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Original article

Intestinal absorption of calcium from yogurt in lactase-deficient subjects

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Summary — Fractional intestinal absorption of calcium (FACa) was measured using radioactive calcium and 200 mg of calcium carrier provided either by yogurt or by $CaCl_2$ in 7 lactase-deficient (L(–)) and 7 normal (L(+)) subjects. During the control period prior to yogurt consumption, mean calcium intake was 819 mg per day in L(–) and 931 mg per day in L(+) subjects (NS). In both groups of subjects yogurt increased FACa from 20.8 ± 3.9% to 26.9 ± 7.2% (P = 0.065) in L(+) subjects and from 20.2 ± 5.6% to 23.5 ± 6.4% (P = 0.050) in L(–) subjects. The significant increase in FACa observed in L(–) subjects indicates that yogurt, which is an autodigesting source of lactose, does not impair calcium absorption. FACa increase could reflect the lower dietary calcium intake in L(–) subjects when compared with L(+) subjects, due to avoidance of milk and non-fermented dairy products which could cause intestinal discomfort. It is concluded that yogurt is a well-tolerated and efficient source of calcium in subjects with lactase deficiency.

calcium absorption / lactase-deficiency / yogurt

Résumé — Absorption intestinale du calcium chez les sujets déficients en lactose consommant du yaourt. *L'absorption fractionnelle du calcium (FACa) a été mesurée en utilisant du calcium radioactif administré avec 200 mg de calcium comme entraîneur, apporté soit sous forme de yaourt soit sous forme de $CaCl_2$ chez 7 sujets déficients en lactase (L(–)) et chez 7 sujets sans déficit lactasique (L(+)). Pendant la période contrôle, avant l'ingestion de yaourt, la consommation moyenne de calcium était de 819 mg par jour chez les sujets L(–) et de 931 mg par jour chez les sujets L(+) (NS). Dans les deux groupes de sujets, l'ingestion de yaourt a augmenté FACa : de 20,8 ± 3,9% à 26,9 ± 7,2% (P = 0,065) chez les sujets L(+) et de 20,2 ± 5,6% à 23,5 ± 6,4% (P = 0,050) chez les sujets L (–). L'augmentation significative de FACa observée chez les sujets L(–) indique que le yaourt, qui induit l'hydrolyse du lactose, n'altère pas l'absorption intestinale du calcium. L'augmentation de FACa observée chez les sujets L(–) pourrait être en rapport avec de moindres apports calciques alimentaires que ceux mesurés chez les sujets L(+), cette différence étant imputable à la non ingestion de lait et de produit laitiers non fermentés qui induisent des troubles dyspeptiques. En conclusion, le yaourt permet un apport diététique de calcium d'origine lactée chez les sujet déficient en lactase intestinale.*

absorption intestinale du calcium / déficit en lactase / yaourt

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INTRODUCTION

Intestinal calcium absorption has been shown to depend in part on the presence of carbohydrates in the gut lumen. In animal experiments lactose, as well as some other sugars, has been shown to increase calcium absorption (Wasserman and Taylor, 1969; Fournier *et al*, 1972). In man, several studies have addressed this issue but the results obtained are conflicting and difficult to compare because of varying methodologies (Greenwald *et al*, 1963; Birge *et al*, 1967; Pansu and Chapuy, 1970; Condon *et al*, 1970; Kocian *et al*, 1973; Cochet *et al*, 1983; Smith *et al*, 1985; Griessen *et al*, 1989). Lactose may have a stimulatory effect on calcium absorption. However, this effect is obviously dependent upon the activity of the intestinal enzyme lactase which hydrolyses lactose to glucose and galactose.

