

Energy Expenditure is Increased Synergistically by Single Bolus Intake of *Lycium barbarum* Fruit (Goji) Juice When Combined with Indigestible Dietary Fiber and/or Caffeine, but not by Fiber or Caffeine alone

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ABSTRACT

L. barbarum increases postprandial energy expenditure (PPEE) and reduces body weight in rodents and central adiposity in humans. To investigate the possible synergistic effect of *L. barbarum* on PPEE with dietary fiber and caffeine, human adult subjects (n=12) randomly consumed a single bolus serving of 1 of 12 dietary samples in a randomized, double-blind, placebo controlled, repeated measures design. The tested products were: placebo, 3 different doses (1, 5 and 10 g) of indigestible soluble dietary fiber, non-caffeinated *L. barbarum* fruit juice (GoChi®), caffeinated *L. barbarum*-containing products (Chi3® and its variation formula, and TAlslim®). The non-*L. barbarum*-containing caffeinated samples consisted of coffee, green tea or 5-Hour Energy® (Living Essentials, Farmington Hills, MI). PPEE was measured by breath oxygen volume immediately before (baseline), 1, 2 and 4 h after sample intake. Samples were randomly tested at weekly intervals following an overnight fast. Consumption of all doses of dietary fiber and non-*L. barbarum*-containing caffeinated beverages did not statistically change PPEE from control levels. However, the addition of *L. barbarum* increased PPEE proportionally with the dose of fiber, and 5 and 10 g dietary fiber plus *L. barbarum* significantly increased PPEE by 8.2 and 8.8%. A low-dose of non-caffeinated *L. barbarum* produced an insignificant increase in PPEE, but all *L. barbarum*-containing products with caffeine increased RMR by 6.3-11.2%. These results show that *L. barbarum* synergizes with indigestible dietary fiber and/or caffeine to increase PPEE in humans.

INTRODUCTION

Abdominal obesity/waist circumference/visceral adipose tissue is a key component of the metabolic syndrome and is strongly associated with increased cardiometabolic risk, cardiovascular events, and mortality. Functional foods or dietary supplements that would help promote a negative energy balance could therefore have an impact on the weight trajectories of a large proportion of the population. Functional foods are foods that have health benefits above and beyond their nutritional value. For weight management, this may increase calorie burning and/or decrease appetite, relative to similar food products or ingredients. We have recently presented that an oral consumption of *Lycium barbarum* fruit (goji) in the form of juice (GoChi®) stimulated postprandial energy expenditure (PPEE) significantly higher than the baseline resting metabolic rate (RMR) through adrenocortical hormone control, and these effects may be related to controlling anthropometric parameters, especially waist circumference reduction. Soluble indigestible dietary fiber is reported to reduce visceral fat accumulation, to stimulate sugar metabolism without spike in blood sugar-glucose control, to increase lipid metabolism without increasing triglycerides, to promote intestinal regularity, to exert a prebiotic effect for replenishment of flora to eliminate those that contribute to obesity, and to increase insulin sensitivity. Tea is reported to promote fat loss through increased oxidation or fat burning in adipocytes, reduction of cholesterol, increased thermogenesis, and by limiting absorption of fat and starch calories through inhibition of pancreatic lipase and amylase. Caffeine is reported to promote body fat loss; to prevent development of overweight and obesity; to enhance thermogenesis; to exert effects on metabolic targets such as satiety, thermogenesis, and fat oxidation; to help to prevent positive energy balance, the prime cause of obesity; and to stimulate metabolism through central nervous system.

However, most functional food ingredients have been individually studied. It is unknown whether the combined intake of various functional foods leads to greater effectiveness than the sum of their individual effects, especially with *Lycium barbarum*. In an attempt to further enhance body weight control, we hypothesized that the simultaneous intake of various dietary ingredients, namely *Lycium barbarum*, dietary fiber, and tea extract would increase calorie burning capability observed with *Lycium barbarum* alone.

To investigate combination effects of these ingredients on the PPEE, which is closely related to a body weight control, a series of resting metabolic rate (RMR; resting EE) and PPEE measurements were conducted in a randomized, double-blind, placebo-controlled crossover manner.

