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REVIEW ARTICLE

DIETARY CALCIUM BIOAVAILABILITY AND A SEARCH FOR CALCIUM SUPPLEMENT SOURCES FOR THAI PEOPLE : A REVIEW

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INTRODUCTION

There seems to be increasing acceptance that an adequate calcium intake is necessary for the maintenance of bone health throughout life. There is emerging evidence that sufficient calcium intake during development is critical for the attainment of peak bone mass which, inturn, is one of the factors retarding the rate of postmenopausal or involutional bone loss later in life. However, there is considerable controversy regarding the recommended intake and the therapeutic value of calcium supplementation. This disagreement is probably due to our insufficent knowledge on calcium absorption, calcium bioavailability from different food stuffs, calcium absorbability of various calcium salts or the multifactorial condition of osteoporosis. This review will attempt to present the current state of the problem and to integrate view of many authors. Considerable speculation may be unavoidable and no concrete conclusion may be drawn, however, the purpose of this review is to highlight the importance of adequate calcium intake and the problem concerning calcium supplementation.

A RECOMMENDED DIETARY ALLOWANCES

There have always been controversy regarding the recommended calcium intake. In 1962, the FAO/WHO Committee on Calcium Requirements suggested that 400 to 500 mg/day was a practical estimate of adult calcium requirements.[1] The 1979 United States Recommended Dietary Allowances (RDAs) for calcium were kept at 800 mg/day for adults, 1200 mg/day for 10-18 years old adolescents and 1200 mg/day for prenant and lactating women.[2] The recent revision of the RDAs for the US extended the recommended intake for adolescents (1,200 mg/day) from its former upper limit of age 18 years to age 24.[3] This revision reflected both the recognition that skeletal consolidation extends well beyond the period of linear growth and that calcium intake is important in acheiving optimal

bone mass. However, many authors have claimed that the 800 mg/day recommendation is too low to maintain maximum calcium retention,[4] positive balance and optimal bone mineralization.[5,6] Realizing women, especially peri-or postmenopausal women, appear to require calcium intakes higher than those suggested in the RDAs, a recent National Institutes of Health Conference on osteoporosis in the US. recommended a calcium intake of 1000 to 1500 mg/day to reduce the incidence of osteoporosis in postmenopausal women.[7]

Ironically, the typical calcium intake of women in the United States are much lower than the RDS for calcium. Average women younger than 23 years consume less than 600 mg calcium daily[8].

When we look at our population in Thailand, despite a lack of data, we would expect a much lower calcium intake as compared to the American or European standard. Except for a small proportion of people belonging to the high socio-economic group, the majority of the population in Thailand obtain their nutritional requirement from plant foods such as rice and vegetables. The intake of food of animal origin such as milk products which are rich in calcium is miniscule because they are expensive. Thus our sources of calcium are very limited. The consequence of long term calcium deficiency may be too clear when one looks at the elderly with their bended back and children with small built. Should we start looking for other sources of calcium supplements concurrently with promoting milk consumption?

There are many factors that make determination of the optimal recommended calcium intake difficult. Lower recommendations are probably based on the observation that the efficiency of calcium absorption increases when intakes are low. It is often said that the intake of many people in the world is considerably less than 800 mg/day without apparent adverse consequences.[9] This view is probably held by too many people in medical and health science career in Thailand. One difficulty in interpreting this observation is that the best method for measuring calcium nutritional status depends on detecting long-term changes in bone calcium. The technique is not possible on a national scale and even for a small group study, a considerable amount of demineralization must occur before loss of bone calcium can be detected. There are other methods for studying calcium absorption and these will be briefly discussed in the following section.

Additional factors that add difficulty to the determination of RDSs are the marked effects that various food constituents and nutritional and metabolic state of the person have on calcium absorption. In other words, calcium absorption is influenced by calcium bioavailability and the physiological conditions eg., growth, pregnancy and lactation.

B. CALCIUM ABSORPTION

Calcium absorption efficiency in humans is typically 15-35% of ingested calcium. Absorption of calcium may occur throughout the entire length of the intestine, from the duodenum to the colon. It is most efficient in the duodenum, but duodenal residence time is so short that only a small fraction of a substantial load is absorbed there. Most of a calcium load is absorbed from the jejunum and ileum where degree of intestinal motility

is lower. There are basically two types of calcium absorption. At low luminal calcium concentration, calcium is absorbed by a saturable, transcellular route that is subjected to physiological and nutritional regulation via vitamin D.[9] This so-called "active transport" (because it uses energy) takes place largely in the duodenum and proximal jejunum.[10] The second type is nonsaturable, essentially independent of nutritional and physiological regulation, and concentration dependent.[10-12] This passive transport exists all along the whole length of the intestine and is dominant under conditions when transcellular transport is down-regulated, as in old age[13] or when the food content of calcium is abundant.[14] The route for this type of transport is paracellular. Relatively little is known concerning the factors that influence paracellular transport. Patency of the tight junctions is clearly a major factor. Therefore increased calcium absorption has been associated with hyperosmolar luminal fluid,[15] increased presence in the chyme of amino acids like lysine[16] or fatty acids of medium chain length,[17] all of which are supposed to result in modifications of tight junction patency.

