Progress in Nutrition 2019; Vol. 21, Supplement 2: 135-144 DOI: 10.23751/pn.v21i2-S.6906

Daily fortified-synbiotic yogurt consumption facilitates appetite control in overweight and obese adults with metabolic syndrome during a weight-loss program: a 10-week randomized controlled trial

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Summary. *Objective:* Weight loss programm is known to increase the appetite and motivation to eat. The aim of the present study was to compare the effect of fortified-synbiotic yogurt (FSY) with calcium, whey protein and vitamin D with low-fat conventional yogurt (LFY) on appetite control in overweight/obese individuals during weight loss. *Method and matrials:* This was a randomized, double-blinded, parallel-arm, 10-week study. Participants were randomly allocated to two groups receiving either two servings (2×250 g)/day of a fortified synbiotic yogurt (FSY) with whey protein, calcium, and vitamin D (n=44) or a low-fat conventional yogurt (LFY) (n=43). All participants were put on a caloric-restricted diet throughout the 10-week study. Fasting Visual Analogue Scale (VAS) was used to measure subjective sensations of appetite in before commencing the study, at weeks 5 and 10 of the study. Fasting plasma concentrations of ghrelin were measured as well. *Result:* Both groups showed a significant (P<0·001) weight loss (-4.3±1.9 kg and -5.12±3.03 kg in the LFY and FSY groups, respectively). A treatment and time×treatment interaction effect indicated that weight loss with FSY induced a smaller increase in desire to eat and hunger and smaller reduction in fullness sensations (P<0.05). Intrisingly, per each kg body fat mass loss during the weight loss, the increase in the desire to eat and hunger as well as decrease in the fullness scores were significanlty lower (P<0.05) in the FSY compared to LFY group. Furthermore, changes in ghrelin concentration correlated with those in desire to eat (r=0.34, P=0.001), hunger (r =0.64, P<0·001) and fullness (r= -0.39, P<0.001) sensations. Although changes in fasting ghrelin concentrations were not significantly diffrerent between groups at the end of the study; the FSY group showed smaller increase in gerlin after 10-weeks study. *Conclusions:* Collectively, our promising results showed that FSY supplementation attenuates the orexigenic effect of body weight loss compared with LFY and in overweight and obese individuals.

Key word: metabolic syndrome, obesity, probiotic yogurt, appetite

Introduction

The global incidence of obesity in adults has doubled over the past 30 years. In many developed nations, one-third of adults are obese (1); thus, there is an urgent need for effective obesity countermeasures (2). An energy-restricted diet as the first choice for weight loss is generally accepted to decrease the risk and severity of obesity-related comorbidity. However, because of undesired side effects including physiological

changes during weight loss, the benefits of weight loss are often short- to medium-term (3). One important side effect of diet-induced weight loss is the increased motivation to eat (4). Changes in the appetite regulation pathway such as increases in appetite-stimulating hormones such as ghrelin and a decrease in satiety hormones such as peptide tyrosine tyrosine (PYY) (5) can lead to weight regain in the long-term (6). Based on these challenges in obesity management, a novel area of research consists of identifying functional foods that may overcome the physiological consequences of energy restriction and facilitate maintenance of weight loss (7).

Dairy products have been shown to facilitate appetite control during weight loss (8), particularly because of their satiating components. These include whey protein, calcium and probably vitamin D. Dairy proteins may enhance satiety and reduce hunger because they affect circulating appetite-regulating hormones that are highly dependent on the type of proteins ingested (9). Whey proteins have a high content of branched-chain amino acids and bioactive components such as lactalbumin (10), which has a faster rate of absorption and digestion than other proteins. This leads to a fast peak in plasma amino acids, contributing to satiety (11) and making this protein suitable during weight loss.

The notion of a calcium-specific appetite control has been previously proposed and highlights the role of calcium intake and/or its stores on subjective hunger/satiety ratings and food intake (12). This potential role of calcium is mediated either by GI-tract hormones such as ghrelin or adipokine leptin (13). The supplementation of calcium by vitamin D increases the effect because vitamin D enhances calcium absorption. A 15- week study on the intake of calcium with vitamin D supplementation showed its affect on energy intake by reducing the spontaneous fat intake (14).