MATERIALS AND METHODS

FreeLife International Inc, Phoenix, Arizona, supplied all commercially available products. Product descriptions of GoChi, Chi3, TAlslim, caffeinated beverages and indigestible soluble dietary fiber are shown in Table 1. *Lycium barbarum* fruit juice (GoChi®) was produced from fresh ripe *Lycium barbarum* fruit, and standardized to contain a content of *Lycium barbarum* polysaccharides (LBP) equivalent to that found in at least 38 g of fresh fruit per 30 ml of GoChi (16 kcal). Placebo control material matched the color, flavor and taste of GoChi and provided no LBP.

Indigestible water-soluble dietary maltodextrin fiber has less than 0.05 kcal/g of energy value, and 1, 5 and 10 g as an indigestible fiber was used in the test. Caffeine (100 mg) in powder form was used for the comparison test. Green tea and coffee were purchased as commercially available products and were brewed before the tests, and caffeine content was adjusted to 100 mg. The placebo liquid meal was commercially available liquid meal (Boost Plus®), and provided 360 kcal/237 ml with 14 g of fat (22% of energy), 45 g of carbohydrate (15%), and 14 g of protein (28%).

Table 1. Tested samples

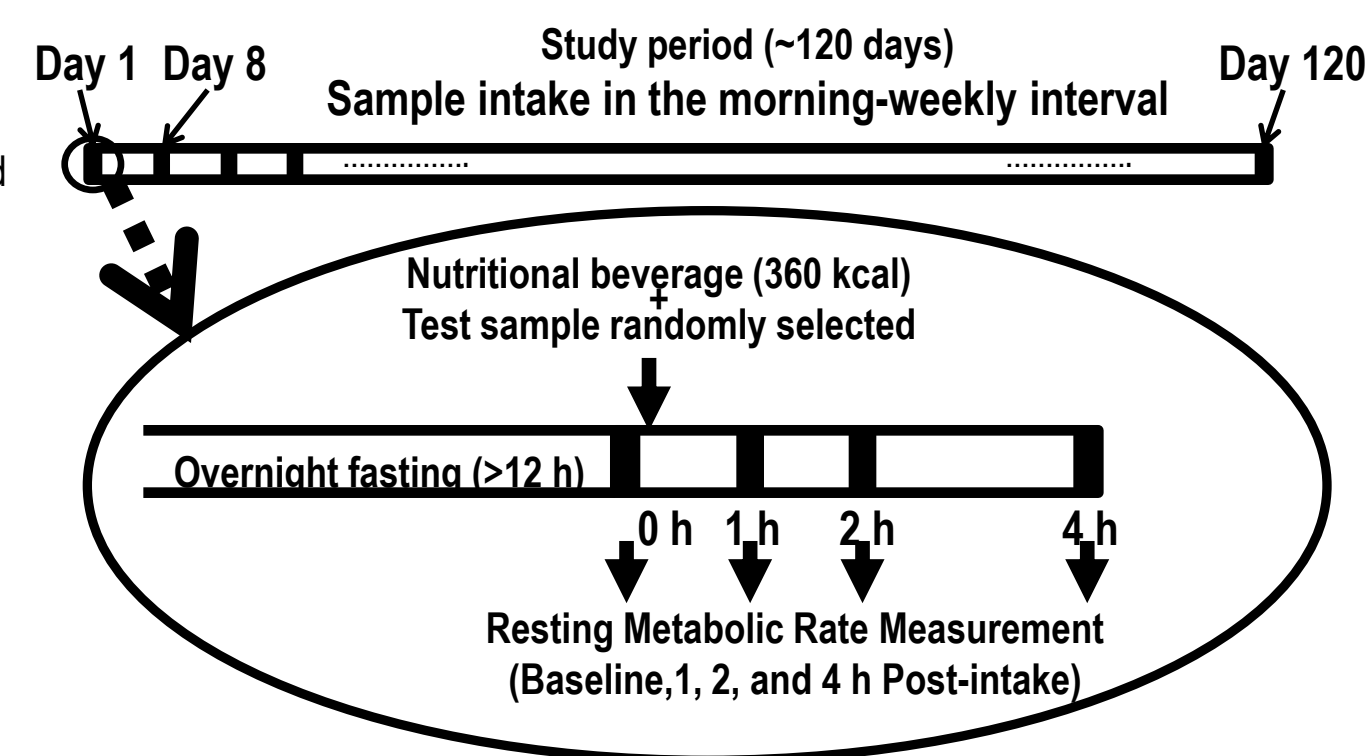
	Lycium barbarum-containing liquid dietary supplements			Caffeinated beverages			Indigestible soluble dietary fiber	
	GoChi	Chi3 (formula A)	Chi3 (formula B)	TAlslim	Green Tea	Coffee		5-Hour Energy
Energy	16 kcal	16 kcal	16 kcal	20 kcal	N/A	N/A	4 kcal	0 kcal
Total volume per serving	30 ml	60 ml	60 ml	60 ml	180 ml	180 ml	60 ml	N/A
Amount of <i>L. barbarum</i> fruit juice per serving	30 ml	30 ml	30 ml	15 ml	N/A	N/A	N/A	N/A
Caffeine	N/A	100 mg	100 mg	100 mg	100 mg	100 mg	100 mg	N/A
Blend of amino acids, caffeine, and others.	N/A	1900 mg Including Caffeine, Taurine, L-Phenylalanine, N-Acetyl-L-Tyrosine, Glucuronolactone, Green tea leaf extract	359 mg Including Caffeine, Taurine, L-Phenylalanine, N-Acetyl-L-Tyrosine, Green tea	930 mg including Caffeine, L-Phenylalanine, N-Acetyl-L-Tyrosine, Mixed Tea blend	N/A	N/A	1870 mg Including Caffeine, Taurine, L-Phenylalanine, N-Acetyl-L-Tyrosine, Malic Acid, Citicoline	N/A
	Niacin	N/A	30 mg	18 mg	N/A	N/A	N/A	30 mg
Vitamin B ₆	N/A	40 mg	3 mg	N/A	N/A	N/A	40 mg	N/A
Folate	N/A	400 µg	400 µg	N/A	N/A	N/A	400 µg	N/A
Vitamin B ₁₂	N/A	500 µg	3 µg	N/A	N/A	N/A	500 µg	N/A
Dietary fiber	N/A	N/A	N/A	5 g	N/A	N/A	N/A	1.5, 10 g
Increased PPEE at 2 h post-intake (ml/min)	25.75 ± 4.1	38.0 ± 6.3*	44.6 ± 7.1*	30.8 ± 6.1*	16.8 ± 5.8	19.0 ± 4.1	17.0 ± 5.3	10.4 ± 4.2
Mean ± SEM								18.3 ± 3.3
								19.5 ± 5.1