From a therapeutic viewpoint, calcium absorption may be modified by altering both types of calcium transport or by increasing or decreasing the amount of calcium ingestion. Transcellular movement can be promoted by vitamin D therapy. However, most of the absorbed calcium is promptly reexcreted in the urine.[18] Moreover, administration of vitamin D or its congeners may lead to undesirable effects on the other target systems ie., kidney and bone. As for modification of the paracellular transport, little is known. Changing calcium intake is probably safest. However, as mentioned earlier, changing calcium intake has different and opposite effects on the two routes of calcium absorption. An increase in calcium intake may lead to down-regulation of the transcellular process,[14] but will increase the paracellular process in direct proportion.

Techniques for measuring calcium absorption

There are many commonly used techniques for measuring calcium absorption all with certain limitations (Table 1). In animal, isolated intestinal cells, brush border membrane vesicles[19] and everted gut sacs[20] provide useful models for studying calcium transport in various parts of the gut. In situ-loops, into which calcium solutions and other metabolites are either injected or infused,[21] are useful for determining calcium fluxes across the mucosa.

Many methods for the determination of calcium absorption in human beings are available. Balance study, one of the most commonly used method, is for the measurement of the apparent absorption of calcium from various diets, and under different physiological conditions. Apparent absorption is the difference between calcium intake and faecal calcium. Since apparent absorption is normally only 20 to 40% of intake,[21, 22] most dietary calcium is unabsorbed and will be excreted in faeces. Therefore, inaccuracies in the collection of faecal samples will cause large errors. An additional limitation of balance studies is that the studies do not account for the secretion of endogenous calcium which may approximate 100 mg/day. Therefore, the obtained value for calcium absorption is substantially underestimated

TABLE 1. Methods for the measurement of intestinal calcium absorption

Human and animal models
Balance studies
Balance with faecal recovery of intravenous isotope
Retention of oral isotope (whole body or part)
Faecal recovery of oral isotope
Intestinal perfusion in vivo
Animal models only
Everted gut sacs
In sity intestinal loops
Isolated intestinal cells and organelles
Membrane vesicles and enzyme studies

TABLE 2. Calcium contents in various green leafy vegetables and tofu (65).

Vegetable	Calcium Content mg/100 g fresh weight)	mg/g ash
Young Kae leaf (Sesania grandiflora, Press)	466.5 ± 39.6	266.3 ± 21.2
Kana, Kale (Brassica olderacea acephala)	432.9 ± 34.2	335.0 ± 32.5
Chaplu (Piper sarrmentosum, Roxb)	478.3 ± 26.0	129.1 ± 14.1
Horapa, Basil (Bcimum basilicum)	395.8 ± 25.3	250.3 ± 33.1
Krached (Neptunia aeracea)	289.1 ±	312.0 ± 29.4
Puk Paew	237.9 ± 13.0	138.2 ± 7.0
White tofu (glycine max Linn)	128.3 ± 16.4	98.4 ± 40.0
Yellow tolu	111.3 ± 4.8	118.3 ± 7.8
Non fat dry milk	645.0 ± (90)	

unless the method is used in combination with the intravenous injection of a calcium isotope for the estimation of endogenous calcium. This method is not practical for testing the absorbability of calcium from calcium preparations. However, it is unique in providing information regarding the long term effect of calcium supplementation on overall body retention of calcium.

A number of methods involve the use of calcium isotopes. The most commonly used are ^{45}Ca (half life, 163.5 days) and ^{47}Ca (half life, 4.7 days). the isotopes are mainly used as an "extrinsic" label. The differences between the intake and faecal output of the isotope can be assumed to be true absorption. Alternatively, the plasma appearance of an orally administered calcium isotope is widely used as an index of calcium absorption. One disadvantage of the technique is that it is qualitative. The data can not be calculated as actual percent absorption since there are many factors which alter the disappearance of the isotope from the plasma.

