POLISH JOURNAL OF NATURAL SCIENCES
Abbrev.: Pol. J. Natur. Sc., Vol 33(2): 247–265, Y. 2018

CONTROVERSY OVER DIETARY SOURCES OF CALCIUM

***Grażyna Cichosz*[1], *Marek Aljewicz*[1], *Marika Bielecka*[1], *Wacław Mozolewski*[2]**

[1] Department of Dairy Science and Quality Management
[2] Department of Meat Technology and Chemistry
University of Warmia and Mazury in Olsztyn, Poland

Key words: bioavailability, calcium, milk, vegetables, bones.

Abstract

This study addresses recent controversies regarding calcium, in view of the dietary intake and sources of protein (animal, vegetable). The results of a meta-analysis, which suggested that milk increases the risk of prostate cancer in men and atherosclerosis in elderly women, were discussed and compared with other research findings. It was demonstrated that prostate cancer is caused by long-term deficiency of vitamin D_3 and vitamin K_2. The bioavailability of calcium appears to be more important than its dietary intake. Various dietary sources of calcium and the health benefits of a balanced diet that adequately meets daily calcium needs were also described.

It was found that plant foods are not good sources of calcium because they contain compounds that limit calcium absorption. Dairy products, in particular full-fat ripened cheese, are the best sources of calcium due to their high calcium content and the presence of vitamins D_3 and K_2.

KONTROWERSJE WOKÓŁ ŹRÓDEŁ WAPNIA W DIECIE

Grażyna Cichosz[1], *Marek Aljewicz*[1], *Marika Bielecka*[1], *Wacław Mozolewski*[2]

[1] Katedra Mleczarstwa i Zarządzania Jakością
[2] Katedra Technologii i Chemii Mięsa
Uniwersytet Warmińsko-Mazurski w Olsztynie, Polska

Słowa kluczowe: biodostępność, wapń, mleko, warzywa, kości.

Address: Marek Aljewicz, University of Warmia and Mazury in Olsztyn, ul. Michała Oczapowskiego 7, 10-719 Olsztyn, Poland, phone: +48(89) 524 51 79, e-mail: marek.aljewicz@uwm.edu.pl

Abstract

Praca dotyczy kontrowersji wokół wapnia w kontekście ilości białka w diecie oraz źródła jego pochodzenia (zwierzęce, roślinne). Odniesiono się do wyników metaanalizy, w której wykazano, że mleko zwiększa ryzyko raka prostaty u mężczyzn oraz miażdżycy u starszych kobiet. Korzystając z licznej przedmiotowej literatury wykazano, że rzeczywistą przyczyną raka prostaty są długotrwałe niedobory witaminy D_3 oraz K_2. Wynika z tego, że bardziej istotna jest biodostępność wapnia niż jego ilość w diecie. Opisano spektrum prozdrowotnych właściwości diety pokrywającej zapotrzebowanie na wapń. Scharakteryzowano ponadto różne źródła wapnia w diecie człowieka.

Wykazano, że produkty roślinne nie są najlepszym źródłem wapnia z powodu różnych składników ograniczających jego biodostępność. Najlepszym źródłem wapnia, ze względu na jego wysoką zawartość oraz obecność witaminy D_3 i K_2, są pełnotłuste produkty mleczarskie, zwłaszcza sery dojrzewające.

Introduction

The effect of different dietary sources of protein on calcium bioavailability

Until recently, even the most ardent opponents of milk regarded dairy products as a good source of bioavailable calcium. However, this belief has been recently called into question. Attempts are being made to demonstrate that proteins of animal origin decrease calcium absorption by increasing urinary calcium excretion (BRANDOLINI et al. 2005). Various authors have suggested that milk and dairy products increase the risk of vascular calcification and prostate cancer (AUNE et al. 2015, DUARTE-SALLES et al. 2014, GAO et al. 2005). The aim of this review is a comparison of calcium content in selected plant and dairy products including ingredients which reduce or stimulate its bioavailability. In this study an attempt was made to can get recommended amounts of calcium while eliminating dairy products from a diet.

