Calcium Requirements and the Diets of Women and Children

A Review of Dairy Resources

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This review concerns the role of calcium in nutrition and health and its relation to the changing American diet. The ideal dietary calcium intakes for women and children represent the United States Department of Agriculture's most recent recommended dietary allowances. Both calcium and total nutrient composition of cow, goat and human milk differ. Goat milk has special utility in the treatment of childhood allergy.

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Overview: The Role of Calcium in Nutrition and Health

The importance of an adequate diet has been known since Biblical times. However, modern scientific study of dietary elements is less than 100 years old. The first advice provided by the U.S. government was published in 1916 in the form of a pamphlet, "Food for Young Children."[1] Recommended dietary allowances (RDAs) were initially proposed in 1941 as a series of diets providing optimal nutrition.[2]

In 1979 the Surgeon General included "improved nutrition" among 15 priority activities in the report on health promotion and disease prevention, *Healthy People*.[3] Shortly thereafter, in 1980, the government assumed a major role in promoting a better diet as a means of improving the health of the population.[4]

By 1988 governmental guidelines had become more specific, focusing on selected dietary elements. Especially prominent was the recommendation that adolescent girls and adult women ". . . increase consumption of foods high in calcium, including low-fat dairy products."[1] This recommendation is not surprising because the adolescent girls shortly will enter their reproductive years. For those who will bear children, calcium will be required to satisfy new demands created by the growth and development of the fetal skeletal system.[5]

The importance of dietary calcium was reaffirmed in the 1990 National Academy of Sciences report *Nutrition During Pregnancy*[6]: "Improvement of diet quality through use of nutritious foods is strongly preferred to supplementation."

Recent critical assessments of the scientific literature and research on dietary calcium and its importance in health suggest that providing a proper diet for adolescent girls and adult women who may become pregnant or who are lactating is too narrow a focus. Adequate calcium intake is also of paramount importance to any individual in the process of building peak bone mass, regardless of age or gender.[5] In general, bone mass increases by radial growth, even after closure of the endochondral growth plates, until about age 30 for trabecular bone and 35 for cortical bone.[5,7] A transient period of stability ensues, after which age-related cortical and trabecular bone loss begins in both males and females. Insufficient accumulation of skeletal mass by adulthood predisposes an individual to fractures later in life.[7]

Age-related bone loss is diphasic. At onset, a protracted slow phase in both sexes precedes by 10 years a transient accelerated phase. In women that phase starts shortly after menopause and continues for 5–10

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years. During women's lifetimes, the combination of slow and accelerated bone loss leads to a 35% diminution in cortical bone mass and a 50% diminution in trabecular bone mass.[8,9] In contrast, men lose only two-thirds of these amounts.

This difference is of vast clinical importance because the osteoporosis resulting from loss of bone mass contributes to as many as 1.3 million fractures annually in persons over age 45.[5] After age 80, one of every three women will sustain an osteoporosis-related hip fracture,[10] of which a significant proportion are fatal.[11] Of the survivors, half are confined to nursing homes for long periods of time.[10] The estimated annual cost of treating osteoporosis-related fractures and their complications ranges from $3.8 to $10 billion.[1,5,7]

Public and medical appreciation of the role of calcium in bone disease has increased greatly in the years following the 1984 NIH Consensus Conference on Osteoporosis.[12] It is simplistic, however, to suggest that calcium only exerts an effect on bone mass and structural integrity. For example, calcium plays an important role in the physiology of the cardiovascular system, acts as a cellular and tissue-level messenger, may be involved in certain neoplastic conditions and interacts with the renal and parahormone systems. Thus the Surgeon General's recommendation that adolescent girls and adult women increase their intake of foods high in calcium, including low-fat dairy products,[1] should be considered carefully by physicians who advise patients on their diets.

The Changing American Diet

The American public has changed its eating habits drastically in recent years. The changes often have been followed by improvements in the nation's nutritional and health status.[13] Indeed, the declines in the incidence of heart disease and stroke have been attributed in no small part to better nutrition.

