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Carnitine Content of Common Korean Foods

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Abstract

Carnitine is considered a conditionally essential nutrient because dietary sources may become important under conditions which either reduce biosynthesis or increase urinary excretion of carnitine. Therefore, it is important to have a database for dietary analysis for carnitine content. Because there is limited data available for the carnitine content of Korean foods, this study was undertaken to analyze the total carnitine (TCNE) content of 146 commonly consumed Korean foods. TCNE concentrations were assayed using a modified radioisotopic method. Beef and pork contained 91.09 and 17.21 mg TCNE / 100 g weight, respectively. Fish and shellfish ranged from 0.28 to 24.87 mg TCNE / 100 g weight. TCNE concentration in milk was 1.77 mg / 100 mL and cheese was 0.49 mg / 100 g weight. Cereals and pulses contained between 0 and 1.43 mg TCNE / 100 g weight. The TCNE concentration of most fruits and vegetables was between 0 and 0.7 mg / 100 g weight. However, mushrooms contained between 2.77 and 7.02 mg of TCNE / 100 g weight. Soy sauce, soybean paste and fermented red pepper soybean paste contained 1.05, 0.28 and 0.5 mg TCNE / 100 g weight, respectively. These results demonstrate that TCNE concentrations are high in meat, fish, shellfish and milk, but low or non-existent fruits and vegetables. However, mushrooms are a substantial source of vegetable derived TCNE. These data will be useful in establishing a database for determining the TCNE content of Korean diets.

Key words: carnitine, Korean foods, database

INTRODUCTION

L-carnitine (β-hydroxy-γ-trimetylamino butyrate) is a water-soluble amine considered to be a conditionally essential nutrient in humans. Carnitine is synthesized in liver and kidney from two essential amino acids, lysine and methionine, and transported in blood to other tissues (1,2). The rate of carnitine biosynthesis is estimated to be about 1.2 μmol / kg b.w. / day (3). Carnitine serves two major functions in the body. First, its best known role is in facilitating entry of long-chain fatty acid into the mitochondrial matrix for utilization in energy-generating processes. Second, carnitine also facilitates removal from mitochondria of short-chain and medium-chain fatty acids that accumulate as a result of normal and abnormal metabolism (4-6). Therefore, carnitine is considered to be essential for normal lipid metabolism.

Major sources of carnitine in the human diet are meat (i.e. beef, sheep, pork) and dairy products (7-9). Because only a select group of foods contribute substantial amounts of carnitine, dietary intakes of carnitine are highly variable. A study in the United States reported that the daily intake of carnitine was typically between 2 and 100 mg but, as much as 300 mg in some cases (10,11). As cereals, fruits and vegetables contain little or no carnitine, the major source of carnitine in vegetarian diets was the fermented soybean product tempeh (3,4). Under normal conditions, in omnivores, about 70 ~ 80% of dietary carnitine is absorbed (12,13). Thus, carnitine synthesis normally provides only one-eighth to one-half of total carnitine available to the organism (4). The daily requirements for carnitine are unknown for humans.

Tanphaichitr and co-workers (14) determined plasma carnitine concentrations in Thai residents of Bangkok (well nourished, with diets including meat, fish and rice) and Ubol (a rural province in Northeast Thailand; diets consisting mainly of rice and raw, fermented fish). Plasma carnitine was lower, but not significantly, in the Ubol residents, but urinary carnitine excretion was much lower and statistically significant. These differences may stem from the predominantly cereal (rice) diets consumed by Ubol residents; which contained little carnitine and were limiting in lysine, the essential amino acid precursor of carnitine. Khan-Siddiqui and co-workers (15) estimated that the carnitine intake of normal Indian men, consuming primarily cereal grain diets, was 9 ~ 15 mg per day, or approximately 15% of the intake from an average Western diet. Clearly, carnitine intake is very low in diets con-

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sisting mainly of plant foods.

Possibly because carnitine has only recently become available as a dietary supplement in Korea, there have been few studies of carnitine status or dietary intake in the Korean population, and there is no data on the carnitine content of commonly consumed Korean foods. Therefore, we analyzed the carnitine content of commonly consumed Korean foods data that will be useful in establishing a database for determining the carnitine content of Korean diets and the carnitine intake of Korean people.