A great number of Caucasian adults are lactase-deficient (Simoons, 1969), and such a defect has been documented in many patients with osteoporosis (Newcomer *et al*, 1978). Lactose maldigestion and malabsorption in lactase-deficiency may lead to calcium deficiency, especially in aged subjects, since intestinal calcium absorption has been shown to decrease with age (Avioli *et al*, 1965; Bullamore *et al*, 1970; Ireland and Fortran, 1973; Gallagher *et al*, 1979). In addition, aged subjects reportedly consume lower amounts of unmodified milk than younger subjects. In order to avoid a diet deficient in calcium and to preserve the stimulatory effect of lactose in the process of intestinal calcium absorption, yogurt or cultured milk may be ingested in large quantities. In individuals with lactase deficiency, the hydrolysis of lactose achieved by the lactase (β-galactosidase) of microorganisms used for yogurt processing is particularly beneficial (Tamine and Deeth, 1980). Therefore, milk provided as yogurt may lead to an improved digestion and absorption of lactose as well as of calcium.

Using a simplified method for the measurement of fractional intestinal absorption of calcium (FACa) (Chanard *et al*, 1974), we have investigated the effect of yogurt on the intestinal absorption of calcium in subjects with normal lactose tolerance and in patients with lactose intolerance in order to explore a possible beneficial effect of this dairy product on calcium availability.

SUBJECT AND METHOD

Subjects

Fourteen volunteers participated in the study. They received a complete explanation of the study and gave informed consent. The study was accepted by the ethical committee of our institution. Subjects were divided into 2 groups: group I comprised 7 healthy normal lactase volunteers (L(+)) aged 23–58 yr and group II comprised 7 lactase-deficient subjects (L(–)) aged 23–74 yr. All were in good health and taking no drugs. Physical examination was normal. Serum calcium, phosphorus, total protein, alkaline phosphatases, creatinine, uric acid and glucose were within normal limits as were serum 25 (OH) cholecalciferol, immunoreactive 63-84 PTH and osteocalcin. Lactose intolerance was detected by a 100 g lactose-tolerance test (Welsh, 1970) and confirmed by breath analysis according to Calloway *et al* (1969).

Study protocol

All subjects were ambulatory and maintained for the control period on their usual diet. Nutritional status was carefully investigated by expert dieticians throughout the study period. At the end of the 4-wk control period, FACa was measured. Thereafter, yogurt was introduced into the diet which remained otherwise unmodified. 125 g of commercial unflavoured yogurt (Danone BSN, France) containing ≈ 6.5 g lactose and 150 mg calcium was taken 3 times a day at the end of each meal. Yogurt was consumed 3 d of preparation. After 8 d of yogurt supplementation, FACa was again measured.

Measurements

Fractional intestinal absorption of calcium was measured as previously described (Chanard *et al*, 1974, 1976) using ^{45}Ca successively administered intravenously (4 µCi = 148 kBq) and then orally (7–8 µCi = 245 – 300 k Bq) 2 h later. The test was performed on subjects who had been fasting for 12 h. The oral dose was given together with 200 mg of elemental calcium as $CaCl_2$ in 100 ml water during the first test and with 150 mg calcium provided by yogurt mixed with 50 mg calcium as $CaCl_2$ during the second test. FACa was measured 2, 4 and 6 h after the oral dose. As an equilibrium of radiocalcium absorbed and radiocalcium remaining in the gut is normally reached within 2–4 h after the oral dose (Birge *et al*, 1969), FACa values have been quoted as the mean of all determinations.

The nutritonal status of the subjects was defined by dietary recall, according to tables which have been established to take into account the characteristics of French dietary habits (Souci *et al*, 1981; Feinberg *et al*, 1991).

Radioactive calcium was measured in a liquid scintillation spectrometer (LS 230 Beckmann Instrument). All counts were corrected for quenching. Blood chemistry was performed according to automatic methods and radioimmunoassays using commercial tests (Oris, Saclay, France).

Statistical analysis

Results were expressed as mean ± SD. Data were analyzed as part of a 2-treatment (Y(–) and Y(+)) open study in which differences between treatment groups and between periods were examined. Differences between L(+) and L(–) groups at baseline were assessed with use of the Wilcoxon rank-sum test for continuous data. Changes from baseline after yogurt ingestion were assessed with Student's paired *t*-test. All tests were 2-tailed and an alpha of 0.05 indicated significance.

