출처 '클린에너지' 출처 : 미국음료시장 보고서, Package Facts / 2019

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2019 미국 음료시장, '클린 에너지'(Clean Energy)가 뜬다

미국 음료시장에 '클린에너지'를 활용한 제품이 뜨고 있다. 오랜기간 미국 음료시장의 우위를 차지해온 스포츠, 에너지 음료가 소비자들의 입맛과 '건강함'과 '내추럴'을 추가하는 최근의 트렌드 변화에 따라 클린에너지를 더해 새로운 음료로 재탄생해 등장하고 있다.

* 클린에너지(Clean Energy) : 커피, 차 등에서 추출한 천연 카페인, 천연 항산화 등의 성분

시장조사기관 '패키지 팩트'(Package Facts)가 공개한 '2019 미국 음료시장 보고서'에 따르면, 스포츠음료와 에너지드링크 사이의 경계가 흐려지며 에너지드링크에 커피 열매, 찻잎 에서 추출한 천연 카페인을 접목시킨 '하이브리드' 음료가 시장에 활력을 불어넣고 있다.

○ 커피를 창의적으로 접목한 RTD 음료 카테고리 확대

맛은 물론 톡 쏘는 탄산의 청량감을 선호하는 젊은 소비자들을 겨냥해 저당, 무당에 에너지 성분을 더한 RTD 커피제품 출시가 늘면서 관련 시장은 매년 급성장세를 보이고 있는 추세다.

패키지 팩트에 따르면 커피 및 RTD 커피 판매는 지난 2018년 415억달러 규모를 기록했으며, 2023년에는 연평균 3.8% 씩 성장하며 총 180억 규모에 이를 것으로 예측된다.

커피에 탄산과 주스를 접목한 색다른 음료는 물론 MCT 오일과 기버터, 코코넛 추출 버터 등을 첨가한 커피도 등장했다.
뉴욕에 본사를 둔 'Kitu Life'는 6온즈 캔 음료에 에스프레소 3잔에 해당하는 180mg의 카페인과 설탕 대신 단백질 농축액, 코코넛 MCT 오일을 첨가해 신진대사 에너지를 제공하는 '수퍼 에스프레소'를 출시했다.

https://www.kati.net/board/boardView.do?board_seq=88306

https://www.foodbusinessnews.net/articles/13659-clean-energy-driving-beverage-innovation

출처

슬로우 칼로리, 팔라티노스

Slow Calorie, Palatinose

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I. 서론

현대사회의 급속한 고령화와 식생활 변화에 의한 비만 인구의 증가로 인해 대사증후군을 비롯한 다양한 성인병은 사회적으로 큰 이슈가 되고 있다. 당뇨병이나 고혈압, 고지혈증과 같은 대사성 질환들은 일단 발병하면 완치가 어렵기 때문에, 개개인 스스로의 예방 노력이 필요하다. 소비자로서의 개인적 식생활 환경 개선은 무엇보다 중요한 일이라 할 수 있지만, 가공 식품 역시 개인의 식생활 환경에 미치는 영향이 매우 크기 때문에, 가공 식품에 이용되는 소재에도 주의 깊은 관찰이 필요할 것이다.

당질을 비롯한 탄수화물은 식품의 가장 중요한 원료로서, 식품에 감미와 조직감을 부여하는 동시에, 생명의 유지나 육체적·지적 활동에 필수적인 기초 영양소이다. 하지만, 최근 설탕이나 액상과당으로 대변되는 당질에 대한 소비자의 이미지는 매우 부정적이기 때문에, 아스파탐, 스테비아, 수크랄로스 등 고감미 감미료들의 수요가 지속적으로 증가하고 있으며, 무칼로리 혹은 저칼로리가 식품산업의 새로운 트렌드를 형성하고 있다.

하지만 최근의 다양한 연구들에 의해 에너지의 양 뿐만 아니라 에너지가 체내에 흡수되는 속도 역시 우리 대사에 큰 영향을 미친다는 것이 밝혀져 왔다. 예를 들어, 소화 흡수 속도가 느린 식품은 인슐린의 과도한 분비를 억제하기 때문에, 칼로리가 같더라도 장기간 섭취하는 경우 내장지방이 감소하고 인슐린 반응성이 개선되는 등의 효과가 보고되었다. 여기서 언급하는 슬로우 칼로리는 과학적 용어는 아니지만, 에너지의 양적인 기준인 칼로리에, 에너지의 질이라 할 수 있는 흡수 속도를 추가한 개념이다.

본 장에서는 천천히 흡수되는 에너지를 뜻하는 "슬로우칼로리"의 개념에 부합하는 팔라티노스를 소개하고자 한다. 팔라티노스는 벌꿀이나 사탕수수에 함유되어 있는 천연 이당류로서, 설탕과 결합 양식이 다른 구조 이성질체이다. 감미는 설탕의 약 45% 정도지만 설탕과 같이 양질의 감미질을 보유하고 있기 때문에, 가공식품에 적합한 당질이다. 팔라티노스는 그 자체의 흡수가 느릴 뿐 아니라, 다른 당질의 소화 흡수를 지연시키는 작용이 있어 슬로우 칼로리 식품 구현에 이상적인 당질이다.

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2. 팔라티노스란?