Recent advances in food technology allow the average consumer a wide array of options for health needs and personal preferences. Growing public awareness of the potentially detrimental effects of saturated fat, cholesterol and excess calories has contributed to these trends. For example, in 1988, 74% of the U.S. population 12 years of age and older were aware of the relationship between fat and heart disease; 70% were aware of the relationship between cholesterol and heart disease.[13]

As consumers have begun to demand truth in labeling in order to make more informed choices, food processors have responded with expanded information about nutrient content, including vitamins, minerals, percent of recommended dietary allowance (RDA) and total caloric content.[14] Whereas nutrient labeling was included on only 42% of food products regulated by the U.S. Food and Drug Administration (FDA) in 1978, it increased to 61% in 1988.[13] The campaign for truthful labeling and enhanced choices has begun to involve the fast food industry and its cooking processes,[15] and additional changes will undoubtedly be forthcoming in the next decade as the government implements proposed food labeling regulations.

Recent changes in the per capita consumption of dairy products exemplify the alterations in American dietary practices. Between 1945 and 1985, for example, per capita milk consumption dropped by about one-third, from 348 to 238 pounds, and whole milk consumption fell by 57% (from 313 to 134 pounds). At the same time, intake of skim and low-fat milks rose by 200% (from 35 to 105 pounds),[16] and per capita consumption of whole and part-whole milk cheeses increased 214% (from 7 to 22 pounds). Part of this change reflects diminished milk consumption on the whole. Part of it also represents consumers' conscious choice to eat dairy products that have greatly reduced fat content.

Dietary Intakes of Women and Children

Despite selective changes in the consumption of dairy products by individuals, others (women and children in particular) consume diets low in the nutrients that are especially concentrated in dairy products. As a result, they are susceptible to long-term consequences of specific nutrient deficiencies such as osteoporosis.

The Continuing Survey of Food Intakes by Individuals (CSFII) provides data on the dietary intakes of women ages 19–50 years and their children ages 1–5 years.[17] This survey is a major component of the National Nutrition Monitoring System, a set of related federal activities intended to provide regular information on the nutritional status of the U.S. population. Whereas children of ages 1–3 and 4–5 years, respectively, met or exceeded the RDAs for most nutrients evaluated (Table I), the dietary intakes of adult women often failed to do so (Table II). Women in both 19–34- and 35–50-year-old groups had diets low in calories (72% and 66% of the RDA, respectively), vitamin B_6 (74% and 70%), calcium (56% and 69%), magnesium (75% and 73%), iron (69% and 66%) and zinc (73% and 69%).

Of equal importance is the fact that although milk

Table I *Comparison of Dietary Intakes of Children Ages 1–3 and 4–5 Years: Continuing Survey of Food Intakes by Individuals (CSFII)[17] Versus Recommended Dietary Allowances (RDAs)[35]*

Nutrient	CSFII, 1–3 yr	RDA (%)	CSFII, 4–5 yr	RDA (%)
Calories	1,369	105	1,510	84
Protein (gm)	51.1	319	55.6	232
Fat (gm)	53.3	—	58.3	—
Carbohydrate (gm)	176.5	—	196.7	—
Vitamins				
Vitamin A (μg RE)	798	200	790	158
Vitamin E (mg α-TE)	5.6	93	5.4	77
Vitamin C (mg)	83	208	86	191
Thiamin (mg)	1.08	154	1.18	131
Riboflavin (mg)	1.52	190	1.65	150
Niacin (mg NE)	13.1	146	14.4	120
Vitamin B_6 (mg)	1.21	121	1.24	113
Folacin (μg)	180	360	193	257
Vitamin B_{12} (μg)	3.77	539	3.86	386
Minerals				
Calcium (mg)	758	95	821	103
Phosphorus (mg)	962	120	1,035	129
Magnesium (mg)	188	235	199	166
Iron (mg)	9.5	95	10.0	100
Zinc (mg)	7.1	71	7.7	77
Sodium (mg)	1,966	—	2,093	—
Potassium (mg)	1,894	—	1,950	—

RE = retinol equivalent; TE = tocopherol equivalent; NE = niacin equivalent.

and milk products account for 76.2% of calcium, 20% of magnesium and zinc and 11% of vitamin B_6 in the total U.S. food supply,[18] milk and milk products contributed only 42% of the calcium, less than 15% of the magnesium and zinc and less than 10% of the vitamin B_6 in the diets of adult women. Children fared somewhat better in that this food group accounted for 64% of the calcium, somewhat less than 30% of the magnesium and zinc and about 15% of the vitamin B_6. Under these circumstances, it appears that substantial numbers of children and adult women fail to utilize a readily available, inexpensive and palatable source of these nutrients.

