downloaded 10/26/26 07:20 AM UTC

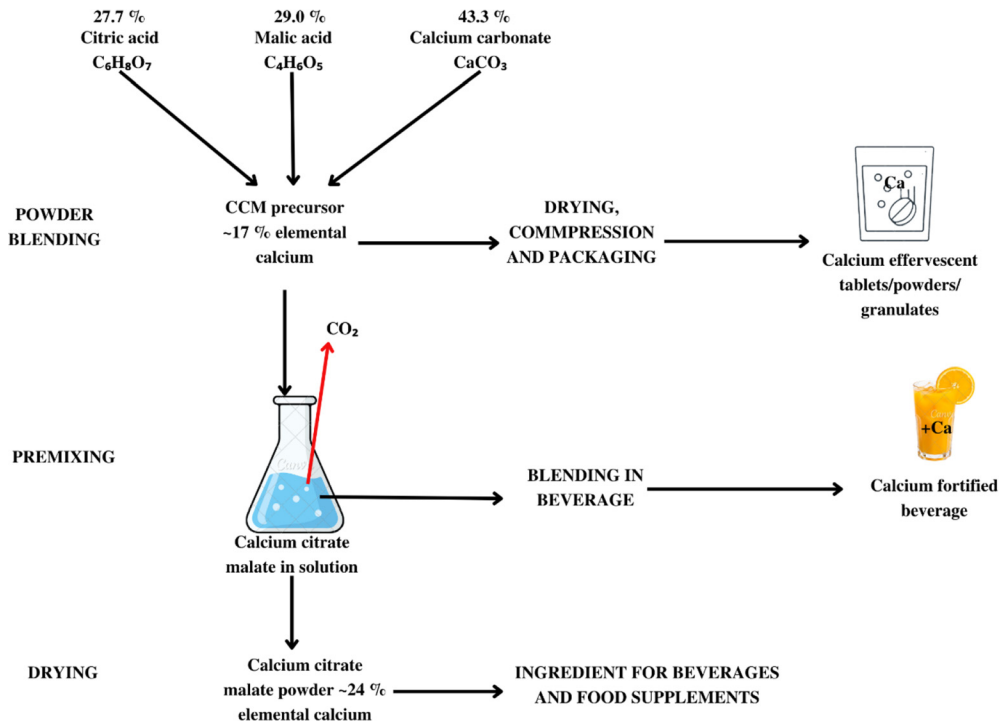

Fig. 2. Simplified scheme of production and use of calcium citrate malate (CCM). Source of images: Canva

CCM upon reaction with water. Based on the patent (Fox et al., 1993) and the authors' formulation experience, the practical example of a formulation for a dry precursor that forms CCM upon reaction with water is presented in Table 2. A commercial formulation based on this principle achieved a calcium dissolution percent of 88.65 ± 0.90%, while spectroscopic analyses

Table 2. Formulation for preparation of dry precursor that forms CCM with molar ratio 6:2:3 upon reaction with water (calcium:citrate:malate) from common ingredients. CO_2 is released upon mixing with water. This non-validated practical example is based on the patent by Fox et al. (1993) and the authors' formulation experience

Ingredient	Mass (%)	Amount for 1 kg of powder (g)	Elemental calcium concentration (%)
Calcium carbonate powder* (99.0% purity)	43.29	432.9	39.6
Citric acid anhydrous	27.71	277.1	0
DL-Malic acid anhydrous	29.00	290	0
CCM precursor mixture	100	1,000	17.14

*Particle size: D_{50}: 12–16 µm, D_{98}: 70 µm was found to be adequate.

Unauthenticated | Downloaded 10/26/26 07:20 AM UTC

were consistent with the conversion of calcium carbonate to CCM during the effervescent reaction (Zhang et al., 2026).

When the described dry mixture is added to water, it releases CO_2, making it suitable as a sodium-free ingredient for effervescent powders or tablets. Effervescent food supplements can be a relevant source of sodium. A recent Slovenian study reported that sodium content was not declared on 77% of effervescent food supplements, because such declaration is not mandatory under EU food supplement labelling legislation. The mean sodium content of calcium effervescent tablets was 136 ± 59 mg per tablet, which was significantly lower than that of effervescent products containing vitamins and minerals (314 ± 109 mg per tablet). This difference suggests that sodium hydrogen carbonate is already partially replaced with calcium carbonate in calcium formulations (Žmitek et al., 2026). Sodium intake from effervescent medicinal formulations has been linked to an increased risk of cardiovascular events (George et al., 2013).

