Functional Foods, Beverages, and Ingredients in Athletics

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SUMMARY

FUNCTIONAL FOODS AND BEVERAGES ARE GROWING IN SALES AND TOTAL NUMBER OF PRODUCTS. MANY OF THESE PRODUCTS ARE MARKETED TOWARD HEALTH-CONSCIOUS AND/OR ACTIVE INDIVIDUALS, MAKING ATHLETES PRIME CONSUMERS. THIS REVIEW EXAMINES THE RESEARCH BEHIND FUNCTIONAL FOODS AND BEVERAGES AND THEIR POTENTIAL APPLICATION IN VARIOUS SPORTING ENDEAVORS.

INTRODUCTION

The generally accepted definition of a functional food or beverage is a product that has an "added physiological benefit above and beyond its naturally occurring benefits." So for instance, orange juice with nothing added is a regular beverage, whereas orange juice with added plant sterols is a functional beverage because the plant sterols are added for a physiological benefit, to help reduce cholesterol. There are few studies on complete functional beverages or food in relationship to athletics. There are, however, several studies on functional ingredients. This article will cover both finished products and ingredients.

Functional foods and beverages target a number of health objectives including enhancing weight loss, improving joint health, increasing muscle and bone strength, decreasing risk factors for cardiovascular disease and type 2 diabetes, enhancing digestion, and decreasing wrinkles (51). However, the line among functional foods and beverages and supplements are sometimes blurred. For example, sports drinks can fall under the categories of beverages or functional beverages because they are created for a specific purpose: to rehydrate and replace electrolyte losses. This is an example of a product that can fit into both categories.

REVIEW OF LITERATURE

Functional foods and beverages marketed to athletes can be broken into several categories (Table). Why would athletes choose functional products? The majority of almost every athlete's diet is composed of food and beverages from the grocery store (and augmented with supplements). By improving health and decreasing illness and injury, athletes may benefit from myriad functional products. In addition, specific products are tailored for performance and/or physique enhancement.

RECOVERY–SORENESS AND INFLAMMATION

Muscle soreness results from mechanical damage to the muscle and biochemical changes within muscle tissue. It is characterized by inflammation, pain, swelling, soreness/stiffness, and markers of muscle injury such as creatine kinase (CK) and lactate dehydrogenase (LDH) (10,39). There are several modalities often used in an attempt to mitigate soreness and inflammation including rest, massage, and active recovery, using foam rollers, submerging in a cold plunge, stretching, and of course, nutrition.

OMEGA-3 FATTY ACIDS

Omega-3 fatty acids, including alpha-linolenic acid (ALA), eicosapentaenoic acid (EPA), and decosahexaenoic acid (DHA), are among the most popular functional ingredients. Aside from the many health benefits associated with omega-3 fatty acids, increased omega-3 concentrations in the blood are associated with decreased levels of proinflammatory markers (interleukin [IL] 6, IL-1ra, tumor necrosis factor [TNF] alpha, and C-reactive protein [CRP]) and higher levels of anti-inflammatory markers (soluble IL-6r, IL-10, and TGF-beta) (17).

DHA and EPA are the preferred omega-3 fatty acids because they do not need to be broken down further, whereas very little ALA is converted to EPA (8–21%) and DHA (4–9%) (Figure) (7).

Although relatively few studies have examined omega-3 intake and modulation of exercise-induced inflammation, clinical and epidemiological research suggests that omega-3 intake may (a) decrease inflammatory

KEY WORDS:
omega-3 fatty acids; caffeine; tart cherries; delayed onset muscle soreness; weight loss; beta-alanine; branched-chain amino acids; whey; digylceride; leucine; fenugreek extract; L-theanine; phosphatidylserine

