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Comparison of the Bioavailability of Calcium from Anchovy, Tofu and Nonfat Dry Milk(NFDM) in Growing Male Rats

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ABSTRACT

This study was to compare the bioavailability of calcium from anchovy and tofu to those of calcium from calcium carbonate($CaCO_3$) as the control diet and non-fat dry milk(NFDM). Rats weighing 50−60g were placed on experimental diets and deionized water at free access for 4 weeks. Diets contained 0.2% calcium from calcium-carbonate, NFDM, anchovy, tofu or 0.5% calcium as calcium-carbonate for control group.

The results obtained were as follows :

1) No significant differences in the apparent absorption of calcium(62.5%−71.0%) were observed in the rats fed four different calcium sources at the level of 0.2% while 0.5% calcium diet group apparently absorbed calcium less efficiently(52.2%).

2) Bone length of tibia and femur was not significantly different among the groups, though 0.5% calcium of control group showed slightly longer length.

3) Tibia fat-free dry weights of 0.2% calcium of NFDM and anchovy diet groups were not significantly different from that of 0.5% calcium of control group. For femurs NFDM, anchovy and tofu groups were similar in their fat-free dry weight to that of 0.5% calcium group.

4) For calcium contents tibia from anchovy treated group showed higher value than calcium-carbonate and tofu groups and the value was not significantly different from that of 0.5% calcium group. In femur NFDM, tofu and calcium-carbonate groups were not significantly different in their calcium content but 0.5% calcium gorup had higher level of calcium than 0.2% calcium groups.

5) The normalized values(NV) show that there was no significant differences in NV among 0.2% $CaCO_3$, anchovy and tofu groups, while NV of NFDM group was significantly lower than that of calcium-carbonate group. NV of 0.5% calcium group was a little more than 50% of those in 0.2% calcium groups.

Though the values obtained for the calcium bioavailability were somewhat variable among experimental products, it was demonstrated that anchovy and tofu are as good as NFDM for the dietary calcium provider when calcium intake is at marginal level.

KEY WORDS : bioavailability of Ca · tofu · anchovy · bone growth.

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Introduction

The major dietary sources of calcium for Korean are vegetable and grain origin, 57.0% of total intake[1], which have been reported as poor sources for calcium availability[2-4]. Phytate, fiber and oxalate in plant are implicated for this[5]. Since dairy products which are highly available calcium sources provide only 10.7% of Korean intake, it is difficult to assure optimum calcium nutrition for Koreans whose average intake is less than RDA, 82.0% of it and an estimated 53.7% of Korean consumed less than 75% of RDA[1].

Chronic low calcium intake has been implicated in the development of osteoporosis, bone fracture, atherosclerosis and hypertension[6-10]. Recently some investigators advise to take higher amount of calcium than present RDA to prevent or postpone the appearance of adverse clinical symptoms of these aging related diseases[11-13]. While there is an advocation for the supplementation of the diet with marketed calcium supplements, it would be more recommendable to utilize normal foods of highly bioavailable calcium sources to maximize bone mass in growth period and to protect from bone loss in the elderly.

Several previous studies[14-16] examined the bioavailavility of calcium from daily foods such as nonfat dry milk(NFDM), cheese, tofu, spinach, cheese, bread, almond powder and sesame seeds and found relative bioavailability is quite variable from 47% of spinach to 100% of NFDM. Anchovy and tofu are widely used for side-dishes in Korea and provide considerable amounts of calcium. Professionals estimate that an average intake of calcium for Korean adult is 491.8mg/day and 10% of total daily calcium intake is from anchovy and 20% from tofu[1]. However, there is few data for their calcium bioavailability compared to the dairy products which are major calcium source in western countries. The major objective of this study is to compare the bioavailability of calcium in anchovy and tofu with that of calcium carbonate or calcium in milk in the aspects of absorption and the growth of bones in growing animals.