팔라티노스(palatinose, isomaltulose, 6-O-α-D-glucopyranosyl-D-fructose)는 봉밀에 미량 포함된 천연의 당질[1-3]이고, 비우식원성의 천연 감미료로서, 1950년대 독일의 Offstein(Pfalz주, 라틴 이름 Palatin)에서 팔라티노스 생산균이 발견된 이래, 세계 각국에서 연구·개발이 이루어져 왔다. 팔라티노스는 설탕과 마찬가지로 포도당과 과당이 결합한 이당류이다(그림 1). 설탕을 원료로 하여, Protaminobacter rubrum CBS 574.77이 생성하는 α-glucosyltransferase(sucrose isomerase)를 작용시켜 생성한다[4]. 원료인 설탕은 포도당과 과당이 α-1, 2 결합으로 결합한 비환원당이지만, 팔라티노스는 α-1, 6 결합으로 결합한 환원 당이다.

3. 팔라티노스의 안전성

팔라티노스는 각종 독성 시험에 의하여 안전성이 확인되고 있고, 국내를 비롯하여, 미국, 유럽, 일본, 대만, 중국 등 대부분의 나라들에서 식품 원료로 사용되고 있다. 일반적인 탄수화물과 마찬가지로 1일 섭취량에 제한이 없으며, 일본에서는 충치의 원인이 되기 어려운 식품으로써 특정보건용 식품으로 인정받았다.

성, 아급성 독성시험과 변이원성 시험이 일본의 재단법인 식품약품 안전센터 하다노 연구소에서 수행되었는데, 급성 독성시험은 Sprague-Dawley계 래트를 이용하여 행해졌으며, 체중 1kg당 검체 32g의 과도한 양을 투여한 경

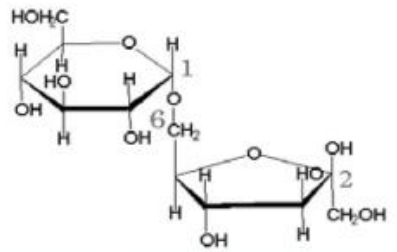

그림 1. 팔라티노스의 화학구조식

유발의 기준인 pH5.5 이하로는 내려가지 않기 때문에, 충치를 유발하지 않는다[12]. 또한, 팔라티노스는 플라그의 기질이 되는 불용성 글루칸의 형성을 저해하기 때문에, 플라그의 형성이 억제된다[13, 14]. 또한, 팔라티노스는 그 자신이 충치의 원인이 되지 않는 비우식원성일 뿐만 아니라, 설탕과 함께 섭취되면, 설탕에 의한 우식의 발생을 억제한다(그림 2)[15, 16].

일본에서는 팔라티노스가 충치의 원인이 되기 어려운 식품으로서 특정보건용 식품으로 인정되었다.

스코어 ~20: 충치가 거의 없다, 20~30: 치아의 열공부에 명확한 손상이 있다, 40~60: 상당히 심각한 충치가 있다

7. 팔라티노스 섭취 후의 혈당치의 변화

팔라티노스는 설탕의 약 1/5의 속도로 분해되기[17]때문에, 설탕과 같이 혈당치가 급격하게 변화하지 않는다. 건

출처

Randomized Controlled Trial > Eur J Clin Nutr. 2021 Apr;75(4):602-610.
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Cognitive performance, mood and satiety following ingestion of beverages imparting different glycaemic responses: a randomised double-blind crossover trial

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Affiliations + expand

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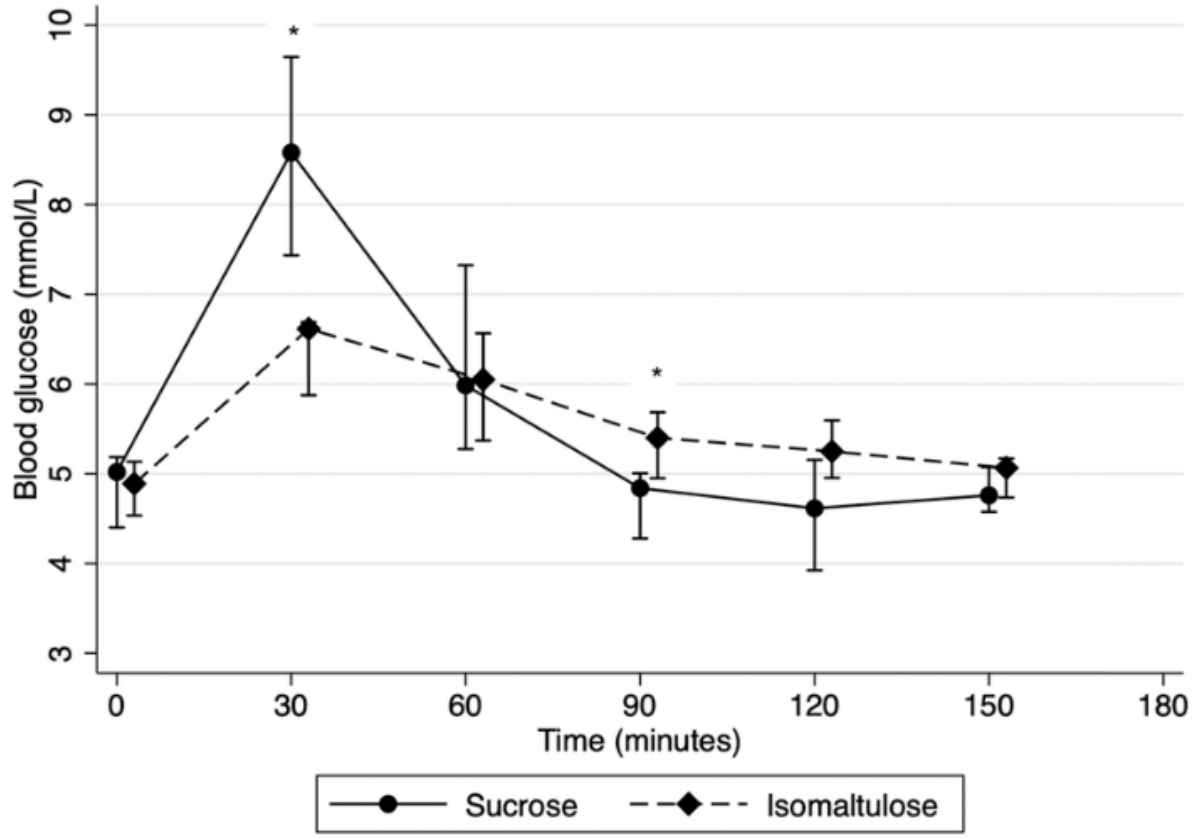
Abstract