*P<0.05 compared to the baseline level (15.7 ± 4.8 ml/min).

Study population. Subjects, 18 y and older were recruited for the study and participants selected for the trial were judged to be healthy. Subjects were excluded from the study if they had known allergies to ingredients in the products, use of any fiber materials, medication or supplements for purpose of weight loss or weight control, appetite suppression and/or energy drinks, had gastrointestinal disease or problems including chronic symptoms such as irritable bowel syndrome, diabetes, cardiac problems (previous myocardial infarction or cardiovascular diseases), were pregnant or breast feeding, or were under anticoagulant therapy with warfarin (Coumadin®). All subjects were fully informed of the purpose of the study, and signed the Human Subjects Informed Consent forms approved by the Internal Review Board under the Helsinki Declaration.

Study design - Resting Metabolic Rate (RMR) and PPEE. To investigate the effect of the products and combination on PPEE, a group comprising 12 subjects (21-53 years, average age=34.5 ± 3.4y, BMI=28.2 ± 1.1 kg/m²) was enrolled. Energy/caloric metabolism activity indicated by RMR was measured by breath oxygen volume (VO₂; ml/min) using hand-held indirect calorimeter (MedGem test kit). Subjects consumed a single bolus intake of 1 serving of each test product after a 12 h overnight fast. VO₂ and RMR/PPEE were measured immediately before (baseline), 1, 2 and 4 h after sample consumption. All subjects were provided a liquid meal (360 kcal, Boost Plus®) and test sample at the completion of the 1st RMR measurement.

Figure 1. Testing procedure of resting metabolic rate (RMR) measurement. RMR was measured by breath oxygen volume (VO₂; ml/min) using a hand-held indirect calorimeter in a randomized, double-blind, placebo-controlled, multiple-period crossover study. All test subjects consumed 1 of 8 separate test samples that were presented randomly to subjects at weekly intervals, and same sample was tested 2 times separately. Study period was up to 120 days.