Materials and Method

1. Animals and general care

Forty male weanling Sprague-Dawley rats weighing 50~60g were purchased(Seoul National Univ. Animal Room) and housed individually in stainless steel, wire-bottomed cages in a temperature and light-controlled environment. The animal room was maintained at 20±2℃ and with a 12-h light/12-h dark cycle. Cages were washed beforehand with ethylene diamine tetraacetic acid (EDTA) solution and rinsed by deionized water. After adaptation of three days on rat chow, rats were placed on experimental diets and deionized water at free access for 4 weeks. Food intake and weight gain were measured twice a week.

2. Diet preparation

Diets were formulated to contain 20% protein, 5% fat, 0.2% calcium(a marginal dietary calcium level for the rat whose requirement is 0.5% of diet)[17] and 0.4% phosphorus. For normal control diet, 0.5% calcium casein-base diet was prepared. The calcium in each diet was provided by the experimental product and calcium carbonate ($CaCO_3$) was the calcium source in the casein-base diets. Dried medium size anchovy and calcium sulfate ($CaSO_4$)-precipitated tofu(Pulmuwon Co.) were purchased locally. They were freeze-dried(Labcon Co, USA) and ground in a blender to pass 50 mesh screen. The nonfat dry milk was a commercial product(Seoul Milk Co.).

Protein was provided by the calcium source and/or by casein. Corn oil was added to all the diets except tofu diet up to 5% fat of the diet. Five kilograms of each diet was made and refrigerated until use. The composition of calcium sources and experimental diets are presented in Tables 1 and 2, respectively.

3. Analysis of calcium sources and experimental diets

Proximate analyses for moisture, lipid, protein, ash, phosphorus and calcium of calcium sources and the experimental diet were performed by procedures based on AOAC(1980)[18]. Three random samples per each diet were analyzed. Atomic ab-

Table 1. Composition of freeze-dried calcium sources[1)]

Test food	Water	Protein	Lipid	Ash	Carbohydrate	Calcium	Phosphorus
					gram/100 gram		
Casein	4.50	91.70	0.51	1.00	2.29	0.02	0.68
NFDM[2)]	3.30	35.20	1.00	7.00	53.50	1.70	1.15
Anchovy	16.70	45.00	6.70	17.40	14.20	2.00	1.55
Tofu	6.70	49.00	28.20	3.70	12.40	0.80	1.01

1) Values are means of 3 determinations.
2) Nonfat dry milk(Seoul Milk Co., Seoul, Korea)

Table 2. Diet compositions for experimental groups

Ingredient	Experimental Groups				
	0.5% $CaCO_3$	0.2% $CaCO_3$	NFDM	Anchovy	Tofu
				gram/kg diet	
Product[1)]	–	–	11.76	100.0	250.0
Casein[2)]	218.1	218.1	173.0	169.0	84.5
Corn oil	49.0	49.0	48.8	52.6	–
Vitamin mix[3)]	10.0	10.0	10.0	10.0	10.0
Mineral mix[4)]	40.0	40.0	40.0	40.0	40.0
α-Cellulose[5)]	50.0	50.0	50.0	50.0	50.0
Choline chloride	2.0	2.0	2.0	2.0	2.0
KH_2PO_4	18.0	18.0	11.6	11.0	6.6
Corn starch	597.4	604.9	544.0	572.4	533.9
DL-methionin	3.0	3.0	3.0	3.0	3.0
$CaCO_3$	12.5	5.0	–	–	–

1) Nonfat dry milk(NFDM), anchovy and tofu were provided as sole source of calcium
2) Casein, 91.7% purity
3) Vitamin mix. was made by based on AIN-76 vitamin mixture(g/kg) : P-aminobenzoic Acid, 11.0132 ; Ascorbic Acid, 101.6604 ; Biotin, 0.0441 ; Vitamin B_{12}, 2.9736 ; Calcium Pantothenate, 5.5000 ; Folic Acid, 0.1982 ; Inositol, 11.0132 ; Menadion(Vitamin K_3), 4.9559 ; Niacin, 9.9119 ; Pyridoxine-HCl, 2.2026 ; Riboflavin; 2.2026 ; Thiamin-HCl, 2.2026 ; Vitamin A-Palmitate(IV), 2000,000 ; Vitamin D_2(IV), 200,000 ; α-1-tocopherol, 1.0000 ; Corn Starch, 713.1217
4) Mineral mix. was made by based on AIN-76 mineral mixture(g/kg) ; Ammonium Molybdate, $(NH_4)Mo_7O_{24}4H_2O$, 0.025 ; Cupric Sulfate, $CuSO_4$, 1.5601 ; Ferric Citrate, 6.2303 ; Mgnesium Sulfate, $MgSO_4H_2O$, 99.8055 ; Manganese Sulfate, $MnSO_4H_2O$, 1.2101 ; Potassium Iodide, KI, 0.0050 ; Sodium Chloride, NaCl, 250.6138 ; Sodium Selenite, Na_2SeO_3, 0.0150 ; Zinc Chloride, $ZnCl_2$, 0.20 ; Corn Starch, 640.34
5) α-Cellulose, Sigma