Background/objective: The relationship between postprandial glycaemic responses and cognitive performance, mood and satiety are inconsistent. The objective of this study is to compare the effects of different glycaemic responses, induced by beverages with different glycaemic index (GI) (sucrose and isomaltulose), and a non-glycaemic control (sucralose), on cognition, mood and satiety.

Subjects/methods: In this double-blinded, randomised crossover trial, healthy adults (n = 55) received sucrose (GI 65), isomaltulose (GI 32) and sucralose (non-caloric negative control) drinks on separate occasions. The Complex Figure test, the Word Recall test, Trail Making Test Part B and the Stroop test were administered 60 min after beverages ingestion. Mood and satiety were tested along with cognitive performance.

Results: Comparing between isomaltulose and sucrose, there were no significant differences in the mean (95% CI) for the following: Complex Figure: immediate recall -0.6 (-1.7, 0.5), delayed recall -0.8 (-1.9, 0.3); Word recall: immediate recall 0.2 (-0.7, 1.1), delayed recall 0.5 (-0.4, 1.4); Trail Making: completing time -2.4 (-7.5, 2.7) s; Stroop: time used for correct congruent responses -9 (-31, 14) ms and correct incongruent responses -18 (-42, 6) ms. No differences among beverages were found in the mood and satiety scores with exception that participants felt more energetic 60 min after isomaltulose ingestion (p = 0.028 for difference with sucrose) and hungrier 30 min after isomaltulose ingestion (p = 0.036 for difference with sucrose; p = 0.022 for difference with sucralose).

Conclusion: Under these study conditions there is no convincing evidence for an effect of glycaemic response on cognitive performance, mood or satiety.



Glycaemic response following the ingestion of sucrose- or isomaltulose-sweetened beverages (n = 12) The values are medians with the vertical bars representing the range of the 25th to 75th percentiles.

출처

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Differential contributions of theobromine and caffeine on mood, psychomotor performance and blood pressure

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ABSTRACT

The combination of theobromine and caffeine, methylxanthines found in chocolate, has previously been shown to improve mood and cognition. However, it is unknown whether these molecules act synergistically. This study tested the hypothesis that a combination of caffeine and theobromine has synergistic effects on cognition, mood and blood pressure in 24 healthy female subjects. The effects of theobromine (700 mg), caffeine (120 mg) or the combination of both, or placebo were tested on mood (the Bond–Lader visual analog scale), psychomotor performance (the Digit Symbol Substitution Test (DSST)) and blood pressure before and at 1, 2 and 3 h after administration. Theobromine alone decreased self-reported calmness 3 h after ingestion and lowered blood pressure relative to placebo 1 h after ingestion. Caffeine increased self-reported alertness 1, 2 and 3 h after ingestion and contentedness 1 and 2 h after ingestion, and increased blood pressure relative to placebo (at 1 h). The combination of caffeine + theobromine had similar effects as caffeine alone on mood, but with no effect on blood pressure. There was no treatment effect on DSST performance. Together these results suggest that theobromine and caffeine could have differential effects on mood and blood pressure. It was tentatively concluded that caffeine may have more CNS-mediated effects on alertness, while theobromine may be acting primarily via peripheral physiological changes.

1. Introduction

Chocolate has long been associated with happiness and improved mood. Although in most cases the sensory aspects of chocolate are most likely responsible for its high consumption, there is evidence that psychoactive ingredients in chocolate may play a part as well [1–6]. Of the various compounds that are present in chocolate, the methylxanthines theobromine and caffeine are known to have psychoactive effects [1].

Caffeine, a non-specific adenosine receptor antagonist, is a well-known psychostimulant which peaks in the blood 30–40 min after ingestion of a 72 mg dose [7]. Moderate doses of caffeine (100–150 mg) increase subjective alertness, stimulation and vigor, improve reaction time in psychomotor tasks and also increase blood pressure [8,9]. However, reported mood and cognition effects from caffeine may be due to withdrawal, since subjects whose daily intake of caffeine was over 100 mg report more negative mood after prolonged deprivation [10]. On the other hand, light caffeine users, who exhibit few withdrawal effects, display improved mood and increased alertness after consumption of caffeine [8,9,11,12]. Enhanced subjective alertness from caffeine, the most often reported behavioral effect, is usually perceived between 30 and 60 min for a moderate dose of 150 mg, alertness plateaus for 1–2 h and then dissipates by 4 h, usually no negative symptoms are reported at a 150 mg dose [9,11,12].

