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Dairy foods and body weight management

Milna Tudor[1], Jasmina Havranek[1], Mauro Serafini[2]*

[1]University of Zagreb, Faculty of Agriculture,
Dairy Science Department, Svetošimunska 25, Zagreb
[2]Antioxidant Research Laboratory, Unit of Human Nutrition INRAN,
Via Ardeatina 546, 00178, Rome, Italy

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Summary

The existing data about the role of dairy foods in body weight management, as a physiological explanation are shown in this paper. There is accumulating evidence about inverse association between body weight and dairy intake. Research showed that obese individuals consume fewer dairies than normal weight people. Also three servings of dairy foods per day in a reduced calorie diet may help accelerate body fat loss when compared to a calorie-restricted diet low in dairy foods. Calcium plays the main role and is present in great amounts in dairy foods. Its anti-obesity effect is attributed to its impact on lypogenesis and lipolysis in adipocytes. Calcium supplements do not have such effect as dairy calcium, possibly due to the effects of other bioactive components in dairy foods such as conjugated linoleic acid, whey peptides, branched aminoacids and lactose which amplify anti-obesity effect. Cross-sectional epidemiological studies confirmed the hypothesis that high dairy food intake can act in a weight management, but prospective studies and randomized controlled intervention trials have yielded inconsistent results. Therefore there is a need of conducting more large population-based clinical trials and meta-analysis.

Key words: dairy foods, milk, obesity, weight management

Introduction

Obesity has been classified as an epidemic. It has become a major world-wide health issue while it directly causes many nutrition-related conditions (Caballero, 2007.). The United States is leading in number of people with weight problems. Over 60 % of its population are considered overweighed (body mass index 26-30 kgm^{-2}) and half of that obsessed (body mass index >30kgm^{-2}) (http://obesity1.tempdomainname.com/subs/fastfacts/obesity_US.shtml). So far, there is no comprehensive epidemiologic study on obesity rate in Croatia, but as a part of The Croatian Health Policy which was established in the year 1999, *The First Croatian Health Project* gave data that obesity is becoming a significant problem in Croatia. Overweight is recorded in 35 % of women and 48 % of men and amongst them 15 % of women and 31 % of men are considered obese (Antonić Degač et al., 2002). The highest number of obese men in the year 2003 is in the north part of Croatia (25 %), while the east region is leading in the number of obese women (26 %) (Heim and Kruhek-Leontić, 2003; Vuletić and Kern, 2005). Obesity causes many health problems. In particular it is associated with the development of type 2 diabetes mellitus, coronary heart disease, osteoarthritis and some types of cancers (Kopelmann, 2000; Ilich, 2005). The effect of a variety of nutrients on changes in a body weight has been

*Corresponding author/Dopisni autor: Phone/Tel.: +385 1 2393 647; E-mail: mtudor@agr.hr

extensively studied. As milk ensures many nutrients with relatively low energy content it is considered as a nutrient-dense food (Drewnowski, 2005; Steijns, 2008). The belief that milk is a very valuable food is long standing. It goes back a long time since Hippocrates said that milk is a most perfect nature's food. It provides all nutrients which human body needs for optimal everyday functioning. Not only that the milk is a great source of vitamins and minerals, but the proportion of its main ingredients (proteins, carbohydrates and lipids) is almost ideal (Havranek, 1995; Tudor and Havranek, 2007). Unfortunately, relatively low consumption of dairy foods is a characteristic of Croatian's population daily diet. The average dairy consumption is 0.3 L of milk and 20 g of cheese which ensures only 500 mg of calcium that is well under daily recommendations for adult person (Antonić Degač et al., 2007). In children and young adult population, milk is often replaced by cheaper or more attractive options such as carbonated soft drinks which contain just sugar (Tudor et al., 2008). Šatalić et al. (2008) reported that among university students (women), 76 % of subjects consume dairy foods daily, 11.6 % consume dairy foods less than once a month, 50.1 % consume carbonated soft drinks and 4.5 % consume it daily. To help in prevention of children obesity, Croatian Dairy Union has started the project with a main goal to ensure that each schoolchild in Zagreb drinks a glass of milk every day (Tudor et al., 2008).

