COMPREHENSIVE REVIEWS IN FOOD SCIENCE AND FOOD SAFETY

Energy Drinks: An Assessment of Their Market Size, Consumer Demographics, Ingredient Profile, Functionality, and Regulations in the United States

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ABSTRACT: The consumption of energy drinks is rapidly increasing, as demonstrated by their large market growth. The targeted demographic group is teenagers, young adults, 18 to 34 y old; although expansion into nontraditional markets is also occurring. It is claimed that energy drinks can offer an increased energy boost related to their ingredient profile of caffeine, taurine, herbal extracts, and vitamins. Research suggests that energy drink formulations, in addition to increasing energy utilization, may also improve mood, enhance physical endurance, reduce mental fatigue, and increase reaction time. However, in most cases, the corresponding mechanisms of action are not clear. In addition, concerns have been raised over their safety and with a currently weak regulatory environment, efforts need to be made to ensure consumer safety. The objective of this article is to review the current U.S. energy drink market with emphasis on its market size, target demographic, active ingredients, potential benefits, safety, and regulations.

Introduction

Energy drinks refer to beverages that contain, besides calories, caffeine in combination with other presumed energy-enhancing ingredients such as taurine, herbal extracts, and B vitamins. They first appeared in Europe and Asia in the 1960s in response to consumer demand for a dietary supplement that would result in increased energy (Reissig and others 2009). In 1962, a Japanese company, Taisho Pharmaceuticals, launched Lipovitan D, one of the very 1st energy drinks, which is still dominating the Japanese market. Lipovitan D contains B vitamins, taurine, and ginseng, which are all frequent constituents of mainstream energy drinks with the intended purpose of providing the consumer with sustained energy, and to reduce mental and physical fatigue (Taisho Pharmaceutical Co. Ltd. 2009). Energy drinks did not make their way into the U.S. market until 1997 when Red Bull was first introduced, which originated and was initially launched 10 y earlier in Austria (Reissig and others 2009). Since the 1960s, the energy drink market has grown into a multibillion dollar business which has been reported as being the fastest growing segment in the beverage industry since bottled water (Agriculture and Agri-Food Canada 2008). Energy drinks have established a viable position in the beverage market as evidenced by their commonplace consumption in the morning, afternoon, and night, not only by the general consumer, but those of age 18 to 34 in particular (Lal 2007). Importance should be placed on consumer safety and the understanding on how these beverages are regulated. The objective of this review is to give a general overview of the current energy drink market in regard to its size, target market, ingredient profile, potential benefits, safety, and regulations.

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Market Size

Energy drinks fall into the category of functional beverages, which also encompasses sports and nutraceutical drinks as

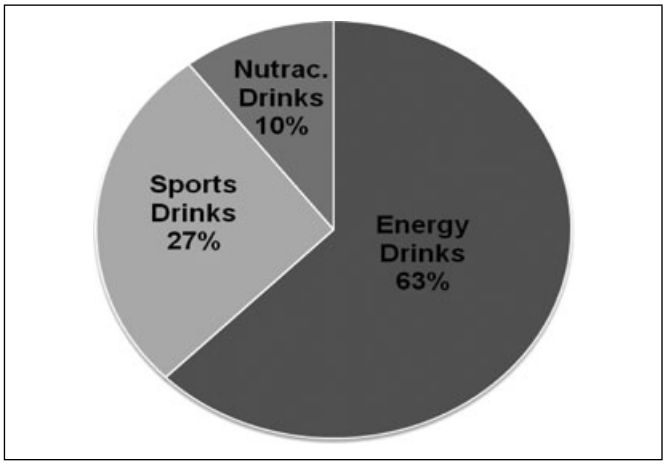


Figure 1—The market share breakdown of the functional beverage category in the U.S. (Datamonitor 2008a).

Table 1—U.S. functional beverage market volume growth (%) and growth forecast, 2007–2012.

Category	2006/07 volume growth (%)	2002–2007 CAGR	2002/07 total	2007–2012 CAGR	2007/12 total
Sport drinks	1.5	11.3	70.7	0.2	0.8
Energy drinks	32.0	45.8	558.7	9.9	60.2
Nutraceutical drinks	5.1	13.6	89.1	1.9	9.8

CAGR = compound annual growth rate.

Table 2—Market share of mainstream energy drinks in the U.S. market.

Brand	Company	Market share (%)
Amp	PepsiCo	3.6
Full Throttle	Coca-Cola Co.	6.9
Rockstar	Rockstar Inc.	11.4
Monster	Monster Beverage Co.	14.4
Red Bull	Red Bull Inc.	42.6

depicted in Figure 1 (Datamonitor 2008a). Sports drinks are designed to be consumed before or during exercise to prevent dehydration, supply carbohydrates, provide electrolytes and typically do not contain caffeine (Coombes and Hamilton 2000). Nutraceutical beverages, on the other hand, are designed to promote and enhance health, usually containing bioactive compounds such as concentrated extracts from teas, fruits, and vegetables or herbs. Additionally, some nutraceutical beverages are found to be fortified with vitamins and minerals and contain significant levels of antioxidants, particularly polyphenols. In some instances, energy drinks could overlay into the nutraceutical beverage category depending on their ingredient composition. The energy drink segment encompasses an array of options including ready-to-drink (RTD), shots, and in powder form. Globally, energy drinks hold 47.3% of the functional beverage's overall market share, while in the United States they comprise 62.6% (Datamonitor 2008a, 2008b). Energy drinks in particular have experienced impressive growth of more than 240% in the United States, as well as abroad, from 2004 to 2009 (Mintel 2009). In 2008, the functional beverage industry reached global sales of $26.9 billion with a compound annual growth rate (CAGR) of 8.6% from 2004–2008. The United States contributed significantly to the functional beverage industry's total accounting for $7.6 billion in revenue and a CAGR of 20.6%. In addition, the U.S. energy drink industry is anticipated to more than double and reach an astounding $19.7 billion in 2013, which is almost a 160% increase from 2008 (Datamonitor 2008a). Within the functional beverage category, the energy drink segment has experienced the largest volume growth and increased annual sales, both in the United States and abroad, reaching $4.8 billion in 2008 in the United States alone (Datamonitor 2008a). This is a higher market value than that reported in the same year for sports drinks ($2.0 billion) and nutraceutical drinks ($0.08 billion). Table 1 depicts volume growth and expected future growth of the functional beverage category. The numbers indicate that energy drinks will see their strongest growth between the years 2007 and 2012 (GMID 2008). This increased growth can be attributed to more private label initiatives, larger container sizes, multi-pack options, sugar-free versions, and juice hybrids that have a more palatable flavor (GMID 2008; Canadean 2009). Currently, there are more than 300 varieties of energy drinks representing more than 200 brands in the United States alone, all purporting to increase energy, longevity, and vitality in some form or another (Energyfiend 2009). Although there is an abundance of energy drinks to choose from, Table 2 shows that the majority of the market share comprises only a handful of varieties, with Red Bull accounting for 42% of the market share (Beverage Spectrum 2008). According to a report by Agriculture and Agri-Food Canada (2008), 1.5 billion cans of Red Bull were sold in the United States in 2004, highlighting the enormity of this industry. The remaining 20% of the market share that is not accounted for in Table 2 represents energy drink brands that correspond to less than 3.6% of the market share. In sum, the energy drink industry has proven extremely profitable and is anticipated to continue with this same success in the years to come with new and innovative product launches reaching a more expanded market.

Target Population

Athletes initially were the primary consumers of energy drinks. However, as the energy drink market grew and expanded into various niche markets, athletes are no longer the primary target. Today, the majority of energy drinks are targeted at teenagers and young adults 18 to 34 y old due to this generation's on-the-go lifestyle and receptiveness to advertisements for these types of products (Lal 2007).