Table
Functional foods and beverages with research-based benefits for athletes

Finished product	Ingredient that can be formulated into various functional food products	Active dose used in research	Research completed on finished product or ingredient
Soreness, inflammation, and recovery			
Carbohydrate-protein beverage		4:1 ratio of carbohydrate and protein	Decreases markers of muscle damage after exhaustive exercise (4,62) and improved performance during repeated bouts of cycling (22)
		Carbohydrate = a variety of sugars	
		Protein = whey protein concentrate	
	Caffeine	5 mg per kg body weight	Reduced pain during submaximal contractions (36), reduced muscle pain during a cycle ergometer bout (19), decreased leg muscle pain in a dose-response manner in low caffeine-consuming males (45)
		5 or 10 mg per kg body weight	
CherryPharm		12 oz CherryPharm twice a day (one 8 oz bottle of CherryPharm contains 50 tart cherries)	Decreased strength loss and pain associated with eccentric exercise (11)
	Beta-alanine	4–6 g/d for at least 4 weeks	Delayed fatigue during intense exercise (25,26,54,55)
	Branched-chain amino acids		Decreased muscle protein breakdown (31,35), attenuated muscle damage, and soreness associated with exercise (45,52)
	Choline and betaine		Choline- and betaine-rich diets are associated with lower levels of inflammatory markers (13)
Finished product	**Ingredient**	**Active dose used in research**	**Research completed on finished product or ingredient**
Weight loss, physique changes			
Celsius		12 oz/d	Raised metabolism after consumption (36), significantly decreased fat mass over time (56)
JavaFit Extreme Energy			Acutely raised resting energy expenditure (57)
JavaFit Diet Plus			Significantly decreased waist girth, hip girth, and body weight with significant group × time decrease in % body fat and fat mass (37)
Enova, diglyceride-rich oil		0.5 g/kg/d DAG-rich oil in place of TAG-rich oil; 10 g/d	Decreased body weight and abdominal body fat when substituted for TAG-rich oil (33,42,46)
	DHA and EPA	6 grams of fish oil compared with 6 grams of sunflower oil	Decreased body fat in the abdomen, decreased overall body fat (23)
	Fabuless	2, 4, and 6 grams	Increased satiety, significantly decreases food intake for 36 h after consumption (8)
Full strength		40 grams whey in a nutrition shake	Augmented weight loss (alone with minimal nutrition intervention) efforts when combined with aerobic and resistance exercise (30)

Table (continued)

Finished product	Ingredient that can be formulated into various functional food products	Active dose used in research	Research completed on finished product or ingredient
Strength gains			
	Whey protein		Stimulates muscle protein synthesis (59,60)
	Leucine		Stimulates muscle protein synthesis, decreases muscle protein breakdown (44)
	Essential amino acids		Increases muscle protein synthesis (49,58,62)
	Torbolic (a fenugreek extract)	500 mg	Significantly increases upper- and lower-body strength and body composition compared with placebo (72).
Focus/concentration			
	l-Theanine	100–200 mg	Helps maintain alertness, focused attention, and accuracy, as well as relaxation (5,32)
	Phosphatidylserine	300–800 mg (27)	Attenuates physical (39,40) and mental stress (15)

DAG = diacylglycerol; TAG = triacylglycerol.

markers, (b) increase blood flow by up to 36% during exercise, and (c) decrease symptoms of rheumatoid arthritis (morning stiffness, tender or swollen joints, and joint pain) (9).

The research on omega-3 fatty acids and soreness/inflammation is both minimal and equivocal and not involving functional products. However, it is an important body of research considering the potential to develop future products. In one study, 22 subjects took fish oil (1.8 g of omega-3 fatty acids) or isoflavones (120 mg soy isolate) for 30 days before exercise and during testing. Each subject also received 100 IU vitamin E to minimize lipid peroxidation. Fifty maximal isokinetic eccentric elbow flexion contractions were used to induce delayed onset muscle soreness (DOMS). Strength parameters, pain, arm circumference, and relaxed arm angle were measured at 48, 72, and 168 hours after exercise. Measures of muscle damage including cortisol, CK, IL-6, TNF-alpha, malondialdehyde, and serum iron were also measured before supplementation, after supplementation, and after exercise. Subjects experienced significant decreases in relaxed arm angle and strength 48 hours after exercise but no other significant differences from baseline. Both treatments had no effect; though, this could be due, in part, to a lack of significant changes in most of the variables measured (30).

