

Calcium Citrate: A Revised Look at Calcium Fortification

*Calcium citrate has advantages over other
calcium salts for use in fortified foods*

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CALCIUM, THE MOST ABUNDANT mineral in our body, is a major constituent of bone and teeth. This mineral also plays an important role in several physiological systems. Inadequate calcium intake is associated with osteoporosis. Furthermore, recent research implies effects on oral bone loss, colon cancer, and hypertension (Cumming, 1990; Barger-Lux and Heany, 1994).

Since the body does not produce minerals, it is totally dependent on an external supply of calcium, nutritional or supplementary. The importance of adequate calcium intake is recognized during the whole life cycle of the human being: Baby's growth, quick skeleton development of children and teenagers, achievement of peak bone mass in adults, women at the child-birth age and lactation, and elderly people, especially women at postmenopausal age in danger of osteoporosis. This recognition has led the NIH to revise the recommendations for calcium intake (NIH Consensus Development Panel, 1994).

The new recommended daily allowances for each age group are shown in Table 1. In particular, the daily allowance for adolescents/young adults and elderly people has increased from the previous recommendation of 800-1,200 mg/day to 1,500 mg/day.

The basic source for calcium is the diet. Yet, based on normal diet and especially with the increasing trends of using processed food, ready prepared meals, "fast food," and "TV meals," only a part of the physiological need for calcium is actually supplied through food consumption (Fleming and Heimbach, 1994). This has led

consumers to an awareness of the need for balancing their calcium intake with enriched food or supplements.

Choosing a Calcium Fortifier

Several commercial calcium salts are available to the food manufacturers for calcium fortification, including carbonate, phosphate, citrate, lactate, and gluconate. A responsible manufacturer, producing a successful brand, would consider a calcium additive with high nutritional value and low interference with the absorption of other nutrients in addition to cost effectiveness, kosher certification, and minimal effects on consistency, mouthfeel, and taste of the product.

Two common measures for comparison of the nutritional value of calcium additives are bioavailability and solubility. In this respect, several factors identified lately in research works are to be taken into consideration:

- In general, organic acids salts of calcium are more bioavailable than the inorganic salts. Calcium content of organic acids salts is shown in Table 2.

- The interaction between calcium and phosphate metabolism suggests that excessive phosphate intake would result in low calcium absorp-

Table 1—Optimal Calcium Requirements recommended by the National Institute of Health Consensus Development Panel

Age group	Optimal daily intake of calcium (mg)
Infant	
Birth-6 mo	400
6-12 mo	600
Children	
1-5 yr	800
6-10 yr	800-1,200
Adolescents/young adults	
11-24 yr	1,200-1,500
Men	
25-65 yr	1,000
Over 65 yr	1,500
Women	
25-50 yr	1,000
Over 50 yr (postmenopausal)	
On estrogens	1,000
Not on estrogens	1,500
Over 65 yr	1,500
Pregnant and nursing	1,200-1,500

tion. 21 CFR section No. 101.72 regulates health claims of calcium-enriched food. A prerequisite is that calcium-to-phosphorous ratio will exceed 1:1 on weight basis. Since there are additional phosphates in food, it is recommended to apply other calcium sources to improve calcium-to-phosphate ratio and obtain sufficient calcium absorption.

- Carbonate, although widely used, neutralizes gastric acid and then much of it is excreted undissolved. The relative absorption of calcium

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Calcium Citrate (continued)

from the different calcium sources is dose dependent in the normal dose range. Comparing calcium citrate to calcium carbonate, for instance, suggests a higher absorption of calcium from 0.5 g calcium dose in calcium citrate than from a 2 g calcium dose in calcium carbonate (Harvey et al., 1988).

- Calcium citrate was found to be absorbed regardless of the levels of gastric acid. Therefore, it is highly bioavailable, and does not cause gastrointestinal effect in individuals with low gastric acid secretion (Avioli, 1988; NIH Consensus Development Panel, 1994).

- The solubility model for prediction of bioavailability was found to be a paradigm (Heany et al., 1990). This is in accordance with the finding that there is an absorption mechanism of a calcium citrate complex in addition to the previous postulation of a single absorption mechanism of calcium ions

Table 2—Calcium Content of Organic Salts

Calcium source	Calcium content (%)
Calcium fumarate	25.9
Calcium aspartate	23.4
Tri calcium citrate tetrahydrate	21.0
Calcium lactate trihydrate	14.7
Calcium gluconate	9.3

only (Avioli, 1988; NIH Consensus Development Panel, 1994).

- Calcium citrate, as opposed to calcium in general, has only a marginal effect interfering with the absorption of other minerals, especially iron (Hallberg et al., 1992).

- A concern has been raised as to the effect of long-term calcium supple-

mentation on the formation of kidney and urinary duct stones. Calcium citrate has been shown to attenuate this risk since it enhances renal excretion of citrate, an inhibitor for crystallization of stone-forming calcium salts (Pak, 1994).

Applications

The updated evidence of high bioavailability attributed to specific absorption mechanisms and low dependence on gastric conditions as well as low effect on uptake of other nutrients suggests calcium citrate as an important source for calcium fortification.

Combining the nutritional value with high calcium content (21%), bland taste, and neutral odor, calcium citrate is recommended for enrichment in fortified products, including baby formula, fruit juices, dairy products, drink mixes, sports drinks, milk products, diet food, diet food mixes, and cereals.

Special grades are direct compressible without additives, a feature useful to produce tablets with the highest calcium content based on bioavailable organic acid calcium salt (Lupin, 1996). A partially hydrated calcium citrate acts as an anticaking agent, especially suitable for use in dry mixes (Vidal and Saleeb, 1993).

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