Several authors have postulated that proteins of animal origin lead to the loss of the bone mineral phase, whereas plant proteins enhance calcium absorption (BRANDOLINI et al. 2005, GAFFNEY-STOMBERG et al. 2014). This hypothesis suggests that diets rich in animal proteins and, consequently, sulfur-containing amino acids cause acidification, which allegedly increases urinary calcium excretion and leads to the loss of the bone mineral phase. Sulfur-containing amino acids are catabolized through oxidation to produce acid-forming SO_3^{2-}. The hydrogen ions released during this process are bound by blood buffer systems and are excreted by the kidneys. Buffer systems maintain the pH of blood at a constant level (7.35–7.45) and decrease the pH of urine (below 5.5). Increased urine acidity promotes calcium loss, however, there is no published evidence to indicate that excreted calcium is liberated by increased bone resorption (BRANDOLINI et al. 2005). Previous studies (MUNGER et al. 1999) demonstrated that higher intake of animal proteins decreases the risk of femoral fracture, whereas plant proteins exacerbate that risk. A study of post-menopausal women revealed that urinary calcium loss was not reduced when dietary meat proteins were replaced with soy proteins (MASSEY et al. 2001). In a cohort study, the source of dietary protein was not significantly correlated with the incidence of bone fractures in men or women (MEYER et al. 1997). Recent research (SHAMS-WHITEET al. 2016, LANGSETMO et al. 2015, FENTON et al. 2011) did not present any evidence to support this hypothesis, either. Both vegetable and animal proteins are characterized by considerable buffer capacity. Unlike meat and cereal products, milk contains mainly alkalizing mineral compounds. For these reasons, the presence of sulfur-containing amino acids in animal proteins does not lead to acidification or the loss of skeletal calcium (MASSEY et al. 2003, 2001).

There is no reliable evidence to indicate that plant proteins supersede animal proteins with regard to their influence on calcium metabolism, the risk of bone fracture or osteoporosis. The claim that sulfur-containing amino acids have a detrimental impact on calcium and bone metabolism is completely unfounded (ROUGHEAD et al. 2005). Contrary findings of studies investigating the influence of proteins on bone density and bone susceptibility to fracture could have resulted from variations in the protein content of the analyzed diets.

In a study of young women, a low-protein diet decreased calcium adsorption (18.4%) as compared with a high-protein diet (26.3%). The absorption of dietary calcium from the gastrointestinal tract increased only after 5–9 weeks into the high-protein diet (KERSTETTER et al. 2003). In post-menopausal women (50–75 years), and in men and women younger than 50 years, a high-protein diet increased calcium absorption and transfer to the bones (ROUGHEAD et al. 2005). In elderly subjects whose diets were supplemented with calcium and vitamin D, higher protein intake improved bone mineral density (BMD) (DAWSON-HUGHES and HARRIS 2002). An adequate supply of protein stimulates the bioavailability of calcium because amino acids are involved in calcium transport across the intestinal wall (KERSTETTER et al. 2005). A positive correlation was observed between the dietary intake of plant and animal proteins and the levels of insulin-like growth hormone (IGF-1) which promotes bone growth (RIZZOLI and BONJOUR 2004, BONJOUR 2005).

The risk of bone fracture associated with osteoporosis increases with age. Observations of elderly patients with orthopedic injuries revealed that a high-protein diet contributed to muscle growth and physical recovery. High muscle mass and adequate physical fitness levels contribute to healthy bone structure (Wolfe 2012, Beasley et al. 2010), minimize the risk of fractures and alleviate the consequences of injuries (Sjöblom et al. 2013). In a cohort study, the susceptibility to bone fractures increased with a decrease in protein intake (<15% in the daily ration) in subjects older than 50 (Langsetmo et al. 2015). Diets deficient in protein lead to loss of muscle mass and reduce IGF-1 levels. A diet rich in milk proteins delivered beneficial effects for patients with hip fractures in comparison with patients whose protein intake was not monitored. A high-protein diet had a more beneficial influence on BMD when it was supplemented with the appropriate amounts of vitamin D_3 (Gunn et al. 2014, Zhou et al. 2013, Berger et al. 2012).

