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PANEL:
Emerging Sports Ingredients

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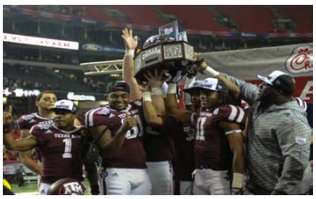

Role of Fruits & Vegetables in Athletes Diet?

Fruits & Vegetables

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- FAV consumption associated with healthy diet
- FAV important dietary source of micronutrients, vitamins, minerals, and phytonutrients
- Antioxidant quality of FAV particularly important for active individuals
- A lack of antioxidants in athletes can lead to excessive ROS and nitrogen production that induce muscle damage, inflammation, immunosuppression, susceptibility to injury, and prolonged recovery.

Lamprecht, Med. Sport Sci., 59:70-85, 2013

Fruits & Vegetables

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- Sport nutritionists' recommend that athletes increase consumption of FAV and/or antioxidants particularly during intense training periods and/or when training/competing at altitude
- Obtaining adequate amounts of FAV in diets of athletes is difficult due to digestive, time, and travel constraints
- Greater use of supplemental FAV concentrates and juices in athletes
- Interest in identifying bioactive nutrients contained in FAV for dietary supplements

Lamprecht, Med. Sport Sci., 59:70-85, 2013

Examples of Botanically-Derived Bioactive Ergogenic Aids

Botanical Bioactives

Theoretical Value in Sport Supplements

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- Nitrates
  - Reduce afterload and blood pressure
  - Increase blood flow and nutrient delivery
  - Ergogenic Value
- Antioxidants
  - Reduce exercise-induced oxidative stress
  - Reduce muscle damage
  - Enhance recovery
- Immune Support
  - Lessen immunosuppressive effects of intense exercise
  - Reduce incidence of URTI
- Glycemic Control
  - Enhance glycogen resynthesis
  - Improve blood glucose regulation
- Ergogenic Bioactive Extracts

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Beet Root Juices / Nitrates

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- Dietary intake of food or juices with high nitrate levels has been reported to promote healthy blood pressure due to a vasodilatory effect
- Studies show consuming BRJ prior to exercise (e.g., 300-500 ml) improves aerobic endurance efficiency
- Some studies suggest nitrate supplementation can also enhance intermittent exercise performance and/or recovery

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Beet Root Juice/Nitrates

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- Larsen et al. (*Acta physiologica. 2007;191:59–66*) reported a reduction in maximal oxygen consumption; and a trend for improvement in time-to-exhaustion accompanying the ingestion of sodium nitrate intake at 0.1 mmol/kg/day for three days.
- Larsen et al. (*Free Radic Biol Med. 2010;48:342–7*) reported a significant reduction in oxygen consumption and improvement in gross efficiency at sub-maximal workloads using the same ingestion schema.
- Bescos et al., (*Med Sci Sports Exerc. 2011;43:1979–86*) found that the consumption of 10 mg/kg of sodium nitrate prior to a cycle ergometer test reduced VO_2peak without influencing time to exhaustion or maximal power output in highly trained cyclist and triathletes.

Inorganic nitrate supplementation improves muscle oxygenation, O(2) uptake kinetics, and exercise tolerance at high but not low pedal rates

Bailey et al. J Appl Physiol. 118(11):1396-405, 2015

EXERCISE & SPORT NUTRITION LABORATORY
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- 7 subjects completed severe-intensity step cycle tests at pedal cadences of 35 rpm and 115 rpm during separate 9-d supplementation periods with NO_3- rich beetroot juice (BR) (providing 8.4 mmol NO_3-/d) and PLA.
- Compared with PLA, plasma nitrite concentration increased 178% with BR ($P < 0.01$).
- There were no significant differences in muscle oxyhemoglobin concentration ([O_2Hb]), phase II Vo_2 kinetics, or Tlim between BR and PLA when cycling at 35 rpm ($P > 0.05$).
- When cycling at 115 rpm, muscle [O_2Hb] was higher at baseline and throughout exercise, phase II Vo_2 kinetics was faster (47 +/- 16 s vs. 61 +/- 25 s; $P < 0.05$), and Tlim was greater (362 +/- 137 s vs. 297 +/- 79 s; $P < 0.05$) with BR compared with PLA.
- Results suggest that ***short-term BR supplementation can increase muscle oxygenation, expedite the adjustment of oxidative metabolism, and enhance exercise tolerance when cycling at a high, but not a low, pedal cadence.***

Nitrate Intake Promotes Shift in Muscle Fiber Type Composition during Sprint Interval Training in Hypoxia

De Smet et al. Front Physiol. 7: 233, 2016

EXERCISE & SPORT NUTRITION LABORATORY
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- 27 moderately-trained participants were allocated to one of three experimental groups: Sprint Interval Training (SIT) in normoxia (20.9% FiO_2) + PLA (N), SIT in hypoxia (15% FiO_2) + PLA (H), or SIT in hypoxia + nitrate (HN).
- All participated in 5 weeks of SIT on a cycle ergometer (30-s sprints interspersed by 4.5 min recovery-intervals, 3 weekly sessions, 4-6 sprints per session).
- Nitrate (6.45 mmol $NaNO_3$) or placebo capsules were administered 3 h before each session.
- SIT decreased the proportion of type IIx muscle fibers in all groups ($P < 0.05$).
- The relative number of type IIa fibers increased ($P < 0.05$) in HN ($P < 0.05$ vs. H), but not in the other groups.
- Compared with H, SIT tended to enhance 30-s sprint performance more in HN than in H ($P = 0.085$).
- *SIT in hypoxia combined with nitrate supplementation increases the proportion of type IIa fibers in muscle, which may be associated with enhanced performance in short maximal exercise.*

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The Effects of Nitrate-Rich Supplementation on Neuromuscular Efficiency during Heavy Resistance Exercise

Flanagan et al. J Am Coll Nutr. 35(2):100-7, 2016

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- 14 resistance-trained consumed an nitrate-rich (NR) or nitrate-poor (NP) supplement for 3 d, performed a bout of heavy resistance exercise, completed a washout, and then repeated the procedures with the remaining supplement.
- Before, during, and after exercise, individual and gross motor unit efficiency was assessed during isometric and dynamic muscle contractions and physical performance, heart rate, lactate, and oxygen consumption (VO_2) were determined.
- NR supplementation resulted in lower initial muscle firing rates at rest and lower mean and maximum firing rates over the course of fatiguing exercise.
- NP supplementation was accompanied by increased mean and maximum firing rates by the end of exercise and lower initial firing rates.
- Nitrate supplementation resulted in higher mean peak electromyography (EMG) amplitudes.
- *Supplementation with an NR beetroot extract-based supplement provided neuromuscular advantages during metabolically taxing resistance exercise.*

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Ingestion of a nitric oxide enhancing supplement improves resistance exercise performance

Mosher et al. J Strength Cond Res. e-pub, April 2, 2016

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- 12 resistance trained males ingested either 70 ml of "BEET It Sport" nitrate shot containing 6.4 millimoles (mmol/L) or 400 mg of nitrate; or a blackcurrant placebo drink.
- Participants completed a resistance exercise session, consisting of bench press exercise at an intensity of 60% of their established 1 repetition maximum (1-RM), for three sets until failure with 2 minute rest interval between sets.
- Results showed a significant difference in repetitions to failure ($p < 0.001$) and total weight lifted ($p < 0.001$).
- No significant differences were seen in lactate, local, or general indicators of fatigue.
- *Nitrate supplementation before exercise improved resistance training performance and work output.*