The popularity of energy drinks among the younger generation is evidenced by 34% of 18 to 24-y-olds being regular energy drink users (O'Brien and others 2008; Mintel 2009). Another report found that about one-half of college students consume at least 1 energy drink per month in the hope to increase their energy level, to compensate for a lack of sleep or to mix with alcohol (Miller 2008). The marketing and branding of many energy drinks reflects the market to which these companies are targeting. A review presented at the 2007 IFE (Intl. Franchise Expo) Americas Food and Beverage Show confirmed that energy drink companies' primary target market was adolescents and young adults (Agriculture

and Agri-Food Canada 2008). Their appraisal stated that many of the energy drink companies were using cross-promotional tactics to reach their consumer base by integrating their product with extreme sporting events, such as the X-games or NASCAR, as well as advertising their products in connection with popular music icons (Agriculture and Agri-Food Canada 2008). In addition to those tactics, energy drink companies are using creative, and in some cases intentionally defiant names for their products to draw in consumers, some examples being Full Throttle, Ammo, Havoc, Hydrive, and Morning Spark (Energyfiend 2009).

The target market for energy drinks is broadening as new products are developed in an effort to reach niche submarkets and differentiate themselves from their competition. Such submarkets include energy drinks just for woman, the carbohydrate-conscious, body-builders, or extreme sports enthusiasts. In 2007, Del Monte Foods launched its 1st energy drink called Bloom Energy claiming that it was formulated specifically with women in mind. Other energy drinks are targeted toward athletes such as Lucozade Sport and Revenge Sport which play up their advertised ability to increase physical performance and reduce fatigue in high-endurance sports. The developers of Energy Fizz reached consumers through a different marketing approach, promoting the convenience of being a powder that is packaged in a small portable tube that can be easily added to water on the go to get that needed energy boost. Although the use of on-the-go drink mixes is not a new concept for the beverage industry as a whole, it is within the energy drink category.

Other energy drinks promote the unique qualities that make them stand out from the rest, such as being all natural, organic, or gluten-free, as well as diabetic- or vegetarian-friendly. Energy drinks are still a developing industry in which a diverse range of new and innovative products will be seen in the years to come, with new innovations geared more toward the increasing number of health-conscious individuals.

Behavioral Impact of Energy Drink Consumption

There have been conflicting results concerning the effect of energy drinks on physiological and cognitive performance. Some studies reported no significant differences in either the physiological or cognitive performance of individuals who have and have not consumed energy drinks (Umana-Alvarado and Moncada-Jimenez 2004; Carvajal-Sancho and Moncada-Jimenez 2005). Research has aimed at determining the behavioral effects that energy drinks have on consumers, specifically, on their mood, concentration, reaction time, alertness, endurance, physical performance, and risk taking. The cognitive and physiological effects after the consumption of an energy drink in comparison to a placebo resulted in significantly improved performance on both secondary memory and speed of attention (Scholey and Kennedy 2004).

Another study looked at the effect of Red Bull on cognitive performance and well-being of the studied subjects, concluding that its consumption had a positive impact, possibly related to the combination of caffeine, taurine, glucuronolactone, and B-vitamins present in the product, rather than just to a single ingredient (Seidl and others 2000; Alford and others 2001). Comparing the consumption of energy drinks to a placebo also revealed that energy drinks had an energizing effect with the strongest effect between 30 to 60 min after consumption with the individuals having sustained energy up to 90 min (Smit and others 2004). The consumption of Red Bull also proved to be beneficial in improving aerobic endurance and anaerobic performance, which supported a previous study where there was a significant increase in overall physical endurance of trained athletes after the consumption of 250 mL of the product (Geiss and others 1994; Alford and others 2001). Another study showed that consuming 500 mL of a commercial energy drink (2.0 g taurine, 1.2 g glucuronolactone, 160 mg caffeine, 54 g carbohydrate, 40 mg niacin, 10 mg pantothenic acid, 10 mg vitamin B6, and 10 μg vitamin B12) before exercise, endurance, and physical performance can be improved in comparison to a flavored placebo (Ivy and others 2009). Improvements in visual information processing, attention, and verbal reasoning have also resulted from the consumption of energy drinks (Warburton and others 2001). Furthermore, a study looked at the effect of an energy blend containing caffeine (80 mg), taurine (1 g), glucuronolactone (6 mg), vitamins (50 mg inositol and vitamin B complex per 250 mL), and sugar (21 g sucrose and 5 g glucose) on counteracting driver sleepiness and concluded that this blend was beneficial in reducing sleepiness and sleep-related driving incidents (Reyner and Horne 2002). There have also been several studies that have looked at the association between energy drink consumption and problem behavior. The results of a recent study concluded that increased energy drink consumption was associated with increased risk-taking behaviors (Miller 2008).

The psychological and performance-enhancing effects of caffeine have been reported after large dosages that are unachievable in everyday circumstances, as well as after consumption of realistic doses (Scholey and Kennedy 2004). Research has shown that a modest consumption of 12.5 to 100 mg of caffeine can improve cognitive performance and mood (Smit and Rogers 2000). Doses of caffeine of 6 mg/kg body weight (BW) and 9 mg/kg BW were equally as effective in increasing exercise performance, concluding that larger doses of caffeine may not deliver a better response (Bruce and others 2000). Another study found that ingesting a sports drink containing caffeine at a level of 2.1 mg/kg BW had an ergogenic effect on exercise performance; however, doses of 3.2 and 4.5 mg/kg BW had a greater effect (Kovacs and others 1998). Based on the literature, it appears that a dose of caffeine of 3 to 6 mg/kg BW would be adequate for this purpose (Graham 2001). Davis and Green (2009) indicated that a definite conclusion cannot be reached on the extent caffeine affects performance and that the exact mechanism of caffeine remains to be elucidated.

On the other hand, an association between consumption of energy drinks and occurrence of cardiovascular events has recently been questioned, although the supporting data are limited. Regardless of the evidence, this association has brought about concerns that have impacted consumer perception and have resulted in bans on the sale of energy drinks in several European countries including Denmark and Norway (Ragsdale and others 2009). To further investigate this phenomenon, a double-blind study was conducted comparing the electrocardiograms of 68 college-aged students before and after consumption of 250 mL Red Bull, concluding that there was no difference between any of the measured cardiovascular parameters (Ragsdale and others 2009). Also the consumption of 2 servings of 480 mL of Monster Energy drink found the same lack of changes in cardiovascular function (Dentzer and others 2009). In another study, young, healthy adults consuming 500 mL of a commercially available energy drink experienced no significant changes in their electrocardiograms in comparison to a placebo group; however, a minimal increase in heart rate and systolic blood pressure was observed (Steinke and others 2009).

Another common practice, especially among college students, is to mix alcohol with energy drinks (O'Brien and others 2008). It was found that almost 25% of all drinker college students mix