sorption spectrophotometry(GBC Scientific Equipment PTY. LTD. MODEL 903, USA) was used to determine calcium content of calcium sources and the diets following dry ashing and diluting by ten times with 1% lanthanum chloride (Tokyo Chem.) solution.

4. Determination of apparent absorption of calcium

Three days fecal samples were collected on the day of 25th to 27th of feeding period. They were cleaned of foreign adhering matter, dried to constant weight and ground to fine powder. Calcium concentration in feces was determined by atomic absorption spectrophotometer following dry ashing and diluting by ten times with 1% lanthanum chloride solution. Apparent absorption of calcium was based on [total daily calcium intake (mg) − total daily fecal calcium output(mg)]/total daily calcium intake(mg).

Table 3. Proximate analysis of the experimental diets[1)]

Diet group	Moisture	Crude fat	Calcium	Phosphorus
		gram/100gram diet		
0.5% $CaCO_3$	6.15	4.80	0.47	0.46
0.2% $CaCO_3$	6.58	5.01	0.18	0.43
NFDM	6.05	4.84	0.19	0.42
Anchovy	6.20	4.96	0.19	0.46
Tofu	6.53	5.35	0.18	0.47

1) Values are means of three determinations

5. Determinations of fat free dry weight, ash weight and calcium content of bones.

After 4 weeks of feeding, animals were fasted overnight and anesthetized by ether. Left legs were excised and kept frozen at −20℃ until analysis. Upon analysis samples were thawed and tissue was removed by autoclaving. Length and weight of wet bones were measured. The lipid in tibia and femur was extracted in Soxhlet apparatus with diethyl ether for 24h and dried in an oven at 95℃ for 24h and stored in a dessicator until they were weighed. Afterward bones were ashed in a muffle furnace at 600℃ for 25h for ashed bone weights. Bone ash was then dissolved in 10 ml of 50% HCl and diluted with 1% lanthanum chloride solution for calcium determinaton by atomic absorption spectrophotometry.

6. Statistical analyses

Data entry and processing were done by SPSS/PC+ for basic statistical analyses. Statistical significances of the data were analzed by one-way analysis of variance and the difference among groups were determined by Duncan's multiple range test. All values were reported as mean± SEM.

Table 4. Body weight, daily food intake and food efficiency ratio(FER)[1)]

Diet group	Initial body wt.(g)	Final body wt.(g)	Daily wt. gain(g)	Daily food intake(g)	FER[2)]
0.5% $CaCO_3$(n=5)	68.2± 2.3^{NS}	197.2± 6.7^{ab}	4.76± 0.21^{ab}	10.9± 0.4^{a}	0.44± 0.01^{b}
0.2% $CaCO_3$(n=7)	69.0± 1.1	186.1± 5.4^{a}	4.34± 0.17^{a}	11.2± 0.4^{a}	0.39± 0.01^{a}
NFDM(n=7)	70.9± 1.3	211.5± 7.5^{b}	5.21± 0.26^{b}	13.1± 0.4^{b}	0.40± 0.01^{ab}
Anchovy(n=5)	71.9± 1.6	216.0± 9.6^{b}	5.34± 0.35^{b}	13.3± 0.2^{b}	0.40± 0.02^{ab}
Tofu(n=7)	70.7± 0.9	207.6± 4.1^{b}	5.07± 0.16^{b}	12.5± 0.4^{b}	0.41± 0.02^{ab}