It is well known that dairy foods, as a good source of calcium, are important for healthy bones and teeth, but just few know that it may be associated with other areas of health benefits, such as hypertension, cancer and weight control (Huth et al., 2006). Moreover, individuals who are dieting often reduce dairy foods in their diet since they are viewed as high fat products (DiRienzo et al., 2003). But on the contrary, recent study outcomes indicate that daily consumption of three servings of milk and dairy foods may be part of the solution, not part of the problem for obesity. Such dietary treatment could act in maintaining optimal body weight or accelerate weight and fat loss during calorific restrictions (Zemel et al., 2000; Carruth and Skinner, 2001; Zemel et al., 2004; Zemel et al., 2005; Davies et al., 2006; Baptista Bueno et al., 2008).

Calcium plays the main role although calcium supplements do not have such a positive effect on body weight as dairy foods. There are other bioactive compounds of dairy foods which could act synergistically with calcium such as conjugated linoleic acid, whey peptides, branched aminoacids and lactose (Goulding, 2003; Layman, 2003; Zemel, 2003; Nagao and Yanagita, 2005; Miller et al., 2007).

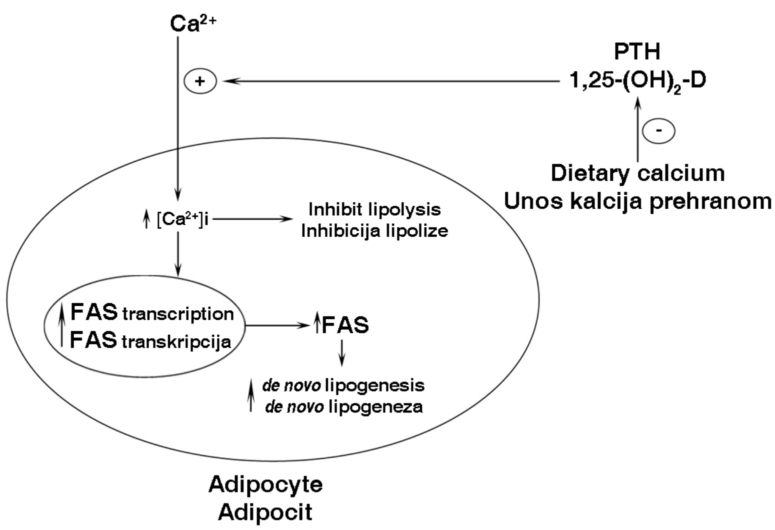

Figure 1: Role of calcium in regulation of adipocyte lipid metabolism (Zemel, 2001)
Slika 1: Uloga kalcija u reguliranju metabolizma masti u adipocitima (Zemel, 2001.)

Since calcium is present in a great amount in dairy foods, the aim of this paper is to review existing data and describe the physiological role of dairy foods and calcium in a human body weight management.

Mechanism of dairy foods in weight management

There are two models which provide the possible mechanism of how calcium influences body weight. First model, the most plausible, explained it through intracellular calcium which plays a critical role in the metabolism of the adipocyte. Its anti-obesity effect is attributed to its impact on lypogenesis and lipolysis. High dietary calcium can suppress concentrations of serum parathyroid hormone (PTH) and 1,25 dihydroxyvitamin D (1,25(OH)$_2$D). Both PTH and 1,25(OH)$_2$D increase concentrations of intracellular calcium ([Ca^{2+}]i) in adipocytes, which leads to a decrease in lipolysis and an increase in lipogenesis through increase of fatty acid synthase (FAS) concentrations in the cell (Xue et al., 2001; Zemel, 2001; Zemel, 2002) (Figure 1).

A study by Gunther et al. (2006) showed that the one year change in serum PTH was positively associated with the change in fat mass in healthy, normal-weight young women (18-31 y). In the same population, an acute increase in dairy calcium does not affect fat oxidation during chronically low calcium intakes, but a long-term increase in dietary calcium leads to an increase in whole-body fat oxidation independently of taking a low-calcium or high calcium meal. These results suggest that a habit of high intake of dairy calcium increases whole-body fat oxidation from any meal. Woman who increase their dairy calcium over a prolonged period, while total energy intake is controlled, will oxidize higher amounts of fat through suppression of serum PTH and also because the long-term adjustment in the ability to oxidize fats and utilize calories, even without a high calcium content in the meal (Gunther et al., 2005). The second proposed mechanism is inhibition of fat absorption in intestines through binding fatty acids in the intestines by calcium and thereby increasing their amount in fecal excretion (Scharger, 2005)