Gut microbiota regulate the metabolic pathways that modulate the physiological state of hunger or satiety. The manipulation and restoration of gut microbiota through biotherapeutics; i.e., application of probiotics and prebiotics in dietary strategies in the form of synbiotics, can enhance satiety and control the appetite (15). Inulin-type fructan, a prebiotic fiber, is a potential candidate to enhance satiety that has positive physicochemical properties such as solubility, viscosity, water-holding capacity and fermentability that could foster its incorporation into a variety of foods (16). Dietary fiber has attracted attention because its consumption is associated with increased satiety and decreased short-term energy intake, which subsequently lowers body weight (17). This effect of fiber may be mediated by lowering the bioavailability of macronutrients, leading to a decrease in energy absorption (18). The production of short-chain fatty acids in the colon after dietary fiber consumption can be may enhance satiety through various mechanisms (19).

At present, in the context of a weight-loss program, the major challenge of a dietary regimen based on functional foods is to minimize the increase in hunger while inducing a caloric deficit (20, 21). Given the superior effects of dairy, prebiotic, probiotic, whey protein and calcium plus vitamin D supplementation on appetite control, the objective of the current study was to maximize the efficacy of intervention through consumption of fortified synbiotic yogurt (FSY) containing whey protein, calcium and vitamin D to determine if a FSY would improve appetite regulation during a 10-week energy restriction (–500 kcal/d) weight loss program compared to low-fat plain yogurt (LFY).

Materials and Methods

Subjects

The participants were recruited through a newspaper advertisement and among individuals referred to Motahari and Imam Reza clinics affiliated to Shiraz University of Medical Sciences. After being assessed for eligibility, 90 overweight and or obese subjects with metabolic syndrome from both genders within the age range of 20-65 years and Body Mass Index (BMI) of 25–35 kg/m^2 were selected between January and March 2017 (Winter) in order to minimize the cutaneous synthesis of vitamin D. Metabolic syndrome was diagnosed in accordance with ATP-III criteria[1] (20). The exclusion criteria of the study were having antibiotic therapy, weight loss greater than 10%

1 National Cholesterol Education Program Adult Treatment Panel III report

of body weight within 6 months prior to the intervention, recent (within four weeks) change in intensity or frequency of physical activities, no usual consumption of low-fat yogurt (LFY) or probiotic products. The participants were also excluded if they were taking multi-vitamin, minerals or omega-3 supplements or medications that could affect appetite, body weight or body composition, calcium or vitamin D metabolism, glucose, and lipid levels. Participants who were pregnant or breast feeding, smoker, allergic to probiotic or dairy products, those who consumed alcohol regularly, and those who were suffering from serious medical conditions (e.g. cancer) were also excluded.

Study protocol

This trial was performed based on the guidelines of declaration of Helsinki. The study protocol was approved by the ethics committee of Shiraz University of Medical Sciences, Shiraz, Iran (IR.SUMS.REC.1395.151) and was registered in Iranian Registry of Clinical Trials (IRCT2017050633836N1). All participants read and signed an informed consent form before enrollment into the study.

Study design and interventions

In this randomized double-blinded controlled trial, 150 participants were screened and 94 eligible participants entered into a 2-week run-in period to obtain detailed information about their dietary intakes and physical activities. Participants were asked to not make any changes to their usual diets or physical activities, and to abstain from consumption of any probiotic foods, synbiotic foods, and calcium and vitamin D supplements during this period. A total of 90 participants were enrolled into this study (Figure 1). Participants were then randomly assigned to the LFY (n=45) or the FSY group (n=45) using four balanced block randomization. The allocation was concealed until the end of the study. The products were provided in identical packages (Zarin Ghazal Dairy Industries Co. (DAITY), Shiraz, Iran)) to blind the participants, investigators, and laboratory staff to group allocation. Two daily servings (2×250 g) of LFY or FSY were provided, one with lunch and one with dinner (Table 1). These yogurt products replaced the participant's typical dairy servings for the 10-week duration of the study. The LFY contained 300 mg of calcium per serving, and no detectable vitamin D. Each serving of the FSY contained and 5 g whey protein, 3 g (~ 1%/weight) inulin as prebiotic, 500 mg calcium, and 500 IU vitamin D_3. The nonprobiotic LFY contained the starter cultures of S. thermophiles and L. bulgaricus and FSY contained the starter cultures of S. thermophiles and L. bulgaricus enriched with at least 10^7 cfu/g bifidobacterium lactis Bb-12 (Chr. Hansen, Hoersholm, Denmark). It has been suggested that 1000 IU/day of vitamin D is effective and safe to increase the circulating level of 25 (OH)D (22). In addition, the selected dose for inulin (6 g/d) in this study was defined based on the previous studies (23).