Theobromine is a caffeine derivative and metabolite found primarily in chocolate; it is highly fat soluble; peaking in the plasma 1–2 h after ingestion [7]. An adenosine receptor antagonist, theobromine appears to have equal affinity for A1 compared to A2A receptors, while caffeine shows a slightly lower affinity for A1 receptors [13]. Theobromine has one fifth the stimulant effect of caffeine, but with a longer half-life in the body [7].

Very few studies have investigated the behavioral effects of theobromine, and thus no clear conclusions can yet be made about its psychoactive profile. Although two early reports found null mood effects from theobromine [14,15], a more recent study by Mumford et al. [16] showed that 5 out of 7 subjects were able to discriminate a high dose of theobromine (560 mg) from a placebo or caffeine dose. The combination of caffeine (19 mg) and theobromine (250 mg) in capsules increased the self-reported mood construct "energetic arousal", and improved cognitive function as measured with a simple reaction time test [1] compared to placebo capsules. Furthermore, the combination of theobromine and caffeine added to novel-flavored drinks increased liking over time in healthy volunteers, indicating that the psychopharmacological effects of these methylxanthines may play

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p = 0.0122, 3 h F(1,56) = 7.91, p = 0.0068] and a decrease in trembling 1 h after consumption F(1,56 = 11.21, p = 0.0015] (data not shown). There was one significant interaction between theobromine and caffeine [F(1,56 = 4.40, p = 0.0405], resulting in decreased trembling as compared to either methylxanthine alone at the 1 h time point (data not shown). The SUM of caffeine symptoms (head-ache, jitteriness, weakness, light-headedness, warmth, fearfulness and trembling hands) revealed significant differences between caffeine vs. placebo during all sessions [1 h F(1,56) = 9.07, p = 0.0039, 2 h F(1,56) = 9.58, p = 0.0031, 3 h F(1,56) = 8.55, p = 0.005] (Fig. 4B).

Blood pressure and heart rate were taken to assess whether treatment-induced cardiovascular changes had noticeable effects on perceived physiological symptoms. Blood pressure is a well-characterized indicator of autonomic system activation. In all intervention groups there was a tendency to an increase in BP over time, possibly related to the morning surge, as baseline measurements were done early in the morning. Compared to placebo caffeine significantly increased diastolic blood pressure 1 h [F(1,56) = 19.93, p = 0.0001] and 3 h after consumption [F(1,56) = 4.30, p = 0.0424,] (Fig. 5A). Systolic blood pressure decreased 1 h after theobromine treatment [F(1,56) = 7.37, p = 0.0087] and increased with caffeine treatment 1 h later [F(1,56) = 7.01, p = 0.0104] (Fig. 5B). Conversely, at all time points theobromine increased heart rate [1 h F(1,56) = 11.17, p = 0.0015; 3 h F(1,56) = 12.75, p = 0.0007] while caffeine decreased it [F(1,56) = 18.23, p = 0.0001] 1 h after consumption (Fig. 5C).

4. Discussion

This study has demonstrated behavioral and cardiovascular effects of two methylxanthines found in chocolate, theobromine and caffeine. Similar to previous reports, caffeine increased alertness and blood pressure. Contrary to our expectations, theobromine in a relatively high dose does not have stimulating properties or caffeine-associated physiological symptoms such as light-headedness. Theobromine has often been described as a stimulant, with one fifth the potency of caffeine on adenosine receptors [13]. However, theobromine had no effect on alertness at any time, although it did decrease blood pressure. Thus it is possible that theobromine affects peripheral physiology, but lacks the strong CNS-activating properties of caffeine. Furthermore, there were no interactions of caffeine and theobromine on mood or blood pressure.

4.1. Explicit mood

As expected, caffeine increased subjective alertness in subjects, however, theobromine did not. There was also no interaction of the two methylxanthines on mood. These results are similar to those found in Mumford et al. [16], where 5 out of 7 subjects reported strong energizing effects of caffeine where only 1 subject did for theobromine. However, since almost all subjects could discriminate doses of 580 mg theobromine, some psychoactive effects were felt. Indeed, a later study demonstrated that 19 mg caffeine + 250 mg of theobromine increased self-reported alertness [1]. Since few studies have shown self-reported alerting effects at doses of caffeine lower than 30 mg the Smit findings suggested a possible stimulating contribution of theobromine. However, the present study shows conclusively for the first time that theobromine does not act as a stimulant alone or in combination with caffeine.

Although theobromine had no alerting effects it did decrease feelings of calmness in subjects during the last session (3 h after ingestion), which indicates a tension-raising effect compared to placebo. This contradiction may be due to the novel sensations of theobromine, which may have stronger action on peripheral adenosine receptors and less in the central nervous system. Theobromine has been reported to have several peripheral activities, such as anti-tussive, diuretic, hypotensive and muscle relaxant properties [18,30]. Animal studies have shown that theobromine has negligible effects on cerebral blood flow and glucose use [31], belying a lack of direct CNS activity. However, animals give high doses of theobromine do show increases in motor activity [32].