RESULTS

Table I indicates the mean values of estimated diet components and energy intake as evaluated during the 2 study periods. When yogurt was introduced, nutritional habits changed slightly. An increase in the consumption of calcium and phosphorus was therefore observed. The mean increase in calcium intake was 166 mg per day (17.8%) in L(+) and 194 mg per day (23.7%) in L(–) subjects respectively.

Fractional absorption of calcium did not differ significantly at 2, 4 and 6 h after the oral dose of ^{45}Ca in each of the 4 subgroups defined as L(+) and L(–) subjects, taking (Y(+)) or not taking (Y(–)) yogurt (table II). In the absence of yogurt, FACa was similar in L(+) and L(–) subjects (20.8 ± 3.9% *vs* 20.2 ± 5.6% (P = NS)). The administration of yogurt induced an increase in FACa both in L(+) and in L(–) subjects: 26.9 ± 7.2% and 23.5 ± 6.4% respectively. In L(–) subjects this increase was significant whereas in L(+) subjects it was not (fig 1).

DISCUSSION

An improvement in intestinal calcium absorption both in healthy subjects with normal lactase activity and in those with lactase deficiency, when a test dose of radiocalcium given together with yogurt compared with radiocalcium given together with calcium chloride in water has been documented.

In L(–) and L(+) subjects, mean FACa was increased after yogurt consumption. This increase was significant in L(–) sub-

Table I. Daily dietary intakes of subjects with and without intestinal lactase deficiency before and after introduction of yogurt in their diet. Values are m ± SD calculated over a week.

	Without yogurt						With yogurt					
	Energy intake (kJ/d)	*Proteins (g/d)*	*Lipids (g/d)*	*Glucides (g/d)*	*Ca (mg/d)*	*P (mg/d)*	*Energy intake (kJ/d)*	*Proteins (g/d)*	*Lipids (g/d)*	*Glucides (g/d)*	*Ca (mg/d)*	*P (mg/d)*
Normal lactase												
Pon	10.10	75	110	280	1270	1400	9.43	70	95	280	1180	1240
Bal	7.82	65	90	200	950	1000	7.44	65	80	195	1100	1100
Son	6.65	55	90	140	690	950	6.67	50	80	170	890	950
Gui	5.79	50	65	150	685	670	6.35	50	60	195	940	620
Avi	7.19	75	80	175	1140	1100	4.64	55	50	110	1150	980
Dou	6.48	50	70	180	665	725	5.43	60	60	130	1200	1040
Bla	10.10	84	120	250	1115	1200	9.20	85	100	240	1220	1320
Mean ± SD	7 74 ±1.73	62 ± 12	89 ± 20	194 ± 52	931 ± 252	1006 ± 257	7.03 ±1.80	62 ± 12	75 ± 19	139 ± 59	1097 ± 131	1036 ± 227
Lactase-deficient												
Sen	6.92	50	95	150	750	950	8.88	90	125	160	1360	1560
Cof	9.15	85	90	260	1380	1190	7.73	80	70	225	1280	1290
Bril	10.28	85	120	260	910	1100	8.28	75	80	240	1220	1410
Doy	5.96	50	65	160	680	700	6.27	55	60	185	960	660
Rei	6.73	50	90	150	780	900	6.52	50	80	160	810	1100
Mon	6.58	45	75	180	650	710	5.85	50	60	165	840	950
Ril	6.88	45	65	220	580	750	7.61	45	70	230	620	800
Mean ± SD	7.40 ±1.67	59 ± 18	86 ± 20	197 ± 49	819 ± 269	913 ± 218	7 31 ±1.12	64 ± 18	78 ± 22	198 ± 40	1013 ± 278	1110 ± 329

Table II. Fractional intestinal absorption of calcium measured 2,4 and 6 h after the oral administration of radiocalcium with (Y (+)) or without (Y (–)) yogurt as carrier, in normal lactase and lactase-deficient subjects.