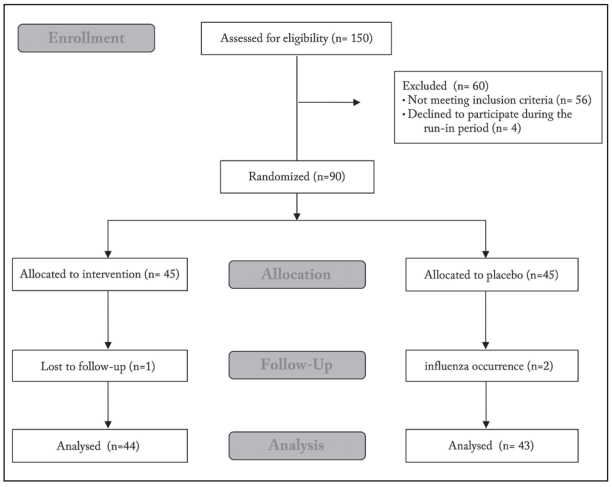

Figure 1. Flow diagram of participants and study design.

Both LFY and FSY were freshly produced and given to the subjects weekly. At each visit, the participants' compliance was assessed. Participants were also

Table 1. Nutritional Composition of FSY and LFY Foods per serving (250g)*

Components	FSY	LFY
Fat (g)	3.5	3.5
Protein (g)	15	10
Fiber (g)	3	0
Calcium (mg)	500	300
Vitamin D (IU)	500	0
Cholesterol (mg)	6	6
pH	4.3	4.3

*Daitey dairy industries company analysis
Abbreviations: LFY = low-fat conventional yogurt group (n=45); FSY = fortified symbiotic yogurt group (n=45).

asked to return the empty packets on their next visit. They were requested to keep yogurt packs in the refrigerator at a temperature below 4 °C, not to use synbiotic, probiotic, and other fermented products during the study period, and to maintain their physical activity levels as usual. In addition, a daily short message was sent to all the participants to remind them to consume their daily yogurt portions. At each visit, the participants' adherence to the intervention was calculated according to the used and unused yogurts. Accordingly, if the patients had taken at least 90% of the products, they were classified as adherent and in a case of missing > 10% of the yogurts at follow-up, they were defined as non-adhered participants. Moreover, any side-effects during the intervention period were addressed during the weekly contacts with the participants. In case of any noticeable adverse-effects or problems, the participants were excluded from the study.

Appetite rating by Visual Analogue Scale (VAS)

The fasting VAS ratings of appetite were completed by subjects at baseline, week 5 and week 10 of the study. VAS consisted of 100-mm lines anchored at each end with opposing statements. Participants placed an'x on the line to show their feeling at that point in time and the score was calculated by measuring the distance in millimeters from the beginning of the line to the position of the 'x' (from left to right). The zero score indicating that the subjects were 'not full at all' and a score of 100 indicating that the subjects were'very full'. Therfore higher scores meaning more fullness. VAS ratings were assessed using five visual scales that measured hunger, fullness and prospective food consumption through the following questions: 'How hungry do you feel?' (I have never been more hungry —I am not hungry at all), 'How satisfied do you feel?' (I am completely empty—I cannot eat another bite), 'How full do you feel?' (Not at all full— Totally full), 'How strong is your desire to eat? (A lot—Nothing at all) and 'How much do you think you could eat now?' (A lot— Nothing at all). Subjects were familiarized with VAS scales before to the commencement of the study.

Biochemical analyses

Appetite related hormone, ghrelin, was measured in the Researcher Core Laboratory at school of nutrition and food sciences (Shiraz), using radioimmunoassay methods with the commercially available reagents kit (Linco Research, St. Charles, MO).