Statistical analysis: Average RMR and PPEE obtained using indirect calorimeter were tested for statistical significance with Student's paired *t* test. RMR was defined as the initial 15-minute measurement period before breakfast consumption. Descriptive statistics were calculated for pre-intervention and each

measurement period for all dependent measures and summarized as means and standard errors. The data were processed using Statistica version 8. Differences were considered significant at P<0.05.

RESULTS

Impacts of the Ingredients in TAlslim and Comparison with various ingredients on PPEE: We have investigated the effect of various ingredients and their combination on PPEE. PPEE in the subjects after consumption of each sample has shown different outcomes. The ingredients formulated in TAlslim, such as GoChi, fiber, caffeine and tea blend alone produced insignificant changes of PPEE from placebo control level. However, intake of a combination of GoChi+fiber, TAlslim and Chi3 had statistically significant increase of PPEE (Figure 2). AUC of the PPEE during 0-4 h post-intake relative to placebo control was significantly increased by 2-3 times more with GoChi+fiber, and TAlslim (P<0.05) (Figure 2). As shown in the kinetic analysis of PPEE and AUC 0-4 h (Figure 2), TAlslim intake has shown statistically significant increase of PPEE compared to the control and baseline level by 8.2% compared to the baseline RMR level (Figure 2). Conversely, placebo control sample, which did not have TAlslim but 360 kcal control liquid meal only, increased PPEE by about 3.6% over the baseline RMR level (Figure 2).

Synergistic effect of *Lycium barbarum* and fiber: We have further tested a combination of *Lycium barbarum* using 15 ml of GoChi and fiber in a various doses (0, 1, 5, and 10 g). Intakes of all doses of fiber alone have not shown any statistically significant increases on PPEE from the baseline level (Figure 3). However, an addition of *Lycium barbarum* to 5 and 10 g of fiber had significant PPEE increase by about 8.2 and 8.8% compared to the baseline RMR level, respectively (P<0.05) (Figure 3). As *Lycium barbarum* alone or any doses of fiber alone did not produce significant increases of PPEE by itself, the impact of a combination of 5 or 10 g of fiber plus *Lycium barbarum* seems a synergistic effect.