MATERIALS AND METHODS

Sample collection and preparation

Carnitine content was determined in 146 common Korean foods. The selected Korean foods consisted of 14 kinds of cereals 17 types of potatoes, sugars, pulse, nuts and seeds 40 kinds of vegetables, mushrooms and seaweeds 14 fruits 37 different meats, fish and shellfishes 10 kinds of eggs, dairy products and fats and 14 types of seasonings and beverages. Food samples were purchased from a city mart and local market in the chonju area.

Samples were homogenized in 0.3 M cold perchloric acid (PCA) and centrifuged at 1660×g for 10 min. The supernatant was collected and stored at -70°C until assayed.

Carnitine assay

Total carnitine was assayed using a radioisotopic method of Cederblad and Lindstedt (16), as modified by Sachan and Rhew. (17). Carnitine was assayed by using carnitine acetyltransferase to esterify the carnitine to [^{14}C]acetate from [1-^{14}C] acetyl CoA to make [^{14}C] acetylcarnitine.

A 100 µL sample was hydrolyzed with 200 µL of 0.5 N KOH at 65°C for 60 min in a shaking water bath (100 spm), and then neutralized with 150 L of PCA/MOPS I solution {1 M 3-(4-morpholino) propane sulfonic acid in 0.6 M PCA}. After cooling in ice, the samples were centrifuged at 1500×g for 10 min and 100 µL of the supernatant was added to 400 µL of reagent mix; (120 µL of 1 M MOPS buffer, pH 7.4; 20 µL of 0.1 M potassium ethyleneglycoltetraacetate pH 7.0; 20 µL of 0.1 M sodium tetrathionate; 200 µL of 0.1 mM [1-^{14}C] acetyl CoA solution and 40 µL of glass distilled water). The reaction was started by 1 unit of carnitine acetyl transferase and carried to completion by incubating at 37°C for 30 min. A 200 µL aliquot of the incubation mixture was charged on to a 1×4.5 cm column packed with ion exchange resin (AG 1×8,200 to 400 mesh, Cl-form). The [1-^{14}C] acetyl carnitine was eluted from the column into a scintillation vial by two 0.5 mL portions of distilled water and counted in 10 mL of liquid scintillation fluid (8.25 g PPO and 0.25 g POPOP per 1 L of toluene) containing 33% (v/v) Triton X-100. Radioactivity of samples was determined in a Beckman LS-3801 liquid scintillation counter (Beckman Instruments, Palo Alto, USA).

Data analysis

Each sample was determined duplicate analyses and carnitine content was expressed as an average value. The total carnitine value was expressed as milligrams and micromoles per 100 g weight of the food.

RESULTS AND DISCUSSION

Carnitine content of cereals

The levels of total carnitine (TCNE) in cereals are shown in Table 1. Rice and glutinous rice contained 0.01 mg TCNE / 100 g wt. and Kareadok and Mujigaedok made of rice contained no TCNE. The carnitine concentrations in rice were similar to those reported by Rebouche et al. (18), and slightly lower than those reported by Giovannini et al. (8), Tanphaichitr et al. (14) and Gustavsen (19). Sweet corn (steamed) had no carnitine and barley, Job's tears, and Foxtail millet contained 0.02, 0.2 and 0.39 mg TCNE / 100 g wt., respectively. The carnitine content of barley seed was similar to that obtained by Panter et al. (20), and corn was similar to that by Mitchell (21). Buckwheat flour contained 0.03 mg TCNE / 100 g wt. and wheat flour had no TCNE. Noodles did not contain TCNE and Ra Myon contained 0.62 mg TCNE / serving. Corn flakes (cereal) did not contain TCNE and loaf bread contained 0.04 mg TCNE / 100 g wt. The carnitine content of corn flakes was similar to the values reported by Rebouche et al. (18), and bread was slightly lower than those reported by Rebouche et al. (18), Giovannini et al. (8) and Gustavsen (19). The TCNE content of cereals was consistently absent or found at very low levels.