4.4. Limitations of this review and future research needs

This review has several limitations. Published evidence on calcium citrate malate (CCM) remains limited compared with more widely used calcium salts. Consequently, some sections, particularly those addressing physicochemical properties, formulation, sensory characteristics, user adherence, and technological performance, rely on a limited number of studies, supplemented by patents, regulatory documents, technical literature, and, in some cases, indirect evidence.

Future research should generate data on the aqueous solubility of CCM across different pH conditions, temperatures, and food matrices. Further work should evaluate its stability during processing and storage, interactions with food components, sedimentation behaviour, beverage clarity, and consumer acceptability.

5. CONCLUSIONS

Calcium citrate malate (CCM) offers adequate aqueous solubility for beverage fortification and effervescent food supplement applications.

Funding: The study received no funding.

Conflict of interest: The author V.V. declares that his previous employer is a manufacturer of products containing calcium (last transaction (salary): July 2024). This review was prepared without financial support or influence.

ACKNOWLEDGEMENTS

AI (InstaText and ChatGPT) was used only to improve language and readability of text. These tools were not used for data analysis, interpretation of results, generation of scientific content, generation of images, or citation of references.

Unauthenticated | Downloaded 10/26/26 07:20 AM UTC

REFERENCES

Abrams, S.A., Griffin, I.J., Hawthorne, K.M., Liang, L., Gunn, S.K., Darlington, G., and Ellis, K.J. (2005). A combination of prebiotic short- and long-chain inulin-type fructans enhances calcium absorption and bone mineralization in young adolescents. *The American Journal of Clinical Nutrition*, 82(2): 471–476, https://doi.org/10.1093/ajcn.82.2.471

Balk, E.M., Adam, G.P., Langberg, V.N., Earley, A., Clark, P., Ebeling, P.R., Mithal, A., Rizzoli, R., Zerbini, C.A.F., Pierroz, D.D., and Dawson-Hughes, B. (2017). Global dietary calcium intake among adults: a systematic review. *Osteoporosis International*, 28(12): 3315–3324, https://doi.org/10.1007/s00198-017-4230-x

Bergel, E., Gibbons, L., Rasines, M.G., Luetich, A., and Belizán, J.M. (2010). Maternal calcium supplementation during pregnancy and dental caries of children at 12 years of age: follow-up of a randomized controlled trial. *Acta Obstetricia et Gynecologica Scandinavica*, 89(11): 1396–1402, https://doi.org/10.3109/00016349.2010.518228

Bronner, F. (2003). Mechanisms of intestinal calcium absorption. *Journal of Cellular Biochemistry*, 88(2): 387–393, https://doi.org/10.1002/jcb.10330

Bronner, F. and Pansu, D. (1999). Nutritional aspects of calcium absorption. *The Journal of Nutrition*, 129(1): 9–12, https://doi.org/10.1093/jn/129.1.9

European Commission. (2009). Commission regulation (EC) No 1170/2009 of 30 November 2009 amending directive 2002/46/EC of the European parliament and of council and regulation (EC) No 1925/2006 of the European parliament and of the council as regards the lists of vitamin and minerals and their forms that can be added to foods, including food supplements (Text with EEA relevance). *OJ L*, Available at: http://data.europa.eu/eli/reg/2009/1170/oj (Accessed 30 July 2026).

European Food Safety Authority. (2007). Calcium citrate malate as source for calcium for use in foods for particular nutritional uses and in foods for the general population (including food supplements) - scientific opinion of the panel on food additives, flavourings, processing aids and materials in contact with food (AFC). *EFSA Journal*, 5(12): 612, https://doi.org/10.2903/j.efsa.2007.612

European Food Safety Authority. (2012). Scientific opinion on the tolerable upper intake level of calcium. *EFSA Journal*, 10(7): 2814, https://doi.org/10.2903/j.efsa.2012.2814

Flanagan, R.J., Hunter, S., Obee, S.J., and Reeves, S. (2022). Plasma clozapine and norclozapine after use of either crushed tablets or suspension compared with tablets. *Journal of Clinical Psychopharmacology*, 42(4): 400–404, https://doi.org/10.1097/JCP.0000000000001560

Fox, M.M., Heckert, D.C., and Luhrsen, K.R. (1993). *Calcium citrate malate composition, application no. US5186965A*.