National findings such as these stress the need for those interested in improving the diets of children and adult women to recommend milk products as an important option. In this regard, a far wider variety of choices exists today than two or three decades ago. The options have been designed to restrict calories, fat and cholesterol in cow milk, among other things, and also to include aseptic packaging for long shelf and refrigerator life.

Another important option is commercially available goat milk, which possesses unique concentrations and forms of specific nutrients (see below). It is particularly suitable for the diets of young children and women. This fact was recognized by the U.S. Department of Agriculture (USDA) in a March 31, 1986, policy letter that authorized its inclusion (if pasteurized and fortified in accordance with established standards) in food packages IV, V and VI of the Supplemental Feeding Program for Women, Infants and Children (WIC).[19]

Nutrient Composition of Cow, Goat and Human Milks

Goat milk is uniquely different from cow milk in the concentration and forms of its nutrients. A comparison of the composition of cow, goat and human milk is given in Table III, in which the data represent average USDA values. The composition (especially fat type and amount) of all mammalian milk varies by breed, season, feed and age of the animal.[20] Cow, goat and human milk provide about 750 kcal/L of energy each. From a practical point of view, the principal difference between these three milk forms is the proportion of energy derived from lactose and protein. In goat and cow milk, the fat, protein and lactose components contribute 50%, 25% and 25% of the energy, respectively. In contrast, these same elements in human milk contribute 55%, 7% and 38%, respectively.[20]

Table II *Dietary Intakes of Women Ages 19–34 and 35–50 Years: Consumption Versus Recommended Daily Allowances*

Nutrient	CSFII, 19–34 yr	RDA (%)[a]	CSFII, 35–50 yr	RDA (%)[b]
Calories	1,590	72	1,458	66
Protein (gm)	62.0	135	59.1	118
Fat (gm)	65.6	—	60.1	—
Carbohydrate (gm)	185.7	—	167.0	—
Vitamins				
Vitamin A (μg RE)	854	107	799	100
Vitamin E (mg α-TE)	7.3	91	6.9	86
Vitamin C (mg)	77	128	77	128
Thiamin (mg)	1.10	100	1.00	91
Riboflavin (mg)	1.41	108	1.25	96
Niacin (mg NE)	16.1	107	16.0	107
Vitamin B_6 (mg)	1.19	74	1.12	70
Folacin (μg)	195	108	183	102
Vitamin B_{12} (μg)	4.58	229	5.16	258
Minerals				
Calcium (mg)	670	56	550	69
Phosphorus (mg)	1,014	85	912	114
Magnesium (mg)	209	75	205	73
Iron (mg)	10.3	69	9.9	66
Zinc (mg)	8.8	73	8.3	69
Sodium (mg)	2,448	—	2,277	—
Potassium (mg)	2,068	—	2,065	—

RE = retinol equivalent; TE = tocopherol equivalent; NE = niacin equivalent.
[a]RDA for women ages 19–34 years.
[b]RDA for women ages 35–50 years.

A second point of difference between cow, goat and human milk is the proportion and type of proteins. Each of the three has an adequate balance of essential amino acids that equals or exceeds Food and Agriculture Organization–World Health Organization requirements.[20] However, important differences exist. Goat milk is closer in protein composition to human milk.

Beta-caseins are the major proteins in human and goat milk, as opposed to the alpha-caseins predominant in cow milk.[21,22] The casein in cow milk is approximately 55% alpha, 30% beta and 15% k; goat milk contains 19% alpha 1, 21% alpha 2 and 60% beta.[21] The casein of goat milk contains more glycine, less arginine and fewer sulfur-containing amino acids than cow milk.[23] Alpha-S-1 casein, which is absent in goat milk and present in cow milk, is responsible for the bitterness of cheeses made from cow milk[24] and for the softer curd and easier digestibility of those made from goat milk.[20]