Carnitine content of potatoes, sugars, pulses, nuts and seeds

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Table 1. Carnitine content of cereals

Foods	mg/100 g wt.	µmol/100 g wt.
Rice (well-milled)	0.01	0.06
Glutinous rice (milled)	0.01	0.06
Barley (whole grain)	0.02	0.02
Sweet corn (steamed)	ND[1)]	ND
Job's tears (milled)	0.2	1.23
Foxtail millet	0.39	2.41
Buckwheat flour	0.03	0.19
Wheat flour (medium flour)	ND	ND
Noodles (dried)	ND	ND
Ra Myon	0.64*	3.83*
Kareadok	ND	ND
Mujigaedok	ND	ND
Corn flakes (cereals)	ND	ND
Loaf bread	0.04	0.25

[1)]ND: not detectable. *mg or µmol/1 serving.

shown in Table 2. Potatoes and sweet potatoes contained 0.03, and 0.11 mg TCNE / 100 g wt., respectively and starch vermicelli had no TCNE. The carnitine content of potatoes in this study was similar to that reported by Rebouche et al. (18) and Giovannini et al. (8), but slightly lower than that by Gustavsen (19). Sugars and honey contained no TCNE and chocolate contained 4.21 mg TCNE / 100 g wt. Kidney beans had relatively high levels of 1.34 mg TCNE / 100 g wt., among pulses. Peas contained 0.11 mg TCNE / 100 g wt., and yellow soybeans and red beans had none. Soybean curd did not contain TCNE, but soybean milk contained 0.06 mg TCNE / 100 mL. The carnitine content of peas was similar to those reported by Gustavsen (19), slightly higher than that by Rebouche et al. (18), and slightly lower than that by Giovannini et al. (8) Among nuts and seeds, peanuts and gingko nuts contained 0.06 mg TCNE / 100 g wt. but chestnuts had no TCNE. Pine nuts and walnuts contained 0.03, and 0.04 mg TCNE / 100 g wt., respectively. Sesame seeds did not contain TCNE. The concentration of carnitine in peanuts, chestnuts and walnuts were slightly lower than reported by Gustavsen (19).

Carnitine content of vegetables, seaweeds, and mushrooms

TCNE was absent or found in very low levels (0.01 ~ 0.7 mg TCNE per 100 g) in most of the vegetables (Table 3). Dried sweet potato stems have a relatively high level, 0.7 mg TCNE / 100g wt., compared to most vegetables. Garlic bulb, carrot and eggplant each contained 0.1 ~ 0.21, sweet pepper 0.06, and onion 0.04 mg TCNE / 100 g wt. Sweet potato stalk, mung bean spouts, green onion, leek, and ginger root each contained 0.03 mg TCNE / 100 g wt. The TCNE contents of soybean sprouts, spinach, green pepper, lettuce, Korean radish root (Daikon), Korean cabbage (Napa) and wild garlic were 0.02 mg / 100 g wt. Doraji (bellflower root) contained 0.01 mg TCNE / 100 g wt., and carnitine was undetectable in cucumber, braken, perilla leaf, cabbage, squash, water dropwort, chwi namul, crown daisy, yul mu (white radish), mallow, stem of taro and tomato. Carnitine contents of carrot, lettuce and spinach in

Table 2. Carnitine content of potatoes, sugars, pulses, nuts and seeds

Foods	mg/100 g wt.	μmol/100 g wt.
Potatoes		
Potatoes	0.03	0.19
Sweet potatoes, stalk	0.11	0.68
Starch vermicelli	ND[1)]	ND
Sugars		ND
Honey	ND	
Chocolate	4.21	25.99
Pulses		
Kidney beans	1.43	8.83
Yellow soybeans	ND	ND
Peas	0.11	0.68
Red beans	ND	ND
Soybean curd	ND	ND
Soybean milk	0.06*	
Nuts and seeds		0.37*
Peanuts	0.06	0.37
Chestnuts	ND	ND
Gingko nuts	0.06	0.37
Pine nuts	0.03	0.19
Walnuts	0.04	0.25
Sesame	ND	ND

[1)]ND: not detectable. *mg or μmol / 100 mL.