Isotope tracer method for measuring calcium absorption from food are based on the assumption that the tracer is absorbed with the same efficiency as the intrinsic food calcium. But, depending on the type of food, extrinsically added radiocalcium may not fully exchange with the stable calcium in food and may have different bioavailability.[23]

C. DIETARY FACTORS AFFECTING CALCIUM ABSORPTION

Absorbability of calcium from different sources is not the same. Milk and milk products, represent significant sources of dietary calcium in certain countries eg., in North America. The excellence of milk as a calcium source is due not only to its high calcium content but also the biological availability or bioavailability of calcium. Cereals, vegetables and fruits may contain high amounts of calcium but with low calcium bioavailability, they provide may be 20% of calcium intake. Meat, poultry and fish supply a very small amount of calcium.

Calbohydrates

The absorption of dietary calcium and supplementary calcium can be influenced by various factors particularly by the simultaneous presence of other dietary consituents such as sugars. Previous investigation has shown that sugars such as glucose and galactose, which are rapidly absorbed in the proximal small intestine, increase the absorption of calcium.[24] Possible explanation is an effect of solvent drag on calcium absorption due to active sugar transport.[24, 25] The presence of glucose in the lumen presumably activates contraction of epithelial cytoskeletal elements, thereby opening tight junctions to permit mass transport of substances by solvent drag through paracellular channels.[25, 26] Glucose polymer, which is a homopolysaccharide derived from partial hydrolysis of corn starch also enhances calcium absorption.[27, 28]

Lactose

The milk sugar lactose has been shown to increase the absorption of calcium by the intestine in a variety of in vitro and whole animal studies.[29-33] These studies showed that lactose could increase calcium absorption in vitamin D deficient rats, that lactose had to be present in the same intestine segment as the calcium to exert its effect, and that lactose caused the greatest enhancement of calcium absorption in the ileum. Lactose is effective in enhancing the uptake of calcium over the whole lifespan of the rat[34] and thus improves skeletal growth and mineralization.[35-37]

Enhancing effect of lactose on intestinal calcium absorption has also been demonstrated in humans. Kabayashi and co-workers[38] further demonstrated that glucose and galactose released by lactose hydrolysis were even more effective in improving calcium absorption. Previous work also suggested that lactose intolerance had a negligible effect on calcium absorption.[39, 40]

Despite a number of theories for the lactose effect, the mechanism is not well established. Lactose stimulated calcium transport may have been due to changes in transepithelial osmotic or electrochemical gradients or alteration in epithelial permeability. Favus and Angeid-Backman[31] found that lactose increased net calcium absorption by increasing the mucosa to serosa flux and reducing the secretory flux from serosa to mucosa. From their results, it is unlikely that the increased absorptive flux of calcium is the result of solvent drag, since lactose reduces net bulk solute flow, which in ileum is in the secretory direction.[41]

Protein

Most research concerned with protein intake and calcium metabolism focuses on the relationship between high protein intake and increased urinary calcium excretion. A relatively long-term high protein intake may lead to the development of mild metabolic acidosis that may result in increased bone resorption, in increased urinary calcium excretion and eventually in the development of osteoporosis.[42] Some earlier investigators believed that calciuria was caused by an increased intestinal absorption of calcium,[43-45] while others could not find any effect of protein on calcium absorption.[46, 47] Since protein consumption leads to an increase in urinary calcium without a concomitant increase in calcium absorption, negative calcium balance can occur when dietary protein is high.

D. SEARCH FOR SOURCES OF CALCIUM SUPPLEMENTS

Milk

In North America and some European countries, milk and milk products represent significant sources of dietary calcium. The excellence of milk as a calcium source is due not only to its high calcium content but also the bioavailability of calcium. The high availability of calcium in milk may be partly due to lactose, the main carbohydrate in

milk, which, as mentioned earlier, enhances calcium absorption.

Another major constituent of milk is casein which comprises about 80% of the total protein in milk.[48] Casein can be hydrolyzed into phosphopeptides which have been shown to promote bone calcification in rachitic children[49] and stimulates duodenal calcium absorption in chicks.[50]

However, there are concerns about milk as a calcium source because of potential offsetting effects of other components. For example, the protein contained in milk could have a negative effect on calcium balance[46, 47, 51-53] through an increase in kidney losses of calcium[53] or through a direct effect on bone resorption.[54] Optimal benefit from the calcium in milk could be obtained by a reduction in protein intake from other sources.[54] Another concern about milk as the main source of calcium is the high incidence of milk intolerance due to lactase deficiency among adults. It has been shown in postmenopausal Caucasian women that lactase deficiency is more frequent in osteoporotic than in nonosteoporotic women.[55-57] Although the etiology of osteoporosis is likely to be multifactorial, it has been suggested that either impaired calcium absorption due to lactose malabsorption or reduced intake of dairy products because of symptoms due to lactose malabsorption could be risk factors.[55-58] However, a recent investigation has shown that milk containing lactose enhances calcium absorption in lactase subjects.[59, 60] Thus the correlation between osteoporosis and lactase deficiency is likely due to the avoidance of dairy products and subsequent reduction in calcium intake. Thus, for those who are intolerant to milk, calcium supplementation may be necessary.