Caffeine increased contentedness, possibly due to alleviation of fatigue effects. Alternatively, caffeine has been shown to modulate dopamine signaling in animals, which may bring on feelings of contentedness [33]. Specifically, central adenosine A2A blockade regulates DARPP-32 phosphorylation and subsequent reward- and motor-related behaviors [34]. A factor which undoubtedly affected the results was the choice and timing of dose. The dose for theobromine is five times that of caffeine dose chosen. Since theobromine's pharmacological activity is one fifth that of caffeine [13], the doses of theobromine and caffeine were expected to show comparable effects on some parameters. However, theobromine had negligible effects on mood and caffeine appeared to have similar mood effects as the combination of methylxanthines. Given that theobromine reaches peak blood levels 3 h after consumption while caffeine peaks 1 h after consumption, it may be that psychoactive effects are not reported earlier due to low brain availability, and that psychoactive effects may be more pronounced at later time points.

Another consideration is the possibility that the explicit mood measure Bond–Lader VAS, which is commonly used for assessing caffeine effects [26,27] may not be as appropriate for theobromine, which seems to have a quite different physiological and psychoactive profile. It is also possible that an implicit mood measure may be more sensitive to its effects.

4.2. Implicit mood

It has long been observed that many subjects have difficulty assessing their internal mood state. Therefore it is of interest to explore possible methods which indirectly measure mood. Such measurement can be done via questionnaires on task engagement and motivation, which often reflect the level of a subject's positive emotion. For instance, subjects in good moods often rate tasks as more interesting and pleasant.

The effects on the Motivation and Workload Questionnaire (rating things as more interesting/less dull) and ERTT (increased rating negative words) suggest theobromine has an effect on mood that is not apparent via the direct mood questionnaires. The decrease in calmness may indeed be explained by the subjects experiencing an unfamiliar sensation that perhaps is not unpleasant, but more difficult to describe. The positive findings of theobromine on implicit mood measures also adds to the discussion in the above section that tests which are sensitive to caffeine effects such as alertness may not be as useful for detecting theobromine effects. In conclusion, implicit mood measurement development needs to be explored further before it can be used as a corollary to more direct mood questionnaires such as the Bond–Lader VAS.

4.3. Cognition

The DSST is a measure of psychomotor speed and working memory. While some labs have shown a performance-improving effect from caffeine [23,24] others have reported null effects [19,20], and these differences may be related to dosage, subject selection criteria and environmental manipulations. In this study caffeine had no effect on the DSST performance, nor did theobromine. However the combination of these methylxanthines decreased reaction time for correct responses as compare to caffeine alone and increased it as compared to theobromine alone. Originally we hypothesized that 120 mg of caffeine may act as a threshold dose for DSST performance enhancement and that theobromine may act synergistically with caffeine to lift performance above threshold. The results suggest that theobromine and caffeine tended to have opposite effects on response time. However, since the DSST is more commonly scored as the

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CLINICAL Pediatric Emergency Medicine

Energy Drinks: The New Eye-Opener For Adolescents

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The availability of caffeine-containing energy beverages, combined with aggressive marketing and urban legend, has promoted their widespread use, particularly among adolescents. The caffeine content of these products is presently unregulated. Rapid growth in the consumption of these supplements has resulted in increasing reports of caffeine poisoning. This article provides a review of caffeine's pharmacokinetics and describes the clinical manifestations and management of caffeine toxicity. Suggestions for future research are also offered.

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KEYWORDS energy drink, adolescents, caffeine, guarana, taurine, carnitine, withdrawal

By promising immediate energy and decreased fatigue, energy drink brands have created a $3.5 billion yearly industry [1]. Aggressive marketing campaigns featuring celebrities and athletes target adolescents and young adults. A culture of blogs, urban legends, and "underground" chic has further increased their appeal. In 2006, more than 30% of adolescents reported using energy drinks, an increase of more than 3 million teens in 3 years [2]. The wide availability of the beverages, from grocery stores, convenience stores and school bookstores makes them readily accessible for purchase by adolescents, even though the products often retail for more than twice the price of "traditional" soft drinks. Although the media has clearly identified the trend toward increasing adolescent energy drink use, little medical literature describes this phenomenon. The goals of this article include identifying major ingredients of energy drinks, as well as a discussion of the pharmacology and toxicology of caffeine.

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Caffeine

The key ingredient in most energy drinks is caffeine, supplemented by a wide variety of amino acids, B vitamins, and herbal supplements [3]. Caffeine is found in a wide variety of beverages and pharmaceuticals, and has been called the most commonly used psychoactive substance in the world [4]. Major sources in the North American diet include coffee and tea for adults, and carbonated sodas, energy drinks, and chocolate for children and adolescents. A range of caffeine concentrations are found in brewed coffee (56-100 mg/100 mL), instant coffee and tea (20-73 mg/100 mL), and colas (9-19 mg/100 mL) [5]. Smaller amounts can be found in chocolate (5-20 mg/100 g) and cocoa (7 mg/5 oz cup) [6]. In addition, over-the-counter medications such as NoDoz and Midol contain between 100 and 200 mg of caffeine per tablet [6].