Satistical analysis

Considering α=0.05 and a power of 80%, a total of 40 participants per group would be required. This number was increased to 45 subjects per group to accommodate a 20% drop out rate (Equation 1). Statistical analyses were performed on completers. A two-way ANOVA with repeated measures on one factor (time) was used to assess the effects of treatment (LFY and FSY) and time, and their interaction on all dependent variables. In addition, regression lines were calculated to investigate the possible relationship betwee VAS ratings and body fat mass change a well as with grelin concentartions. All statistical analyses were performed using the SPSS software version 19.0. Statistical significance was set at a P value of <0·05. Data are expressed as means and standard deviations (1).

Results

The results showed no significant differences between the two groups (FSY vs. LFY) with respect to demographic characteristics, anthropometric measures, physical activity or dietary intake at baseline (Table 2).

Table 2 shows that total energy intake did not differ between groups at baseline, but in both groups as expected decreased significantly (P<0.05) during the intervention (LFY = -456±511 kcal, FSY = -619±775 kcal); indicating the participants followed their caloric-restriction diet effectively. Overall, the values shown in Table 3 suggest the excellent adherence of study completers to the study diets.

Both groups showed a significant (P<0.001) reduction in body weight (-4.3±1.9 kg and -5.1±3.0 kg in the LFY and FSY groups, respectively) and body fat mass (-1.70±2.44 and -3.39±4.66 kg in the LFY and FSY groups, respectively) at end-study compared to baseline. Reductions in body fat mass were greater (P=0.023) in the FSY group compared to the LFY group. Table 2 shows that, at baseline, there was no significant difference between-group for the fast-

Table 2. Baseline participant characteristics

	LFY (n=43)	FSY (n=44)	P-value
Age (years)*	45.6±8.7	45.4±8.9	0.927
Sex Male Female	17 (39.5%) 26 (60.5%)	17 (38.6%) 27 (61.4%)	0.932*
Height (cm)	164.1±8.8	165.4±6.7	0.527
Mass (kg)	83.3±11.2	82.5±11.5	0.763
BMI (kg/m^2)	30.8±2.2	30.1±2.6	0.125
WC (cm)	105.3±7.9	103.8±8.3	0.389
Fat mass (kg)	30.8±7.3	29.8±5.8	0.465
Gerlin (pg/ml)	735.32±143.4	765.5±177.0	0.386
Hunger (mm)	57.63 ± 9.36	60.80 ± 7.79	0.10
Fullness (mm)	26.65 ± 7.77	28.74 ± 9.05	0.825
Satiety (mm)	47.05 ± 11.42	46.89 ± 10.86	0.947
Desire to eat (mm)	55.80 ± 11.55	54.87 ± 12.84	0.547
PFC (mm)	53.70 ± 7.51	55.57 ± 9.02	0.766
Physical activity (MET.min/week)	775±998	987±1488	0.438
Sun exposure (minute/day)	23±12	21±10	0.417
Energy intake (kcal)	2276±790	2102±517	0.228
Calcium intake (gr/d)	683.42±244	732.65±356	0.456
Vitamin D (IU/d)	17±36	27±44	0.253

Note: All outcomes reported as mean ± standard deviation. P-value from independent samples t-test; *Chi-square test.
Abbreviations: LFY = low-fat conventional yogurt group; FSY = fortified symbiotic yogurt group; BMI = body mass index (kg/m^2); PFC= prospective food consumption; WC = waist circumference; 25(OH)D = 25-hydroxyvitamin D; MET = metabolic equivalent.

Table 3. Comparison of physical activity and dietary intakes between groups during the study period*

	LFY (n=43)	FSY (n=44)	
	Mean ± SD	Mean ± SD	P-value
Calorie intake, kcal	1656±741	1646± 516	0.940
Carbohydrate intake, g	203.7±52.50	213.60±42.70	0.333
Protein, g	64.30±17.40	66.66±10.00	0.431
Fat, g	46.90±8.40	48.50±10.86	0.437
Fiber intake, g	18.35±8.26	18.49±9.5	0.944
Calcium, g	825.0 ±178	816.2±154.8	0.801
Vitamin D, ug	0.20±0.53	0.48±1.2	0.152
Physical activity (MET.min/week)	824.59±769.28	743.03±1043.89	0.680