A third difference relates to fat content. The lipid composition of goat, cow and human milks is presented in Table IV. Goat milk contains more of the essential fatty acids (linoleic and arachidonic acids) and a higher proportion of short-chain and medium-chain fatty acids than cow milk. The higher proportion of short- and medium-chain fatty acids in goat milk suggests that the fat in goat milk may be more readily digested and absorbed than cow milk because lipases attack ester linkages of such fatty acids more readily than those of longer chains. Unlike cow milk, goat milk does not contain agglutinin.[20] As a result, the fat globules in goat milk do not cluster, thus facilitating digestion and absorption.[25]

The final difference between cow, goat and human milks relates to calcium. Compared with cow milk, goat milk contains 13% more calcium, 25% more vitamin B_6, 47% more vitamin A, 134% more potassium and 350% more niacin. It is also higher in chloride, copper and manganese. The RDA for selenium was established for the first time in 1989 on the basis of research in China. The RDA for selenium in children ages 1–5 years is 20 μg per day; for women ages 19–50 it is 55 μg per day. Bioavailability trials have indicated that organically bound forms of selenium are better retained than inorganic forms, but both forms resulted in increased glutathione peroxidase activity.[26,27] A recent study comparing the selenium content of human, cow and goat milk showed that goat milk contained 27–28% more of this essential nutrient than cow milk.[28] The study reported that there is 13.3 ng/mL in whole goat milk

NOTE: SEE LAST PAGE FOR PUBLISHED ERRATUM ON TABLE IV.

compared with 9.6 ng/mL in whole cow milk; skim milk contains 13.1 and 9.5 ng/mL in goat milk and cow milk, respectively.

Goat milk resembles cow milk in its iron content, averaging 20–200 μg/mL each of lactoferrin and transferrin.[20] In contrast, human milk contains >2 mg/mL of lactoferrin and <50 μg/mL of transferrin.

Milk and Infant Allergy

Cow milk allergy (CMA) is estimated to occur in approximately 7–8% of all infants and about 2% of exclusively breast-fed infants.[29] A recent British study reported that 20–25% of formula-fed infants undergo a change from whey-based to casein-based formula, within the first six weeks after birth.[30] Studies in the United States indicate that a similar proportion of formula-fed infants have their formulas changed, usually to a soy-based formula.[31] The usual therapy for CMA is soy-based formula, although an estimated 20–50% of infants with cow milk sensitivity or intolerance also have an adverse reaction to soy milk.[32] The American Academy of Pediatrics suggests the use of evaporated milk for infant formula when infants have CMA because the heat used during the evaporation process renders the casein more digestible (smaller curd tension) and less allergenic.[33]

Evaporated goat milk would be particularly suitable for the formula of CMA infants because its casein, which is more readily digestible than that of cow milk, is made more so by the evaporation process. The directions for using evaporated goat milk for 24 hours' basic formula specify 12 ounces evaporated goat milk, 24 ounces of water (boiled) and 3½ tablespoons of corn syrup or 7 tablespoons of dextramaltose. This formula provides approximately 715 calories. As a food for the first year of life, goat milk in all commercially available forms (fresh, evaporated or powdered) must be appropriately diluted before use because of high potassium and chloride content.

The absence of alpha-S-1 casein may explain why infants who are allergic to cow milk often tolerate goat milk.[20,34] The offending allergenic protein may or may not be present in the substituted milk, however, and cross-reactions have been known to occur. Therefore, goat milk may not always be tolerated by individuals with other food allergies. In the dietary therapy of food allergies, the professional advice of a registered dietician, nutritionist or physician should always be sought.

For infants over age six months goat milk is adequate in vitamin A and niacin, riboflavin, thiamin and pantothenic acid, but it is deficient in vitamins C, D, B_6 and folate, which must be added as a supplement.[20] Some but not all commercially available brands of goat milk have been fortified with both

Table III *Comparative Composition of Cow Milk and Goat Milk, Per 100 Grams**

Nutrient	Cow milk	Goat milk	Human milk
Protein (gm)	3.3	3.6	1.0
Fat (gm)	3.3	4.2	4.4
Carbohydrate (gm)	4.7	4.5	6.9
Calories	61	69	70
Phosphorus (gm)	93	111	14
Calcium (gm)	119	134	32
Magnesium (mg)	13	14	3
Iron (mg)	0.05	0.05	0 03
Zinc (mg)	0.38	0.30	0.17
Sodium (mg)	49	50	17
Potassium (mg)	152	204	51
Vitamin A (IU)	126	185	241
Thiamin (mg)	0.04	0.05	0.014
Riboflavin (mg)	0.16	0.14	0.04
Niacin (mg)	0.08	0.28	0.18
Vitamin B_6 (mg)	0.04	0.05	0.01