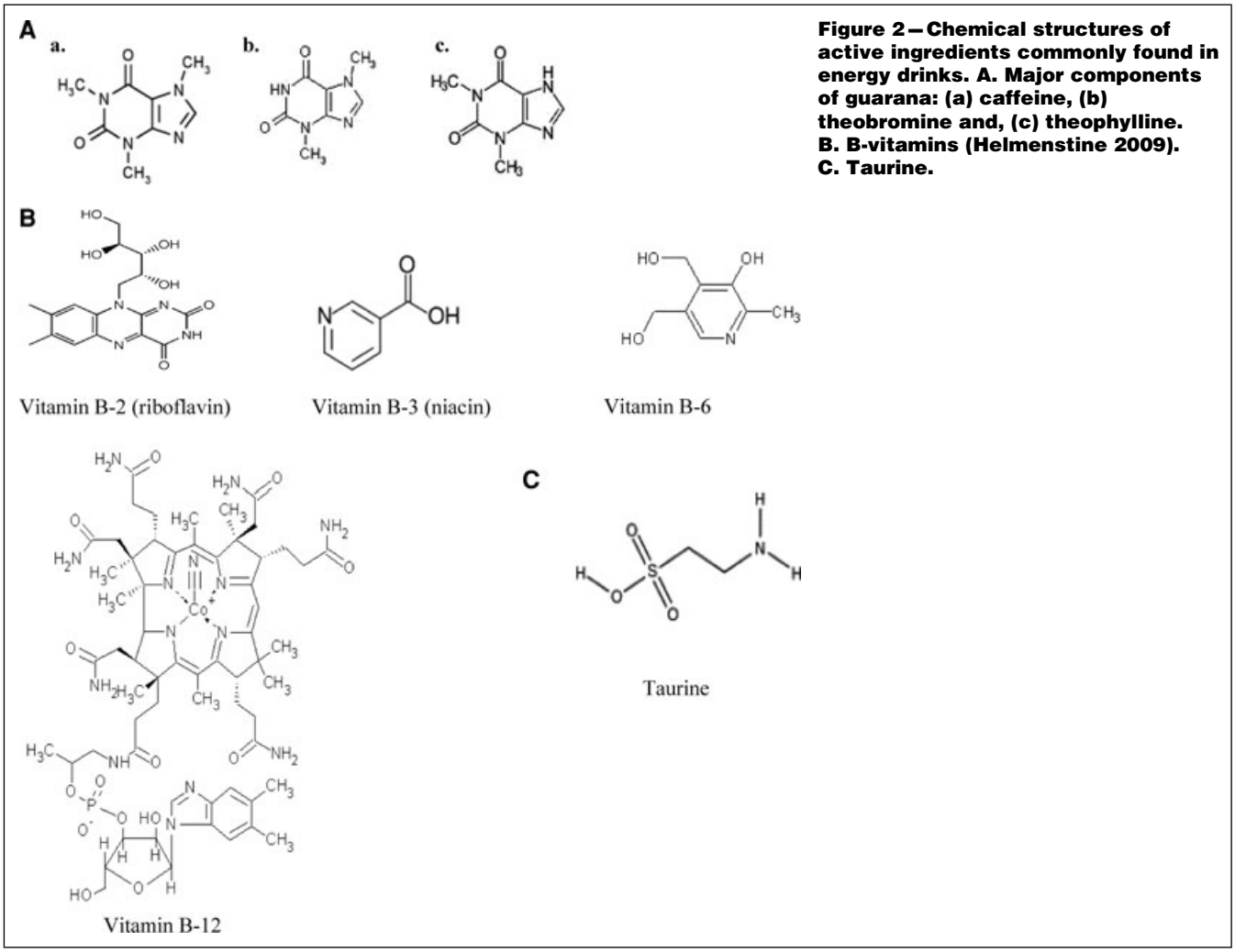


Figure 2—Chemical structures of active ingredients commonly found in energy drinks. A. Major components of guarana: (a) caffeine, (b) theobromine and, (c) theophylline. B. B-vitamins (Helmenstine 2009). C. Taurine.

alcohol with energy drinks (O'Brien and others 2008). The concept of alcoholic energy drinks has been a very controversial issue in which the alcohol industry has received much criticism due to the dangers that have been associated with this trend. There have been several studies that have shown that the consumption of energy drinks in combination with alcohol have resulted in a decreased level of perceived intoxication, which could result in an increased number of driving accidents or other alcohol-related incidents (Ferreira and others 2006; Marczinski and Fillmore 2006). The masking effect that energy drinks are proposed to have over alcohol intoxication is due to the combination of the stimulatory effect of caffeine and the depressant effect of alcohol on the body, hindering the true awareness of the typical signs of alcohol intoxication such as drowsiness (Oteri and others 2007). However, one study found no significant differences among subjects who consumed alcohol in combination with energy drinks and those who just consumed alcohol (Ferreira and others 2004).

Further research is needed to better understand this association as well as increased awareness of the potential dangers that could result from the combination of alcohol and caffeinated beverages.

Active Ingredients

Although there are hundreds of energy drinks in the market, many share very similar ingredient profiles. Most of these unique energy blends consist mainly of caffeine and taurine at varying concentrations. In addition, sugar is typically added; however, many brands have sugar-free options available as well. Sugar is widely used in energy drinks because it is a source of rapid energy. Other ingredients that are commonly incorporated into these products are ginseng, guarana, yerba mate, and green tea extracts. Figure 2 and 3 show the chemical structures of the more frequently used active ingredients in energy drinks. The various ingredient combinations are critical because those give a beverage its distinct overall flavor, the amount of energy, as well as the duration at which that energy will last, and lastly the claimed health properties of the beverage. Table 3 is a compilation of the popular energy-enhanced beverages that are currently sold and their ingredient breakdown.

Caffeine

The majority of energy drinks contain caffeine as an active ingredient due to its stimulatory effect on the central nervous

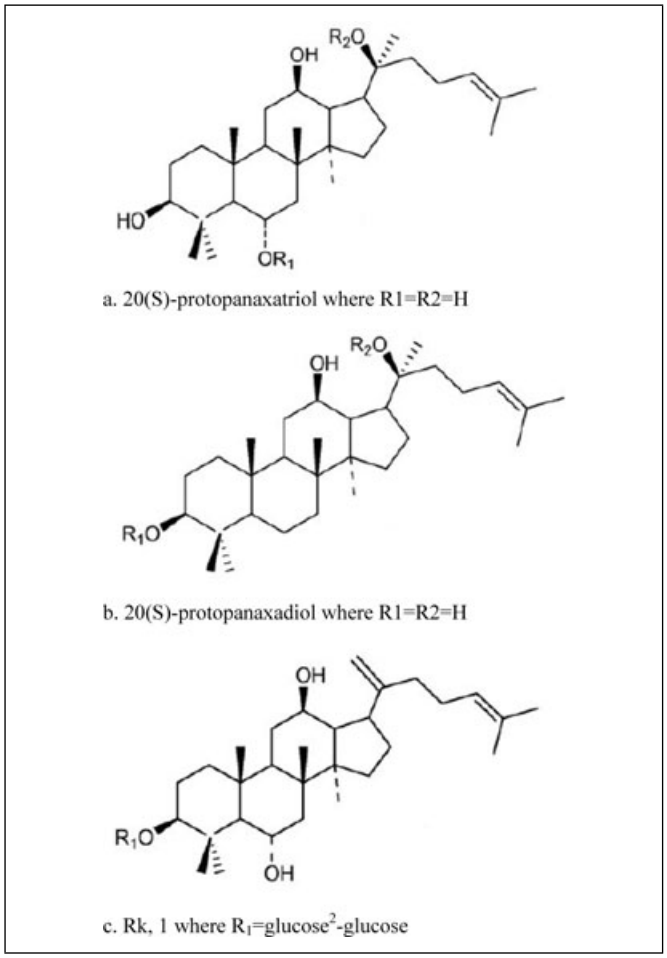


Figure 3—Selected ginsenosides isolated from Panax ginseng (Kim and others 2007).

system. Figure 4 shows a comparison of the caffeine concentration of several mainstream commercial energy drinks with brewed coffee, yerba mate, and green tea. Additionally, Table 3 gives the ingredient list of a variety of energy-enhanced beverages indicating the presence of caffeine.