Studies analyzing intestinal absorption of calcium as well as parathormone (PTH) and IGF-1 levels which determine calcium metabolism did not confirm the hypothesis that a high-protein diet contributes to calcium deficiency. However, high protein intake accompanied by low calcium intake could compromise the bioavailability of the analyzed nutrient. Kerstetter (1994) demonstrated that protein intake of 50 g decreased the supply of bioavailable calcium by 60 mg, but only in calcium-deficient diets. The influence of protein on the calcium balance should be analyzed based on the calcium-to-protein ratio (mg calcium : g protein). When the said ratio is below 20:1, high protein intake could have a negative effect on the calcium balance. The calcium-to-protein ratio is estimated at 36:1 in milk and fermented milks, 33-36:1 in ripened cheese, 48:1 in white cabbage and 16:1 in broccoli. However, most food products are characterized by an adverse calcium-to-protein ratio which is determined at 7–12:1 in cottage cheese, 2–5:1 in bread and only 0.7:1 in pork (Zmarlicki 2009, Zitterman 2002). Therefore, protein, calcium and vitamin D_3 are independent determinants of bone metabolism when consumed in the appropriate amounts. A balanced diet that meets protein, calcium and vitamin D_3 requirements is a very important consideration, in particular in children, adolescents and the elderly (Grillenberger et al. 2006).

Calcium and the risk of prostate cancer and vascular calcification

A meta-analysis revealed that high calcium intake increases the risk of prostate cancer by 39% on average (Gao et al. 2005). A cohort study demonstrated a correlation between the intake of milk and dairy products and the incidence of prostate cancer. Daily calcium intake in excess of 1500 mm (diet and supplements) increased the risk of prostate cancer relative to daily intake levels below 500 mg (AUNE et al. 2015, MICHAËLSSON et al. 2014). According to some studies, excess calcium inhibits the conversion of vitamin D_3 to 1,25 $(OH)_2D_3$, a derivative with anticarcinogenic properties (GILBERT et al. 2011).

The above findings suggest that prostate cancer is most probably caused by long-term deficiency of vitamin D_3 which inhibits proliferation, stimulates cell differentiation and induces apoptosis, thus preventing carcinogenesis. Vitamin D_3 also controls hormonal metabolism, decreases progesterone and estradiol levels, and prevents the estrogen-induced proliferation of cancer cells (JEONG et al. 2015, FELDMAN et al. 2014). A clinical study demonstrated that the risk of prostate, lung, breast and colon cancer decreased proportionally with plasma levels of $1,25(OH)_2D_3$ (FRIEDMAN and BACHOW 2013). Similar conclusions can be derived from an epidemiological study which revealed that the risk of prostate, breast and colon cancer is significantly lower in populations with higher vitamin D_3 levels (CHEN et al. 2010, HUNCHAREK et al. 2009).

Vitamin K_2 also delivers numerous health benefits. Menaquinone controls the activity of proteins responsible for calcium deposition in bodily organs. Calcium is transported from the cardiovascular system to the skeleton by osteocalcin, also known as bone gamma-carboxyglutamic acid--containing protein (BGLAP). In the human body, vitamin D_3 is essential for the synthesis of osteocalcin. Osteocalcin has to undergo carboxylation in the presence of vitamin K_2 before it can be bound to skeletal minerals (GUNDBERG et al. 2012). Osteocalcin has a number of other biological roles: it stimulates insulin secretion from the pancreas, influences insulin sensitivity at the cellular level, and determines the number and activity of spermatozoa (DI NICOLANTONIO et al. 2015).