1) Values are Mean± SEM.
2) FER : Food efficiency ratio=(Daily weight gain, g/Daily food intake, g)
a,b : different superscripts within the same column are significantly different by Duncan's multiple range test at $p<0.05$
NS : Not significant

Results and discussion

1. Body weight gain and Food efficiency ratio

Data for body weight and food intake are shown in Table 4. The weight gain was lower in the group fed 0.2% calcium-carbonate diet than those of NFDM, anchovy and tofu groups and there was no significant difference among 0.5% calcium-carbonate, NFDM, anchovy and tofu groups. Food efficiency ratios(FERs) were similar among groups. However FER of 0.5% calcium with calcium-carbonate, 0.44, was significantly higher than that of 0.2% calcium with calcium-carbonate, 0.39. These results indicate that dietary calcium level of 0.2% did not distinctively restrict the growth of animals, though either calcium-carbonate provided as calcium source or casein as protein source appear to have reduced the food intake compared to the other natural dietary sources of tofu, NFDM and anchovy.

Table 5. Apparent absorption of calcium in different diet groups[1)]

Diet group	Ca intake (mg/day)	Fecal calcium (mg/day)	AAC[2)] (%)
0.5% $CaCO_3$ (n=5)	79.3± 5.61^a	37.1± 1.96^b	52.2± 4.7^a
0.2% $CaCO_3$ (n=7)	29.8± 1.07^a	10.6± 0.68^a	64.4± 2.2^b
NFDM (n=7)	32.4± 1.05^a	9.2± 0.91^a	71.4± 3.3^b
Anchovy (n=5)	31.1± 0.22^a	11.7± 1.31^a	62.5± 4.1^{ab}
Tofu (n=7)	33.5± 1.70^a	9.8± 1.11^a	71.0± 7.0^b

1) Values are Mean± SEM
2) Apparent Absorption of Calcium
a,b : different superscripts within the same column are significantly different by Duncan's multiple range test at $p<0.05$
ns : Not significant

2. Apparent absorption of calcium

Apparent absorption was measured by the differences between the total calcium intake and fecal calcium output during the last three days of this study. There was no significant difference in the apparent absorptions in four different dietary calcium sources at 0.2% calcium level showing slightly higher values in NFDM and tofu diet groups(Table 5). Many previous studies showed that intestinal absorption of dietary calcium is limited average of 30% in human adult[5)19)]. Especially in plant origin foods such as spinach and soybean the presence of oxalate and phytate are accused of the drastic reduction in absorption resulting in less than 10%[5)]. In this study tofu, the soybean product may have less amount of phytate than would affect the absorption negatively. Also the physiological state of rapid growth and marginal level of intake facilitate the high absorption, 62.5~71.4%, observed in the present study. Previous reports by other investigators showed similar[20)] or higher range[11)] of absorption efficiency.

Different calcium sources in this study also differ in their protein composition such as milk protein, fish protein and soy protein. Previous studies indicated that true absorption would be influenced by the kind of dietary proteins by altering the urinary excretion of calcium[19)21)22)]. However the intestinal absorption was not affected by the source of protein as shown in Table 5. Pie and Paik[13)] also reported that fecal excretion of calcium was not affected by two different dietary protein sources, meat and soy protein when human subjects took 600mg of calcium daily.

The amount of calcium intake in 0.5% calcium-carbonate group was above two fold of other groups and the fecal output was over three fold. Accordingly significant decrease in the efficiency of absorption was observed. It has been known that the efficiency of absorption usually increases with the low level of calcium intake. This tendency may be facilitated by improved active transport[5] and adaptation to the low intake. Similar physiological adaptation would be anticipated in the excess intake of calcium. Recent study with ovarectomized rats there was no difference in total calcium absorption between 1.06% level of dietary calcium and 0.53%[11]. Though the authors indicated the supplementation of calcium be beneficial for osteoporosis the data present doubt on the efficacy of high dose calcium supplementaion because of their drastic reduction in absorption efficiency by increased intake.