The main mechanism of action of caffeine, in concentrations typically achieved after the consumption of a caffeinated beverage, is to act as an adenosine receptor blocker in the brain (Dunwiddie and Mansino 2001; Pettenuzzo and others 2008). Caffeine has a similar chemical structure to that of adenosine allowing caffeine to attach to the adenosine receptors. The blockage of adenosine to the neurons causes the sleep promoting effects of adenosine to stop, resulting in the neurons speeding up instead of slowing down (Ferre 2008). Caffeine is also known to increase the secretion of epinephrine, which can lead to a variety of secondary metabolic changes that can positively affect physical or mental performance (Graham 2001). Once ingested, caffeine is rapidly absorbed from the gastrointestinal tract and undergoes demethylations which result in paraxanthine (84%), theobromine (12%), and theophylline (4%); with the xanthenes theobromine and theophylline having very similar chemical structures compared to caffeine (Safranow and Machoy 2005) (Figure 5). Caffeine has been widely studied in a variety of areas regarding human health and performance and it is evident that caffeine consumption can increase energy utilization (Smit and Rogers 2002). Many studies also confirm its ability to enhance mood and alertness (Kaplan and others 1997; Smit and Rogers 2002; Lorist and Tops 2003), exercise performance (Graham 2001; Doherty and Smith 2004), the speed at which information is processed, awareness, attention, and reaction time (Cysneiros and others 2007). Caffeine has also been shown to reduce some of the negative side effects associated with sleep loss. Some studies suggest that caffeine can contribute to improved alertness and performance at doses of 75 to 150 mg after acute sleep loss and doses of 200 to 600 mg after a night or more without sleep (Bonnet and others 2005).

Caffeine also has a stimulatory effect on thermogenesis (Acheson and others 1980; Dulloo and others 1989; Astrup and others 1990; Bracco and others 1995). In addition, caffeine consumption has also been linked to reduced food intake (Tremblay and others 1988; Racotta and others 1994; Lima and others 2005) and to promote lipolysis in both animals and humans (Hasegawa and Mori 2000; Zheng and others 2004; Kobayashi-Hattori and others 2005; Lopez-Garcia and others 2006).

A review regarding caffeine consumption concluded that among the healthy adult population, a moderate daily caffeine intake of $\leq$400 mg (equivalent to 6 mg/kg/d for a 65 kg person) was not associated with any adverse effects (Nawrot and others 2003). Figure 4 shows a comparison of the amount of caffeine found in commonly consumed beverages. The average caffeine content of an energy drink typically ranges from 80 to 140 mg/8 oz, well below this $\leq$400 mg per day limit and is comparable to consuming 5 ounces of coffee or 2 cans of a caffeinated soft drink (Malinauskas and others 2007). However, it is important to be aware of the serving size since many of the 16-oz containers hold 2 servings. Caffeine also has a diuretic effect regardless of its consumption as energy drink, tea, or coffee (Riesenhuber and others 2006). There are, however, several studies that conclude that caffeine consumption at physiologically relevant dosages does not cause diuresis (Falk and others 1990; Scott and others 2004; Armstrong and others 2007; Goldstein and others 2010). Nonetheless, caution should be exercised in regard to the amount of caffeine consumed per day. Caffeine has a long history of safe use and overwhelming scientific evidence maintains that when consumed in moderation (300 to 400 mg/d/adult) no adverse effects should occur.

Taurine

Taurine (2-aminoethyl sulfonic acid) is a sulfur containing amino acid that is the most abundant amino acid found naturally in our bodies, primarily in the retina and skeletal and cardiac muscle tissue (Timbrell and others 1995; Imagawa and others 2009). Taurine is derived from the metabolism of methionine and cysteine (Huxtable 1992; Stipanuk 2004).

It is also present in common food items such as meat and fish. It has been estimated that the average daily human intake of taurine is between 40 and 400 mg (Shao and Hathcock 2008). The incorporation of taurine into energy drinks and other products has increased a great deal over the past 10 y with taurine also being one of the most extensively used and studied amino acids (Shao and Hathcock 2008). Energy drinks launched between 2004 and 2008 were evaluated for the presence of taurine. The results showed that 1 in 4 (27%) energy drinks in 2004 contained taurine, whereas in 2008 it was reduced to 1 in 5 (21%) (Mintel 2009). This reduction could be due in part to a cost saving initiative or the incorporation of alternative ingredients in the product formulation.

Taurine is associated with a variety of physiological functions including neuromodulation, cellular membrane stability,

Table 3—Energy-enhanced beverages and their ingredient breakdown.

Name	Company	Serving size (fl oz)	Caffeine per serving (mg)	Calories per serving	Sugar per serving (g)	Active ingredients	Claims	Source
				Energy drinks				
Amp	PepsiCo, Inc.	8	71	110	28	Guarana seed extract, caffeine, maltodextrin, taurine, Panax ginseng root extract		www.ampenergy.com
Full Throttle	The Coca-Cola Co.	8	72	111	29	Caffeine, guarana, taurine, carnitine, ginseng, sucrose		www.thecoca-colacompany.com
GURU	GURU Beverage Co.	8.3	97	100	22	Guarana seed extract, Panax ginseng root extract, Ginkgo biloba leaf extract	100% Natural	www.guruenergy.com
Hydrive	Hydrive Energy	15.5	145	30	6	Sucrose, caffeine, taurine, L-carnitine, L-arginine		www.hydriveenergy.com
Monster	Monster Beverage Co.	8	80	100	27	L-carnitine, glucose, caffeine, guarana, inositol, glucuronolactone, maltodextrin		www.monsterenergy.com
NOS	The Coca-Cola Co.	8	130	110	26	Taurine, L-carnitine, caffeine, inositol, Panax ginseng extract		www.drinknos.com
Red Bull	Red Bull GmbH	8.3	80	110	27	Taurine, glucuronolactone, caffeine		www.redbull.com
Red Bull Simply Cola	Red Bull GmbH	12	45	130	31	Coca leaf, kola nut	All natural cola	www.redbull.com
Rockstar	Rockstar Energy Drinks	8	80	140	31	Taurine, Ginkgo biloba leaf extract, caffeine, guarana seed extract, inositol, L-carnitine, Panax ginseng extract, milk thistle extract		www.rockstar69.com
Rockstar Juiced	Rockstar Energy	8	80	100	22	Taurine, Ginkgo biloba leaf extract, caffeine, guarana seed extract, inositol, L-carnitine, Panax ginseng extract, milk thistle extract		www.rockstar69.com
Sambazon Amazon Energy	Sambazon Inc.	8	80	80	19	Organic guarana extract, guayaki organic yerba mate, Steaz green tea extract	Antioxidants Superfruit	www.sambazon.com

continued

Table 3—(Continued)

Name	Company	Serving size (fl oz)	Caffeine per serving (mg)	Calories per serving	Sugar per serving (g)	Active ingredients	Claims	Source
SoBe Energy	PepsiCo Inc.	8	32	110	27	Caffeine, taurine, ginseng root extract, guarana seed extract		www.pepsiproductfacts.com
Venom Energy-Black Mamba	Dr. Pepper/ Seven Up, Inc.	8	80	120	28	Taurine, L-carnitine, caffeine, guarna, inositol, glucuronolactone, maltodextrin		www.venomenergy.com
Enhanced juices								
Cranergy	Ocean Spray Cranberries Inc.	8	70	35	9	Green tea extract		www.thedailyplate.com
Sambazon Rio Energy	Sambazon Inc.	8	50	130	25	Organic guarana extract, guayaki organic yerba mate	Antioxidant Superfruit	www.sambazon.com
Zola	Amazon Preservation Partners	8	24	170	29	Guarana seed powder, antioxidant blend	Nature's Energy Drink	www.zolaacai.com
Enhanced Coffee Dinks								
Full Throttle Coffee+ Energy	The Coca-Cola Co.	8	71	148	24	Coffee, taurine, ginseng extract, carnitine, caffeine, guarana extract		www.thecoca-colacompany.com
Java Monster-Mean Bean	Monster Beverage Co.	8	85	100	15	L-carnitine, glucose, caffeine, guarana, inositol, glucuronolactone, maltodextrin		www.monsterenergy.com
Rockstar Roasted Coffee + Energy	Rockstar Energy	8	120	100	17	Taurine, Ginkgo biloba leaf extract, caffeine, guarana seed extract, inositol, L-carnitine, Panax ginseng extract, milk thistle extract		www.rockstar69.com
Enhanced Waters								
Hiball Energy-original	Hiball Inc.	10	75	0	0	Taurine, guarana, ginseng, B-vitamins, RDI, natural caffeine		www.hiballer.com
Snapple Antioxidant Water	Snapple Beverage Corp.	8	25	50	12	Caffeine, guarana seed extract, epigallocatechin gallate		www.snapple.com

continued

Table 3—(Continued)