All outcomes reported as mean ± standard deviation. *The extra fiber, protein, calcium and vitamin D intake provided by the fortified synbiotic yogurt in the FSY group is not shown.Comparison of variables with normal distribution between two groups were analyzed by t-test and for inter groups paired t-test. For variables without normal distribution between two groups Man-Whitney was used and for inter groups analyses Wilcoxon was used. Abbreviations: LFY = low-fat conventional yogurt group; FSY = fortified symbiotic yogurt group; MET = metabolic equivalent.

ing ratings of appetite sensations. The results of the repeated measure showed that, the fasting appetite scorings changed differently between LFY and FSY groups, as observed significant ($P<0.05$) treatment and time×treatment interaction effect observed for fullness and desire to eat sensations. Furthermore, a significant ($P<0.05$) time×treatment interaction effect observed for hunger (Table 3). In fact, a smaller increase in the hunger and desire to eat and smaller reduction in fullness were observed in the FSY subjects than that in the LFY subjects during the 10-week study. Furthermore, this sensations have been more analysed and compared to the established relationship between the changes in appetite sensations and change in body fat mass previously reported by Gilbert etl (21). Interestingly, although the FSY group lost more body fat mass than LFY, the increase in the desire to eat and hunger and decrease in the fullness score were significanlty lower in the FSY compared to LFY group (Fig 2-4). According the results of the regression analysis, the

Table 4. Fasting appetite sensations between groups over the course of the weight-reducing programme

	Group						P-value		
	LFY			FSY					
	Baseline	Week 5	Week 10	Baseline	Week 5	Week 10			
	Mean±SD	Mean±SD	Mean±SD	Mean±SD	Mean±SD	Mean±SD	Time	Treatment	Time×treatment
Hunger (mm)	57.63 ± 9.36	73.41 ± 10.65a	76.64 ± 9.80a	60.80 ± 7.79	68.84 ± 9.15b	69.20 ± 8.25b	<0.001	0.093	0.015
Fullness (mm)	26.65 ± 7.77	23.03 ± 8.25	21.74 ± 7.76	28.74 ± 9.05	26.10 ± 9.28	24.84 ± 10.76	<0.001	0.003	0.035
Satiety (mm)	47.05 ± 11.42	42.54 ± 12.30	40.36 ± 12.88a	46.89 ± 10.86	46.25 ± 8.97	45.74 ± 9.29b	0.033	0.072	0.167
Desire to eat (mm)	55.80 ± 11.55	69.56 ± 13.32a	72.97 ± 9.52a	54.87 ± 12.84	60.59 ± 17.77b	57.51 ± 13.14b	<0.001	0.006	0.002
PFC (mm)	53.70 ± 7.51	68.73 ± 8.28	64.44 ± 11.32	55.57 ± 9.02	66.82 ± 10.32	64.51 ± 10.38			

Note: All outcomes reported as mean ± standard deviation. PFC, prospective food consumption

decrease of an each kg of fat mass during the weight loss diet result in an increase of 4.15 mm in the desire to eat in the LFY and 2.2 in the LFY group (Fig 2). Similarly an increase of 4.01 mm in the hunger score in the LFY and 0.86 in the FSY group was obserevd (Fig 3). Regarding the change in fullness sensation, a decrease of 2.84 mm in the LFY and 1.34 mm in the FSY group was observed (Fig 4). The changes in