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The effects of beetroot juice supplementation on indices of muscle damage following eccentric exercise

Clifford et al. EJAP. 116(2): 2016

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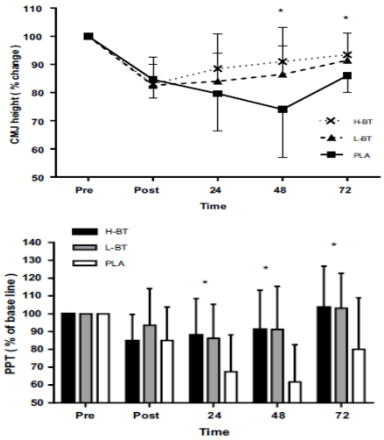
- 30 males consumed high-dose BRJ (H-BT; 250 ml), a lower dose of BRJ (L-BT; 125 ml), or PLA immediately (x3 servings), 24 (x2 servings) and 48 h (x2 servings) following completion of 100-drop jumps.
- Maximal isometric voluntary contractions (MIVC), countermovement jumps (CMJ), pressure pain threshold (PPT), creatine kinase (CK), interleukin-6 (IL-6), interleukin-8 (IL-8) and tumor necrosis factor-alpha (TNF-alpha) were measured pre, post, 2 (blood indices only), 24, 48 and 72 h following the drop jumps.
- *Acute BRJ supplementation attenuated muscle soreness and decrements in CMJ performance induced by eccentric exercise* while MIVC, CK, IL-6, TNF-alpha and IL-8 were not affected.



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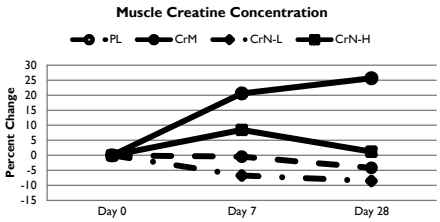
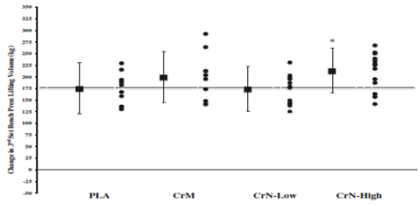
Acute and chronic safety and efficacy of dose dependent creatine nitrate supplementation and exercise performance

Galvan et al. JISSN 13:12, 2016

- Day 0 – 7: Loading Phase (4 doses/d)
  - PL: **26 g dextrose**/d
  - CrM: **12 g CrM** + 2 g flavoring + 8 g dextrose/d
  - CrN-L: **6 g CrN** + 2 g flavoring + 8 g dextrose/d
  - CrN-H: **12 g CrN** + 2 g flavoring + 8 g dextrose/d
- Day 8 – 28: Maintenance Phase (1 dose/d)
  - PL: **6.5 g dextrose**/d
  - CrM: **3 g CrM** + 0.5 g flavoring + 2 g dextrose/d
  - CrN-L: **1.5 g CrN** + 0.5 g flavoring + 2 g dextrose/d
  - CrN-H: **3.0 g CrN** + 0.5 g flavoring + 2 g dextrose/d
- Muscle creatine increased significantly by d-7 in the CrM and CrN-High groups, but then decreased by d-28 for CrN-High.
- ***Some ergogenic benefits were observed among groups most likely due to influence of nitrate.***
- CrN delivered at 3 g was well-tolerated, demonstrated similar performance benefits to 3 g CrM, and within the confines of this study, there were no safety concerns.
- ***There was no evidence that CrN at recommended or twice recommended doses is more efficacious than CrM at the doses studied.***





Montmorency Tart Cherries

- Consumption of foods high in polyphenols, particularly anthocyanins, have been associated with improved health
- Tart cherry juice and powders have antioxidant properties and is thought to activate antioxidant response genes.
- Use of tart cherry juice/concentrates theorized to reduce exercise-induced oxidative stress and muscle damage.
- Some evidence of improved weight loss in animals
- Long-term supplementation theorized to enhance recovery and training tolerance

Effects of powdered Montmorency tart cherry supplementation on an acute bout of intense lower body strength exercise in resistance trained males

Levers et al. JISSN. 12:41, 2015

EXERCISE & SPORT NUTRITION LABORATORY
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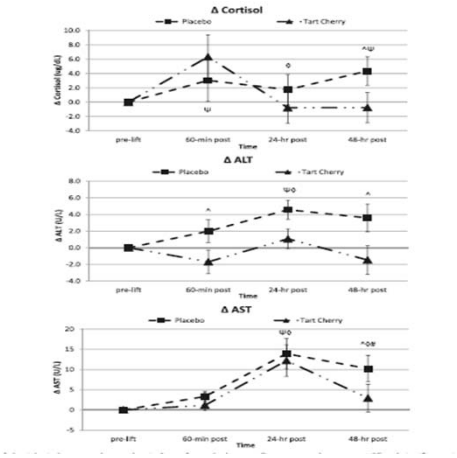
- 23 resistance-trained men were randomly assigned to ingest, in a double blind manner, capsules containing 480 mg/d of a PL or powdered tart cherries (TC) for 10-d prior to and for 48-h post-exercise.
- Subjects performed 10 sets of 10 reps at 70% of a 1-RM back squat exercise after 10-d of supplementation.
- Fasting blood samples, isokinetic MVCs, and quadriceps muscle soreness ratings were taken pre-lift, 60-min, 24-h, and 48-h post-lift.
- *TC supplementation attenuated muscle soreness, strength decrement during recovery, and markers of muscle catabolism in resistance trained individuals.*



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Effects of powdered Montmorency tart cherry supplementation on acute endurance exercise performance in aerobically trained individuals

Levers et al. JISSN. 13:22, 2016

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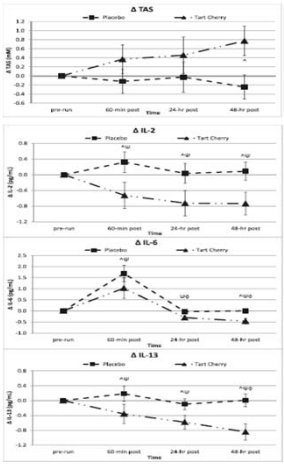
- 27 endurance-trained athletes ingested, in a double-blind manner, capsules containing 480 mg of PL or powdered TC for 10-d prior to performing a half marathon and for 48-hr post-run.
- Fasting blood samples and quadriceps muscle soreness ratings were taken pre-run, 60-min, 24 and 48-h post-run.
- *TC supplementation attenuated markers of muscle catabolism, reduced immune and inflammatory stress, better maintained redox balance, and increased performance in aerobically trained individuals.*



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Recovery facilitation with Montmorency cherries following high-intensity, metabolically challenging exercise