Average caffeine consumption in the United States and Canada ranges from approximately 1 mg/kg per day in children to 3 mg/kg per day in adults [7,8]. Intake has been known to be much higher in certain European countries such as Denmark, where consumption reaches 7 mg/kg per day [3]. Canadian recommendations for daily caffeine are no more than 85 mg for children aged 10 to 12 years, no more than 300 mg in women of childbearing age, and no more than 400 to 450 mg in the remaining adult population [9].

The Food and Drug Administration has limited the caffeine content of sodas to 65 mg per 12 oz (18 mg/100 mL); however, energy drinks are not currently subject

Table 1 Energy drink products with caffeine content, selected additional ingredients and calories per container.

Product	Caffeine content	Container size	Caffeine per container	Also Contains	Calories per container
Full Throttle (Original)	300 mg/L	16 ounces	144 mg	Guarana, taurine, carnitine, ginseng	200
Monster (Original)	**	16 ounces	**	Guarana, taurine, carnitine, ginseng, inositol, glucuronolactone	200
Mountain Dew Amp Energy	295.8 mg/L	8.4 ounces	71 mg	Guarana, taurine, ginseng	120
Diet Pepsi Max	194.5 mg/L	12 ounces	46 mg	Ginseng	0
Red Bull	320 mg/L	8.4 ounces	80 mg	Taurine, inositol, glucuronolactone	110
Rockstar Energy Drink	333.3 mg/L	16 ounces	160 mg	Guarana, taurine, carnitine, ginseng, inositol, ginko, milk thistle	280
SoBe No Fear	362.5 mg/L	16 ounces	174 mg	Guarana, taurine, carnitine, ginseng, inositol, grape seed extract	260
Coffee (Brewed)	420 mg/L	8 ounces	100 mg	N/A	0-5
Coca-Cola	95 mg/L	8 ounces	34 mg	N/A	97

* All product information derived from manufacturer websites or product label ** Listed as "energy blend" – caffeine content unknown.

to the same Food and Drug Administration regulations [10]. Energy drinks such as Red Bull and SoBe No Fear often contain between 14 and 31 mg of caffeine per 100 mL [10]. Although their caffeine concentration (in milligrams per milliliter) may be similar to coffee, energy drinks are often packaged in significantly higher volumes, resulting in increased caffeine intake. SoBe No Fear contains 141 mg of caffeine per 16 oz (473 mL) bottle, the equivalent of 1 1/2 cups of brewed coffee, or 4 cans of regular Coca-Cola (Table 1).

Guarana and Other Caffeine-Containing Ingredients

Guarana is derived from the seeds of *Paullinia cupana*, a South American plant known for its stimulant properties. Guarana contains large amounts of caffeine (4%-8%), theobromine, theophylline, and a high concentration of tannins [11]. Although caffeine concentration may vary widely in guarana preparations, 3 to 5 g of guarana provides approximately 250 mg of caffeine [12]. The effects of guarana ingestion are necessarily similar to caffeine; however, the duration of action may be much longer with guarana because of the presence of saponins and tannins [13].

Besides guarana, other caffeine-containing herbal ingredients found in energy drinks include kola nut, tea, yerba mate, and cocoa [14]. Inclusion of these ingredients does not necessitate caffeine labeling, and their presence may not be included in calculations of caffeine content. They nonetheless contribute to the overall caffeine content of a beverage.

Taurine

Taurine, the most abundant amino acid in animal tissue, is produced by the metabolism of methionine and cysteine [15]. Taurine plays a role in multiple metabolic processes, ranging from osmoregulation to antioxidation to glycolysis [16]. Dietary sources include meat, dairy products, and fish; an average diet provides 20 to 200 mg of taurine daily [16]. In addition, the belief that taurine is essential during neonatal development led to its supplementation of infant formula in the early 1980s, even though this practice has never been rigorously studied [17]. Taurine is an essential amino acid in cats where its deficiency leads to retinal degeneration [18]. As a dietary supplement, taurine is marketed for promotion of biliary health, eye health, and prevention and treatment of congestive heart failure. Little is known regarding the effects of high-dose or long-term taurine use in children and adolescents.

Ginseng

Ginseng, or *Panax ginseng*, is an East Asian herb that has been used for centuries to improve memory and stamina [19]. Although little medical literature supports these uses, ginseng has been incorporated into a variety of energy drinks. Although adverse effects associated with ginseng use tend to be mild, more serious complications have been reported, including diarrhea, vaginal bleeding, severe headache, and Stevens-Johnson syndrome [20,21]. Many of these effects may be attributed to contaminants; agranulocytosis in 4 patients taking ginseng had been linked to unreported phenylbutazone and aminopyrine contained in the preparation [22]. Herb-drug interactions in ginseng use include decreased international normalized ratio when concomitantly used with warfarin and the theoretical risk of hypoglycemia when used with antidiabetic agents [23,24]. A ginseng abuse syndrome has also been reported, characterized by morning diarrhea, hypertension, rashes, insomnia, and irritability [25]. Little is known regarding the effects of ginseng in children and adolescents [26].