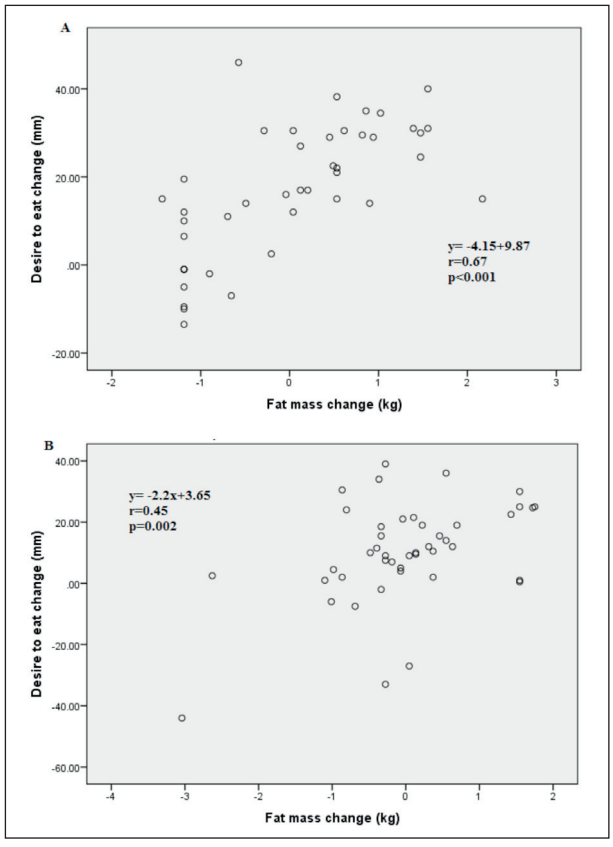

Figure 2. Relationship between changes in fasting desire to eat sensation and fat loss in the LFY (A) and FSY (B).

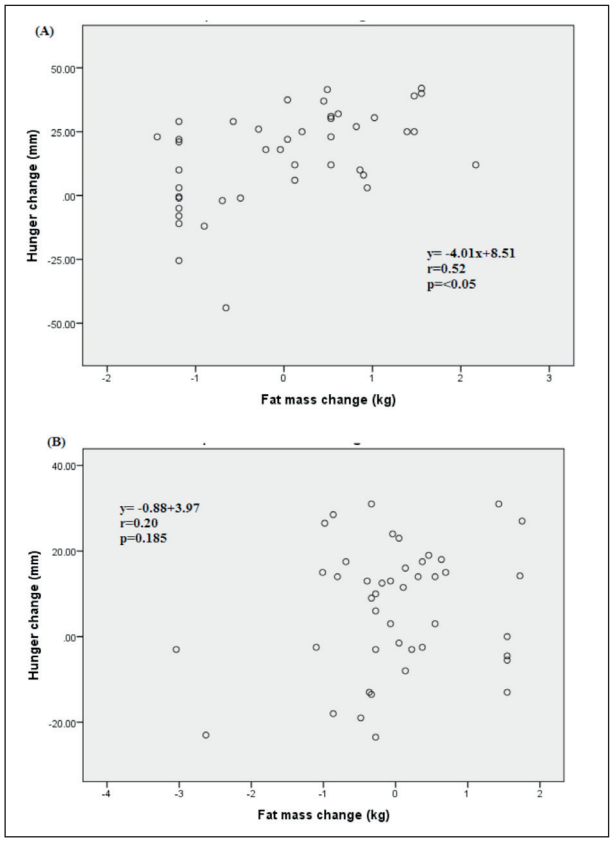

Fig. 3. Relationship between changes in fasting hunger sensation and fat loss in the LFY (A) and FSY (B).

fasting gerlin were also measured in the two groups. Although changes in ghrelin concentrations were not diffrerent between groups (+27.06±58.04 pg/ml and +15.09±50.69 pg/ml in the LFY and FSY groups, respectively); the FSY group showed smaller increase in gerlin after 10-weeks study. Furthermore, in response to the intervention, the decrease of an each kg of body fat mass result in an increase of 7.15 pg/l in the gerlin in the FSY and 13.65 pg/l in the LFY group.

The results of regression analysis on 87 compeleter show a negative association between change in fasting gerlin concenterations and desire to eat (r=0.34, P=0.001), hunger (r =0.64, P<0·001) and fullness (r= -0.39, P<0.001) sensations.

Discussion

The purpose of the present study was to investigate the possibility that FSY facilitates appetite control under energy-restricted diet. In line with our hypothesis, an energy-restricted diet, which led to significant weight loss in both groups, was found to have orexigenic effects that decreased when the subjects received FSY.