Bell et al. Appl Physiol Nutr Metab. 40(4):414-23, 2015

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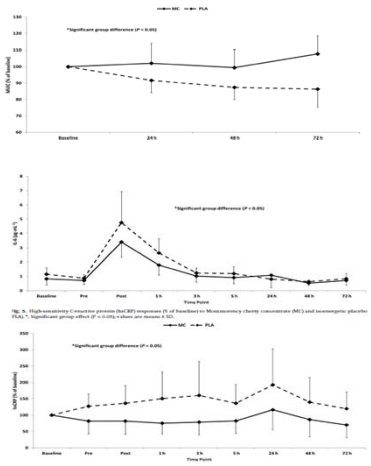
- 16 trained cyclists consumed 30 mL of PL or MC twice per day for 8-d.
- On day 5. participants completed a 109-min cycling trial designed to replicate road race demands.
- Functional performance (MVIC) cycling efficiency, 6-s peak cycling power) and DOM were assessed at baseline, 24, 48, and 72 h post-trial.
- Blood samples collected at baseline, immediately pre- and post-trial, and at 1, 3, 5, 24, 48, and 72 h post-trial.
- MVIC ($P < 0.05$) did not decline in the MC group (vs. PLA) across the 72-h post-trial period and economy ($P < 0.05$) was improved in the MC group at 24 h.
- IL-6 ($P < 0.001$) and hsCRP ($P < 0.05$) responses to the trial were attenuated with MC (vs. PLA).
- *MC concentrate can be an efficacious functional food for accelerating recovery and reducing exercise-induced inflammation following strenuous cycling exercise..*



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The effects of Montmorency tart cherry concentrate supplementation on recovery following prolonged, intermittent exercise

Bell et al. Nutrients. (7): 2016

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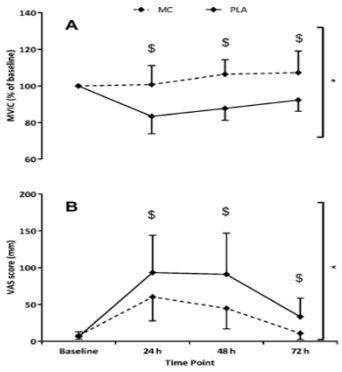
- 16 semi-professional, male soccer players consumed either MC or PLA supplements for 8-d (30 mL x 2/d).
- On day 5, participants completed an adapted version of the Loughborough Intermittent Shuttle Test (LISTADAPT).
- MVIC, 20 m Sprint, counter movement jump (CMJ), agility and muscle soreness (DOMS) were assessed at baseline, and 24, 48 and 72 h post-exercise while measures of inflammation (IL-1-beta, IL-6, IL-8, TNF-alpha, hsCRP), muscle damage (CK) and oxidative stress (LOOH) were analyzed at baseline and 1, 3, 5, 24, 48 and 72 h post-exercise.
- Performance indices (MVIC, CMJ and agility) recovered faster and muscle soreness (DOMS) ratings were lower in the MC group ($p < 0.05$).
- Acute inflammatory response (IL-6) was attenuated by MC.
- *MC is efficacious in accelerating recovery following prolonged, repeat sprint activity, such as soccer and rugby.*



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Fenugreek Seed Extract

Theoretical Ergogenic Benefits

- Fenugreek (*Trigonella foenum-graecum*) is a leguminous plant originating in India and North Africa.
- Suksomboon et al (*J Enthnopharm. 137:1328-33, 2011*) reported that FG significantly decreased Hb1AC with no effect on fasting BG.
- Neelakantan et al (*Nutr J. 13:7, 2014*) conducted a meta-analysis on 10 studies and reported that FG significantly reduced Hb1AC and fasting BG in diabetics.
- FG supplementation with CHO theorized to increase glycogen replenishment, promote glucose uptake, enhance insulin and glucose mediated creatine retention

Poole et al. *JISSN*. 7:34, 2010.

Glycogen resynthesis and exercise performance with the addition of fenugreek extract (4-hydroxyisoleucine) to post-exercise carbohydrate feeding

Slivka et al. Amino Acids. 35(2):439-44, 2008

- Muscle biopsies were obtained prior to and following 5 h of cycling at 50% of peak cycling power to promote muscle glycogen.
- Subjects ingested immediately after and 2 h after exercise dextrose (GLU) (1.8 g/kg) or GLU with FG containing 1.99 +/- 0.20 mg/kg of 4-hydroxy-isoleucine (GLU + FG) in a randomized, cross-over, double blind manner.
- Biopsies were obtained 4 h post-exercise and subjects received a standardized meal along with FG or PLA .
- At 15 h post-exercise subjects underwent their final muscle biopsy before completing a simulated 40 km cycling time trial.
- There was no difference in muscle glycogen at any time between GLU and GLU + FG.
- 40 km time trial performance was similar for average power output (221 +/- 28 vs. 213 +/- 16 watts) and for time to completion (69.7 +/- 3.7 vs. 70.5 +/- 2.2 min) for the GLU and GLU + FG, respectively.
- ***Results do not support an effect of fenugreek supplementation on glycogen resynthesis.***

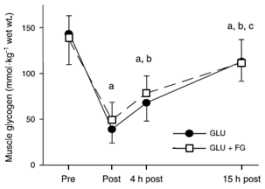

Fig. 2. Changes in muscle glycogen content with 5 h of cycling exercise (Pre–Post) and recovery (4 h Post, 15 h Post) in response to post exercise glucose (*GLU*) and glucose with fenugreek (*GLU + FG*) post exercise feedings. *a* $p < 0.05$ from pre (main effect for time); *b* $p < 0.05$ from post (main effect for time); *c* $p < 0.05$ from 4 h post (main effect for time). Data are mean ± SD

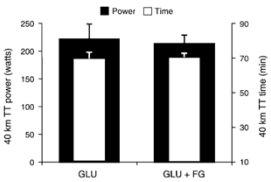

Fig. 3. Simulated 40 km time trial performance (left axis power, right axis time) with glucose (*GLU*) and glucose with fenugreek (*GLU + FG*) post exercise feedings. Data are mean ± SD

The effects of a commercially available botanical supplement on strength, body composition, power output, and hormonal profiles in resistance-trained males

Poole et al. JISSN. 7(34), 2010

EXERCISE & SPORT NUTRITION LABORATORY
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- 9 RT men were matched and randomly assigned to ingest in a double blind manner capsules containing 500 mg of a PL or Fenugreek.
- Subjects participated in a supervised 4-day per week periodized RT program.
- At 0, 4, and 8-weeks, subjects underwent body composition, 1-RM strength, muscle endurance, and anaerobic capacity testing.
- Significant interaction effects were observed among groups in changes in body fat (FEN: -2.3 +/- 1.4%BF; PL: -0.39 +/- 1.6 %BF, $p < 0.001$), leg press 1-RM (FEN: 84.6 +/- 36.2 kg; PL: 48 +/- 29.5 kg, $p < 0.001$), and bench press 1-RM (FEN: 9.1 +/- 6.9 kg; PL: 4.3 +/- 5.6 kg, $p = 0.01$).
- No significant interactions were observed among groups for anaerobic capacity or muscular endurance on bench press or leg press
- ***500 mg of this proprietary Fenugreek extract had a significant impact on both upper- and lower-body strength and body composition in comparison to placebo in a double blind controlled trial.***

Table 3 Body composition changes within and between groups

Variable	Group	Baseline (T1)	Week 4 (T2)	Week 8 (T3)	Between Group
Body Weight	FEN	90.2 ± 18.2	89.9 ± 18.2	90.4 ± 17.7	G = 0.305
(kg)	PLA	85.7 ± 12.7	85.0 ± 13.9	85.8 ± 12.4	T = 0.244
					G × T = 0.803
Lean Mass	FEN	157.7 ± 23.9	160.2 ± 23.8‡	162.6 ± 22.9†	G = 0.640
(kg)	PLA	157.2 ± 19.5	156.4 ± 22.4	158.2 ± 19.5	T = 0.004†
					G × T = 0.057
Body Fat %	FEN	19.4 ± 8.4	17.8 ± 8.4 †	17.1 ± 8.6 †	G = 0.298
	PLA	16.3 ± 4.8	16.0 ± 4.8	15.9 ± 4.5	T < 0.001†
					G × T < 0.001†

Abbreviations: FEN = fenugreek supplement group, PLA = placebo group.
Symbols: † = Significant between group difference ($p < 0.05$), ‡ = Within group difference from baseline (T1), $p < 0.05$.