3. Bone growth and calcium retention in the bone

The data for bone length, weight and calcium content of tibia and femur are shown in Table 6. The dietary treatments of different calcium level and calcium source had no significant effect on the length of tibia and femur. Though the control group of 0.5% calcium diet showed a little longer bone length. Fat-free dry weight and ash weight of total bone are similar to the values repo-

Table 6. Weights, lengths, ash weight and Ca contents of tibia and femur from rats fed experimental diets[1)]

Diet group	Length (cm)	Wet wt. (g)	Fat-free dry wt. (g)	Total Ash (g)	Total Ca content (mg)	BC/DB[2)] (%)	BC/BA[3)] (%)
Tibia							
0.5% CaCO3 (n=5)	3.20 ± 0.06^{NS}	0.38 ± 0.03^{b}	0.18 ± 0.01^{b}	0.12 ± 0.01^{b}	68.70 ± 2.41^{b}	38.36 ± 2.67^{NS}	61.06 ± 5.13^{a}
0.2% CaCO3 (n=7)	3.06 ± 0.05	0.27 ± 0.01^{a}	0.14 ± 0.00^{ab}	0.08 ± 0.00^{a}	53.71 ± 1.97^{a}	36.56 ± 1.19	64.71 ± 4.42^{ab}
NFDM (n=7)	3.07 ± 0.08	0.27 ± 0.02^{a}	0.14 ± 0.01^{ab}	0.07 ± 0.00^{a}	56.71 ± 3.55^{ab}	39.66 ± 1.94	79.96 ± 3.59^{b}
Anchovy (n=5)	3.10 ± 0.03	0.30 ± 0.02^{ab}	0.16 ± 0.01^{b}	0.09 ± 0.01^{a}	62.20 ± 3.11^{b}	38.00 ± 1.13	73.60 ± 5.12^{ab}
Tofu (n=7)	3.06 ± 0.06	0.34 ± 0.02^{b}	0.14 ± 0.01^{a}	0.08 ± 0.01^{a}	52.79 ± 2.26^{a}	39.34 ± 2.08	68.27 ± 5.45^{ab}
Femur							
0.5% CaCO3 (n=5)	2.73 ± 0.04^{NS}	0.46 ± 0.04^{b}	0.21 ± 0.02^{b}	0.13 ± 0.01^{b}	78.80 ± 2.53^{c}	38.60 ± 2.49^{NS}	60.44 ± 4.59^{a}
0.2% CaCO3 (n=7)	2.61 ± 0.04	0.35 ± 0.03^{a}	0.17 ± 0.01^{a}	0.10 ± 0.00^{a}	61.21 ± 1.61^{a}	36.06 ± 1.46	60.73 ± 2.75
NFDM (n=7)	2.55 ± 0.07	0.37 ± 0.02^{ab}	0.18 ± 0.01^{ab}	0.10 ± 0.01^{a}	64.14 ± 3.55^{ab}	36.33 ± 1.58	66.44 ± 3.09
Anchovy (n=5)	2.63 ± 0.04	0.39 ± 0.01^{ab}	0.19 ± 0.01^{ab}	0.10 ± 0.01^{a}	69.60 ± 2.87^{b}	35.96 ± 0.96	71.42 ± 1.89
Tofu (n=7)	2.63 ± 0.06	0.42 ± 0.01^{b}	0.18 ± 0.01^{ab}	0.10 ± 0.01^{a}	62.07 ± 1.71^{ab}	36.07 ± 2.58	65.31 ± 4.28

1) Values are Mean± SEM
2) Total Bone Calcium(mg)/Defatted Total Bone Weight(mg)×100
3) Total Bone Calcium(mg)/Total Bone Ash(mg)×100
a,b : different superscripts within the same column are significantly different by Duncan's multiple range test at $p<0.05$
NS : Not significant

rted in previous studies[12)15)16)]. However the total calcium content of both bones, 52~69mg for tibia, 61~79mg for femur are somewhat greater than others, 44~64mg for tibia[15)], 44~58mg for femur [12)], and the cause of this variation is uncertain. The amount of calcium and ash in the whole bone appears to respond either to the dietary calcium sources or levels(Table 6). Fat-free dry weights of tibia from 0.5% calcium-carbonate, NFDM and anchovy diet groups and those of femurs from 0.2% calcium diet groups were not significantly different. Ash content of tibia and femur did not differ significantly among experimental calcium sources, however they appear to respond to the total amount of calcium absorbed as showing high ash deposition in 0.5% calcium group.