Vitamin K_2 is also active in arteries where it regulates the activity of matrix GLA protein (MGP). MGP removes calcium from arteries and other soft tissues, and it is activated through carboxylation in the presence of vitamin K_2. In vitamin K_2 deficiency, osteocalcin and MGP remain inactive (noncarboxylated), which increases the risk of osteoporosis and vascular calcification. Calcium accumulated in soft tissues cannot be removed or transported to bones and teeth by any other factor. Unlike osteocalcin which is present in bone tissue, MGP is active throughout the entire body (WALLIN et al. 2008).

Prostate cancer is not caused by dairy products or dairy calcium (PARODI 2003, PARODI 2005). Calcium requirements can be adequately met by consuming a calcium-rich diet, but only when the supplied calcium is bioavailable. Calcium metabolism is determined by milk fat components, in particular vitamins D_3 and K_2. Fat-free dairy products and calcium supplements can pose certain risks. Research indicates that the risk of prostate cancer associated with high calcium intake is, in fact, exacerbated by a deficiency of vitamins D_3 and K_2 (DI NICOLANTONIO et al. 2105, CHEN et al. 2010, LI et al. 2007). Increased intake of vitamin K_2 minimizes that risk (LAMSON and PLAZA 2003, NIMPTSCH et al. 2008).

Dietary components limiting the bioavailability of calcium

Foods of plant origin contain components that significantly reduce the bioavailability of mineral compounds, including calcium (BUCHOWSKI 2015, GUÉGUEN and POINTILLART 2000). A diet rich in fiber improves peristalsis, decreases the risk of obesity and colon cancer (SCHLEMMER et al. 2009). However, fiber creates insoluble chelate compounds that limit the bioavailability of mineral nutrients and trace elements. Very strong chelate bonds are formed between calcium and phosphate groups found in oatmeal, which can decrease the calcium bioavailability by up to 65% (KŁOBUKOWSKI et al. 2014, SKIBNIEWSKA et al. 2010, WEAVER et al. 1991). Chitosan supplements also lower the bioavailability calcium by more than 20% (RODRÍGUEZ et al. 2008). The bioavailability of calcium from *Brassica oleracea* vegetables is relatively high due to high concentrations of uronic acids, despite the presence of insoluble fiber fractions (MÜLLER-MAATSCH et al. 2016, WEAVER et al. 1991). Uronic acids, whose content ranges from 10% in non-cellulosic plant fiber to 40% in fruits and vegetables, inhibit calcium absorption (360 mg of calcium can be absorbed daily from a vegetarian diet). However, up to 80% of uronic acids are fermented in the intestines, therefore, significant amounts of calcium are released and absorbed in the colon (LOUIS et al. 2016, PIEPER et al. 2015). Colonic calcium absorption is also enhanced by organic acids in *Brassica oleracea* plants which form highly available low-molecular-weight complexes with calcium ions. For these reasons, white cabbage and broccoli are abundant sources of calcium whose bioavailability is similar to that of milk calcium (PARK at al. 2013, LUCARINI et al. 1999).

Calcium absorption is inhibited by methylated pectins (BOSSCHER et al. 2003, POWELL et al. 1982) which are widely used in the production of juice, jam, jelly and baby food. However, according to CUMMINGS et al. (1979), even high levels of dietary pectins do not compromise calcium absorption. Methylene groups bind around 80% of uronic acids, thus preventing the formation of insoluble complexes with calcium ions. Therefore, the inhibitory effect of dietary fiber on calcium bioavailability is determined by the content of uronic acids (PIEPER et al. 2015, GUÉGUEN and POINTILLART 2000).