Table 4 Training adaptations within/between groups from baseline (T1) through week 8 (T3)

Variable	Group	Baseline (T1)	Week 4 (T2)	Week 8 (T3)	Between Group
Bench Press	FEN	105 ± 26	111 ± 27‡	114 ± 27‡	G = 0.891
1RM (kg)	PLA	107 ± 22	109 ± 22‡	111 ± 22‡	T < 0.001†
					G × T = 0.008†
Leg Press	FEN	334 ± 74	384 ± 79‡	419 ± 87†‡	G = 0.077
1RM (kg)	PLA	316 ± 63	344 ± 66‡	364 ± 68‡	T < 0.001†
					G × T < 0.001†
Bench Press	FEN	7.9 ± 1.9	7.6 ± 1.9	8.2 ± 1.8	G = 0.091
80% to failure	PLA	7.3 ± 1.5	7.0 ± 1.5	7.5 ± 1.7	T = 0.154
					G × T = 0.984
Leg Press	FEN	12.2 ± 4.1	11.8 ± 3.8	10.8 ± 4.4	G = 0.035
80% to failure	PLA	12.0 ± 2.5	12.1 ± 2.8	11.3 ± 2.9	T = 0.168
					G × T = 0.821
Peak Power	FEN	1141 ± 222	1161 ± 198	1183 ± 200‡	G = 0.428
(watts)	PLA	1091 ± 215	1115 ± 231	1132 ± 237	T = 0.002†
					G × T = 0.074
Mean Power	FEN	628 ± 96	640 ± 107	643 ± 103	G = 0.363
(watts)	PLA	616 ± 90	609 ± 95	611 ± 85	T = 0.507
					G × T = 0.036†

Abbreviations: FEN = fenugreek supplement group, PLA = placebo group.
Symbols: † = Significant between group difference ($p < 0.05$), ‡ = Within group difference from baseline (T1), $p < 0.05$, = Within group difference from week 4 (T2).

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Pumpkin Seed Extract

Theoretical Ergogenic Benefits

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- Oil extracted from pumpkin seeds purported to reduce prostrate enlargement, decrease inflammation, serve as an antioxidant, and have neuroprotective effects
- Some evidence of enhanced glucose control
- Theorized to reduce oxidative stress and inflammation following intense exercise
- Theorized to improve glucose control and glycogen replenishment

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Improvement in HDL cholesterol in postmenopausal women supplemented with pumpkin seed oil: pilot study

Gossell-William et al. Climacteric. 14(5), 558-64, 2011

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- 35 postmenopause women were administered 2 g/d of wheat germ oil (PLA) or pumpkin seed oil (PSO) for 12-weeks.
- Fasting lipids, glucose and blood pressure were measured and an 18-point questionnaire regarding menopausal symptoms was administered.
- Women receiving PSO showed a significant increase in HDL-c (0.92 +/- 0.23 vs. 1.07 +/- 0.27 mmol/l) and decrease in DBP (81.1 +/- 7.94 vs. 75.67 +/- 11.93 mmHg).
- There was also a significant improvement in the menopausal symptom scores (18.1 +/- 9.0 vs. 13.2 +/- 6.7) with a decrease in severity of hot flushes, less headaches and less joint pains being the main contributors.
- Women in the group receiving PLA reported being more depressed and having more unloved feeling.
- ***This pilot study showed PSO had some benefits for postmenopausal women and provided strong evidence to support further studies***.

Table 3 Median (interquartile range, IQR) for severity of menopausal symptom score (range 0–3). Score for each item ranged from 0 for absent to 3 for severe. Of the 18 items, 13 showed no change from baseline

	Median (IQR)		*p Value*	
	Baseline	*12 weeks*	*Within group (Wilcoxon signed rank)*	*Between group at 12 weeks (Mann–Whitney)*
Hot flushes				
WGO	1.5 (1–2)	2 (1–2)	0.822	0.470
PSO	2 (1–2)	1 (1–2)	0.049*	
Headaches				
WGO	0 (0–2)	0 (0–1)	0.511	0.685
PSO	1 (0–2)	0 (0–1)	0.026*	
Depression				
WGO	0 (0–0)	1 (0–2)	0.009*	0.046†
PSO	0 (0–1)	0 (0–1)	0.364	
Unloved feelings				
WGO	0 (0–0)	1 (0–2)	0.026*	0.042†
PSO	0 (0–1)	0 (0–0)	0.089	
Joint pain				
WGO	1.5 (0–2)	1 (0–2)	0.801	0.663
PSO	2 (1–2)	1 (1–2)	0.030*	

WGO, wheat germ oil; PSO, pumpkin seed oil
†, Significant $p < 0.05$ between groups at 12 weeks; *, significant $p < 0.05$ when compared to baseline

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Pumpkin (Cucurbita moschata) fruit extract improves physical fatigue and exercise performance in mice.

Wang et al. Molecules. 17(10), 11,864-76, 2012

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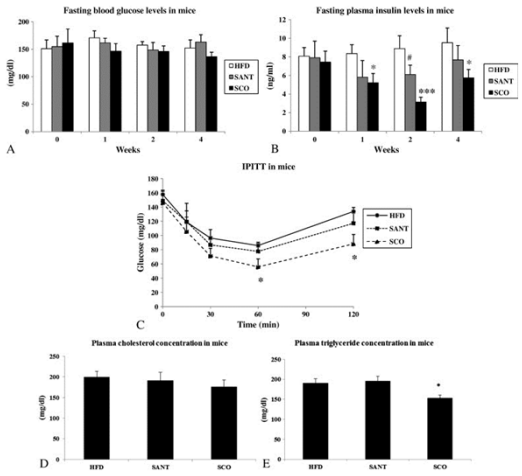
- Male ICR mice were fed 0. 50, 100, or 250 mg/kg of pumpkin fruit extract (PFE) for 14 days.
- Swim time to exhaustion and forelimb grip strength measurements were obtained.
- Results revealed ***that CME significantly increased body weight loaded (5%) swim time*** to exhaustion by 1.68 to1.99-fold, plasma glucose by 1.34 to 1.4-fold, and displayed ***increased muscle & hepatic glycogen levels*** following exercise.
- ***Grip strength increased*** by 1.23 to 1.3-fold in the CME groups.
- There were dose dependent trends of decreased plasma lactate (14.7-19%), creatine kinase (CK) (30-36.2%), and ammonia levels (33.6-44%) in all CME treatment groups following a daily acute bout of swimming.
- Ergogenic studies need to be conducted in humans.