*Adapted from *Composition of Foods: Dairy and Egg Products.*[36]

Table IV *Lipid Composition of Goat, Cow and Human Milks, in Grams Per 100 Grams**

Fatty acid (carbons:double bonds)	Goat milk	Cow milk	Human milk
Saturated, total	2.08	2.67	2.01
C4:0	0.11	0.13	—
C6:0	0.06	0.09	—
C8:0	0.04	0.10	—
C10:0	0.08	0.26	0.06
C12:0	0.09	0.12	0.26
C14:0	0.34	0.32	0.32
C16:0	0.88	0.91	0.92
C18:0	0.40	0.44	0.29
Monounsaturated, total	0.96	1.11	1.66
C16:1	0.08	0.08	0.13
C18:1	0.84	0.98	1.48
C20:1	Trace	—	0.04
C22:1	Trace	—	Trace
Polyunsaturated, total	0.12	0.15	0.50
C18:2	0.08	0.11	0.37
C18:3	0.05	0.04	0.05
C18:4	Trace	—	—
C20:4	Trace	—	0.03
C20:5	Trace	—	Trace
C22:5	Trace	—	Trace
C22:6	Trace	—	Trace

*Adapted from *Composition of Foods: Dairy and Egg Products.*[36]

folate and vitamin D at the level of 25% of the RDA (e.g., Meyenberg Goat Milk Products, Santa Barbara, CA). Evaporated and powdered forms of goat milk are available in all 50 states and Puerto Rico. Fresh goat milk is also available in selected locations throughout the country, particularly in the West and South.

Conclusion

Goat milk is a nutritious dairy option. Well suited to the nutritional needs of women, infants and children, it can also be used by any individual concerned with obtaining adequate calcium from a natural dietary source. Its unique composition makes it useful for feeding infants who have cow milk allergy, children who have food allergies and adults in the convalescent stage of illness. Goat milk is a traditional food in most parts of the world; in the United States it often is regarded as a "boutique" dairy option. Because it equals or exceeds the nutrient composition of cow milk, goat milk may be favored as a staple food source by more individuals in the coming decade.

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Erratum

We wish to bring the readers' attention to two points regarding our article "Calcium Requirements and the Diets of Women and Children: A Review of Dairy Resources," which appeared in the August 1992 issue of *The Journal of Reproductive Medicine*. The headings in the first two columns of Table IV should be reversed. The correct table is presented below.

Table IV *Lipid Composition of Cow, Goat and Human Milks, Per 100 Grams**

Fatty acid (gm)	Cow milk	Goat milk	Human milk
Saturated, total	2.08	2.67	2.01
C4:0	0.11	0.13	—
C6:0	0.06	0.09	—
C8:0	0.04	0.10	—
C10:0	0.08	0.26	0.06
C12:0	0.09	0.12	0.26
C14:0	0.34	0.32	0.32
C16:0	0.88	0.91	0.92
C18:0	0.40	0.44	0.29
Monounsaturated, total	0.96	1.11	1.66
C16:1	0.08	0.08	0.13
C18:1	0.84	0.98	1.48
C20:1	Trace	—	0.04
C22:1	Trace	—	Trace
Polyunsaturated, total	0.12	0.15	0.50
C18:2	0.08	0.11	0.37
C18:3	0.05	0.04	0.05
C18:4	Trace	—	—
C20:4	Trace	—	0.03
C20:5	Trace	—	Trace
C22:5	Trace	—	Trace
C22:6	Trace	—	Trace

*Adapted from *Composition of Foods: Dairy and Egg Products*, Agriculture Handbook No. 8-1. Agricultural Research Service, Washington, D.C.: U.S. Department of Agriculture, 1976.

Although we stated that alpha-S-1 casein is absent in goat milk, it has recently come to our attention that the level of this protein is variable, depending on the breed and sample.[1] In addition, infants who are allergic to cow milk may be able to tolerate goat milk because of differences in protein content, probably the whey proteins.[2]

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