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Cognitive effects of guarana supplementation with maximal intensity cycling

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Abstract

The aim of this study was to investigate the effects of guarana supplementation on cognitive performance before and after a bout of maximal intensity cycling and to compare this to an equivalent caffeine dose. Twenty-five participants completed the randomised double-blind crossover trial by performing cognitive tests with one of three supplements, on three different days: guarana (125 mg/kg), caffeine (5 mg/kg) or placebo (65 mg/kg protein powder). After 30 min of rest, participants performed simple (SRT) and choice reaction time (CRT) tests, an immediate word recall test and Bond–Lader mood scale. This was followed by a cycling $\dot{V}O_{2max}$ test, and cognitive tests were then immediately repeated. Guarana supplementation decreased CRT before exercise (407 (SD 45) ms) in comparison with placebo (421 (SD 46) ms, $P = 0{\cdot}030$) but not caffeine (417 (SD 42) ms). SRT after exercise decreased following guarana supplementation (306 (SD 28) ms) in comparison with placebo (323 (SD 32) ms, $P = 0{\cdot}003$) but not caffeine (315 (SD 32) ms). Intra-individual variability on CRT significantly improved from before (111·4 (SD 60·5) ms) to after exercise (81·85 (SD 43·1) ms) following guarana supplementation, and no differences were observed for caffeine and placebo ($P > 0{\cdot}05$). Alertness scores significantly improved following guarana supplementation (63·3 (SD 13·8)) in comparison with placebo (57·4 (SD 13·4), $P = 0{\cdot}014$) but not caffeine (61·2 (SD 12·8)). There were no changes to $\dot{V}O_{2max}$, immediate word recall or any other Bond–Lader mood scales. Guarana supplementation appears to impact several parameters of cognition. These results support the use of guarana supplementation to possibly maintain speed of attention immediately following a maximal intensity exercise test ($\dot{V}O_{2max}$).

Key words: Paullinia cupana: Reaction time: Alertness: Cognitive performance: Nutrition

Guarana (Paullinia cupana) is a native fruit of the Amazonian basin which has been used as a traditional medicine for centuries by indigenous populations[1]. The purported biological effects of supplementation are extensive. Reports demonstrate guarana to possess psychoactive and diuretic properties, as well as exhibiting antioxidant and anti-fungal effects[2]. Positive stimulating and cognitive effects of guarana have also been reported, with the high caffeine content of its seed (up to 6 % dry weight) being the predominant suggested mechanism of action[3]. Indeed, caffeine supplementation possesses a strong efficacy for improvements in a variety of cognitive[3] and physical performances[4]. The ubiquitous psychostimulant is predominantly metabolised in the liver by the cytochrome P450 enzyme system[5]. Cytochrome P450 isoform 1A2 (CRP1A2) mediates the main caffeine demethylation reaction of N-3 demethylation to paraxanthine, which equates up to 90 % of caffeine demethylation[5,6]. The antagonism of adenosine receptors also modulates the rapid movement across the blood–brain barrier which consequently augments dopamine concentrations in the brain[6], resulting in heighted alertness, vigilance, attention and reaction time[3]. However, despite the possible ergogenic effects derived from the caffeine content in guarana, reports suggest that the caffeine content is small in typically consumed doses, and in some cases lower than the pharmacological threshold required for humans[7]. As such, some studies indicate that additional components may also be the contributing mechanism[1,7,8]. Consequently, guarana has become increasingly popular in commercial markets worldwide, particularly in the soft drink and supplementation industry[1,2].

Initial studies conducted by Galduróz and colleagues[9,10] evaluated the acute (1 g/d for 3 d) and chronic (1 g/d for 150 d) cognitive effects of guarana supplementation in young and elderly individuals but found no changes to cognition, sleep or anxiety in either group. No further studies have assessed the long-term effects, but several studies have since reported significant acute cognitive changes following guarana supplementation[7,11–15]. Kennedy *et al.*[11] found both speed of attention and secondary memory were improved by a 75 mg dose of guarana. The increase in speed of attention is reflected in a decrease of reaction time observed in several other studies[8,11,14,15]. Haskell *et al.*[7] corroborated that secondary memory was improved with both 75 and 37·5 mg of guarana. Notably, the lower

Abbreviations: CRT, choice reaction time; ES, effect size; IIV-I, intra-individual variability– inconsistency; SRT, simple reaction time.

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dose contained less than 9 mg of caffeine, which is considered less than the threshold for pharmacological activity in humans[7]. It is therefore speculated that other pharmacokinetic components of guarana (tannins, saponins and flavonoids such as catechins and epicatechins; methylxanthines such as theobromine and theophylline) may be working synergistically with caffeine to enhance the psychoactive effects of the supplement[1,7–9,11]. Comparing the effects of guarana to caffeine alone may therefore help elucidate the contribution of the other components within the supplement.

Successful performance in many modern sports necessitates an athlete's capacity to simultaneously control a variety of physiological and cognitive loads. Such sports include modern pentathlon whereby optimal cognitive functioning is essential during combined events (laser-run)[16] or team sports where many relevant external attentional cues demand quick and accurate decisions. Though it is recognised that moderate exercise improves cognitive performance, higher/maximal intensities are said to worsen cognitive performance[17]. Yet to the best of our knowledge, only four studies so far have considered how physical activity may alter the cognitive effects of guarana supplementation, all of which have used moderate intensity exercise (60 % $\dot{V}O_{2max}$/peak power and/or rating of perceived exertion (RPE) 13/20) for 30–40 min[6,8,13,16]. An interaction between physical activity and guarana supplementation was reported in only one of the studies, where mean reaction time decreased following guarana supplementation in pentathletes after running at an RPE of 13 on the Borg scale[16]. Moreover, only one study reported any significant changes to cognition following guarana supplementation alone, and both a decreased reaction time and stable autonomic nervous system (heart rate variability) were reported[8]. It is therefore difficult to determine whether the absence of significant changes was the result of combining physical activity and guarana, or due to other extenuating factors.