Subject	*Age*	*Sex*	*Without yogurt*				*With yogurt*			
			2 h	*4 h*	*6 h*	*m*	*2 h*	*4 h*	*6 h*	*m*
Normal lactase										
Pon	23	M	19.3	30.2	23.1	24.2	36.0	42.0	33.1	37.0
Bal	27	M	24.4	31.1	31.1	26.1	30.0	42.0	32.0	32.0
Son	23	F	27.0	20.0	17.0	21.3	19.1	21.0	15.9	18.7
Gui	25	F	18.9	23.1	22.7	21.6	30.0	36.0	31.0	32.3
Avi	22	F	16.8	13.0	14.7	14.8	21.5	28.0	22.5	24.0
Dou	24	F	13.4	15.1	21.8	16.8	17.1	20.2	17.9	18.3
Bla	58	F	20.1	22.0	21.0	21.0	25.0	27.0	25.0	26.0
Mean ± SD			20.0 ± 4.5	22.1 ± 6.9	20.9 ± 3.9	20.8 ± 3.9	25.5 ± 6.8	29.7 ± 8.0	25.3 ± 6.9	26.9 ± 7.2
Lactase-deficient										
Sen	25	F	25.6	33.6	30.7	30.0	38.8	28.2	33.0	33.3
Gof	23	M	18.1	23.9	23.1	21.7	25.2	28.8	26.2	26.7
Bri	24	M	22.3	19.3	26.5	22.7	33.0	29.0	27.0	29.7
Doy	62	M	18.5	20.0	18.5	19.0	19.0	20.1	21.0	20.0
Rei	69	M	20.0	21.0	19.0	20.0	18.0	18.5	18.5	18.0
Mon	72	F	14.7	19.2	14.2	16.1	15.4	18.1	17.6	17.0
Ril	74	F	13.0	12.0	10.9	12.0	20.2	20.0	19.1	19.8
Mean ± SD			18.9 ± 4.3	21.3 ± 6.5	20.4 ± 6.9	20.2 ± 5.6	24.2 ± 8.7	23.1 ± 5.3	23.2 ± 5.7	23.5* ± 6.4

* Indicates significant changes between Y (–) and Y (+).

jects but not in L(+) subjects. The discrepancy between L(–) and L(+) subjects may be explained by the small size and the age heterogeneity of the groups.

The increase in calcium absorption may be the result of several enhancing nutrients contained in yogurt (Pointillart *et al*, 1986) including casein (Mykkänen and Wassermann, 1980) and lactose (Wasserman and Taylor, 1969). In man, previous studies of calcium absorption in lactase-deficiency have yielded conflicting results, the presence of lactose increasing (Pansu and Chapuy, 1970), decreasing (Condon *et al*, 1970; Kocian *et al*, 1973; Debongnie *et al*, 1979) or having no particular effect (Tremaine *et al*, 1986) on calcium absorption. In agreement with our findings, Cochet *et al* (1983) in their extensive study on such subjects found that an oral load of 50 g of lactose significantly increased FACa by 37% in the L(+) subjects. However, in L (–) subjects they observed a decrease of 18% in total calcium absorption. Similarly,

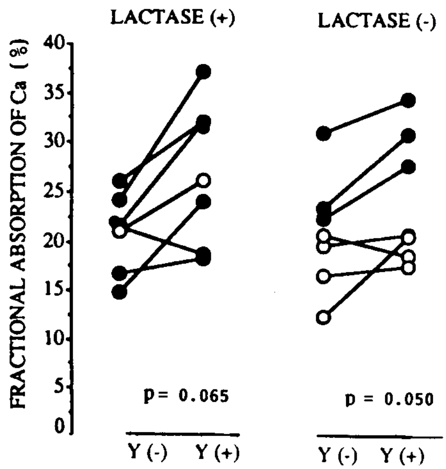

Fig 1. Mean values of FACa measured after oral administration of radiocalcium given either with yogurt (Y(+)) or with $CaCl_2$ in water (Y(–)) as carrier, in normal lactase (lactase(+)) and lactase-deficient (lactase(–)) subjects. Closed circles indicate "young" subjects and open ,circles "old" (see text).