Table 1
The mean content of calcium and compounds limiting calcium bioavailability from plant foods

Specification	Total calcium content [mg/100 g]	Calcium available [%]	Fiber [g/100 g]	Phytic acid [g/100 g]	Oxalic acid [mg/100 g]
Kale	300	38,9	3	7,9	1,3
Nut (almond)	250	nd	8.8	4.88	0.3
Parsley	245	nd	6.1	nd	0
Nut (brazil)	150	nd	8.5	3.3	0.1
Celery	138	36.9	1.8	5.2	8.4
Cabbage	40	24.8	3.3	traces	traces
Seed of sunflower	100	nd	10.1	nd	0
Nut (walnut)	89	nd	6.4	3.44	0
Spinach	92	5.1	6.3	0.22	870
Green bean	49	nd	3.1	nd	0
Carrot	42	nd	3.9	nd	0
Red cabbage	35	nd	3.4	nd	0
Broccoli	33	22.9	2.4	0.16	traces
Garlic	30	nd	16.9	nd	0
Leek	30	nd	3.2	nd	0
Cucumber	28	nd	1.4	nd	0
Kohlrabi	25	nd	3.3	nd	0
Onion	23	nd	1.9	nd	0
Pumpkin	22	nd	2.6	nd	0
Lettuce	19	nd	1.6	nd	0
Cauliflower	22	23.4	2.1	traces	1
Pumpkin	18	nd	2.6	nd	0
Red bean	12	26.5	9.1	0.75	0
Nut (pine)	11	nd	5.1	0.2	0.1
Tomato	9	nd	1.7	nd	0

nd – not detected, USDA 2016; BUCHOWSKI et al. (2015)

Cereal products contain phytates which are composed of numerous phosphate groups (Bong et al 2016) that form insoluble complexes with Ca^{2+} ions (Israr et al. 2017). Oxalates, which are found in large quantities in tea, in particular red tea, and coffee, form insoluble salts with calcium. Solvents present in coffee also inhibit mineral absorption (Higdon and Frei 2006).

Many foods of plant origin (nuts, cereals, fruits and vegetables) are characterized by high calcium content (Table 1), but they are not ample sources of dietary calcium due to the presence of compounds that inhibit calcium absorption (fiber, uronic acids, phytates and oxalates). The calcium content of 1 glass of milk is equivalent to that of 8 cups of spinach, 5 cups of red beans or 2 cups of broccoli (Weaver and Boushey 2003, Miller et al. 2001). The bioavailability of calcium from most plant-based products, including cereals, generally does not exceed 10%.

Phosphates are widely used in the production of convenience foods (soft drinks, processed meats, sweets, bread), and their consumption usually exceeds the recommended levels. Excess dietary phosphates compromise the healthy Ca:P ratio, which increases PTH levels, inhibits the synthesis and release of 1,25(OH)2D, and limits the bioavailability of calcium (Lenton et al. 2015, Guéguen and Pointillart 2000).

Raw foods with high calcium content are not always abundant sources of this nutrient due to an unfavorable Ca:P ratio. Soybeans contain 240 mg of calcium per 100 g, but they are characterized by an undesirable Ca:P ratio of 1:3. Herrings are abundant in calcium at 86 mg Ca/100 mg, but their Ca:P ratio is 1:5. Dairy products are characterized by the most favorable Ca:P ratio of 1.3:1 (Aljewicz et al. 2018). Milk and dairy products do not contain compounds that interfere with calcium absorption such as phytates, oxalates, uronic acids or insoluble fiber, which are plentiful in cereals, fruits and vegetables (Baye et al. 2015, Wolf et al. 2000).

Milk and dairy products: the best source of bioavailable calcium

Milk and dairy products are the best sources of dietary calcium. They are abundant in bioavailable calcium and are characterized by optimal Ca:P and calcium:protein intake rations. The bioavailability of calcium is additionally enhanced by fat-soluble vitamins $D_{3,}$ K_2 and selected peptides that are produced during digestion. In lactose-intolerant subjects, undigested lactose consumed as a component dairy products arrives in the large intestine without being absorbed in the small intestine. This undigested lactose stimulating growth of saccharolytic bacteria in the intestine, decrease in ammonia content and increase acidity in intestinal digesta (ALJEWICZ et al. 2018, KŁOBUKOWSKI et al. 2004, 2014). The bioavailability of calcium from milk, fermented milks and ripened cheeses generally reaches 30–45%, but it can be as high as 75% in pregnant women and athletes due to metabolic adaptation. Two glasses of milk or yogurt meet daily calcium requirements in 60%. Ripened cheese is an even more abundant source of dietary calcium, and 50 g of cheese meets daily calcium needs in around 40%. Ripened cheese has a high content of bioavailable calcium (Table 2).