Table 3. Carnitine content of vegetables, seaweeds and mushrooms

Foods	mg /100 g wt.	μmol /100 g wt.
Vegetables		
Cucumber	ND[1)]	ND
Sweet potato stalk (dried)	0.73	4.51
Soybean sprout	0.02	0.12
Mungbean spout	0.03	0.19
Braken (boiled)	ND	ND
Doraji (bellflower root)	0.01	0.06
Sweet pepper (green)	0.06	0.37
Spinach	0.02	0.12
Perilla leaf	ND	ND
Green pepper	0.02	0.12
Green onion (large)	0.03	0.19
Lettus	0.02	0.12
Leek	0.03	0.19
Cabbage	ND	ND
Squash (immature)	ND	ND
Water dropwort	ND	ND
Korean radish root (Daikon)	0.02	0.12
Korean cabbage (Napa)	0.02	0.12
Onion	0.04	0.25
Carrot	0.1	0.62
Eggplant	0.1	0.62
Garlic, Bulb	0.21	1.30
Ginger root	0.04	0.25
Wild garlic	0.02	0.12
Chwi Namul	ND	ND
Crown daisy	ND	ND
Yul Mu	ND	ND
Mallow	ND	ND
Stem of taro (boiled)	ND	ND
Tomato	ND	ND
Parsley	ND	ND
Seaweeds		
Sea lettuce	0.06	0.37
Laver (dried)	ND	ND
Sea mustard (dried)	0.07	0.43
Sea tangle (dried)	0.01	0.06
Sea mustard, stem	0.03	0.19
Mushrooms		
Oyster mushroom	7.02	43.33
Flammulina velutipes	3.29	20.31
Lentinus edodes	2.77	17.10
Agaricus bisporos	3.87	23.89

[1)]ND: not detectable.

this study were slightly higher than reported by Rebouche et al. (18), Giovannini et al. (8) and Panter et al. (20), but similar to those reported by Gustavsen (19). Carnitine content of eggplant and ginger root were similar to those obtained by Gustavsen (19), and squash and cucumber were slightly lower than those of Gustavsen (19). Carnitine values of cabbage and tomato in this study were in close agreement with Panter et al. (20), Giovannini et al. (8) and Gustavsen (19). Seaweeds had low carnitine levels in the range of 0~0.07 mg TCNE / 100 g wt. Sea lettuce contained 0.06 mg TCNE / 100 g wt. and laver had no TCNE. Sea mustard and sea mustard stem contained 0.07, and 0.03 mg TCNE / 100 g wt., respectively and sea tangle contained 0.01 mg TCNE / 100 g wt.

The TCNE contents in mushrooms were higher than in vegetables. Oyster mushroom contained 7.02 and *Agaricus bisporos* 3.87 mg TCNE / 100 g wt. *Flammulina velutipes* (Velvet foot) contained 3.29 mg TCNE / 100 g wt. and *Lentinus edodes* (Shiitake) contained 2.77 mg TCNE / 100 g wt. The concentration of carnitine in oyster mushroom and *Agaricus bisporos* were higher than the value obtained by Gustavsen (19). The TCNE contents of mushrooms are as high as the levels in some meats and fishes, therefore mushrooms substantial source of vegetable derived TCNE in Korean diets.

Carnitine content of fruits

Most fruits have little if any carnitine (Table 4). Raisins had the highest concentrations at 0.21 mg TCNE / 100 g wt. Persimmons, melons and apples contained 0.01 and grapes and bananas 0.02 mg TCNE / 100 g wt. TCNE concentrations in pears was 0.03 and kiwi 0.06 mg TCNE / 100 g wt. TCNE was undetectable in oranges, strawberries, satsuma mandarine, peaches and pineapples. Carnitine content of peaches and pineapples from this study were slightly lower than that reported by Rebouche et al. (18) and Giovannini et al. (8). Carnitine content of apples and pears were slightly lower than that reported by Giovannini et al. (8), Rebouche et al. (18) and Gustavsen (19). Carnitine concentrations in bananas and apples were slightly higher than those obtained by Rebouche et al. (18), but strawberry concentrations were in close agreement. Carnitine contents of apple, orange, pear, banana, melon, kiwi were similar to the values obtained by Gustavsen (19).