Plant components

It is known that some green leafy vegetables contain high calcium content. It has also been known for a long time that feeding whole wheat products to humans can result in a negative calcium balance which is assumed to be due to the phytate content of the added fibres. Calcium phytate is an unabsorbable complex[6] but phytate is digested in the lower intestine.[62, 63] Thus, calcium would be freed from its complex with phytate and be absorbed in the lower intestine. There is a report that the fibre itself impairs calcium absorption but an equivalent amount of pure phytate has a negligible effect on calcium balance.[64]

We, Thai people, obtained calcium from fruits, vegetables and nuts. However, it appears that the consumption of fruits and vegetables may impair calcium absorption. When fruits and vegetables are added to the diet, calcium intake is increased but calcium balance negative. In an attempt to find an alternative source of calcium we studied the bioavailability of calcium in a number of green leafy vegetables. Table 2 shows the calcium content in 5 vegetables and tofu. As seen in Fig. 1 oral administration of homogenized raw vegetables to rats resulted in intestinal calcium secretion instead of absorption. In contrast absorption of elemental calcium from ashed vegetables (placed in muffle furnace at 550°C for 8 hours) was between 50-80% of intake (Fig. 2). We confirmed the nonabsorbability of calcium from raw vegetables by studying the absorption of calcium from dry raw

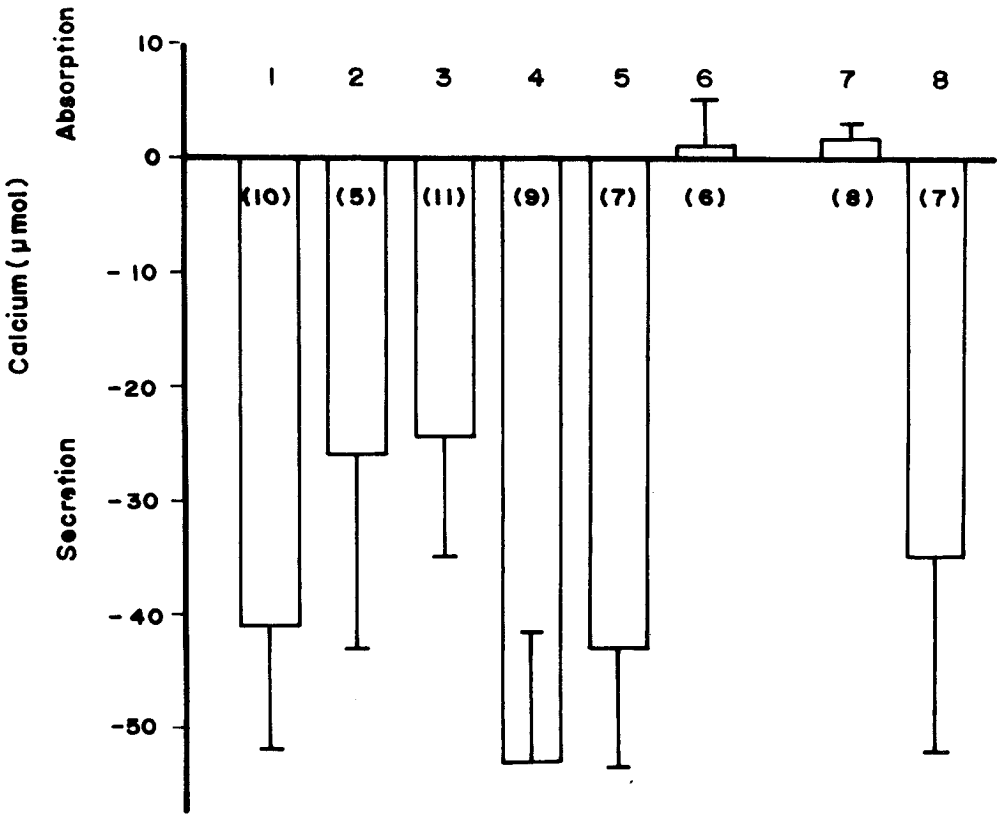

Fig. 1. Calcium absorption and secretion 2 hours after oral administration of homogenized raw vegetables or tofu in fasted rats which also received an iv. injection of ^{45}Ca in 2.5 mM $CaCl_2$. The difference between administered calcium and calcium in luminal content at the end of experiment represented net absorption. Endogenous secretion of calcium was calculated from luminal ^{45}Ca content,[65] (1, Kae leaf; 2, Kana; 3, Chaplu; 4, Horapa; 5, Krached; 6, Puk Paew; 7, White tofu; 8, Yellow tofu)