Table 2

Selected dairy products ranked by calcium content; the mean content of vitamin K, calcium and protein in different chesses

Cheese	Calcium [mg/100 g]	Protein [mg/100 g]	Vitamin D [ug/100 g]	Menaquinone-4 [μg/100 g]	Menaquinone-7 [μg/100 g]
Parmesan	1253	36	0.475	7.1	0.215
Swiss	961	27	0.500	7.4	nd
Gruyere	950	30	0.600	45.5	0.022
Edam	770	25	0.500	0.033	0.012
Gouda	740	25	0.500	nd	0.006
Mozzarella	716	22	0.375	4.1	nd
Cheddar	711	23	0.600	nd	0.025
Brie	540	21	0.500	nd	0.014
Blue	500	22	0.525	nd	0.223
Cammbert	350	21	0.450	nd	0.017
Buttermilk	115	3.21	1.300	0.2	0.1
Milk	113	3.5	0.100	0.8	nd
Yoghurt	107	3.47	0.100	0.6	nd
Cream	98	7	0.625	19	nd
Cottage	53	11	0.075	0.9	nd
Butter	24	0.84	0.000	15	nd

Source: own compilation based on USDA 2016, MANOURY et al. 2013, HOJO et al. 2007, SCHURGERS et al. 2000

The bioavailability of cheese calcium is additionally enhanced by proteins, bioactive peptides, fat-soluble vitamins D_3 and K_2, as well as short-chain saturated fatty acids (butyric, acetic and propionic acids). Fatty acids present in milk fat and synthesized by gut microbiota increase: acidity of cecal content, ionization of minerals and permeability of colonocytes by changing osmotic pressure, and they stimulate the absorption of mineral nutrients, including calcium (DEN BESTEN et al. 2013, CANANI et al. 2011). Ripened cheese also contains long-chain saturated fatty acids which limit calcium bioavailability by forming soaps that are not digested in the human gastrointestinal tract. The amount of precipitated calcium ions increases proportionally to the length of the fatty acid chain and its saturation (ALJEWICZ et al. 2014, GUÉGUEN and POINTILLART 2000). Calcium from cottage (acid-set) cheese is more easily absorbed due to high ionization and lower fat content. Despite the above, cottage cheese contains approximately 10-times less calcium than ripened cheese (SIEMIANOWSKI et al. 2014).

The protein content of cheese ranges from 7% to 36% (Table 2). Protein influences parathyroid glands which stimulate the production of PTH responsible for calcium adsorption. Cheese proteins are digested to produce biologically active peptides, including phosphopeptides, which enhance calcium availability by preventing the formation of insoluble phosphate. Calcium is transported across the intestinal wall with the involvement of amino acids (TANG and SKIBSTED 2016). High protein intake always improves bone mineral density (ALJEWICZ et al. 2018, O'CALLAGHAN et al. 2017, BUCHOWSKI 2015, GUÉGUEN and POINTILLART 2000).

Ripened cheese is the richest source of bioavailable calcium whose content ranges from 350 to 1253 mg/100 g (Table 2). Vitamins D_3 and K_2 are responsible for the absorption of calcium in the small intestine and its deposition in bones. Vitamin D_3 is essential for the healthy function of parathyroid glands and kidneys. It is also required for the synthesis of osteocalcin, a protein that transports calcium ions to bones. Osteocalcin has to undergo carboxylation in the presence of vitamin K_2 before it can be bound to the bone mineral phase. Vitamin D_3 and K_2 deficiency inhibits the synthesis of proteins which are responsible for depositing calcium in bones and teeth (SAHNI et al. 2015, HUANG et al. 2015).