Name	Company	Serving size (fl oz)	Caffeine per serving (mg)	Calories per serving	Sugar per serving (g)	Active ingredients	Claims	Source
Vitamin Water-tropical citrus	Glaceau	8	50	0	0	Guarana, B-vitamins		www.glaceau.com
Water Joe	Water Joe	8	70	0	0	Artesian water, natural caffeine	Natural-extracted from coffee beans	www.waterjoe.com
Extreme energy drinks								
Charge! Super Shot	LaBrada Nutrition	2.5	200	0	0	Caffeine, B-vitamins, vitamin C, antioxidant complex	2435 mg natural antioxidants	http://www.labrada.com/moreinfo_supershot.shtml
EndoRush	BSN	4	85	5	0	Caffeine, Vinca alkaloids, L-tyrosine, acetyl–tyrosine, glucuronolactone		http://www.bodybuilding.com/store/bsn/end.html
Red Bull Energy Shot	Red Bull GmbH	2	80	25	6	Taurine, glucuronolactone, caffeine, B-vitamins		www.redbull.com
Redline	VPX	4	125	0	0	Caffeine, yerba mate, green tea, vitamin C	The ultimate energy rush	www.energyfiend.com
5 Hour Energy Shot	Living Essentials LLC	2	138	4	0	Taurine, glucuronolactone, malic acid, N-acetyl L-tyrosine, L-phenylalanine, caffeine		www.5hourenergy.com
6 Hour Power	NVE Pharma-ceuticals	1.7	125	40	10	Caffeine, guarana, yerba mate, taurine	10000% B12	http://www.extremeenergy6hourshot.com/

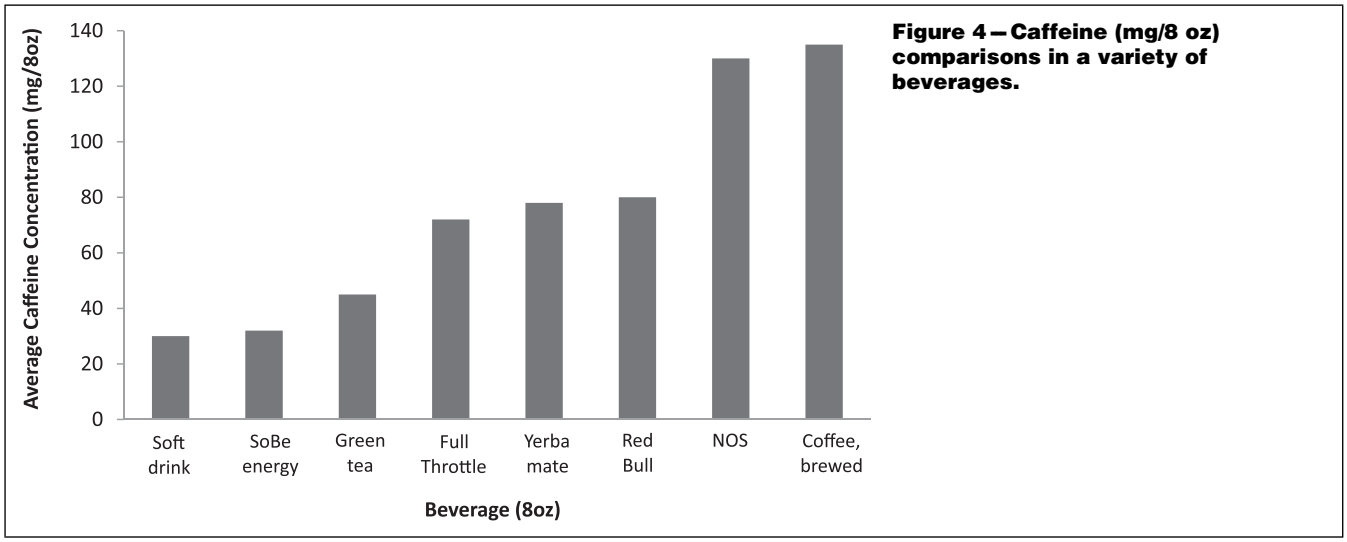


Figure 4—Caffeine (mg/8 oz) comparisons in a variety of beverages.

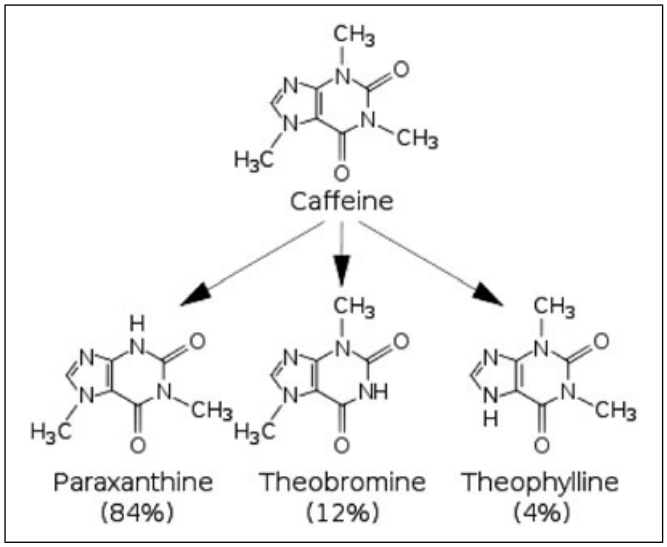


Figure 5—Metabolism of caffeine into its 3 metabolic dimethylxanthines.

and modulation of intracellular calcium levels, both, *in vitro* and *in vivo* (Huxtable 1992; Timbrell and others 1995; Brosnan and Brosnan 2006). However, further research is needed to better explain the underlying mechanisms of action. Furthermore, taurine has been seen to enhance endurance performance and to aid in the reduction of lactic acid buildup after exercise (Matsuzaki and others 2002; Imagawa and others 2009).

In the body, taurine undergoes mainly conjugation to form bile salts as well as degradation to sulfate (Munro and Renwick 2006). This metabolism allows for larger dietary intakes of taurine, with excess eliminated unchanged in the urine (Munro and Renwick 2006).

Methods have been developed to discriminate between synthetic taurine and that derived from natural sources, suggesting an inferior nutritional value of the former (Gioacchini and others 1995). However, more research is needed to conclude whether there is a significant physiological difference between taurine from natural or synthetic sources.

The synthetic taurine that is present in energy drinks is found in very large concentrations. Taurine analysis of 80 different energy drinks showed an average concentration of 3180 mg/L which is equivalent to 753 mg/8 oz (Triebel and others 2007). Several studies have been conducted aimed to determine the effect of taurine at various dosages ranging from 375 to 8000 mg/d, resulting in no adverse effects (Mantovani and de Vivo 1979; Kendler 1989; Ikeda 1977). Other studies have also looked into the safety of taurine in humans and found no adverse effects (Sirdah and others 2002; Brons and others 2004; Zhang and others 2004). Although there has been no evidence showing taurine to cause any adverse health effects, concern has been raised since not enough research has been conducted on the effects of large quantities of taurine in combination with other ingredients commonly found in energy drinks.

Guarana

Guarana comes from the *Paullinia cupana* plant, indigenous to South America. It originated in the Amazon basin in Brazil, where it has had a long history of use (Angelo and others 2008). It is commonly known for its small-berry like fruit it produces, which contains 1 to 3 dark seeds, which accounts for the only edible part of the guarana plant (Scholey and Haskell 2008). The seeds contain a significant amount of caffeine, with 1 g of guarana being equivalent to about 40 mg caffeine (Finnegan 2003). Guarana contains other xanthine alkaloids, specifically theobromine and theophylline, however, at much lower levels compared to caffeine (Weckerle and others 2003). In addition to the caffeine content, guarana also contains relatively high amounts of saponins, flavonoids, and tannins, all contributing to its bioactive properties including its antioxidant activity (Espinola and others 1997; Mattei and others 1998). Guarana has become an increasingly common natural additive in energy drinks in recent years largely for its stimulatory effect (Scholey and Haskell 2008). It has been stated that the caffeine from guarana is released at a slower rate compared to pure caffeine, giving off a more subtle and lengthier stimulatory effect (Scholey and Haskell 2008). It is purported that this slower release is due to guarana being insoluble in water as well as containing tannins and saponins (Edwards and others 2005).