Dairy calcium and body weight regulation

One of the earliest observations that dairy foods may help in the body weight regulation occurred during the course of conducting a clinical trial of the antihypertensive effect of calcium in obese African Americans. Calcium intake was increased from 400 to 1000 mg/day by feeding two cups of yoghurt/day for one year. A significant reduction in blood pressure occurred, as well as an unexpected 4.9 kg reduction in body fat (Zemel et al., 2000). Later, these findings were confirmed by a study in which body fat loss was the primary endpoint. With no change in caloric intake for 24 weeks, healthy, obese African-American adults were maintained on a low calcium (500mg/day)/low dairy (<1 serving/day) diet or a high dairy (1200mg/day including three servings of dairy) diet. No changes in body weight is reported, but increased dairy consumption resulted in significant increase in lean body mass ($p<0.04$) and reductions in total body fat ($p<0.01$) and trunk fat ($p<0.01$) what can be seen in figure 2 (Zemel et al., 2005). Another indication of increased lipolysis is a significant ($p<0.01$) increase in plasma glycerol levels in the high dairy consumption group while there is no significant change in the low dairy group (Zemel et al., 2002).

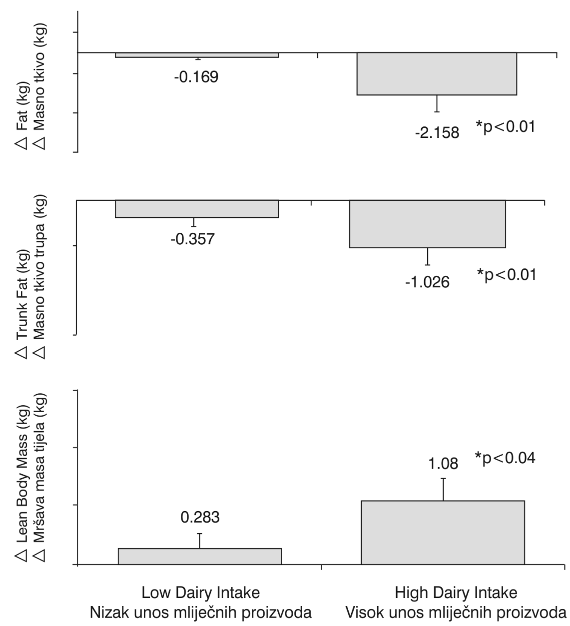

Figure 2: Effects of dairy diet on total body fat, trunk fat and lean body mass (Zemel et al., 2005)

Slika 2: Utjecaj mliječne prehrane na udio ukupnog masnog tkiva u tijelu, masnog tkiva trupa i mršave mase tijela (Zemel i sur., 2005.)

Also large population studies have identified strong inverse correlations between adiposity and calcium intake. McCaron et al. (1984) noted a significant inverse relation between dietary calcium and body weight in an analysis of the first National Health and Nutrition Examination Survey (NHANES-I) database. Zemel et al. (2000) in an analysis of the NHANES-III database, found a very strong inverse association between obesity and calcium intake. The relative risk of being in the highest quartile of body fat for 4 different quartiles of dietary calcium intake with age, race/ethnicity, activity level and caloric intake as covariates was examined. The relative risk (RR) of high body adiposity was found to be greatest in those with the lowest calcium intake and was progressively lower as calcium intake increased. RR was 0.75 for the 2nd quartile, 0.40 for the 3rd quartile and 0.16 for the 4th quartile of calcium intake for woman (Figure 3).

The cross-sectional study conducted in adult population in Brazil showed a significant negative association of calcium intake with BMI. The prevalence of being overweight decreased as intake of calcium increased (Baptista Bueno et al., 2008). On contrary, it has been reported there is no association between BMI and dairy foods intake among young Japanese women. The possible reasons are small BMI (20.8±2.6 kg/m^2) and relatively low intakes of calcium (269±93 mg/1000 kcal) and dairy foods (80±63 g/1000 kcal) (Murakami et al., 2006) which indicates the threshold effect and importance of dietary habits.