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Quercetin

Theoretical Ergogenic Benefits

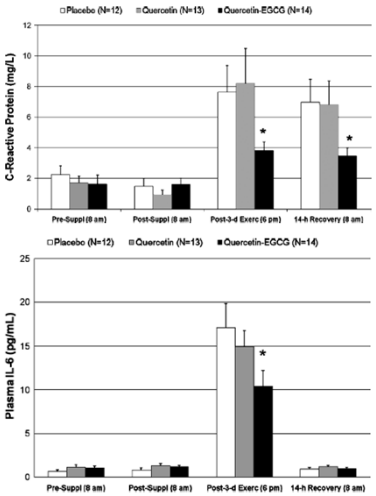
- Quercetin is a plant pigment found in many foods such as onions, apples, berries, tea, grapes and red wine.
- Classified as flavonoid
- Quercetin and rutin are used in many countries for blood vessel health and are ingredients of numerous multivitamin preparations and herbal remedies.
- Theorized to reduce immunosuppressive effects of intense exercise, oxidative stress, and improve aerobic exercise capacity.

http://www.raysahelian.com/quercetin.html

Effects of quercetin and EGCG on mitochondrial biogenesis and immunity

Neiman et al. Med Sci Sports Exerc. 41(7), 1467-75, 2009

- Trained cyclists (N = 39) were randomized to placebo (P), Q (1 g/d), or Q-EGCG (400 mg/d Q, 400 mg/d EGCG) for 14-d before, during, and 1 wk after a 3-d period in which subjects cycled for 3 h/d at approximately 57% Wmax.
- Blood, saliva, and muscle biopsy samples were collected before, after 2 wk of supplementation, after 3-d of exercise, and after 3-d recovery.
- Plasma quercetin was increased in the Q and Q-EGCG trials while granulocyte oxidative burst activity (GOBA) was increased with Q-EGCG.
- After the 3rd exercise bout, significant decreases for CRP, IL-6, and IL-10 were seen with Q-EGCG.
- Granulocyte colony-stimulating factor and CRP were reduced in Q-EGCG 14 h after exercise.
- *Q-EGCG supplementation augmented GOBA and countered inflammation after 3 d of heavy exertion in trained cyclists.*



Quercetin's influence on exercise performance and muscle mitochondrial biogenesis

Nieman et al. Med Sci Sports Exerc. 42(2), 338-45, 2010

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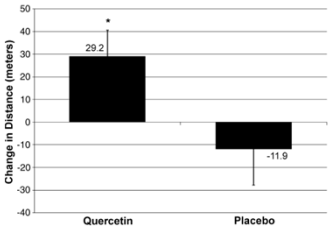
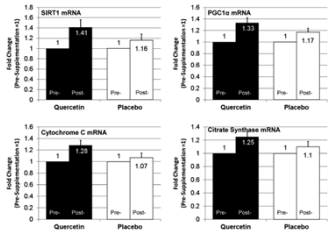
- Untrained males (N = 26) were randomized to placebo (P) or Q (1 g/d) 14-d
- Subjects provided blood and muscle biopsy samples prior to and following supplementation.
- Plasma Q levels rose significantly in Q versus P.
- During the 12-min trial, the net change in distance achieved was significantly greater during Q compared with P (29.5±11.5 vs -11.9±16.0 m, respectively).
- Skeletal muscle messenger RNA expression tended to increase (range = 16-25%) during Q versus P for sirtuin 1, peroxisome proliferator-activated receptor gamma coactivator-1alpha, cytochrome c oxidase, and citrate synthase.
- Muscle mitochondrial DNA (relative copy number per diploid nuclear genome) increased 140 ± 154 (4.1%) with Q compared with -225 ± 157 (6.0% decrease) with P.
- ***Q supplementation (1 g/d) for 14-d, promoted a small but significant improvement in 12-min treadmill time trial performance and modest but insignificant increases in the relative copy number of mitochondrial DNA and messenger RNA levels of four genes related to mitochondrial biogenesis.***





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The dietary flavonoid quercetin increases VO(2max) and endurance capacity

Davis et al. Int J Sport Nutr Exerc Metab. 20(1), 56-62, 2010

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- 12 volunteers were randomly assigned to ingest 500 mg of Q two times/d or a PLA for 7-d in a double-blind, crossover manner.
- Baseline VO_2max and bike-ride times to fatigue were established.
- After treatment both VO_2max and ride time to fatigue were determined.
- Q supplementation were associated with a modest increase in VO2max (3.9% vs. placebo; $p < .05$) along with a substantial (13.2%) increase in ride time to fatigue ($p < .05$).
- These data suggest that as little as ***7 days of Q supplementation can increase endurance without exercise training in untrained participants.***

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The effect of quercetin supplementation on selected markers of inflammation and oxidative stress

Askari et al. J Res Med Sci. 17(7), 637-41, 2012

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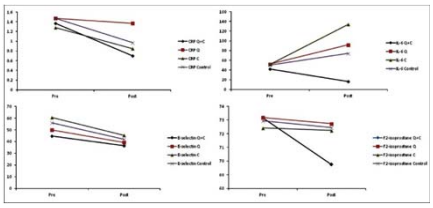
- In a double-blind and randomized manner, 15 subjects ingested 500 mg Q + 250 mg vitamin C, (Q+C), 500 mg of Q, 250 mg of vitamin C (C) or a PLA for 8-weeks.
- IL-6, CRP, E-selectin and F2-isoprostane were measured before and after intervention.
- Significant differences were observed in IL-6 (P<0.1), CRP (P<0.01) and F2-isoprostane for Q+C. Q+C had marginally smaller F2-isoprostane (P<0.1) and interleukin 6 than PLA. There were marginal differences in CRP between Q+C and Q compared to PLA.
- *8-wks of Q+C supplementation was effective in reducing oxidative stress and reducing inflammatory biomarkers*

Group		CRP (mg/L)	P-value*	Interleukin 6 (pg/mL)	P-value	E-selectin (ng/mL)	P-value	F2-isoprostane (pg/mL)	P-value
Q+C	Pre	1.37 ± 0.06		42.09 ± 10.41		44.73±3.58		73.15±0.38	
	Post	0.70 ±0.14	0.098*	16.0 ±4.76	0.049**	36.54±2.74	0.43	69.75±1.26	0.074*
		t=5.56 (P<0.01)		t=2.09 (P=0.068)		t=2.09 (P=0.085)		t=2.35 (P=0.035)	
Q	Pre	1.47±0.25		52.1±9.91		49.89±7.14		73.18±0.53	
	Post	1.37±0.23	0.095*	91.7±30.08	0.64	39.22±8.57	0.85	72.73±0.8	0.41
		t=2.07 (P=0.76)		t=2.10 (P=0.23)		t=2.12 (P=0.086)		t=0.49 (P=0.635)	
C	Pre	1.28±0.12		51.71±17.20		60.57±5.75		72.42±0.86	
	Post	0.85±0.15	0.26	134.14±45.23	0.32	45.28±1.80	0.86	72.24±0.81	0.16
		t=2.07 (P=0.04)		t=2.18 (P=0.11)		t=2.18 (P=0.085)		t=1.14 (P=0.29)	
Control	Pre	1.47±0.07		50.5±16.87		56.00±6.92		72.94±0.7	
	Post	0.97±0.13		74.13±34.41		42.00±3.59		72.44±1.13	
		t=3.67 (P=0.01)		t=2.16 (P=0.85)		t=2.14 (P=0.094)		t=0.37 (P=0.72)	

*Between group comparisons significant at: *P<0.1, **P<0.05 versus placebo; Q: quercetin alone; C: vitamin C alone; and Control: placebo



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The effects of quercetin supplementation on body composition, exercise performance and muscle damage indices in athletes

Askari et al. Int J Prev Med. 4(1), 21-6, 2013

- 60 male athletes ingested 500 mg of Q with 250 mg vitamin C (Q+C), Q alone, C alone, or a PLA for 8-wks in a randomized, double blind manner.
- Participants maintained their normal exercise and PA levels.
- Q promoted greater gains in LBM, TBW, RMR, and total energy expenditure.
- No significant effects were observed in changes in VO_2max.
- *Q supplementation in athletes may improve some indices of performance*.