More than 99% of the calcium in the body is present in the bone mass. Thus calcium content in the bone could serve as an indicator of dietary calcium availability, rather valid than apparent absorption of calcium. The limitation would be some different responses among bones presumably because of their different growth spurt and the importance of body maintenance. The calcium content in two different bones in this study showed complex response(Table 6), but it can be said that 0.2% level of dietary calcium is marginal for bone growth when the calcification process was evaluted as bone ash and calcium content rather than the length of bones. Anchovy appears to provide more readily available calcium for bones. And higher calcium intakes up to optimum intake(0.5%) induce higher bone calcium deposition as shown in many studies[15)21)]. Recent reports demonstrated the histological evidence for bone development with various calcium sources either dietary or supplements and argued the bioavailability[10)13)]. Previous study by Kim et al.[15)] showed that the source of protein affected bone calcium and ash deposition. In their study casein, white fish protein and gluten were examined and showed casein was the most effective one in bone ash deposition in growing rats, which is contrary to the present study. It is difficult to draw any conclusion from these data whether casein is better source than fish protein or soy protein for bone calcification.

To eliminate any effect of diets on other components of bone, the total bone calcium content (BC) as percentage of fat-free dry weight(DB) or ash(BA) was used for the bioavailability of dietary calcium[16)]. The values for BC/BA and BC/DB in this study are 60~80% and 36~40%, respectively and they are greater than others showing under similar experimental conditions 38~40% for BC/BA[15)] and 24~26% for BC/DB[12)].

Table 7. Relative bioavailability of calcium found in bones from various calcium sources[1)]

Diet group	Normalized value[2)]	Relative bioavailability[3)]
Tibia		
0.5% $CaCO_3$ (n=5)	36.54± 1.86[a]	51.8%[a]
0.2% $CaCO_3$ (n=7)	70.58± 1.77[c]	100.0%[c]
NFDM (n=7)	61.81± 3.30[b]	87.6%[b]
Anchovy (n=5)	66.33± 2.80[bc]	94.0%[bc]
Tofu (n=7)	63.38± 3.22[bc]	89.8%[bc]
Femur		
0.5% $CaCO_3$ (n=5)	41.84± 1.68[a]	50.8%[a]
0.2% $CaCO_3$ (n=7)	82.32± 3.12[c]	100.0%[c]
NFDM (n=7)	69.95± 3.94[b]	84.9%[b]
Anchovy (n=5)	74.18± 2.02[bc]	90.1%[bc]
Tofu (n=7)	74.76± 3.70[bc]	90.8%[bc]

This discrepancy seems mainly due to higher total calcium content of bone as mentioned above. Values for BC/BA in tibia shown in Table 6 indicate NFDM is superior to other experimental calcium sources and calcum-carbonate is the inferior one. On the other hand, values for BC/DB and BC/BA in femur showed no difference upon calcium sources and levels. This may indicate the validity of these criteria and selection of the bone to represent whole body bones need further examination.

4. Relative bioavailability

Other reports on calcium bioavailability showed much difference in food intake due to different calcium source and they utilized normalized value to evaluate bioavailability[16]. Normalized value(NV) was obtained by dividing tibia or femur calcium(mg) by total calcium intake(g) to correct the differences in calcium intakes among diet groups. Relative calcium bioavailability was determined by arbitrarily setting NV of 0.2% calcium-carbonate at 100%. The relative BV(RBV) for tibia and femur were 100%, 100% for calcium-carbonate, 87.6%, 84.9% for NFDM, 94.0%, 90.1% for anchovy and 89.8%, 90.8% for tofu, respectively. There was no significant difference in RBV among 0.2% calcium-carbonate, anchovy and tofu calcium and they were higher than RBV for NFDM. In agreement with this study, the study of Poneros and Erdman[14] also showed the RBV of tofu(107%) was significantly higher than that of NFDM(95%), and those of tofu and calcium-carbonate(100%) were not different. Fiber content and phytic acid presence in soy products have been one of the concern that may inhibit the availability of calcium. The results of present study and others indicate that calcium-sulfate or calcium-carbonate precifitated tofu provides highly available calcium rather superior to the calcium in NFDM. This may partly due to the beneficial effect of plant protein than animal protein in the aspect of calcium balance as reported by Pie and Paik[21].