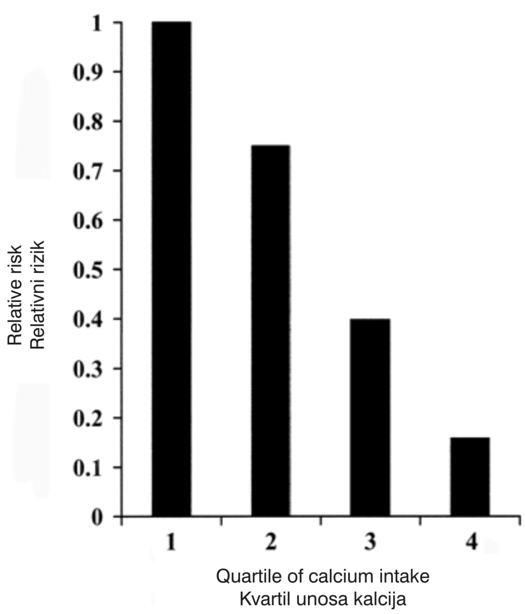

Figure 3: Relative risk (RR) for adiposity development depending on the quartile of dietary calcium intake (Zemel et al., 2000)

Slika 3: Relativni rizik (RR) za razvoj pretilosti ovisno o kvartilu unosa kalcija (Zemel i sur., 2000.)

Carruth and Skinner (2001) reported that higher longitudinal intakes of calcium and servings of dairy foods are associated with lower body fat in preschool children. Five clinical studies of calcium intake, designed with a primary skeletal end point, were re-evaluated to explore associations between calcium intake and body weight and significant negative associations were found for all investigated age groups (3rd, 5th and 8th decades) (Davies et al., 2006). A recently published cross-sectional survey, carried out in a very large Portuguese population (n=39,640) showed that high milk consumption is associated with significantly lower body mass index (BMI) in the entire population but post-menopausal woman. The lack of relationship in older women might be due to the hormonal status, but awaits further investigation (Marques-Vidal et al., 2006). The CARDIA study (Coronary Artery Risk Development in Young Adults) gave data that overweight individuals consume fewer dairies than the normal weight group. Also dairy consumption was positively associated with more whole grains, fruits and vegetables and inversely to the sugar-sweetened soft drink intake (Pereira et al., 2002). On the other hand, the Amsterdam growth and health longitudinal study which followed a cohort of men and women from age 13 to age 36 years reported a weak inverse relation of calcium intake with body composition. Also there are no differences observed between middle (800-1200 mg/day) and high (>1200 mg/day) groups of calcium intake. That suggests a threshold of 800mg/day above which calcium intake has no additional beneficial effect on body composition. But what is important here, is the fact that Dutch population has relatively high daily consumption of dairy foods. Although there were no significant correlations observed for BMI, high dietary calcium intake was related to a lowered skinfold sum (Boon et al., 2005).

Dietary calcium accelerates weight and fat loss during caloric restrictions

Zemel et al. (2004) with a randomized, placebo-controlled trial performed in 32 obese adults has shown that increases in dietary calcium significantly augment weight and fat loss secondary to energy restriction (deficit of 500 kcal/day). Increase from ~400 to 1200 mg of dietary calcium/day increase weight and fat loss by 26 % and 28 %, respectively. The same effect was shown in a trial with 29 obese African Americans which were randomized to the low or high dairy diets and placed on a caloric restriction regimen (-500 kcal/day). Weight and fat loss on the high-dairy diet were ~2-fold higher compared to the low dairy diet which is seen in Figure 4 (Zemel et al., 2005).

On the contrary, Melanson et al. (2005) showed that under energy balance conditions, there is no effect of high-dairy diet (3-4 servings per day, ~1400 mg of calcium/day) on respiratory quotient or 24-hour macronutrient oxidation. But under energy deficit conditions (-600 kcal/day) fat oxidation was significantly increased on the high-dairy diet. Trials on animals confirmed this data. aP2-agouti transgenic mice were placed on energy restricted diet. Energy restriction on the low calcium diet failed to reduce intracellular Ca^{2+} and only reduced body weight and fat pad mass by 11 % and 8 %, respectively. In contrast, energy restriction in conjunction with high calcium diet reduced intracellular calcium and resulted in 19 % to 29 % reductions in body weight and 42 % to 69 % decreases in fat pad mass, depending upon the calcium source (calcium carbonate supplements or dairy foods). Interestingly, the animals on the low calcium diets were unable to increase adipocyte lipolysis or suppress lipogenesis despite being on an energy-restricted diet. In contrast, the high calcium diets caused reductions in fatty acid synthase expression and two- to three- fold increases in lipolysis (Shi et al., 2001). During energy restricted diet a threshold effect might be also present which is seen in the study where reduction diet containing 1400 mg of calcium in dairy products through 48 weeks does not enhance weight reduction more beyond what is seen with diet containing 800 mg of calcium (Thompson et al., 2005).