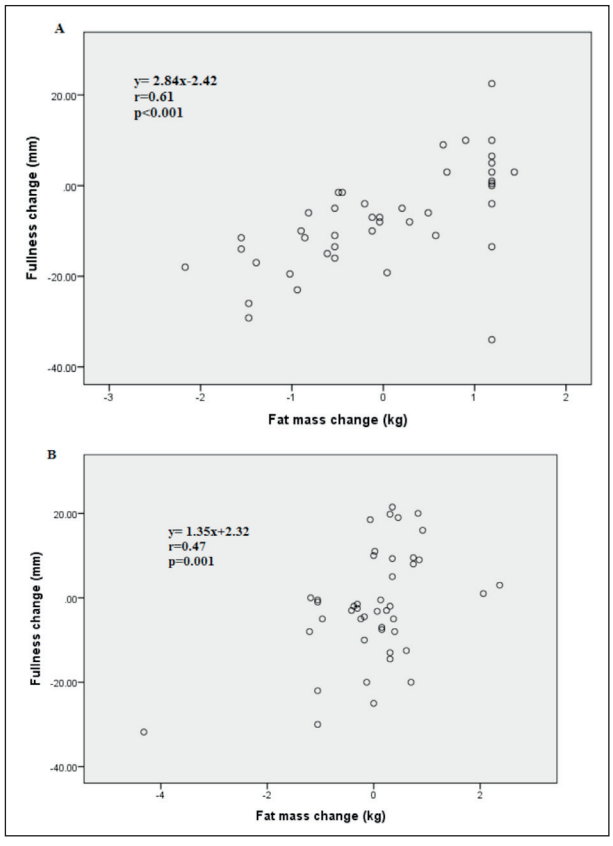

Fig. 4. Relationship between changes in fasting fullness sensation and fat loss in the LFY (A) and FSY (B).

The long-term effect of dairy-fortified products on fasting appetite regulation, as evaluated in the present study, has been little explored. A previous study found a positive effect of milk supplementation on appetite sensation during an energy-restricted diet (8). The results of the present study showed that fortification of yogurt with whey protein, calcium and vitamin D had a greater satiating effect than plain yogurt. It influenced the fasting appetite rating and reduced the influence of weight loss on hunger and the motivation to eat. Taken together, these promising results suggest that FSY intervention may help maintain appetite sensations at an optimal level during weight loss.

Previously reported findings (24, 25) support the effect of this weight loss diet on appetite and are in line with the findings of the present study. The increase in hunger and desire to eat and the decrease in a feeling of fullness in response to fat loss observed in the present study may have a negative effect on the maintenance of weight loss. The association between fat mass loss and change in appetite sensation has been evaluated by Gilbert et al. (21). They reported that the decrease of each kg of fat mass during weight loss diet resulted in an increase of 5.8 mm in the desire to eat rating and a decrease of 3.6 mm in the fullness sensation at fasting state. For example, a reduction of 10% in weight in a 120-kg woman as recommended for obesity management (26) lead to 9 kg fat mass loss. When considering that weight loss through caloric restriction produces 75% fat loss and 25% fat free mass loss (27), this fat loss resulted in a 52-mm increase in fasting desire to eat and a 32-mm reduction in fasting fullness according to the 150-mm VAS scale (21). This could seriously increase the risk of weight regain, as the fasting desire to eat predicted ad libitum energy intake at lunch time (28).

The important and interesting result of the present study was a lower increase in the hunger, desire to eat sensation and ghrelin concentration and a greater increase in the fullness rating in the FSY group compared to LFY group per kg of fat mass loss. The inter-

action of inulin, prebiotic fiber and other ingredients such as whey protein, calcium and vitamin D can increase the satiety effect of FSY as a functional food. The consumption of inulin-type fructans as prebiotic fibers can positively affect appetite control and regulation and also energy intake (29). A systematic review of prebiotics and satiety have concluded that long-term consumption of inulin-type fructans (inulin or oligofructose) is associated with reductions in energy intake and body weight (17) and a decrease in self-reported satiety (30). Mixed results in the low number of human studies in this area have been reported. In one study, yogurt had a greater satiating effect than other isocaloric beverages and the effect increased when the yogurt was enriched with 6 g of inulin (31). These results are similar to those of the present study. Similarly, the addition of 5 g of inulin to 100 g water has a reducing effect on ad libitum lunch and total daily energy intake in slightly overweight women (32). In contrast, a chocolate bar containing 10 g of inulin had no effect on appetite ratings or energy intake after one-time consumption in healthy young women (33). The suppressing effect of prebiotics such as inulin on appetite have been associated with a reduction of the orexigenic hormone ghrelin as well as elevation of anorectic gut hormones, PYY and glucagon-like peptide 1 (GLP-1). In fact, fermentable fiber may be involved in releasing gut hormones, which can positively affect appetite control through an increase in SCFA by colonic fermentation (34).