Table 4. Carnitine content of fruits

Foods	mg/100 g wt.	μmol/100 g wt.
Persimmon (hard)	0.01	0.06
Orange	ND[1]	ND
Strawberry	ND	ND
Grape	0.02	0.12
Grape, Raisin	0.21	1.30
Banana	0.02	0.12
Satsuma mandarine	ND	ND
Peach (canned, yellow)	ND	ND
Melon	0.01	0.06
Pineapple	ND	ND
Apple	0.01	0.06
Pear	0.03	0.19
Kiwi	0.07	0.43
Jujube (dried)	ND	ND

[1]ND: not detectable.

Carnitine content of meats, fish, and shellfish

The carnitine content of meats, fishes and shellfishes are shown in Table 5. Beef had the highest carnitine content of all foods at 91.09 mg / 100 g wt.; a similar value to those reported by Rebouche et al. (18), Giovannini et al. (8) and Tanphaichitr et al. (14) and higher than that by Mitchell (21). Loin, belly, and ribs of pork contained 17.21, 11.42, and 11.99 mg TCNE / 100 g wt., respectively.

Table 5. Carnitine content of meats, fishes and shellfishes

Foods	mg/100 g wt.	μmol/100 g wt.
Meats		
Beef, Loin	91.09	562.28
Pork, Loin	17.21	106.23
Pork, Belly	11.42	70.49
Pork, Ribs	11.99	74.01
Chicken, Thigh	4.93	30.43
Chicken, Breast	5.90	36.42
Chichen, Wing	1.74	10.74
Ham (pork products)	6.63	40.93
Fishes		
Flounder	3.96	24.44
Mackerel	3.49	21.54
Pacific saury	3.36	20.74
Anchovy (boiled-dried)	2.51	15.49
Alaska pollack (frozen)	12.90	79.63
Alaska pollack (dried)	6.93	42.78
Spanish mackerel	4.85	29.94
Yellow croaker	1.65	10.19
Bluefin tuna (canned)	0.26	1.60
Hair tail	4.32	26.67
Chinese red-sided culter	6.52	40.25
Pacific herring	6.17	38.09
Fluke	4.86	30.00
Conger eel	6.94	42.84
Shellfishes		
Oyster	19.24	117.77
Cirb shell	7.16	44.20
Turban shell	24.87	153.52
Whelk	11.18	69.01
Little neck clam	2.64	16.30
River snail	ND[1]	ND
Whip-arm octopus	7.74	47.78
Common squid	0.01	0.06
Shrimp	2.35	14.51
Crab	2.0	12.35
Jelly-fish	ND	ND
Common sea squirt	2.65	16.36
Sea cucumber	0.59	3.64
Fish paste	0.05	0.31
Solen	0.28	1.73

[1]ND: not detectable.

Carnitine values of pork were similar to those reported by Gustavsen (19), and lower than those by Rebouche et al. (18) and Tanphaichitr et al. (14). Breast, thigh and wing of chicken contained 5.9, 4.93, 1.74 mg TCNE / 100 g wt., respectively, which were similar to the values reported by Gustavsen (19) and Giovannini et al. (8), and higher than those of Rebouche et al. (18). Porcine ham contained 6.63 mg TCNE / 100 g wt.

Alaska pollack was the fish with the highest carnitine content at 12.90 mg / 100 g wt. Dried Alaska pollak, Chinese red-sided culter, conger eel and Pacific herring contained 6.17~6.94 mg TCNE / 100 g wt., and Spanish mackerel, hair tail and fluke contained 4.32~4.85 mg TCNE / 100 g wt. Flounder, mackerel and Pacific saury contained 3.36~3.96 and anchovy, yellow croaker and bluefin tuna 0.26~2.51 mg TCNE / 100 g wt. The concentration of carnitine in Pacific herring from the present study was higher than that reported by Gustavsen (19), whereas mackerel was similar, and flounder and bluefin tuna (canned) were lower than their values.

Turbanshell had the highest carnitine concentration of all shellfishes, at 24.87 mg / 100 g wt. Oyster and whelk contained 19.24 and 11.18 mg TCNE / 100 g wt., respectively; cirb shell, little neck clam and tiver snail contained 7.16, 2.64, and 0 mg TCNE / 100 g wt., respectively. Whip-arm octopus, common squid, shrimp, and crab contained 7.74, 0.01 mg, 2.35, and 2.0 mg TCNE / 100 g wt., respectively. Common sea squirt and sea cucumber contained 2.65, 0.59 mg TCNE / 100 g wt., respectively; jelly-fish had no carnitine. Fish paste and solen contained 0.05, and 0.28 mg TCNE / 100 g wt., respectively. The concentration of carnitine in crab was similar to that reported by Gustavsen (19).