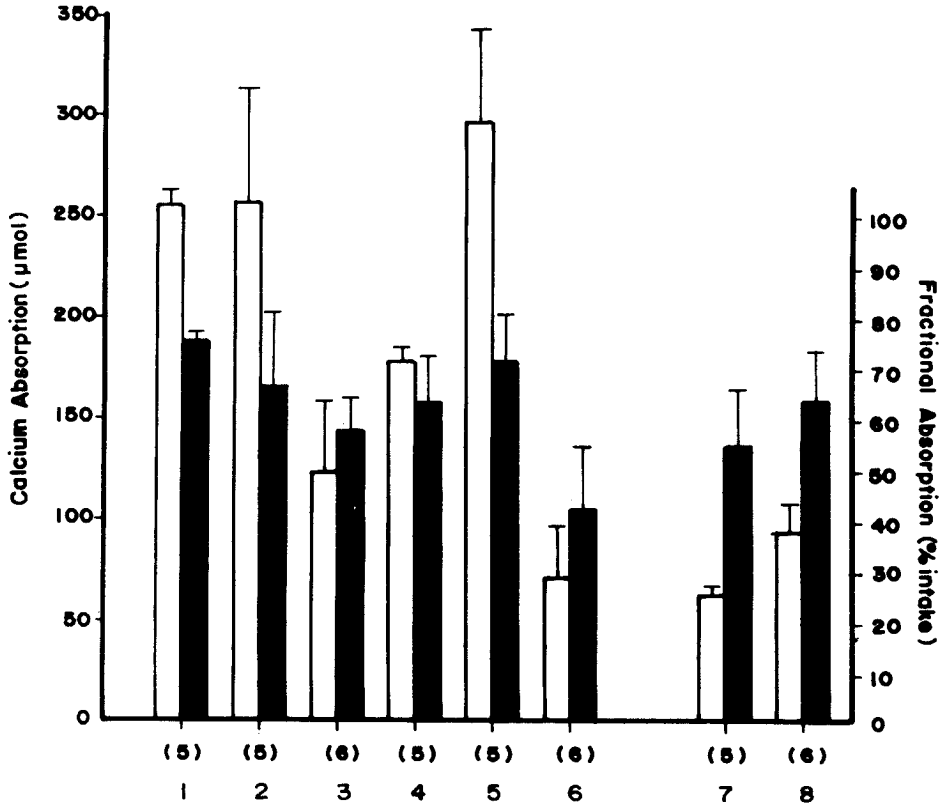

Fig. 2. Calcium absorption 2 hours after oral administration of ashed vegetables or ashed tofu in fasted rats which also received an iv. injection of ^{45}Ca in 2.5 mM $CaCl_2$.[65]