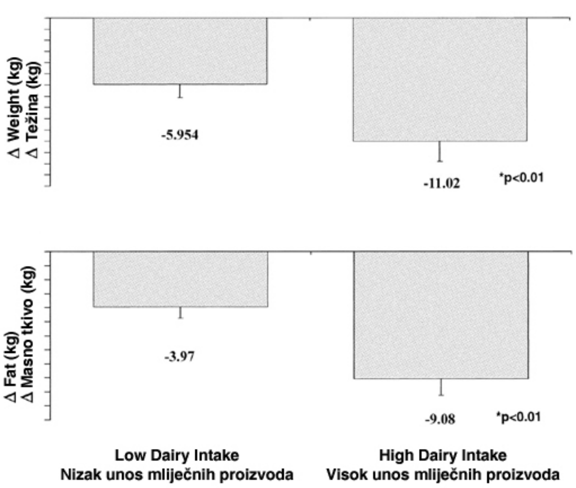

Figure 4: Effects of dairy diet on weight and fat loss after energy restricted diet (Zemel et al., 2005)

Slika 4: Utjecaj mliječne prehrane na smanjenje tjelesne težine i masnog tkiva nakon energetski restriktivne dijete (Zemel i sur., 2005.)

Role of calcium supplements *versus* diary foods in augmenting weight and fat loss

In studies in both rodents and humans it was found that calcium from dairy foods has a more profound effect on fat loss than calcium from supplements (Carruth and Skinner, 2001; Gunther et al., 2006). The trial with aP2-agouti transgenic mice showed that dairy calcium is significantly more potent in reduction of fatty acid synthase (FAS) expression and increase of lipolysis or suppresing lipogenesis (Shi et al., 2001). Shapses et al. (2004) gave 1000 mg/day of supplemental calcium to obese women (n=100) on a weight loss program for 6 months. There was no significant difference between the calcium supplemented (calcium citrate malate or calcium citrate) and the placebo group for body weight or fat mass changes. Weight loss was recorded in a randomized, placebo-controlled trial with 32 obese adults. They were maintained for 24 weeks on balanced deficit diets (500 kcal/day deficit) and randomized to a standard diet (400-500 mg of dietary calcium/day supplemented with placebo), a high-calcium diet (standard diet supplemented with 800 mg of calcium/day) or high-dairy diet (1200 to 1300 mg of dietary calcium/day supplemented with placebo). Patients assigned to the standard diet lost 6.4±2.5 % of their body weight, which was increased by 26 % on the high-calcium diet and 70 % on the high-dairy diet. Fat loss was significantly higher (26 %) on the high-dairy diets in comparison to high-calcium diet (Zemel et al., 2004). In a randomized, double-blind, placebo-controlled intervention study 110 young normal weight girls were randomly assigned to receive 500 mg Ca/day as calcium carbonate for 1 year. Two groups of girls were selected according to habitual calcium intake. Habitual dietary calcium intake is inversely associated with body fat, but calcium supplements have no effect on body weight, height or body fat over 1 year. It is possible that the effect of calcium on body weight is only exerted if it is ingested as part of a meal (Lorenzen et al., 2006). In an intervention trial, combination of nutritional and lifestyle counseling with consumption of fortified dairy products (with calcium and vitamin D_3) for 12 months was found to have favourable changes in anthropometric (skinfold's thickness, leg's fat, leg's lean body mass) and body composition indices compared to calcium supplementation alone (Manios et al., 2009).