Gallagher, J.C., Riggs, B.L., and DeLuca, H.F. (1980). Effect of estrogen on calcium absorption and serum vitamin D metabolites in postmenopausal osteoporosis. *The Journal of Clinical Endocrinology and Metabolism*, 51(6): 1359–1364, https://doi.org/10.1210/jcem-51-6-1359

George, J., Majeed, W., Mackenzie, I.S., MacDonald, T.M., and Wei, L. (2013). Association between cardiovascular events and sodium-containing effervescent, dispersible, and soluble drugs: nested case-control study. *BMJ*, 347: f6954, https://doi.org/10.1136/bmj.f6954

German Nutrition Society. (2013). New reference values for calcium. *Annals of Nutrition and Metabolism*, 63(3): 186–192, https://doi.org/10.1159/000354482

Unauthenticated | Downloaded 10/26/26 07:20 AM UTC

Gerstner, G. (2002). Calcium Lactate Gluconate – the innovative solution for extra calcium. *Innovations in Food Technology*, 2002(16): 2–3, Available at: https://web.archive.org/web/20120111121130/http://www.jungbunzlauer.com/media/uploads/pdf/Special_Salts/Calcium_Lactate_Gluconate_Aug02.pdf.

Goltzman, D., Mannstadt, M., and Marcocci, C. (2018). Physiology of the calcium-parathyroid hormone-vitamin D axis. *Frontiers of Hormone Research*, 50: 1–13, https://doi.org/10.1159/000486060

Goss, S.L., Lemons, K.A., Kerstetter, J.E., and Bogner, R.H. (2007). Determination of calcium salt solubility with changes in pH and P_{CO2}, simulating varying gastrointestinal environments. *The Journal of Pharmacy and Pharmacology*, 59(11): 1485–1492, https://doi.org/10.1211/jpp.59.11.0004

Hackett, A.F., Rugg-Gunn, A.J., Allinson, M., Robinson, C.J., Appleton, D.R., and Eastoe, J.E. (1984). The importance of fortification of flour with calcium and the sources of Ca in the diet of 375 English adolescents. *The British Journal of Nutrition*, 51(2): 193–197, https://doi.org/10.1079/bjn19840023

Hansen, K.E., Jones, A.N., Lindstrom, M.J., Davis, L.A., Ziegler, T.E., Penniston, K.L., Alvig, A.L., and Shafer, M.M. (2010). Do proton pump inhibitors decrease calcium absorption? *Journal of Bone and Mineral Research*, 25(12): 2786–2795, https://doi.org/10.1002/jbmr.166

Haynes, W.M. (2016). *CRC handbook of chemistry and physics*, 97th ed. CRC Press, Boca Raton.

Heaney, R.P. (2001). Factors influencing the measurement of bioavailability, taking calcium as a model. *The Journal of Nutrition*, 131(4): 1344S–1348S, https://doi.org/10.1093/jn/131.4.1344S

Heaney, R.P., Dowell, M.S., and Barger-Lux, M.J. (1999). Absorption of calcium as the carbonate and citrate salts, with some observations on method. *Osteoporosis International*, 9(1): 19–23, https://doi.org/10.1007/s001980050111

Heaney, R.P. and Rafferty, K. (2006). The settling problem in calcium-fortified soybean drinks. *Journal of the American Dietetic Association*, 106(11): 1753, author reply 1755 https://doi.org/10.1016/j.jada.2006.08.008

Heaney, R.P., Recker, R.R., Stegman, M.R., and Moy, A.J. (1989). Calcium absorption in women: relationships to calcium intake, estrogen status, and age. *Journal of Bone and Mineral Research*, 4(4): 469–475, https://doi.org/10.1002/jbmr.5650040404

Heaney, R.P., Recker, R.R., and Weaver, C.M. (1990a). Absorbability of calcium sources: the limited role of solubility. *Calcified Tissue International*, 46(5): 300–304, https://doi.org/10.1007/BF02563819

Heaney, R.P. and Weaver, C.M. (1995). Effect of psyllium on absorption of co-ingested calcium. *Journal of the American Geriatrics Society*, 43(3): 261–263, https://doi.org/10.1111/j.1532-5415.1995.tb07333.x

Heaney, R.P., Weaver, C.M., and Fitzsimmons, M.L. (1990b). Influence of calcium load on absorption fraction. *Journal of Bone and Mineral Research*, 5(11): 1135–1138, https://doi.org/10.1002/jbmr.5650051107

Heller, H.J., Greer, L.G., Haynes, S.D., Poindexter, J.R., and Pak, C.Y. (2000). Pharmacokinetic and pharmacodynamic comparison of two calcium supplements in postmenopausal women. *Journal of Clinical Pharmacology*, 40(11): 1237–1244, https://doi.org/10.1177/009127000004001108

Holt, C. (1997). The milk salts and their interaction with casein. In: Fox, P.F. (Ed.), *Advanced dairy chemistry Vol. 3: Lactose, water, salts and vitamins*. Springer, US, Boston, MA, pp. 233–256.