	Total	Quercetin+ Vitamin C	Quercetin+ Placebo	Placebo+ Vitamin C	Placebo+ Placebo	*P* value*	*P* value**
Weight (kg)							
Before	67.48±10.81	65.92±10.051	70.79±12.66	69.95±9.61	63.66±10.24	0.241	0.234
After	66.96±10.47	66.19±9.99	70.64±13.26	68.30±9.69	62.85±7.92	0.277	
P value***	0.975	0.465	0.98	0.023	0.154		
LBM							
Before	55.42±6.42	55.23±6.12	55.70±7.51	57.66±4.85	53.12±6.80	0.324	0.264
After	55.95±6.28	56.38±6.53	56.33±8.10	57.67±5.34	53.14±4.14	0.329	
P value***	0.000	0.004	0.217	0.364	0.016		
TBW							
Before	39.91±4.62	39.78±4.42	40.09±5.41	41.524±3.48	38.25±4.88	0.324	0.263
After	40.28±4.52	40.59±4.69	40.56±5.82	41.53±3.85	38.25±2.98	0.326	
P value***	0.000	0.004	0.199	0.369	0.017		
BMI (kg/m^2)							
Before	22.24±3.31	21.41±3.00	23.52±3.82	22.82±3.49	21.35±2.67	0.211	0.268
After	21.98±3.28	21.29±2.56	23.36±4.05	22.21±3.53	21.16±2.74	0.281	
P value***	0.228	0.556	0.91	0.053	0.349		
WHR							
Before	0.76±0.06	0.74±0.06	0.79±0.05	0.76±0.06	0.77±0.04	0.077	0.093
After	0.75±0.06	0.73±0.06	0.79±0.06	0.74±0.06	0.76±0.05	0.109	
P value***	0.002	0.047	0.665	0.039	0.063		
BMR							
Before	1569.57±113.70	1572.53±114.44	1568.92±124.69	1605.50±82.79	1531.14±127.23	0.399	0.263
After	1577.22±105.86	1588.80±118.39	1577.76±130.39	1609.15±76.76	1527.58±78.04	0.266	
P value***	0.001	0.017	0.402	0.155	0.086		
TEE							
Before	2417.15±175.09	2421.60±176.17	2416.28±192.09	2472.42±127.47	2358.00±195.98	0.400	0.264
After	2428.90±163.06	2446.73±182.30	2429.61±200.97	2478.07±118.14	2352.58±120.28	0.267	
P value***	0.001	0.018	0.414	0.156	0.08		

*ANCOVA, **Repeated measure ANOVA, ***Paired *t* test. LBM: Lean body mass, TBW: Total body water, BMI: Body mass index, WHR: waist-to-hip ratio, BMR: Basal metabolic rate, TEE: Total energy expenditure

	Total	Quercetin+ Vitamin C	Quercetin+ Placebo	Placebo+ Vitamin C	Placebo+ Placebo	*P* value*	*P* value**
VO_{max} (L/min)							
Before	2.68±0.55	2.72±.529	2.52±0.645	2.81±0.61	2.68±0.42	0.616	0.173
After	2.88±0.43	2.99±0.321	2.72±0.49	3.08±0.42	2.69±0.38	0.047	
P value***	0.001	0.024	0.123	0.02	0.55		
Distance (m)							
Before	1192.028±206.50	1297.76±208.09	1108.36±220.89	1206.46±214.57	1133.63±134.76	0.10	0.37
After	1217.23±205.09	1289.07±221.74	1092.84±201.21	1233.92±209.85	1250.08±135.46	0.07	
P value***	0.950	0.31	0.197	0.50	0.004		
Functional capacity (METs)							
Before	15.26±1.55	15.97±1.67	14.77±1.50	15.32±1.76	14.8±0.90	0.19	0.103
After	15.78±1.46	16.01±1.62	15.00±1.56	16.20±1.24	15.90±1.18	0.16	
P value***	0.144	0.628	0.343	0.07	0.08		

*ANCOVA, **Repeated measure ANOVA, ***Paired *t* test, METs: Metabolic equivalent

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Grape Seeds & Extracts

Theoretical Ergogenic Benefits

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- Grape skins and/or seeds are rich sources of proanthocyanins, anthocyanins, catechins, quercetin, and resveratrol.
- Evidence that consumption of grape extracts can reduce blood pressure
- Theorized to reduce exercise-induced oxidative stress and/or inflammation and possibly affect endurance capacity.

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Grape extract improves antioxidant status and physical performance in elite male athletes

Lafay et al. J Sports Sci Med. 8(3), 468-80, 2009

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- 20 athletes ingested a PLA or 400 mg/d of a GE for 30-days during training.
- Antioxidant capacity, oxidative stress, skeletal cell muscle damage, and other general biomarkers were determined before and after 30-days of supplementation.
- GE increased the ORAC and urinary isoprostane while preventing reductions in FRAP and decreasing CK levels.
- Explosive power was significantly increased in a cohort of handball players
- GW improved the oxidative stress/antioxidant status balance in athletes while showing some evidence of improved performance.

Table 4. Body weight, plasma and urinary parameters, and relative values of effort test, before (D0) and after (D30) supplementation of GE or placebo in handball players. Values are means (±SEM) of 10 determinations performed in duplicate on samples from different subjects; n = 10 handball players.