In another study, 40 healthy untrained males (aged 18–35 years) supplemented for 14 days with a product containing 300 mg mixed tocopherols, 800 mg flavonoids, and 300 mg DHA ($n = 20$) or placebo ($n = 20$). On day 7, they performed an eccentric-only arm curl exercise, and the researchers measured exercise-induced markers of cell damage (CK and LDH) and the inflammatory mediators CRP and IL-6 at baseline, day 7 (eccentric exercise-induced injury), day 10, and day 14. Both groups experienced significant increases in pain, CK, and LDH, as well as a decreased range of motion for 3 days. There were significant group differences in IL-6 and CRP indicating

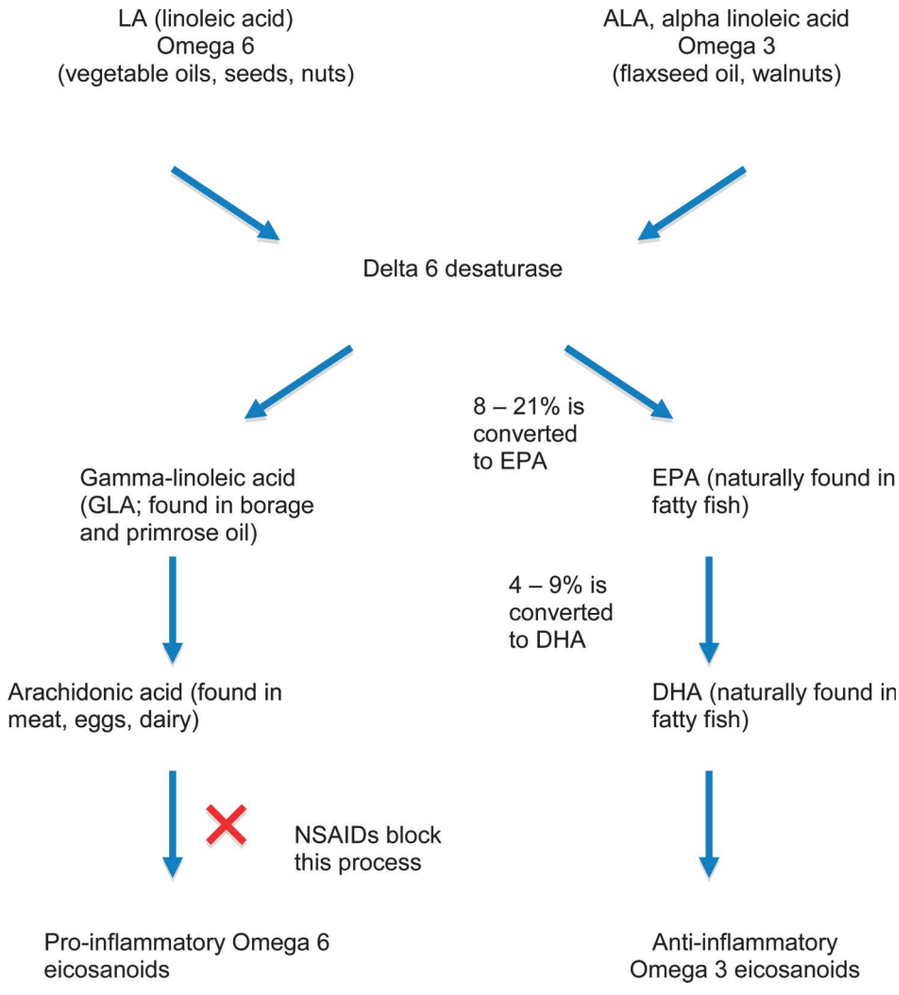

Figure. Omega-6 and omega-3 metabolism (simplified version) (6,18).

that the supplement was effective in reducing markers of inflammation in this group of untrained males. However, from this study, it is impossible to say if DHA alone would make a difference (48).

Another study found that supplementation with 3.6 g/d of fish oil for 6 weeks had no effect on exercise-induced increases in leukocytes and CK compared with that of placebo (61). And a study in 22 women found no differences in measures of inflammation (cortisol, CK, IL-6, and TNF-alpha) after DOMS caused by maximal isokinetic eccentric contractions (30). A cross-sectional retrospective cohort study examining diet and grip strength in older men and women (aged 59–73 years) found that of all dietary factors examined, dietary fatty fish consumption was the most important. The authors concluded that this may be because of the anti-inflammatory actions of omega-3 fatty acids (50).

In addition to the health benefits attributed to fish oil consumption, these studies provide preliminary but mixed support that fish oil supplementation may be effective in offsetting the soreness and inflammation that result after intense damaging exercise.