There is, however, no conclusive research that shows the caffeine release and absorption from guarana to be any different from that of pure caffeine (Bempong and Houghton 1992). Guarana has been suggested to improve cognitive performance, mental fatigue, and mood at physiologically relevant dosages; an effect supported by several research studies (Haskell and others 2007; Kennedy and others 2008; Scholey and Haskell 2008). Guarana has also been associated with inducing lipid metabolism, probably due to its methylxanthine content (Lima and others 2005). Additionally, guarana has been shown to exert no toxic effects when consumed both in acute high dosages as well as in chronic lower dosages (Mattei and others 1998).

Ginseng

Ginseng is a herb that has been used for over 2000 y by people in East Asian countries including China, Japan, and Korea as a remedy for various diseases and for promoting longevity (Lee and others 2005; Nam and others 2005). *Panax ginseng* is the primary commercial species and is often referred to as Korean or Asian ginseng. Siberian ginseng (*Eleutherococcus senticosus*) is not truly a ginseng since it contains eleutherosides as its active constituent and no ginsenosides. *P. ginseng* is a small, shade-loving perennial shrub that reaches about 60 cm in height and belongs to the plant family Araliacae. The entire ginseng plant has been used for medicinal purposes; however, the root is the most prominent and dominates the commercial sales. The roots are typically not harvested until after the 5th or 6th year of growth when their ginsenoside concentrations are at their peak (Hu 1976; Mahady and others 2001). After harvest, *P. ginseng* can undergo further processing, including drying and bleaching of the root with sulfur dioxide forming "white ginseng" or steaming the root and air-drying it to form "red ginseng" (Hu 1976; Mahady and others 2001).

The market for ginseng products and ginseng-related products has been estimated at $3.5 billion worldwide and is forecast to increase as a result of the increased research on its pharmacological effects (Hong and others 2006). There are several reported health benefits of ginseng which include being an immune stimulant, producing improved physical and mental conditions, and having antistress, antiaging, antioxidant, and anti-inflammatory properties (Coon and Ernst 2002; Lu and others 2009). These pharmacological properties are attributed to its active constituents, with ginsenosides being the most biologically active accounting for 2% to 3% of ginseng (Okazaki and others 2006; Lu and others 2009). Ginsenosides are secondary metabolites from the ginseng root. They are triterpene saponins and more than 40 of these compounds have been isolated and identified (Nah and others 2007). Each ginsenoside has its own unique structure, therefore, various pharmacological effects can result (Lu and others 2009). Many studies have investigated a single purified ginsenoside rather than analyzing a ginseng root extract in its entirety to determine and explain the various mechanisms of action of ginseng (Zhou and others 2004; Cheng and others 2005; Hofseth and Wargovich 2007). Ginsenosides have been found to inhibit ROS production, stimulate NO production, improve central nervous system function, and prevent cardiovascular and other diseases (Lu and others 2009). A systematic review and meta-analysis concluded that there is insufficient evidence to have a conclusive statement on the effect of ginseng on physical performance, psychomotor performance, and cognitive function (Vogler and others 1999). Interestingly, the same study concluded that ginseng may be effective against diabetes mellitus and that more research is needed on this subject (Vogler and others 1999). However, another study concluded that there is conflicting evidence on the beneficial effects of ginseng on blood glucose (Yeh and others 2003). A randomized placebo-controlled clinical trial also assessed the effects of *P. ginseng* extract G115, at a dose of 200 to 400 mg/d, on mood and other psychological parameters in young healthy subjects (Cardinal and Engels 2001). At the end of the study, no improvements were observed in any measured parameter, indicating that ginseng has no beneficial effects on mood or memory in young healthy subjects (Cardinal and Engels 2001). However, a different study reported improvements in mental fatigue after the administration of 200 mg *P. ginseng* G115 (Reay and others 2005). This study also concluded that 200 and 400 mg of *P. ginseng* G115 extract resulted in significant reductions in blood glucose levels (Reay and others 2005). A recent review evaluated the potential beneficial effects of ginseng on hyperglycemia (Luo and Luo 2009). It was found that American ginseng increased insulin production and reduced death of pancreatic β-cells. Also, it decreased blood glucose in patients with type II diabetes as well as in streptozotocin-induced diabetic animals (Luo and Luo 2009). It was concluded that further research is needed to identify the component(s) in ginseng which may be responsible for these favorable effects.

In view of the increasing popularity of ginseng and its reported pharmacological effects, it is important to know whether or not there are any health risks for the consumer. Based on several studies conducted with animals and humans, ginseng is "generally considered safe" (Coon and Ernst 2002). However, the use of ginseng in very high doses has resulted in some side effects, which included hypertension, diarrhea, and sleep disturbances (Coon and Ernst 2002). Nevertheless, many other studies have claimed that, in comparison with other phytomedicines, ginseng has not been shown to produce serious side effects or dangerous interactions with other drugs (Nah and others 2007).

Yerba Mate

Yerba mate comes from the *Ilex paraguariensis* plant which is native to South America where its main function is for the production of yerba mate tea (Heck and de Mejia 2007). Yerba mate tea is a commonly consumed beverage in South American countries and has been for centuries; however, it is increasing in popularity globally due to its content of a variety of bioactive components including polyphenols, xanthines, flavonoids, saponins, amino acids, minerals, and vitamins (Heck and de Mejia 2007). The abundant array of phytochemicals present in yerba mate has been connected to various health benefits. Yerba mate possesses anti-inflammatory and antidiabetic properties as well as acts as an inhibitor to oxidative stress (Heck and de Mejia 2007; Markowicz-Bastos and others 2007). Moreover, yerba mate has shown *in vitro* cytotoxicity to cancer cells and inhibition against topoisomerase II, which plays a role in cell division and therefore works to inhibit cancer cell proliferation (Heck and de Mejia 2007); however, *in vivo* studies are needed. Yerba mate also has a positive impact on the management of obesity, both *in vivo* and *in vitro* (Pang and Choi 2008; Arcari and others 2009; Martins and others 2009). The consumption of yerba mate significantly improved the serum lipid parameters in normolipidemic and dyslipidemic individuals (de Morais and others 2009). Furthermore, yerba mate enhanced the reduction in LDL-cholesterol levels in individuals who were also under statin therapy (de Morais and others 2009).

In addition, yerba mate is a central nervous system stimulant due to its high caffeine concentration, which is the primary reason for yerba mate to be incorporated into energy drink formulations. The caffeine concentration in 1 cup (8 oz) of yerba mate tea is equivalent to about 78 mg, which is very comparable to 8 oz of Red Bull, which contains 80 mg (Heck and de Mejia 2007).

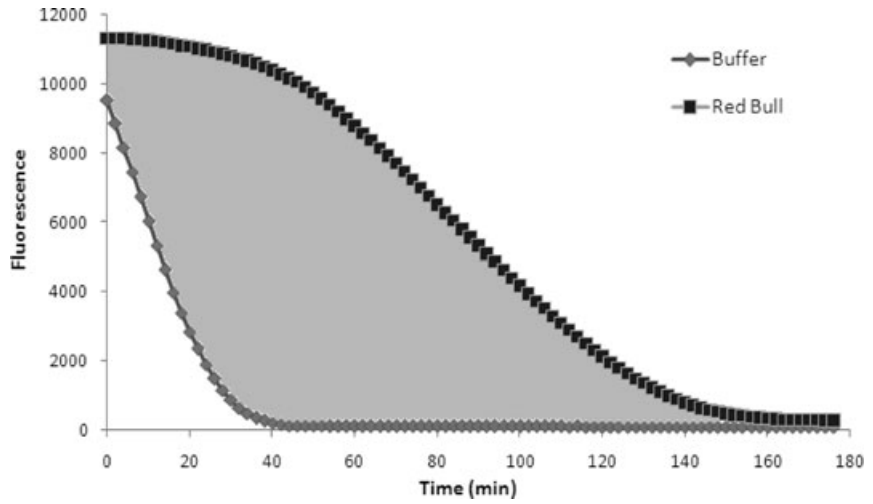


Figure 6—Diagram of the fluorescence degradation of an energy drink in comparison to the control buffer over time.