	Placebo n=10		Grape extract n=10	
	D0	D30	D0	D30
Weight (kg)	88.5 (5.7)	86.5 (5.4)	88.4 (5.7)	87.1 (5.7)
Biomarkers of antioxidant status and oxidative stress				
ORAC ($\mu mol \cdot L^{-1}$)	13 678 (487)	13 946 (482)	13 336 (384)	15 132 (536) ***
FRAP ($\mu mol \cdot L^{-1}$ Fe^{2+})	1 168 (57)	988 (39) ***	1 110 (45)	1 060 (55) #
LDLox (mU·mL-1)	537 (174)	562 (189)	622 (202)	693 (229)
SOD ($U \cdot g^{-1}$ Hb)	2 381 (116)	2 549 (122) *	2 710 (157) ‡	2 679 (113) #
GPx ($\mu mol \cdot min^{-1} \cdot g^{-1}$ Hb)	17.0 (1.4)	14.2 (1.5) *	18.8 (1.7)	18.0 (1.6) #
Catalase ($mol \cdot min^{-1} \cdot g^{-1}$ Hb)	.580 (.056)	.545 (.090)	.640 (.044)	.681 (.088)
Vitamin E ($\mu g \cdot mL^{-1}$)	12.0 (.5)	12.0 (.7)	12.2 (.6)	12.9 (.7) ##
Vit E/cholesterol ratio ($\mu g \cdot mg^{-1}$)	6.7 (.3)	6.9 (.3)	6.9 (.4)	7.5 (.5) *#
Vit C ($\mu mol \cdot L^{-1}$)	65.8 (9.1)	55.5 (9.1)	59.3 (5.1)	54.7 (5.8)
Isoprostanes ($ng \cdot mg^{-1}$ creatinine)	1.3 (.1)	1.7 (.2) *	1.3 (.2)	1.3 (.2) #
Biomarker of skeletal muscle damage				
Creatine phosphokinase ($UI \cdot L^{-1}$)	704 (223)	725 (326)	790 (300)	464 (120)
General plasmatic biomarkers				
Triglycerides ($g \cdot L^{-1}$)	.47 (.04)	.58 (.07)	.53 (.05)	.66 (.10)
Cholesterol ($g \cdot L^{-1}$)	1.81 (.1)	1.76 (.10)	1.78 (.10)	1.78 (.10)
Ferritin ($\mu g \cdot L^{-1}$)	69.1 (14.7)	57.8 (13.3) *	68.8 (15.5)	56.8 (13.0) *
Urea ($g \cdot L^{-1}$)	.29 (.02)	.28 (.01)	.30 (.05)	.27 (.06)
Triglycerides ($g \cdot L^{-1}$)	14.6 (.20)	14.56 (.19)	14.52 (.21)	14.87 (.30) *
Effort test				
Performance (EnRJ45, %)	-4.4 (6.1)		19.5 (9.7) †	
Explosive power (RJ110, %)	-3.57 (2.50)		2.82 (4.25)	
Fatigue (RJ5, %)	2.95 (3.47)		10.85 (6.88)	

*, ** and *** denote $p < 0.05$, $p < 0.01$ and $p < 0.001$, respectively, from the pre-treatment (D0) by paired t test. # and ## denote $p < 0.05$ and $p < 0.01$, respectively, from the placebo post-treatment (D30) by paired t test. † significantly ($p < 0.05$) different from the placebo relative values by paired z test. ‡ significantly ($p < 0.05$) different from the placebo pre-treatment (D0).

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Potential ergogenic activity of grape juice in runners

Toscano et al. Appl Physiol Nutr Metab. 40(9), 899-906, 2015

- 28 runners were randomized into either a group that received grape juice (GJ) or an isocaloric PLA.
- Time-to-exhaustion, anaerobic threshold test, and aerobic capacity tests were performed, together with assessments of markers of oxidative stress, inflammation, immune response, and muscle injury, performed at baseline and 48 h after supplementation.
- GJ increased (15.3%) running time-to-exhaustion without significant improvements in either anaerobic threshold (3.6%) or aerobic capacity (2.2%).
- GJ exhibited significant increases in total antioxidant capacity (38.7%;), vitamin A (11.8%), and uric acid (28.2%), whereas alpha-1-acid glycoprotein significantly decreased (20.2%) and high-sensitivity CRP remained unchanged.
- ***GJ ingestion shows an ergogenic effect in recreational runners by promoting increased time-to-exhaustion, accompanied by increased antioxidant activity and a possible reduction in inflammatory markers.***

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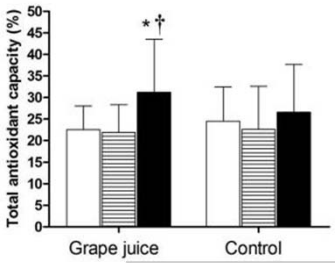
Table 2. Effects of red grape juice on physical performance tests.

	Initial	28 days	Δ (%)
Exhaustion test (min)			
GJG	89.1±49.9	101.9±56.0†	↑15.3±9.2
CG	69.0±34.0	68.2±33.2	↓2.2±23.9
Anaerobic threshold (km/h)			
GJG	10.6±2.3	11.0±2.4	↑3.6±14.6
CG	11.8±2.1	11.6±2.8	↓1.6±19.6
$\dot{V}O_{2peak}$ (mL/(kg·min))			
GJG	45.0±8.1	45.9±8.8	↑2.2±11.9
CG	48.8±10.0	49.9±10.9	↑2.3±9.0

Note: Data are expressed as the mean ± SD. CG, control group; GJG, grape juice group; $\dot{V}O_{2peak}$, peak oxygen consumption.
†Significant difference ($p < 0.05$) compared to baseline values (paired *t* test and unpaired *t* test).



Betaine

Theoretical Ergogenic Benefits

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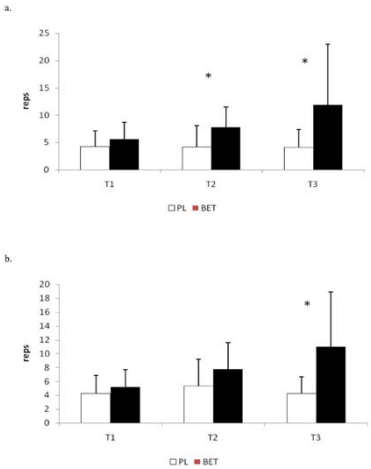
- Betaine is a trimethyl derived from the amino acid glycine that is involved in the metabolism of choline and homocysteine.
- Dietary sources of betaine include spinach, cereal grains, seafood, wine, and sugar beets.
- Several studies have reported that betaine supplementation improves muscle endurance, strength, and/or power.
- According to Cholewa et al. (*Amino Acids, 46(8), 2014*) mechanisms may involve the stimulation of lipolysis and inhibition of lipogenesis via gene expression and subsequent activity of lipolytic-/lipogenic-related proteins, stimulation of autocrine/endocrine IGF-1 release and insulin receptor signaling pathways, stimulation of growth hormone secretion, increased creatine synthesis, increases in protein synthesis via intracellular hyper-hydration, as well as exerting psychological effects such as attenuating sensations of fatigue.

Effect of betaine supplementation on power performance and fatigue

Hoffman et al. JISSN. 6(7), 2009

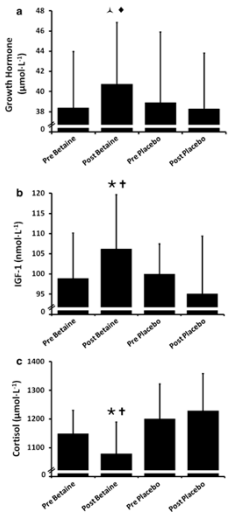
- 24 males were randomly assigned to ingest BET or a PLA for 14-d
- Subjects were tested at 0, 7, and 14-d
- No differences were seen in the repetitions performed to exhaustion or in the number of repetitions performed at 90% of both peak and mean power between the groups in the bench press exercise.
- The number of repetitions performed in the squat exercise for BET was significantly greater ($p < 0.05$) than that seen for PLA after 7-d.
- The number of reps performed at 90% or greater of peak power in the squat exercise was significantly greater for BET at 7 and 14-d than PLA.
- No differences were seen in any power assessment (VJP, BPT, WAnT) between the groups
- ***14-d of betaine supplementation in active, college males appeared to improve muscle endurance of the squat exercise, and increase the quality of repetitions performed.***