CAFFEINE

Caffeine is a multifaceted ingredient that plays several roles in sports performance and weight loss. In doses of 4 mg/kg, caffeine can increase mental alertness and improve logical reasoning, free recall, and recognition memory tasks (53). In addition, caffeine can help increase time to exhaustion in endurance exercise bouts (2,14), decrease ratings of perceived exertion during submaximal endurance exercise (12), and improve physical performance during periods of sleep deprivation (36).

Caffeine may also play an important role in recovery by helping reduce muscle pain and soreness. In a double-blind, placebo-controlled, repeated measures experiment, 9 college-aged girls were given 5 mg caffeine per

kilogram of body weight (equivalent to approximately 2 cups of coffee per person) or placebo 24 and 48 hours after 64 eccentric actions of their dominant quadriceps induced by electrical stimulation. One hour after ingestion, DOMS was measured by visual analog scale and force loss was estimated by maximal voluntary isometric contractions and submaximal voluntary eccentric contractions. Caffeine reduced pain significantly during the maximal contractions and had a small effect on pain reduction during the submaximal contractions. Although the exact mechanism by which caffeine may work has not been elucidated, the authors surmised that caffeine may reduce pain by blocking the adenosine released during inflammation (35).

Additional studies lend support to the link between caffeine and decreased muscle soreness. Sixteen college-aged girls were given 5 mg of caffeine per kilogram of body weight or placebo. One hour later subjects completed 30 minutes of cycling on an ergometer at 80% peak aerobic capacity. The group that consumed caffeine experienced significantly less leg muscle pain in comparison to placebo (19). And, in a double-blind, within-subjects, dose-response study, low caffeine-consuming males ($n = 12$) were given either 5 mg caffeine per kilogram of body weight or 10 mg caffeine per kilogram of body weight or placebo 1 hour before 30 minutes of moderate intensity cycling exercise (60% $\dot{V}O_2$peak). Caffeine significantly and linearly affected leg muscle pain ratings suggesting that caffeine may have a dose-response effect on leg muscle pain (45).

In addition, a study found that the coingestion of a large quantity of caffeine (8 mg/kg body weight) with carbohydrate (4 g/kg body weight) after carbohydrate-depleting endurance exercise led to significantly greater (66%) glycogen resynthesis than ingestion of carbohydrate alone (47). Future studies will have to determine if smaller doses of caffeine work as well.

Besides energy drinks, coffee, tea, and supplements, caffeine has been formulated into instant oatmeal (Spark Energy Instant Oatmeal), Jelly Belly Extreme Sports Beans, NRG potato chips, various brands of chewing gum (Blitz and Jolt), Foosh energy mints, Snickers Charged bars, and many additional functional foods and beverages. It should be noted, however, that integrating caffeine into a functional product may negate or increase some of the effects of caffeine on exercise performance. Therefore, like any ingredient placed into a supplement, food, or beverage, just because one functional food containing caffeine is or is not effective, this does not mean that a similar product will or will not be effective.

Caffeine is found in the beans, leaves, or fruit of over 60 plants and therefore may be found on product labels under names such as guarana berries (*Paullinia cupana*); mateine (found in maté and *Ilex paraguariensis*); coffee (*Coffea arabica*); black, green, and white tea (*Camilla sinensis*); kola nut (*Cola acuminata* and *C. nitida*); and chocolate or cocoa (*Theobroma cacao*) (42).

TART CHERRY JUICE

Tart cherries are loaded with antioxidant anthocyanins, which exhibit in vitro antioxidant and anti-inflammatory activities (63). However, juice processing and exposure to heat, light, and air can destroy anthocyanins (21).

In a randomized, placebo-controlled, crossover study, 14 male college students consumed 12 oz CherryPharm cherry juice (made with tart cherries) or placebo twice a day for 8 consecutive days. On the fourth day, they performed a bout of eccentric elbow flexion (2×20 maximum contractions). Isometric elbow flexion, strength, pain, muscle tenderness, and relaxed elbow angle were measured before and for 4 days after the eccentric exercise. Two weeks later, the protocol was repeated with the groups switched (those taking the cherry juice took the placebo and vice versa) and the opposite arm performed the eccentric exercise for the second bout. In the cherry juice trial, strength loss and pain were significantly decreased in comparison to placebo. Strength loss over the 4 days after the eccentric exercise was 4% with the cherry juice and 22% with the placebo. There were no significant between-group differences in relaxed elbow angle and muscle tenderness (11).