Hylander, E., Ladefoged, K., and Jarnum, S. (1990). Calcium absorption after intestinal resection. The importance of a preserved colon. *Scandinavian Journal of Gastroenterology*, 25(7): 705–710, https://doi.org/10.3109/00365529008997596

Institute of Medicine. (2011). *Dietary reference intakes for calcium and vitamin D*. The National Academies Press (US), Washington, DC, pp. 1132.

Jeon, U.S. (2008). Kidney and calcium homeostasis. *Electrolytes & Blood Pressure : E & BP*, 6(2): 68–76, https://doi.org/10.5049/EBP.2008.6.2.68

Unauthenticated | Downloaded 10/26/26 07:20 AM UTC

Keller, J.L., Lanou, A., and Barnard, N.D. (2002). The consumer cost of calcium from food and supplements. *Journal of the American Dietetic Association*, 102(11): 1669–1671, https://doi.org/10.1016/s0002-8223(02)90355-x

Kressel, G. (2010). Bioavailability and solubility of different calcium-salts as a basis for calcium enrichment of beverages. *Food and Nutrition Sciences*, 1(2): 53–58, https://doi.org/10.4236/fns.2010.12009

Kubantseva, N., Hartel, R.W., and Swearingen, P.A. (2004). Factors affecting solubility of calcium lactate in aqueous solutions. *Journal of Dairy Science*, 87(4): 863–867, https://doi.org/10.3168/jds.S0022-0302(04)73230-0

Lips, P. (2012). Interaction between vitamin D and calcium. *Scandinavian Journal of Clinical and Laboratory Investigation*, 243: 60–64, https://doi.org/10.3109/00365513.2012.681960

Luccia, B.H.D. and Kunkel, M.E. (2002). Psyllium reduces relative calcium bioavailability and induces negative changes in bone composition in weanling Wistar rats. *Nutrition Research*, 22(9): 1027–1040, https://doi.org/10.1016/S0271-5317(02)00408-6

Martini, L. and Wood, R.J. (2002). Relative bioavailability of calcium-rich dietary sources in the elderly. *The American Journal of Clinical Nutrition*, 76(6): 1345–1350, https://doi.org/10.1093/ajcn/76.6.1345

Miller, J.Z., Smith, D.L., Flora, L., Slemenda, C., Jiang, X.Y., and Johnston, C.C. (1988). Calcium absorption from calcium carbonate and a new form of calcium (CCM) in healthy male and female adolescents. *The American Journal of Clinical Nutrition*, 48(5): 1291–1294, https://doi.org/10.1093/ajcn/48.5.1291

Mishra, S., Stierman, B., Gahche, J., and Potischman, N. (2021). *Dietary supplement use among adults: united States, 2017–2018*. NCHS Data Brief, No. 399, https://doi.org/10.15620/cdc:101131

Nath, A., Mondal, S., Csighy, A., Molnár, M.A., Pásztorné-Huszár, K., Kovács, Z., Koris, A., and Vatai, G. (2017). Biochemical activities of lactose-derived prebiotics – a review. *Acta Alimentaria*, 46(4): 449–456, https://doi.org/10.1556/066.2017.46.4.7

Punzalan, C., Budnitz, D.S., Chirtel, S.J., Geller, A.I., Jones, O.E., Mozersky, R.P., and Wolpert, B. (2019). Swallowing problems and dietary supplements: data from FDA adverse event reports, 2006–2015. *Annals of Internal Medicine*, 171(10): 771–773, https://doi.org/10.7326/M19-0947

Radhakrishnan, C., Sefidani Forough, A., Cichero, J.A.Y., Smyth, H.E., Raidhan, A., Nissen, L.M., and Steadman, K.J. (2021). A difficult pill to swallow: an investigation of the factors associated with medication swallowing difficulties. *Patient Preference and Adherence*, 15: 29–40, https://doi.org/10.2147/PPA.S277238

Recker, R.R. (1985). Calcium absorption and achlorhydria. *The New England Journal of Medicine*, 313(2): 70–73, https://doi.org/10.1056/NEJM198507113130202

Reymondier, A., Caillet, P., Abbas-Chorfa, F., Ambrosi, V., Jaglal, S.B., Chapurlat, R., and Schott, A.-M. (2013). MENOPOST–calcium and vitamin D supplementation in postmenopausal osteoporosis treatment: a descriptive cohort study. *Osteoporosis International*, 24(2): 559–566, https://doi.org/10.1007/s00198-012-1999-5