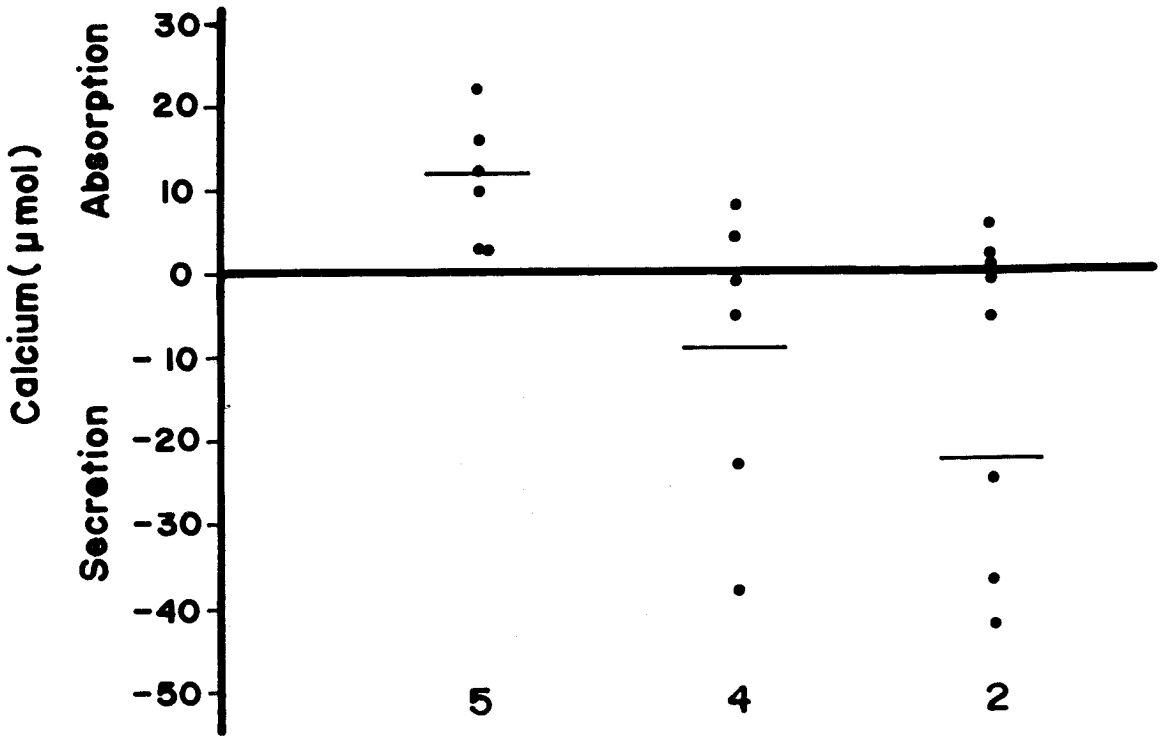

Fig. 3. Calcium absorption and secretion 2 hours after oral administration of dry raw vegetable powder (2, Krached; 4, Chaplu; 5, Kana)

vegetable powder. As seen in Fig. 3, absorption was minimal, and in some cases, secretion occurred. Thus we concluded that leafy vegetables despite their high calcium contents, were not suitable as sources of calcium because of the low calcium bioavailability and that they tended to induce calcium loss through increased intestinal calcium secretion.

There have been attempts to identify the components of plant fibres that inhibit calcium absorption. The major components that are thought to be responsible for suppressing calcium absorption are phytate, uronic acids and oxalate.

Spinach, a commonly consumed green leafy vegetable contains high calcium content but also contains high oxalic acid content which has been found to reduce[66, 67] or have no effect on calcium absorption.[68] The ratio of calcium to oxalate is usually less than 0.5, indicating that all of the calcium contained in green leaves is bound to oxalate.[69]

Uronic acid is another major factor which binds calcium to fibre. It constitutes 10% of the noncellulosic fraction of cereal fibre and 40% of this fraction in fruits and vegetables.[70] In high fibre diets such as those consumed in the tropics including Thailand, the fibre and uronic acid contents may be 50 to 150 g respectively, so that all of the calcium in the diet could be bound. However, over 80% of dietary uronic acids are fermented in the human intestine[71] so that much of the calcium may eventually be released and become available for absorption by the colon.

Phytate occurs naturally in cereals and soy beans. It is known to inhibit absorption and retention of calcium but data are often conflicting and there is no general agreement as yet.[72-73] A recent work showed a positive but weak correlation between amounts of faecal phytate and calcium.[74] Oku and his group[75] demonstrated that reduced absorption of calcium associated with high fibre diet may result from mechanical abrasion of the intestinal mucosa.[75]

The impairment of calcium absorption by fibre component is nutritionally significant. From the above discussion, one can predict that diet low in calcium and high in cereals, vegetables and fruits can put a person into negative calcium balance. Precautions should be taken especially when advocating diets for children, patients with nutritional disorder; and pregnant or lactating women.

Soy products

In view of the recent trend toward increased, consumption of soybeans and soy protein extended food for human consumption, studies have been carried out to evaluate the nutritional value of these products. Nutritionists, however, are concerned with the bioavailability of minerals from soybeans since they contain considerable quantities of both phytate and components of dietary fibres. Soybean products contain 1.4-2.2% phytate on a dry basis[76] and appreciable amount of 6% dietary fibres, especially if the hull is not removed prior to processing.

Forbes and coworkers[77] investigated the effect of 3 types of soy products on the bioavailability of calcium. They found that the bioavailability of calcium added as calcium carbonate to full fat soy flour, freeze-dried soy beverage or soy concentrate was the same

as when added to casein diets. These results, suggest that calcium fortification of soy protein products will result in good utilization of calcium.

Soy bean curd or tofu is another type of soybean products which is widely consumed. Tofu is high in phytate and commercially prepared tofu is typically a rich source of calcium because calcium is added during processing via the use of various calcium salts as soy protein precipitants. Study comparing tofu and cheese diets in premenopausal woman demonstrated that substitution of tofu for cheese everted a negative effect on calcium.[78] This negative calcium balance is probably caused by the high phytate which forms insoluble salt with calcium. The unsuitability of tofu as calcium source is shown by our results in Fig. 1.