Ripened cheese and other dairy products contain calcium that is highly bioavailable on account of the optimal Ca:P ratio and the presence of compounds that enhance calcium absorption (proteins, peptides, amino acids, vitamins D_3 and K_2, short-chain saturated fatty acids) (KŁOBUKOWSKI et al. 2004, GUÉGUEN and POINTILLART 2000).

Health benefits of calcium

A healthy diet that meets daily calcium requirements is one of the pillars of health protection programs. The recommended daily calcium intake is determined by age, gender and health status. It is set at 800–1000 mg Ca for healthy adults, 1300 mg Ca for pregnant and breastfeeding women, and up to 1200 mg Ca for menopausal women. In women with chronic calcium deficits, pregnancy and breastfeeding increase the risk of osteoporosis because lactation decreases bone mineral density. In children, calcium requirements are very high (1200 mg daily) during periods of intensive growth which involve the growth of new bone tissue. An increase in young people's peak bone mass by only 10% could decrease the risk of osteoporosis-related bone fractures by 50% in adulthood (HOSKING et al. 2016, ARONOW 2011, KERSTETTER et al. 2003).

Diets rich in calcium decrease the risk of dental caries and periodontitis. The hard tissue of teeth develops between the fourth week of fetal life and 20 years of age. The building blocks of hard tissue (calcium as well as fluoride and magnesium) contribute to healthy tooth development and prevent tooth decay (MOYNIHAN and PETERSEN 2004). During prolonged calcium deficiency, the missing amounts of calcium are "borrowed" from the jaws, which can lead to gum disease. The calcium intake of patients (aged 29–40 years) suffering from periodontitis was low at 400 mg Ca daily or less (the recommended daily intake is around 800 mg Ca). The problem was resolved by supplementing the studied subjects' diets with calcium in the daily amount of 1000 mg for 180 days (NISHIDA et al. 2000, ADEGBOYE et al. 2016).

Epidemiological research indicates that diets deficient in calcium increase the body mass index (BMI) in both children (BERKEY et al. 2005) and adults (KEAST et al. 2015, ARRUDA and HOTAMISLIGIL 2015, WEAVER AND BOUSHEY 2003). Dairy products are much more likely to promote weight loss than calcium supplements. The above was demonstrated by a study of 32 obese men and women who were placed on low-calcium (400–500 mg Ca/day), high-calcium (1200–1300 mg Ca/day, including 800 mg from calcium supplements) and high-dairy (3–4 servings of dairy products containing 1200–1300 mg Ca/day) diets for 24 weeks. Their daily energy intake was reduced by 500 kcal. The high-dairy diet led to the greatest reduction in body mass among respondents with identical daily calcium intake levels (HUTH et al. 2006).

Milk proteins are responsible for the higher bioavailability of calcium from dairy products than calcium supplements. Whey proteins are abundant in branched-chain amino acids, such as leucine, which regulate the flow of energy from adipose tissue to muscles. They contribute to muscle growth and exert anabolic effects during weight loss (ZHU et al. 2013, ABARGOUEI et al. 2012). Calcium reduces the energy value of high-fat dairy products by forming soaps with long-chain saturated fatty acids. Synergistic interactions between calcium and bioactive fat components, including vitamins D_3 and K_2 and conjugated linoleic acid (CLA), also contribute to weight loss (Kamycheva et al. 2003, Zemel and Miller 2004).

Diets that meet daily calcium needs also reduce the risk of insulin resistance. The Cardia program demonstrated that the above risk was 72% lower in obese subjects consuming dairy products than in obese respondents with a low intake of milk and milk products. Dairy products contain bioavailable calcium which influences insulin secretion and controls tissue resistance to insulin (Pereira et al. 2002). Magnesium, biologically active peptides, n-3 α-linolenic acid and, indirectly, vitamins D_3 and K_2 deliver similar effects (Ralston et al. 2012, Zemel et al 2004). Dairy foods are highly effective in the prevention and treatment of obesity and type 2 diabetes because they contain highly bioavailable calcium which enhances lipolysis and the release of triglycerides from adipocytes, regulates insulin secretion and insulin resistance at the cellular level (Mensink 2006).