While some values for calcium bioavailability within the same experimental source are variable in different bones, it may be due to different rate and time of bone growth in tibia and femur. It can be concluded that all tested products in the present study are highly bioavailable calcium sources. Of particular interest is that calcium from anchovy and tofu are readily available for the deposition of calcium in bones. Tofu and anchovy are used widely in daily meal preparation, thus sufficient consumption of these foods and calcium-enriched soy products as tofu and soy milk can be an important contributor for the calcium nutrition for the individuals who avoid dairy products because of lactose intolerance, food habit, and concern for hypercholesterolemia.

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= 국문초록 =

칼슘공급원으로서 건멸치, 두부, 탈지분유의 체내이용성 연구

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본 연구는 한국인의 주요 칼슘공급원인 건멸치와 두부의 칼슘 체내이용효율을 탈지분유나 탄산칼슘 중의 칼슘 이용효율과 비교 분석하고자 하였다.

체중 50~60g의 이유된 흰쥐를 0.5% 칼슘의 대조군, 0.2% 칼슘 수준의 탄산칼슘군, 탈지분유군, 멸치군 및 두부군의 다섯군으로 나누어 실험식이와 탈이온수를 4주동안 자유섭취 방법으로 공급하였다. 식품 중 칼슘의 체내이용성 지표로 칼슘의 흡수율, 뼈의 길이 및 칼슘함량 등을 측정하여 분석한 결과는 다음과 같다.

1) 칼슘흡수율은 0.2% 칼슘수준의 식이를 섭취한 실험군간에는 유의적인 차이가 없었고(62.5~71.4%), 0.5% 칼슘수준의 대조군이 다른 군들에 비해 유의적으로 낮았다(52.3%).

2) 뼈 길이는, 경골과 대퇴골 모두 실험군간에 유의적인 차이를 보이지 않았지만, 0.5% 칼슘의 대조군이 다른 실험군들에 비해 다소 높게 나타났다.

3) 탈지건조무게는 경골(Tibia)의 경우 대조군과 0.2% 칼슘군들간에 유의적인 차이가 없었고, 대퇴골(Femur)의 경우 대조군, 탈지분유군, 멸치 및 두부군간에 유의적인 차이를 보이지 않았으나 0.2% 탄산칼슘군에서 유의적으로 낮았다.

4) 총 회분량은 대조군이 경골과 대퇴골에서 유의적으로 높게 나타났다. 칼슘함량은 경골에서 0.2% 칼슘군 중 멸치군이 탄산칼슘군이나 두부군보다 유의적으로 높았고 0.5% 대조군과는 차이가 없었다. 대퇴골에서는 대조군이 유의적으로 높았으며 멸치군, 탈지분유군, 두부군의 순으로 높게 나타났다.

5) 총 칼슘섭취량에 대한 경골과 대퇴골의 칼슘함량을 NV(Normalized Value)라 하였을 때, 0.2% 칼슘수준에서 NV는 탄산칼슘군, 멸치군, 두부군, 탈지분유군의 순으로 높게 나타났고, 탈지분유군만이 탄산칼슘군보다 유의적으로 낮았다. 0.5% 칼슘군의 NV는 0.2% 군들의 50% 수준이었다.

본 연구에서 조사된 칼슘공급원의 이용효율은 측정방법에 따라 다소 차이를 보이지만, 칼슘섭취가 marginal(0.2%)한 수준에서 멸치와 두부는 칼슘공급원으로서 우유에 못지않은 효과가 있음이 증명되었다.