Kocian *et al* (1973) reported that 39 g lactose had a detrimental effect on calcium absorption in L(–) subjects. Condon *et al* (1970) have shown that the daily ingestion of 60 g of lactose decreased fecal and urinary calcium excretion and induced a positive calcium balance but their study was limited to L(+) subjects. Many of these discrepancies may be explained by differences in methodology and especially by different amounts of lactose administered together with the test dose of calcium in order to measure calcium absorption. In our study, where yogurt was used 3 d after manufacture, an average of 6.5 g lactose was mixed with radioactive calcium to measure FACa. Other differences in methodology such as pH and temperature may also play a part, since lactose hydrolysis produced by *Lactobacillus bulgaricus* and *Streptococcus thermophilus* is inhibited at pH < 4.6 and at storage temperature. The beneficial role of the enzymatic activity of microorganisms contained in yogurt has been clearly shown by Kolars *et al* (1984), who demonstrated enhanced lactose absorption in L(–) subjects after the ingestion of yogurt.

A possible effect of age on FACa cannot be asserted in the present study, since only 1 L(+) subject and 4 L(–) subjects were > 50 yr. Irrespective of intestinal lactase activity, mean FACa measured before yogurt consumption was 17.6% and 22.1% in old and young subjects, respectively. This difference confirms the hypothesis that FACa decreases with age (Avioli *et al,* 1965; Bullamore *et al,* 1970; Ireland and Fortran, 1973), independently of diet and hormonal imbalance. Since osteoporosis is a major health problem in the aging population, reflecting calcium deficiency, adequate intestinal absorption of calcium throughout the entire life probably is a key factor. Insufficient dietary intake of calcium clearly contributes to diminished bone mass (Birge *et al,* 1969; Newcomer *et al,* 1978; Gallagher *et al,* 1979; Cauley *et al,* 1988). In addition, dietary calcium supplementation has been shown to decrease fracture rate in postmenopausal osteoporosis, even though this finding still remains controversial (Riggs *et al,* 1982; Holbrook *et al,* 1988). Intestinal lactase deficiency appears to be frequent in osteoporotic patients and 2 factors could contribute to their negative calcium balance (Scrimshaw and Murray, 1988). The first is calcium deficiency due to avoidance of dairy products because of gastrointestinal disturbances associated with the osmotic effect of nonhydrolyzed lactose. The second is impaired calcium absorption from lactose-containing foods because the facilitating effect of lactose on lumen to-blood calcium transfer is suppressed.

In our relatively small group of L(–) subjects, the modest amount of lactose administered with yogurt did not lead to a decrease in FACa. In keeping with this, Smith *et al* (1985) have demonstrated that the quantity of lactose physiologically present in dairy products, either as milk or as yogurt, does not impair calcium absorption in L(–) subjects. Similar results have been obtained by Griessen *et al* (1989), at least in lactase-deficient subjects drinking milk without intestinal discomfort.

CONCLUSION

To conclude, yogurt which is an autodigesting source of lactose, does not impair calcium absorption in L(–) subjects. Moreover, yogurt has an enhancing effect on FACa which was only found to be significant in L(–) subjects. When compared to L(+) subjects, this discrepancy may be due to a lower dietary intake of milk and calcium in L(–) subjects as documented by dietary recall. However we cannot exclude a direct effect of yogurt linked to the amount of hydrolyzed lactose. This latter hypothesis has been challenged by Recker *et al* (1988) who has indicated in postmenopausal women of unknown lactasic activity, that calcium absorbability from milk, yogurt, cheese and calcium carbonate was not significantly different. Nevertheless, in L(–) subjects yogurt may be a substitute for non-fermented dairy products, allowing an adequate calcium diet without intestinal discomfort.

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