Dairy products are a good source of protein such as whey and casein. The concept of protein-induced satiety is well accepted; therefore, FSY supplemented with whey protein supplemented should have an additional effect on satiety. Regarding the effect of whey protein on appetite, studies have shown that it has a stronger effect on food intake than proteins such as casein, soy and egg (35). The beneficial effects of whey may be associated with its amino-acid content. The high content of branched-chain amino acids such as leucine, isoleucine, valine, lysine and threonine increases the rate of digestion and absorption of whey protein over that of other proteins. This property leads to a rapid peak in essential plasma amino acids (36) s><volume>66</volume><dates><year>2013</year></ dates><isbn>0195-6663</isbn><urls></ that might contribute to their effect on satiety (11). Furthermore, the effect of whey protein on the incretin hormones, GLP-1 and glucose-dependent insulinotropic polypeptide can affect the appetite (37). The decrease in hunger and desire to eat and increase in fullness can be partly explained by the difference in the relative amounts of protein ingested in the FSY group in response to weight loss.

The fortified yogurt provided a particularly high dose of dietary calcium (1000 mg/d). Intake of dietary calcium by our participants at baseline was low; therefore, receiving the high dose of calcium overcame the dietary calcium deficiency and may partially explain the observed effect of FSY on the attenuation of the diet-induced motivation to eat. The concept of calcium-specific appetite has been introduced by Tordoff (14). Although human and animal studies have reported limited and inconsistent results regarding the role of calcium in regulating appetite, some studies indicate that a dietary pattern rich in dairy foods and calcium results in enhanced subjective ratings of feeling satisfied and reduced dietary fat intake through modest increases in plasma PYY concentration. In addition, supportive findings for the facilitating effect of calcium supplementation on appetite control in the context of a weight-reducing program have been reported. This effect can be increased when calcium is supplemented with vitamin D. Calcium with vitamin D supplementation significantly reduced spontaneous energy/fat intake during a buffet-type meal in obese women (14). In another study, calcium plus vitamin D supplementation affected appetite control during weight loss.

Although weight loss did not differ in our study, the significant reduction in body fat mass compared to LFY and improved appetite control with FSY may be clinically relevant. Therefore, in weight management programs, functional foods that oppose the physiological consequences of energy restriction are meaningful targets. The efficacy of satiating functional foods when used in combination with a restrictive diet should be further evaluated (7). Furthermore, the significant association that was seen between the changes in ghrelin concentration and those in appetite sensation support the importance of using VAS in the study of appetite control during weight reduction.

The present study is unique in that appetite assessment and dietary intake was measured after 10 weeks of intervention, whereas most other studies have measured short-term hunger and satiety. This is a unique randomized controlled trial as it evaluated the effect of FSY on appetite control in obese persons with metabolic syndrome during long-term intervention.

A strength of this study was the high adherence rate to consuming the yogurt in both groups and a novel aspect of the study design was the composition of the fortified yogurt. It included both appetite-related hormone, grelin, and a self-reported VAS measurement for appetite. A limitation was that the multiple components added to the FSY made it difficult to identify which component was most effective for appetite control. Another limitation was the reliance on self-reported appetite measures and nutrient intake by participants. Although we appreciate the effect of FSY on appetite, our protocol did not allow exact confirmation of the effects on spontaneous daily energy intake because participants had to follow their personalized energy-restricted diet prescription.

In conclusion, FSY provided during an energy-restricted diet program reduced weight loss-related increases in appetite. It is suggested that this effect can be due to the suppression of appetite mainly by inulin and whey protein and partly by calcium and vitamin D supplementation. This indicates that consumption of two daily servings of a synbiotic dairy product with 3 g of inulin fortified with whey protein, calcium and vitamin D may control appetite while contributing to the intake of dietary fiber, calcium and vitamin D. Therefore, food-based strategies that support this aim are warranted.

Acknowledgments

The present article was extracted from the PhD dissertation written by Mohsen Mohammadi Sartang, and was financially supported by Shiraz University of Medical Sciences, Shiraz, Iran (no.95-11455). The authors are grateful to the participants for their kind and enthusiastic cooperation. A special thanks goes to the staff of Daity Dairy Company for providing the yogurt.

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