On the other hand, concerns have been raised regarding an association between yerba mate and the occurrence of certain types of cancer, specifically oral, esophageal, lung, bladder, and renal (Heck and de Mejia 2007). However, there is no conclusive evidence that this association is a result of the consumption of yerba mate but rather due to various lifestyle choices including smoking and excessive alcohol consumption. In addition, these cases have primarily been reported in certain areas of South America where large amounts of yerba mate are consumed at very hot and damaging temperatures which could lead to increased absorption of carcinogens found in cigarette smoke or other environmental pollutants (Heck and de Mejia 2007).

B Vitamins

B vitamins are a group of 8 individual water-soluble vitamins, usually referred to as the B complex when grouped together, and all play essential roles in cellular processes. B vitamins are incorporated into many of the mainstream energy drinks. A typical can of 250 mL may contain 360% of the recommended daily allowance (RDA) of B6, 120% of B12, and 120% of B3 (niacin). The container size varies among brands and it may hold multiple servings. The addition of excess amounts of B vitamins is also observed in the more extreme energy drinks like 5-Hour Energy which contains 8333% of the RDA for vitamin B12 and 2000% of the RDA for B6. It is claimed that the consumption of these large amounts of B vitamins increases mental alertness and focus, as well as improves mood. The average person, however, consumes the RDA of B vitamins from a typical diet since B vitamins are found in a variety of foods including bananas, lentils, potatoes, tuna, and turkey. Vitamins B2 (riboflavin), B3 (niacin), B6 (pyridoxine, pyridoxal, pyridoxamine), and B12 are the most common of the B vitamins that are incorporated into energy drink formulations. Vitamin B2 is a coenzyme in the metabolism of carbohydrates. Vitamin B3 plays a major role as a coenzyme in energy metabolism, fat synthesis, and fat breakdown (Wardlaw and Smith 2009). Vitamin B6 is a group of 3 structurally similar compounds that all can be converted into the vitamin B6 coenzyme which aids in the utilization of carbohydrates, fats, and proteins (Wardlaw and Smith 2009). Vitamin B12 assists in folate metabolism and in nerve function (Wardlaw and Smith 2009). Since all of the B vitamins are water soluble, once the RDA has been met, the excess vitamins are excreted from the body via urine. Although the consumption of a large amount of B vitamins does not possess any adverse health effects, the logic behind the extreme amounts of B vitamins in these beverages is not well rationalized.

Beverage Health Functionality

In addition to the energy-enhancing substances in energy drinks, many also contain a variety of health-promoting constituents, including antioxidant polyphenols contributed by the various fruits or tea extracts added to the beverage formulations. Products high in antioxidants are important because they help protect the cells in the body from the damaging effects of free radicals known to damage proteins, lipids, and DNA, reducing the risk of diseases such as cancer and coronary heart disease (Awika and others 2003; Miller and others 2006). Polyphenols contain antioxidant properties and have been found to aid in the prevention of several degenerative diseases including cardiovascular disease and cancer (Scalbert and others 2005). Several mainstream energy drinks, 16 nontea-based and 15 tea-based, were analyzed for their antioxidant content using the oxygen radical absorbance capacity (ORAC) assay, a widely used and preferred method due to its biological relevance to the *in vivo* antioxidant effectiveness (Prior and others 2003; Davalos and others 2004). The ORAC method uses the peroxyl radical which is the most common free radical in the human body (Mermelstein 2008). In short, as illustrated in Figure 6, the ORAC assay quantifies the antioxidant content by measuring the decrease in fluorescence over time, and then compares the areas under the curve for the different test substances to a vitamin E analog (Trolox) standard curve (Prior and others 2003; Davalos and others 2004). ORAC assessment of energy drinks in our laboratory resulted in a range of antioxidant capacities among the nontea-based beverages of 286.3 $\pm$ 63.9 to 3393.2 $\pm$ 106.1 μM Trolox equivalents (eq.), with an average of 1275.4 μM Trolox eq. The tea-based energy drinks had much higher antioxidant capacities with a range of 1749.8 $\pm$ 212.7 to 45824.2 $\pm$ 1430.6 μM Trolox eq., and an average of 10597.9 μM Trolox eq. (Figure 7). The ORAC method has limitations and *in vivo* studies are needed to evaluate if there are real physiological implications due to the ORAC values determined in different energy drinks.

The total polyphenol concentration was measured in the same energy drinks with the Folin–Ciocalteu method. This method