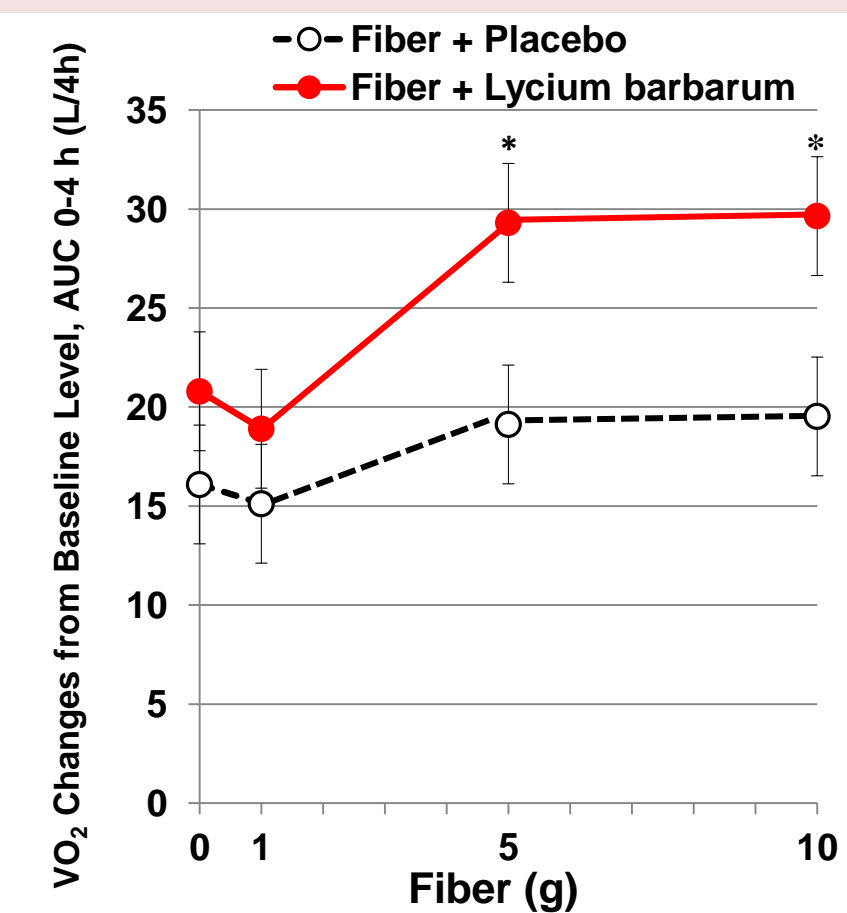


Figure 2. Time-course (A) and Area Under the Curve (AUC) during 0-4 hr (B) of Breath Oxygen Level (VO₂) as an Indication of Postprandial Energy Expenditure (PPEE) after a Single Bolus Intake of Various Preparations in Healthy Human Subjects. Each value indicates mean ± SEM. *P<0.05 compared to pre-intervention (baseline)