WEIGHT LOSS AND PHYSIQUE CHANGES

Research indicating that caffeine can increase both lipolysis and thermogenesis (1) has pushed this ingredient to the forefront of the weight loss category (3,20). Two caffeine-containing functional beverages have research backing their thermogenic benefits and their ability to enhance weight loss and fat loss over time: Celsius and JavaFit coffee.

Celsius contains approximately 200 mg caffeine (guarana), green tea leaf (containing 10% ECGC), and ginger root along with B vitamins, vitamin C, and calcium.

In one of the first studies on this beverage, 20 college students drank 12 oz either Diet Coke or Celsius and change in metabolism over a 3-hour period was measured. The study was then repeated with the groups switched. After reviewing the results from both trials, the researchers found that Diet Coke slightly increased metabolism but Celsius significantly raised metabolism for the 3 hours after consumption (37).

JavaFit coffee also has research indicating it works as a functional weight loss beverage. In a randomized double-blind study, 10 subjects were given either 1.5 cups of JavaFit Energy Extreme (450 mg caffeine, 360 mg citrus aurantium, 1200 mg garcinia cambogia, and 225 μg chromium polynicotinate) or 1.5 cups of a commercially available coffee. JavaFit Energy Extreme raised resting energy expenditure (REE) in comparison to regular coffee in 7 of the 10 subjects studied (24). In a study on a reformulated version of JavaFit Energy Extreme (62 mg added caffeine, green tea

extracts, niacin, and garcinia cambogia) calorie burn increased for up to 3 hours after consumption in comparison to Folgers coffee (56). Both of these studies indicate that either version of JavaFit Energy Extreme with added caffeine raises REE acutely.

Aside from the 2 biggest categories, recovery and weight loss/maintenance, functional ingredients will be formulated into more products in coming years.

PRACTICAL APPLICATION

Athletes should incorporate functional foods and beverages into their diet based on their goals and overall diet. Though, all adult athletes (unless otherwise directed by their physician) should consider consuming fatty fish or fish oil supplements. Although there is no "dose" that we can prescribe to athletes based on the current body of literature, it is prudent to follow the American Heart Association (AHA) guidelines and consume a variety of fatty fish at least twice a week (for those without documented coronary heart disease). According to the AHA, prospective secondary prevention studies suggest that taking EPA + DHA ranging from 0.5 to 1.8 g/d (either as fatty fish or as supplements) significantly reduces deaths from heart disease and all causes. For ALA, a total intake of 1.5–3 g/d is considered beneficial (29). The adequate intake for total omega-3 fatty acids from ALA (a small percentage of ALA is broken down into EPA and DHA in the body) is 1.6 g/d in men and 1.1 g/d in females (1.4 for those who are pregnant and 1.3 for lactating women) (27).

Aside from consuming EPA and DHA, athletes may be able to mitigate soreness induced by exhaustive exercise such as cycling and running by choosing a carbohydrate-protein beverage in place of carbohydrate-only beverage (4). In addition, consuming anthocyanin-rich tart cherries or a minimally processed tart cherry juice may help decrease measures of inflammation and soreness. And finally, picking up a functional beverage or food with caffeine and consuming it after exercise will not only help an athlete stay alert but may also augment muscle glycogen resynthesis and decrease DOMS. How much caffeine? Try 5 mg per kilogram of body weight and no more than 250–300 mg/d to begin with. Doses of 250–300 mg or more per day may result in tachyarrhythmia (rapid irregular heartbeat) and difficulty sleeping. Pregnant women should definitely keep their caffeine consumption below 300 mg/d (16,28).

For weight loss or physique changes, there are many products that a person can incorporate into their diet. Whey protein should be the first consideration given its effects on muscle protein synthesis. Whey protein shakes and products can be considered functional or engineered foods depending on the particular application. Adding fish oil, replacing regular oil with Enova, and considering functional beverages with caffeine are additional considerations. When it comes to nutrition products that can enhance strength gains, whey, essential amino acids, and leucine are clear leaders. However, there is room for innovation with functional foods and beverages that can augment strength gains.

Nutrition can play a role in sport psychology by decreasing stress and enhancing focus and concentration. With increased functional food and beverage offerings in future years, it is important to ensure that the ingredients and/or finished product has sufficient research to support its recommendation. When it comes to an athlete's diet, it is prudent to consider current dietary intake and options available, including functional foods and beverages.

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