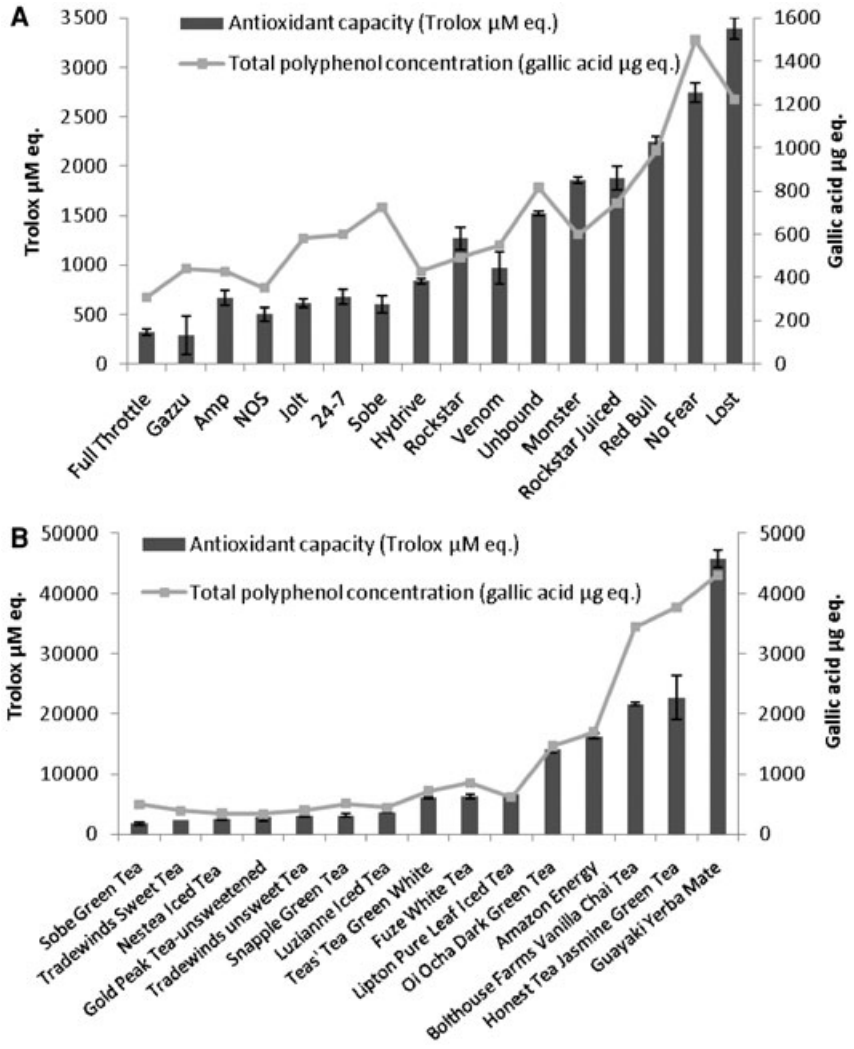


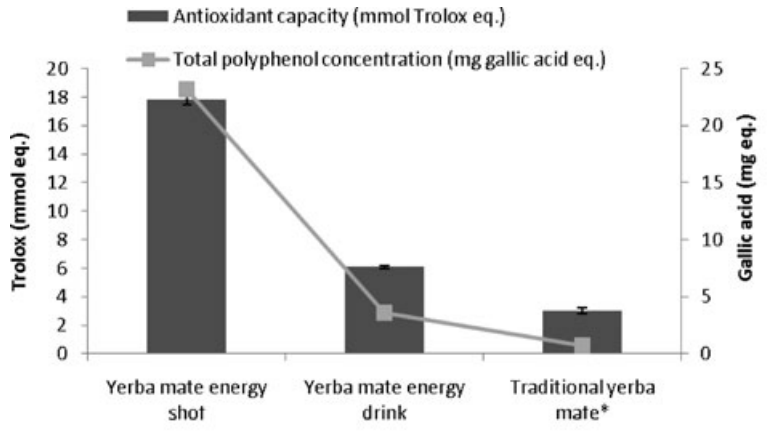
Figure 7—A. Comparison showing the relationship of antioxidant capacity with total polyphenol concentration for 16 commercialized energy drinks. B. Comparison showing the relationship of antioxidant capacity with total polyphenol concentration for 15 commercialized tea-based energy drinks.

measures the reduction of the Folin–Ciocalteu reagent with the polyphenols present in the energy drinks and is quantified as total gallic acid equivalents (Chandra and de Mejia Gonzalez 2004). The total polyphenol concentration among the nontea-based beverages ranged from 309.4 ± 1.3 to 1497.5 ± 68.5 μg gallic acid eq. with an average of 673.2 μg gallic acid eq. The tea-based beverages had a range of 496.1± 66.3 to 43010.2 ± 18.9 μg gallic acid eq., with an average of 1318.7 μg gallic acid eq. Figure 7A shows a comparison of the antioxidant capacity and the total polyphenol concentration in analyzed commercially available nontea-based energy drinks. Figure 7B presents the results for the tea-based energy drinks. In addition to those energy drinks, yerba mate tea-based beverages were also analyzed for their antioxidant capacity and their total polyphenol concentrations (Figure 8). Yerba mate tea-based energy drinks contained 100-fold higher amounts of antioxidants and polyphenols compared to the mainstream nontea-based energy drinks and the traditional brewed yerba mate tea. Furthermore, the Guayaki yerba mate tea, illustrated in Figure 7B, had the largest antioxidant and polyphenol content among the tea-based drinks suggesting the potential of yerba mate as an additive in energy drink formulations.

According to market research by Mintel, about 60% of the U.S. respondents stated that they look for antioxidants when shopping for functional beverages, an area in which energy drink companies capitalize (Lal 2007; Mintel 2007). Increasing the antioxidant and polyphenol contents of energy drinks could be a key driver to increased sales and can be accomplished by incorporating yerba mate, green tea, ginseng, or fruit juice such as pomegranate and acaí into new beverage formulations. A future trend that could prove to be very effective would be for energy drink companies to increase the functionality of their beverages to target the growing number of health-conscious consumers (Lal 2007). Areas in which these companies could expand could be the inclusion of vitamin and mineral fortification, organic options, all natural, no artificial flavors, preservatives or natural pigments, weight control formulations, incorporation of fruits, as well as continuing with the low carbohydrates and low sugar options that are already highly visible in the market.

Safety and Regulations

The regulation of energy drinks varies throughout the world with the United States having one of the less stringent systems.



* The traditional yerba mate tea was prepared by mixing 10 g tea with 1 L boiling water at 98 °C and holding/stirring for 10 min then filtering (Chandra and de Mejia Gonzalez 2004)

Figure 8—Antioxidant capacity and total polyphenol concentration is 100-fold higher in yerba mate tea-based beverages compared to mainstream energy drinks.

The U.S. Food and Drug Administration (FDA 2003) code of federal regulations, nr 21CFR182.1180, lists caffeine, a main component in energy drinks, as generally recognized as safe (GRAS) when used in cola drinks, at a level of 0.02% caffeine, totaling 71 mg for a 12-oz soft drink. This regulation, however, does not apply to energy drinks. In the United States, energy drink companies have no limitations over the caffeine content of their beverages because the FDA has placed no restrictions on an upper caffeine limit in these types of beverages. Thus, scientific as well as public concern has developed due to the increasing numbers of energy drinks entering the market having caffeine concentrations well above those of mainstream energy drinks, which contain on average 10 mg/oz. Energy drink companies must, however, adhere to labeling regulations for caffeine. Those regulations in the United States state that caffeine along with any other ingredient must be listed on the product label if added to the product as an ingredient. However, the actual amount of caffeine, or any other ingredient for that matter, does not need to be listed on the label leaving consumers uninformed in regard to the amount they are consuming. Efforts are being done to change this lack of regulation as discussed in the 5th amino acid assessment workshop giving priority to developing a safe upper limit for taurine due to its high concentration in many energy drinks (Munro and Renwick 2006). However, to date there have not been any reported cases of adverse effects due to the consumption of taurine, ginseng, or guarana at levels that are typically found in mainstream energy drinks (Clauson and others 2008). Many countries have addressed this concern and have developed regulatory guidelines for energy drink manufactures to follow. The Australia New Zealand Food Authority (ANZFA) defined a distinct category of beverages called "formulated caffeinated beverages" which must contain no less than 145 mg/L and no more than 320 mg/L of caffeine, which includes "all caffeine present from whatever source." The European Union has not set an upper limit for caffeine; however, if the beverage contains more than 150 mg/L, the product label must read "High Caffeine Content" followed by the amount of caffeine (European Union Commission Directive 2002/67/EC). An initial 1st step needs to be taken by the FDA in regard to the regulation of energy drinks, which could be as simple as requiring the manufacturer of these products to list the caffeine content as well as supply warnings if their product contains caffeine in the amount of a specified upper level. Increasingly diverse segments of the population, including children, are choosing to consume energy drinks, which amplifies the importance for the FDA to implement a formal regulatory plan for the production and sales of energy drinks.

Perspectives

Energy drinks have had exponential growth since their arrival into the United States and this trend can be expected to continue in the United States as well as abroad. With a society of time-scarce consumers struggling to maintain a work-life balance and a younger generation accepting the products market appeal, this growth most likely will continue. The market is becoming flooded with new energy drinks, many with unusual names and claims of a higher energy boost compared to the previous one, all to get a foot in the door and be noticed. There is, however, a select few mainstream energy drinks that do control the majority of the market and do not have excessive amounts of caffeine, with the majority containing less caffeine than an 8-oz cup of coffee. In addition to caffeine, a variety of other active ingredients such as taurine, guarana, and B vitamins are incorporated into energy drinks to increase some sort of an effect of the product. Besides new product launches endorsing their new improved and longer-lasting energy boost, new developments are anticipated geared toward increasing the health functionality of energy drinks which will gain market acceptance due to an increasingly health-driven society. However, research needs to continue regarding the potential benefits of these products to support the claims. The potential health risks associated with heavy consumption of these beverages have gone unaddressed and there ought to be a greater need to establish proper regulations. Public concern has been raised regarding the lack of information that is provided on energy drink labels as well as the high caffeine concentrations that are present in some of the more "extreme" energy drinks. To ensure consumer safety, warning labels must be present on energy drinks that contain elevated levels of their active ingredients, especially caffeine. In addition, an acceptable upper limit must be put in place for the allowable amount of caffeine that can be put in energy drinks just like there is for cola beverages. Enhanced regulations may rid the "extreme," highly caffeinated energy drinks from store shelves and thus protect consumers.

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