Calcium deficiency increases vascular resistance, whereas diets rich in calcium decrease vascular resistance and lower blood pressure. High intake of calcium increases urinary sodium excretion and inhibits neurotransmitters, such as noradrenaline, which induce vascular contraction (Trialists'Collaboration, Blood Pressure Lowering Treatment et al. 2015, Hofmeyr et al. 2014, Massey 2001). Biologically active peptides also play an important role in blood pressure control by inhibiting the enzyme that converts angiotensin I to angiotensin II and by inactivating bradykinin. Whey protein tetrapeptides as well as phosphopeptides have hypotensive properties, and they enhance the absorption of calcium, magnesium and potassium (Engberink and Hendriksen 2009). The effectiveness of milk and dairy products in treating high blood pressure was demonstrated by the DASH diet (Dietary Approaches to Stop Hypertension). Two weeks into the program, the DASH diet contributed to a reduction in blood pressure, which was more pronounced in hypertensive patients than in subject with healthy blood pressure. The reported reduction in blood pressure and the time required to achieve a therapeutic effect were comparable to the outcomes of pharmacological treatment. The DASH diet also delivered additional health benefits that cannot be achieved with pharmacological treatment, including a reduction in homocysteine levels, decrease in body mass (by 4.9 kg on average) and the absence of side effects (Lin et al. 2003).

A clinical study demonstrated that higher calcium intake reduces the risk of colon cancer and slows down tumor growth in humans. Calcium exerts anticarcinogenic effects by inhibiting hyperproliferation of intestinal epithelial cells, i.e. an abnormally *high rate* of their *proliferation* by rapid *division*. Calcium also binds bile acids, fatty acids and phosphates into insoluble salts, thus minimizing their irritating effects and their ability to stimulate the proliferation of intestinal epithelial cells (FLEET 2006, LARSSON et al. 2006). The Nurses' Health Study performed on around 88,000 women and 44,000 men demonstrated that the risk of colon cancer in subjects consuming 700–800 mg of calcium daily was 40–50% lower than in subjects whose daily calcium intake was limited to 500 mg (WU et al. 2002, KESSE et al. 2005). A meta-analysis performed by KEUM et al. (2014) also revealed that the risk of colon cancer was reduced by 9% per every 300 mg of ingested dietary calcium.

According to epidemiological research, the incidence of cancer is significantly lower in countries with a high consumption of ripened cheese (France, Italy, Greece) than in countries with lower cheese intake (Belgium, the Netherlands, Great Britain). The anticarcinogenic properties of ripened cheese can be attributed to its high calcium content as well as the presence of potent antioxidants (CLA, α-tocopherol, β-carotene, vitamins A and D_3, phospholipids, ether lipids), medium-chain and short-chain saturated fatty acids that exert protective effects on the intestinal mucosa (GALLUS et al. 2006, GROSS 2005).

Conclusions

A healthy calcium balance is more likely to be determined by the bioavailability of calcium than its dietary intake. Plant foods, including products with high calcium content (vegetables, nuts, cereals, fruits), are not always good sources of calcium. They lack vitamins that control calcium metabolism, and they contain compounds (fiber, phytates, oxalates, uronic acids) that limit calcium absorption. Due to the presence of the bioactive peptides as well as vitamins D_3 and $K_{2,}$ dairy products are much more effective in preventing diet-dependent diseases than calcium supplements. The DASH diet provides robust evidence that milk and dairy products are effective in the treatment of obesity, atherosclerosis and hypertension.

Translated by JOANNA MOLGA

Accepted for print 4.04.2018

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