The use of soy-based infant formulas has increased as an alternate to cow milkbased formulas in conditions of milk protein intolerance, in cases of lactase deficiency and in postdiarrheal periods. Because of the appreciable increase in use of these alternative feedings, we should be concerned about its adequacy in supporting normal growth and skeletal maturation. The bioavailability of minerals such as zinc and calcium may be reduced by being bound to phytate. Ricket has been reported in very-low birth-weight infants receiving soy-based feedings.[79] Full term infants fed soy-based formula have demonstrated normal growth and development using weight, length, and head circumference as indices.[80] However, other studies show that bone mineral content is much less[81] and bone maturation is reduced[82] in infants fed soy protein formulas versus cow milk formula. The decreased bone mineral content in soy-fed infants suggests that the retention of minerals may be lower even though these formulas contain greater amounts of calcium and phosphorus than the cow milk formula. The long-term significance of lower bone mineral content in the first year of life has not been determined. It is worth noting that the bone mineral content of soy-fed infants is similar to that of breast-fed infants, with vitamin D supplements. In other word, the bone mineral content of cow milk-fed infants appears hypermineralized when compared to that of breast fed infants.

A recent investigation compared soy-based vs casein based diets demonstrate that the source of dietary carbohydrate (presence or absence of lactose) rather than the protein type is mostly responsible for the differential effects of the diets on bone mineral retention.[83] The calcium and phosphorus contents is increased in the vertebral bones but not in the limb bones in the casein diet group, suggesting that the vertebrae are more sensitive to the influence of diet on bone minerals.

Thus, increased consumption of dietary fibre and soybean products has undesirable effects as well as beneficial. But calcium fortification of soy protein products should result in good utilization of calcium especially if added tho soya milk.

Calcium salts

In general, foods are much to be preferred over supplements as sources of calcium. However milk and dairy products which are the best source of calcium are not readily available to Thai people and calcium absorption from food is generally inefficient. Thus,

our remedy for calcium deficiency may lie with the use of calcium supplements despite controversy regarding therapeutic value of calcium provided as food and as calcium salts.

There are at least four factors refulating the absorbability of calcium from calcium salts (1) solubility of calcium salt in the acid medium of the stomach, (2) reprecipitation of calcium salt upon entering the alkaline medium of the small intestine, (3) binding of calcium to anions in the neutral environment of the small-intestine, and (4) limited exposure of calcium to absorptive site of distal bowel due to enclosure in faecal material.

Calcium carbonate is the most widely used supplement, mainly because it contains more elemental calcium per gram. Other salts that are commonly used as supplement include calcium gluconate, calcium lactate, and calcium citrate. These salts differ in their solubility in water with calcium lactate with the highest solubility (7.9 g/dl water) followed by calcium gluconate (3.85 g/dl water), calcium citrate (96 mg/dl water) and calcium carbonate (5.6 mg/dl water). There are controversies regarding calcium bioavailability from these salts.

Calcium carbonate has a high solubility at pH 6 or less. Its solubility, therefore, is proportional to gastric acid secretion and is virtually insoluble without acid secretion. As for calcium citrate, the solubility of the liquid form is independent of gastric acid secretion but that of the solid form is high below pH 4. At zero acid secretion solid calcium citrate is slightly soluble. However, calcium complexation with citrate is substantial while complexation with bicarbonate anions (as in the case of calcium carbonate in solution) in minimal.

Based on the physiochemical properties of these salts, soluble form of calcium citrate is a suitable calcium salt for elderly who has a reduced gastric acid secretion or for those taking drug without food for it provides the highest amount of ionic calcium. For those with efficient acid secretion, calcium carbonate should provide moderate amount of absorbable ionic calcium especially if taken with food.

Three studies using different techniques of measuring calcium absorption have reported better calcium absorption from more soluble calcium salts.[84-86] Other studies finding no difference in calcium absorption in normal young subjects,[87-89] suggest that calcium salts may be solubilized by gastric acid, so that by the time these salts leave the stomach, calcium from all salts is equally solubilized. Gregor *et al.*[90] compared nine commercially available calcium sources including various calcium salts and natural products such as oyster shell and dolomites with nonfat dry milk for calcium bioavailability in rats fed for 20-27 days. With growth, apparent calcium absorption and bone calcium levels as criteria, calcium from these sources is equally well-utilized. On the other hand more recent investigations report better calcium absorption from calcium citrate than from calcium carbonate[91, 92] and show that solubility of a calcium source has very little influence on its absorbability.[93]

The use of calcium supplements by postmenopausal women is growing rapidly in affluent community. Because calcium absorption is often impaired in aging persons, many new calcium preparations with high absorbability have been introduced. Among

them, tricalcium phosphate has been shown to be adequately absorbed without inducing calcium excretion into the gut as seen with other phosphate salts.[94]

In general, oral calcium supplementation does not appear to be associated with any appreciable risks. There is no indication that high calcium diet increases the risk of arteriosclerosis or hypercalciuria-induced nephrolithiasis. On the other hand, supplementary dietary calcium provides protection against osteoporosis. It decreases hyperproliferation of colonic epithelial cells,[95] a biomarker of increased susceptibility to colon cancer by forming insoluble complexes with bile acids and unabsorbed fatty acids which cause mucosal irritation.