Betaine supplementation enhances anabolic endocrine and Akt signaling in response to acute bouts of exercise

Apicella et al. EJAP 113(3), 2013

- 12 trained ingested 1.25 g BID of BET or PLA for 2-weeks in a double-blind and crossover manner with a 2-wk washout
- Before and after each 2-week period, subjects performed an acute exercise session (AES).
- Circulating GH, IGF-1, cortisol, and insulin were measured. Vastus lateralis samples were analyzed for signaling proteins (Akt, p70 S6k, AMPK).
- BET (vs. P) supplementation approached a significant increase in GH and significantly increased IGF-1 while decreasing cortisol with no affects on insulin.
- BET increased resting total muscle Akt while potentiating phosphorylation (relative to P) of Akt (Ser(473)) and p70 S6 k (Thr(389))
- ***BET (vs. placebo) supplementation enhanced both the anabolic endocrine profile and the corresponding anabolic signaling environment, suggesting increased protein synthesis.***



Pre-Workout Supplements

Theoretical Ergogenic Benefits

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- A number of energy drinks and pre-workout supplements (PWS) have been developed and marketed to athletes.
- The primary ergogenic properties in most of these supplements appears to be water, carbohydrate, and caffeine.
- More recently PWS's have been developed that not only contain nutrients that may affect acute exercise performance (e.g., carbohydrate, caffeine, nitrates, etc.), but also nutrients that can increase energy expenditure, reduce catabolism, and promote protein synthesis thereby enhancing training adaptations when taken regularly during training (e.g., amino acids, creatine, β-alanine, etc.).
- There has been increased interest in examining the acute and chronic safety and efficacy of PWS's marketed to active individuals as well as whether adding potentially ergogenic nutrients to PWS's may promote additive benefits.

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Effects of acute ingestion of a pre-workout dietary supplement with and without p-synephrine on resting energy expenditure, cognitive function and exercise performance

Jung et al. JISSN. 11(1): P35-36, 2014 (Full Manuscript in Review)

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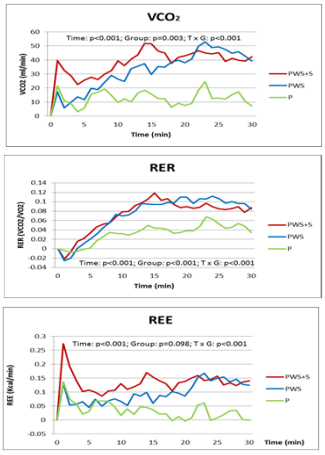
- In a DBCPC manner; 25 apparently men and women (21.76±3.00 yr, 15.24±5.26% fat, 25.09±3.03 kg/m^2) had resting blood pressure (BP), heart rate (HR), 12-lead electrocardiographs (ECG), and resting energy expenditure (REE) measured for 10 minutes.
- Participants then ingested a dextrose flavored placebo (P); a pre-workout supplement (PWS) containing 3.0 g beta alanine, 2 g creatine nitrate, 2 g arginine AKG, 300 mg of N-acetyl tyrosine, 270 mg caffeine, 15 mg of Mucuna pruriens; or, the PWS with 20 mg of synephrine (PWS+S).
- Ingesting a PWS increased resting VO_2, VCO_2, RER, and tended to increase REE values in comparison to a placebo.
- Addition of 20 mg of synephrine to the PWS resulted in a greater increase in the metabolic response during the first 5-10 minutes after ingestion but differences were not as apparent thereafter and AUC values were not significantly different between the PWS and PWS+S groups.
- PWS and PWS+S ingestion did not result in a significantly different HR or BP responses compared to P responses.



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Effects of acute ingestion of a pre-workout dietary supplement with and without p-synephrine on resting energy expenditure, cognitive function and exercise performance

Jung et al. JISSN. 11(1): P35-36, 2014 (Full Manuscript in Review)

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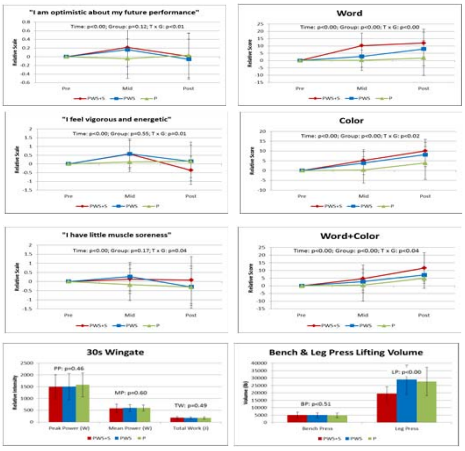
- Ingesting a PWS and PWS with 20 mg of synephrine 30-minutes prior to exercise enhanced perceptions of readiness to perform and cognitive function with no significant effects on anaerobic capacity or isotonic lifting volume.



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Effects of ingesting a pre-workout dietary supplement with and without synephrine for 8 weeks on training adaptations in resistance-trained males

Jung et al. The FASEB Journal. 29:1 Suppl LB238, 2015; JISSN. 12: Suppl 1:P4, 2015 (Full Manuscript in Review)

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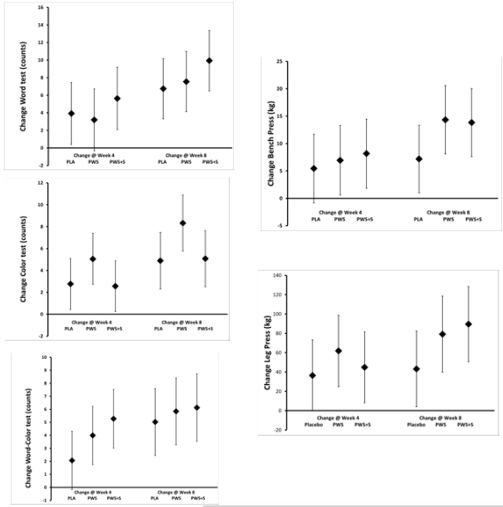
- RT males (N=80) were randomly assigned to supplement their diet in a double-blind manner with a flavored placebo (PLA); a PWS containing beta alanine (3 g), creatine nitrate (2 g), arginine alpha-ketoglutarate (2 g), N-Acetyl-L-Tyrosine (300 mg), caffeine (284 mg), Mucuna pruiriens extract standardized for 15% L-Dopa (15 mg); or, the PWS with Citrus aurantium (PWS+S) extract standardized for 30% synephrine (20 mg) once per day for 8-weeks during training.
- No significant interactions were observed among groups for body composition, resting heart and blood pressure, readiness to perform questions, 1RM strength, anaerobic sprint capacity, or blood chemistry panels.
- Significant increases in 1RM strength and cognitive function were observed, generally showing greater effects in the PWS and/or PWS+S groups compared to the PLA group after 4-weeks of training.



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Summary

- FAV contain nutrients reported to promote health
- Athletes consume inadequate amounts of FAV
- Supplementation of FAV concentrates have been shown to enhance health in athletes
- Athletes may benefit from use of FAV derived supplements that provide:
  - Nitrates
  - Antioxidants
  - Nutrients that support immune function
  - Glycemic control
  - Ergogenic nutrients
- This is an encouraging area of future research and application in the dietary supplement industry