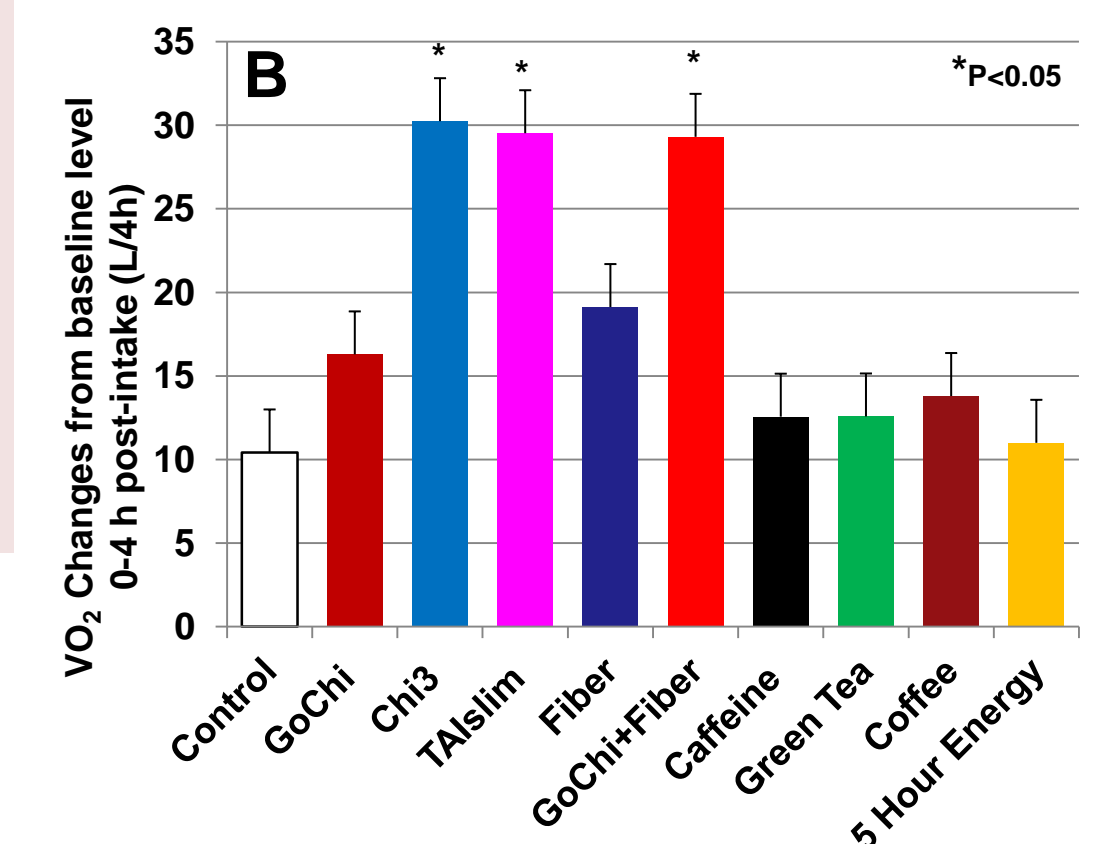
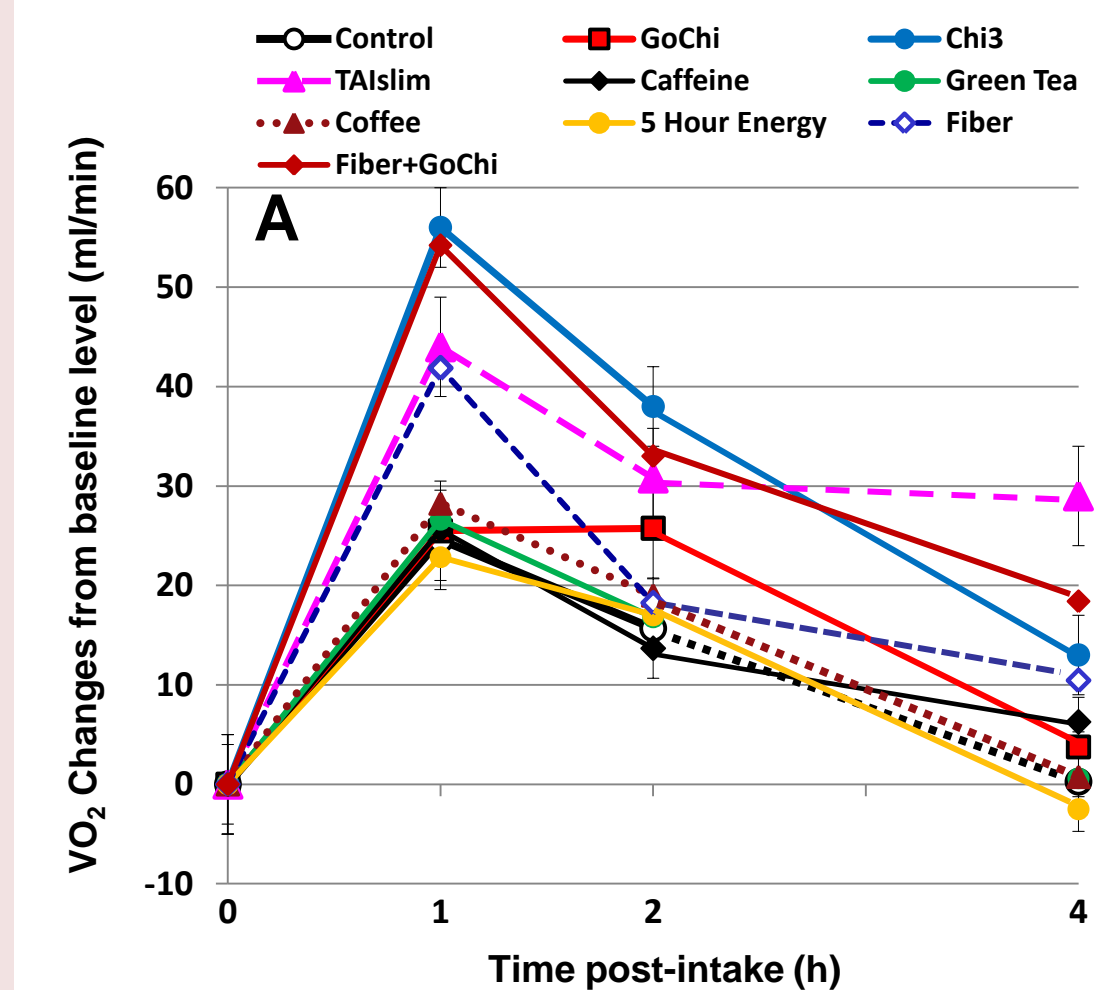


Figure 3. Impacts of Indigestible Soluble Dietary Fiber with/without *L. barbarum* (GoChi) on Breath Oxygen Level (VO₂) as an Indication of Postprandial Energy Expenditure (PPEE) in Healthy Human Subjects. Each value indicates mean ± SEM. *P<0.05 compared to pre-intervention (baseline)

CONCLUSION

These results suggest that, compared to common caffeinated beverages or fiber alone, *L. barbarum*-containing products exhibit synergistic and longer-lasting stimulating effects on energy/caloric metabolism in humans. These may be related to various obesity and metabolism-related hormonal levels, and further studies will clarify more details of mechanism of action.