Carnitine content of eggs, dairy products, oils, fats, seasonings, and beverages

TCNE content of eggs, dairy products, oils and fats, seasonings and beverages are shown in Table 6. Chicken and quail eggs contained 0.07, and 0.1 mg TCNE / 100 g wt., respectively. Carnitine content of chicken eggs was higher than that reported by Rebouche et al. (18), and lower than that by Giovannini et al. (8) and Tanphaichitr et al. (14). Among dairy products, milk contained 1.77 and cheese 0.49 mg TCNE / 100 g wt. Carnitine content of milk was lower than that reported by Tanphaichitr et al. (14), Giovannini et al. (8), Rebouche et al. (18) and Gustavsen (19), and the carnitine content of cheese was lower than that reported by Rebouche et al. (18) and Gustavsen (19). Yoghurt and curd type yoghurt contained 0.86, and 2.7 mg TCNE / 100 g wt., respectively. Carnitine content of yoghurt was similar to that reported by Gustavsen (19). Ice cream contained 0.68 mg TCNE / 100 g wt., which was lower than reported by Gustavsen (19). Butter, margarine and sesame oil contained 0.31, 0.07, 0 mg TCNE / 100 g wt., respectively; butter had a higher level than other fats because it is a food of animal origin.

Table 6. Carnitine content of eggs, dairy products, oils and fats, seasonings and beverages

Foods	mg/100 g wt.	μmol/100 g wt.
Eggs		
Chicken egg (whole)	0.07	0.43
Quail egg (whole)	0.1	0.62
Dairy products		
Milk	1.77*	10.93*
Cheese	0.49	3.02
Yoghurt	0.86*	5.31*
Yoghurt, Curd type	2.7	16.67
Ice cream (chocolate)	0.68	4.20
Oils and Fats		
Butter	0.31	1.91
Margarine	0.07	0.43
Sesame oil	ND*[1)]	ND*
Seasonings		
Soybean paste	0.28	1.73
Fermented red pepper paste	0.5	3.09
Chongkuk jang	0.05	0.31
Soy Sauce	1.05*	6.48*
Ta Si Da, Beef	11.96	73.83
Mayonnaise	0.07	0.43
Tomato ketchup	0.02	0.12
Beverages		
Orange juice	ND*	ND*
Grape juice	0.04*	0.25*
Cola	ND*	ND*
Cider	ND*	ND*
Sik Hye	ND*	ND*
Coffee (instant)	0.03*	0.19*
Green tea	ND*	ND*

[1)]ND: not detectable. *mg or μmol / 100 mL.

Among seasoning, soy sauce, soybean paste, and fermented red pepper soybean paste had 1.05, 0.28, and 0.5 mg TCNE / 100 g wt., respectively, which were higher than most grains and vegetables. Chongkuk jang contained 0.05 and ta si da (beef) 11.96 mg TCNE / 100 g wt. Mayonnaise and tomato ketchup contained 0.07, and 0.02 mg TCNE / 100 g wt., respectively.

With the exceptions of grape juice and coffee (0.04 and 0.03 mg / 100 mL, respectively) none of the beverages contained carnitine. The lack of carnitine in orange juice was inconsistent with the results of Rebouche et al. (18), Gustavsen (19) and Giovannini et al. (8), who detected small amounts. The grape juice concentration was similar to that reported by Rebouche et al. (18) and Gustavsen (19) and the concentration in coffee was higher than was obtained by Rebouche et al. (18). The lack of carnitine in cola was in agreement with Rebouche et al. (18). The variations of carnitine contents appeared to be due to differences in samples used for analysis.

These results demonstrated that TCNE concentrations are high in meats, fish, shellfish and milk, as foods of animal origin. However, cereals fruits and vegetables, as foods of plant origin, have very low carnitine levels, with the notable exception of mushrooms. These data will be useful in establishing a database for the carnitine content of Korean foods, which, in turn will be useful in determining carnitine content of Korean diets. Furthermore, this data may be useful for establishing recommended dietary intakes for carnitine in the future.

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