The mechanism of this additional dairy effect is not yet clear, but it was suggested that it may is due to other bioactive components in dairy products like conjugated linoleic acid (Nagao and Yanagita, 2005), whey peptides (Zemel, 2003), branched aminoacids (Layman, 2003) and lactose (Goulding, 2003). High proportion of branched chain aminoacids in whey peptides may act in synergy with calcium to contribute to the antiobesity effect. Additionally they can contribute by repartitioning dietary energy from adipose tissue to skeletal muscle (Miller et al., 2007). Causey and Zemel (2003) investigated which components of dairy foods beyond calcium might affect weight and body fat in mice. Mice were first made obese, and then either continued on the same diet or restricted to 70 % of the energy intake and fed with high calcium using milk casein or soy with or without a whey-derived angiotensin converting enzyme inhibitor. The commercially prepared whey mineral isolate contains calcium, phosphorus, magnesium, potassium and other minerals isolated from whey. The high Ca diets caused a 32 % augmentation of fat loss versus the low Ca diet. Milk had the greatest impact on fat loss by 62.5 % versus other high Ca diets. Whey minerals provided no additional fat loss, but the addition of the whey ACE inhibitor to the whey minerals resulted in increased fat loss versus whey minerals alone. Thus, whey components may contribute to the anti-obesity effect of dairy, but the overall effect may be synergistic among multiple components of dairy. Although conjugated linoleic acid, which major source are dairy foods, has been shown to reduce body fat and increase lean body mass in some experimental animal studies, the effects in humans are still conflicting (Miller et al., 2007). Another possibility is the chemical form of calcium. In dairy products calcium is largely found as calcium phosphate, and it is possible that phosphate contributes to the effect on body weight. Usually in studies, calcium present in supplements was calcium citrate, calcium citrate-malate or calcium carbonate (Shapses et al., 2004; Davies et al., 2006).

Conclusion

As obesity is becoming a huge world-wide health issue and there is a growing international awareness of a need for joint action. Proven physiological explanation of the Ca role in adipocytes, inverse association between dairy intake and body weight and acceleration of body weight and fat loss during energy restricted diet high in dairy, shows that dairy foods could be a part of the strategy for combating obesity. Bioactive components such as conjugated linoleic acid, whey peptides and branched aminoacids give dairy foods better anti-obesity role than calcium supplements have. Still, prospective studies and randomized controlled intervention trials have yielded controversial results, but cross-sectional epidemiological studies confirmed the hypothesis that high dairy food intake can act in a weight management. Because of that, as future direction, there is a need for conduction of a large population based clinical trials and also metha analysis.

Mlijeko i mliječni proizvodi i regulacija tjelesne mase

Sažetak

U radu su prikazani postojeći rezultati istraživanja o ulozi mlijeka/mliječnih proizvoda u regulaciji tjelesne mase, kao i fiziološko objašnjenje mehanizma djelovanja. Mnogo je dokaza o inverznom odnosu između tjelesne mase i unosa mlijeka/mliječnih proizvoda. Istraživanja su pokazala da

pretile osobe konzumiraju manje mlijeka/mliječnih proizvoda od osoba s optimalnom tjelesnom masom, kao i da prilikom redukcijske dijete tri jedinice serviranja mlijeka/mliječnih proizvoda ubrzavaju gubitak masnog tkiva u usporedbi s redukcijskom dijetom siromašnom mlijekom/mliječnim proizvodima. Glavnu ulogu igra kalcij koji je u velikim količinama prisutan u mlijeku. Njegov anti-pretilost učinak sastoji se od utjecaja na lipogenezu i lipolizu u adipocitima. Suplementi kalcija nemaju takav učinak kao i kalcij iz mlijeka, vjerojatno zbog djelovanja ostalih bioaktivnih komponenti prisutnih u mlijeku kao što su konjugirana linolna kiselina, sirutkini peptidi, razgranate aminokiseline i laktoza koji pojačavaju anti-pretilost učinak. Presječne studije potvrdile su hipotezu da konzumacija mlijeka/mliječnih proizvoda u većim količinama može igrati ulogu u reguliranju tjelesne mase, no prospektivne studije i randomizirane kontrolirane interventne studije dale su proturječne rezultate. Stoga postoji potreba za provedbom većih populacijskih kliničkih studija kao i meta analiza.

Ključne riječi: mlijeko, mliječni proizvodi, pretilost, regulacija tjelesne mase

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