Romanchik-Cerpovicz, J.E. and McKemie, R.J. (2007). Fortification of all-purpose wheat-flour tortillas with calcium lactate, calcium carbonate, or calcium citrate is acceptable. *Journal of the American Dietetic Association*, 107(3): 506–509, https://doi.org/10.1016/j.jada.2006.12.003

Sakhaee, K., Bhuket, T., Adams-Huet, B., and Rao, D.S. (1999). Meta-analysis of calcium bioavailability: a comparison of calcium citrate with calcium carbonate. *American Journal of Therapeutics*, 6(6): 313–321, https://doi.org/10.1097/00045391-199911000-00005

Scheurer, H. and McNamee, A. (1989). *Chewable, non-gritty calcium citrate tablet, application no. US4882161A*.

Unauthenticated | Downloaded 10/26/26 07:20 AM UTC

Sheikh, M.S., Ramirez, A., Emmett, M., Santa Ana, C., Schiller, L.R., and Fordtran, J.S. (1988). Role of vitamin D-dependent and vitamin D-independent mechanisms in absorption of food calcium. *The Journal of Clinical Investigation*, 81(1): 126–132, https://doi.org/10.1172/JCI113283

Shkembi, B. and Huppertz, T. (2021). Calcium absorption from food products: food matrix effects. *Nutrients*, 14(1): 180, https://doi.org/10.3390/nu14010180

Smith, N.W., Dave, A.C., Hill, J.P., and McNabb, W.C. (2022). Nutritional assessment of plant-based beverages in comparison to bovine milk. *Frontiers in Nutrition*, 9: 957486, https://doi.org/10.3389/fnut.2022.957486

Smith, K.T., Heaney, R.P., Flora, L., and Hinders, S.M. (1987). Calcium absorption from a new calcium delivery system (CCM). *Calcified Tissue International*, 41(6): 351–352, https://doi.org/10.1007/BF02556676

Tordoff, M.G. (1996). Some basic psychophysics of calcium salt solutions. *Chemical Senses*, 21(4): 417–424, https://doi.org/10.1093/chemse/21.4.417

Van den Heuvel, E.G., Muijs, T., Van Dokkum, W., and Schaafsma, G. (1999). Lactulose stimulates calcium absorption in postmenopausal women. *Journal of Bone and Mineral Research*, 14(7): 1211–1216, https://doi.org/10.1359/jbmr.1999.14.7.1211

Vičič, V., Mikuš, R., and Ferjančič, B. (2024). Review of history and mechanisms of action of lactulose (4-O-β-D-Galactopyranosyl-β-D-fructofuranose): present and future applications in food. *Journal of Food Science and Technology*, https://doi.org/10.1007/s13197-024-05997-z

Weaver, C.M., Gordon, C.M., Janz, K.F., Kalkwarf, H.J., Lappe, J.M., Lewis, R., O'Karma, M., Wallace, T.C., and Zemel, B.S. (2016). The National Osteoporosis Foundation's position statement on peak bone mass development and lifestyle factors: a systematic review and implementation recommendations. *Osteoporosis International*, 27(4): 1281–1386, https://doi.org/10.1007/s00198-015-3440-3

Whisner, C.M., Martin, B.R., Nakatsu, C.H., Story, J.A., MacDonald-Clarke, C.J., McCabe, L.D., McCabe, G.P., and Weaver, C.M. (2016). Soluble corn fiber increases calcium absorption associated with shifts in the gut microbiome: a randomized dose-response trial in free-living pubertal females. *The Journal of Nutrition*, 146(7): 1298–1306, https://doi.org/10.3945/jn.115.227256

Zhang, Q., Tang, Y., Nie, H., Wang, X., Wang, G., and Xiao, C. (2026). Pharmacological characteristics and solubility profiles of calcium supplement preparations: a comparative study with clinical implications. *PharmaNutrition*, 35: 100470, https://doi.org/10.1016/j.phanu.2025.100470

Žmitek, K., Hribar, M., Hristov, H., Vičič, V., and Pravst, I. (2026). Hidden sodium in effervescent food supplements: labelling practices and product composition. *Journal of Food Composition and Analysis*, 155: 109224, https://doi.org/10.1016/j.jfca.2026.109224

Open Access statement. This is an open-access article distributed under the terms of the Creative Commons Attribution-NonCommercial 4.0 International License (https://creativecommons.org/licenses/by-nc/4.0/), which permits unrestricted use, distribution, and reproduction in any medium for non-commercial purposes, provided the original author and source are credited, a link to the CC License is provided, and changes – if any – are indicated.

Unauthenticated | Downloaded 10/26/26 07:20 AM UTC