CONCLUSION

We have no doubt that milk and dairy products are the best source of calcium and that people who consume a lot of dairy products should reduce their protein intake from other sources to avoid excessive urinary excretion of calcium. However, the majority of Thai people, being in the low socio-economic group who cannot afford dairy products, are also high risked group to have calcium deficiency for their diets are mainly rice and vegetables. Since promoting milk consumption is effective only in affluent society, we suggest that calcium supplementation is the best remedy. Calcium supplements should be in the form of cheap and readily available calcium salts or obtained from natural products such as shrimp carapace, shell and bone. Calcium supplementation programme can be run together with the protein supplementation programme already in progress for rural school children. We would like to suggest the home made calcium fortificated soya milk as supplement drink.

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บทคัดย่อ

คนไทยมีปัญหาเรื่องกระดูกและฟันมาก ซึ่งสาเหตุหนึ่ง คือการขาดแคลเซี่ยม หากเปรียบเทียบกับมาตรฐานของประเทศตะวันตกหรือมาตรฐานขององค์การอนามัยโลกแล้วคนไทยได้รับแคลเซี่ยมจากอาหารต่ำมาก ทั้งนี้เนื่องจากอาหารที่มีคุณค่าทางแคลเซี่ยมสูงเป็นผลิตภัณฑ์จากสัตว์ เช่นนมและครีม ซึ่งนอกจากจะมีประมาณแคลเซี่ยมสูงแล้วยังให้แคลเซี่ยมในรูปที่ดูดซึมได้ง่าย คนไทยโดยเฉพาะในวัยเจริญเติบโตในส่วนน้อยเท่านั้นที่มีโอกาสดื่มนมเป็นประจำ ประชากรส่วนใหญ่ของประเทศไม่มีโอกาสบริโภคอาหารประเภทนม จึงขาดเอ็นไซม์แลคเทสซึ่งใช้ในการย่อยน้ำตาลแลคโทสในนม จึงยิ่งไม่ดื่มนมเพราะทำให้มีอาการท้องอืดหรือท้องเสีย ดังนั้นเราจึงพยายามมองหาประเภทของอาหารที่จะใช้เป็นอาหารเสริมสำหรับแคลเซี่ยม ก็พบว่าผักใบเขียวหลายชนิดมีปริมาณแคลเซี่ยมสูง หลังจากการทดสอบเราพบว่าการบริโภคผักเดิบชนิดต่าง ๆ เต้าหู้ขาวและเต้าหู้เหลือง ซึ่งมีปริมาณแคลเซี่ยมสูงซึ่งน่าจะเป็นแหล่งแคลเซี่ยมที่ดี นอกจากจะไม่มีการดูดซึมแคลเซี่ยมแล้วกลับทำให้ร่างกายสูญเสียแคลเซี่ยมโดยมีการหลั่งออกมาในโพรงลำไส้ ทั้งนี้อาจเนื่องมาจากผักมีสารหลายชนิดเช่นกรดออกซาลิค กรดไฟทิค และกากผัก ซึ่งจับแคลเซี่ยมอย่างแน่น จึงไม่เหมาะที่จะใช้เป็นอาหารเสริมแคลเซี่ยมดังนั้นการที่จะเพิ่มปริมาณแคลเซี่ยมในอาหารคงต้องอาศัยการเติมเกลือแคลเซี่ยมโดยเฉพาะชนิดที่มีราคาถูกและหาได้ง่าย เช่นเกลือแคลเซี่ยมคาร์บอเนท หรือแคลเซี่ยมธรรมชาติในรูปของเปลือกกุ้งเปลือกหอยปน เป็นต้น

เนื่องจากในปัจจุบันได้มีการสนับสนุนให้โรงเรียนในชนบททำน้ำเต้าหู้ให้นักเรียนบริโภคเป็นอาหารโปรตีนเสริม และการวิจัยแสดงให้เห็นว่าแคลเซี่ยมดูดซึมได้ดีจากน้ำเต้าหู้ คณะผู้วิจัยจึงขอเสนอแนะให้ใช้ น้ำเต้าหู้ซึ่งเติมแคลเซี่ยมเป็นอาหารเสริมโปรตีนและแคลเซี่ยมที่มีราคาถูกและเตรียมง่าย