It is apparent that guarana supplementation affects several areas of cognition which could be highly appealing to athletes who compete in sports that rely heavily on accurate and efficient decision-making processes for successful performance. However, thus far, evidence on how guarana supplementation affects cognitive performance during physical activity is equivocal and limited, particularly as all previous studies have only considered moderate intensities. Increasing the intensity of physical activity is likely to alter the associated fatigue and may therefore interact differently with supplementation compared with moderate intensities of exercise. Therefore, the aim of this study was to evaluate the effects of guarana supplementation on cognitive performance, before and after a bout of maximal intensity exercise. It was hypothesised that guarana supplementation would improve cognitive performance in comparison with caffeine and placebo following a bout of maximal intensity exercise.

Methods

Subjects

Twenty-seven physically active participants were recruited from the local university and cycling clubs and two dropped out due to injury or personal extenuating circumstances leaving twenty-five (age: 21 (SD 1) years, height: 172·4 (SD 15·3) cm, mass: 68·5 (SD 12·6) kg). The participants comprised eighteen males and seven females. Participants were considered physically active if they met the UK recommended physical activity guidelines (at least 30 min of moderate intensity activity five times per week). The mean daily caffeine intake of participants was 122 (SD 114) mg. All participants completed both informed consent and physical activity readiness questionnaire forms prior to participation. This study was approved by the UCL Research Ethics Committee in line with the Declaration of Helsinki.

Supplementation

Employing a double-blind randomised crossover design, participants attended the exercise laboratory on 3-separate days, each 1-week apart. Participants were asked not to eat in the 2-h before testing and not to consume caffeine or alcohol in the 24-h prior to testing. During the intervention, participants were also asked to maintain their regular diet and not to consume any supplements. On each visit, participants drank a different supplement in a randomised order: caffeine (5 mg/kg) (Caffeine, Loughborough, Fisher Scientific), guarana (125 mg/kg) (Guarana Powder, Brighton, The Guarana Company Ltd.) or placebo (65 mg/kg) (protein powder containing undenatured whey protein isolate and instantising agent). The caffeine dose in both caffeine and guarana supplement is in line with the suggested protocol of use by the International Olympic Committee[4]. Supplements were diluted in 250 ml of room temperature water and placed into opaque water bottles by an independent member of staff. To minimise olfactory and taste input, participants were instructed to hold their nose while drinking. To enhance the blinding and reduce bias further, participants were initially informed of the broad scope of the study ('investigating the influences of different supplements on exercise and cognitive function') but were not informed about the specific supplements and their purported effects. HPLC was performed to determine the caffeine content of the guarana supplement. This was found to be 3·99 %. The guarana dose was then calculated to match the caffeine content of the caffeine supplement given. After drinking the supplement, participants relaxed quietly for 30 min. Following this, participants completed the first set of cognitive tests (see below for protocol).

A $\dot{V}O_{2max}$ test was then completed on a cycle ergometer (CareFusion, Vyaire Medical) using a ramp protocol of 25–40 W per minute based on the participants reported level of physical activity. First, a 3-min warm up with no resistance (0 W) was completed. Thereafter, participants started at 0 W and continued until volitional fatigue. The criteria for achieving $\dot{V}O_{2max}$ were (1) to attain an respiratory exchange ratio (RER) above 1·1, (2) to achieve a plateau in VO_2 and (3) heart rate reading (SD 10) beats/min of the age-predicted max[18]. The $\dot{V}O_{2max}$ was determined by the highest $\dot{V}O_2$ value that was recorded from the 15-s averages, at this point the peak power output was also recorded. After a 5-min cool down (consisting of unloaded cycling), cognitive tests were repeated.

Cognitive tests

All cognitive tests were completed on the Computerised Mental Performance Assessment System (COMPASS) (Northumbria

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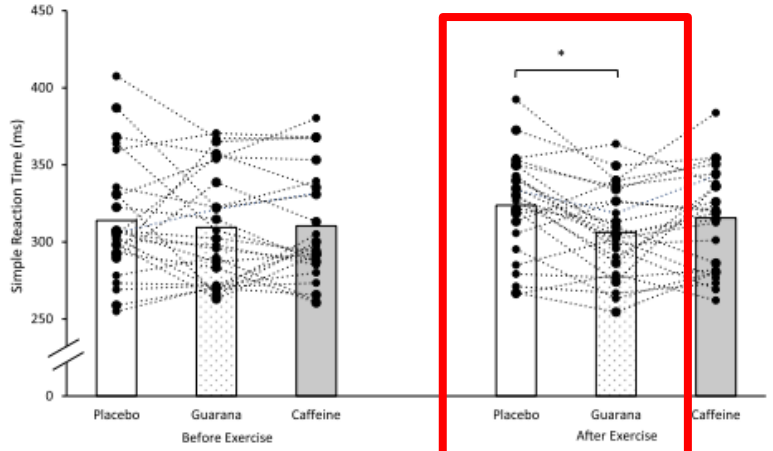

Fig. 1. Mean and individual simple reaction time (SRT) before and after exercise. *Signifies a significant difference ($P \leq 0.05$) between supplements and SRT.

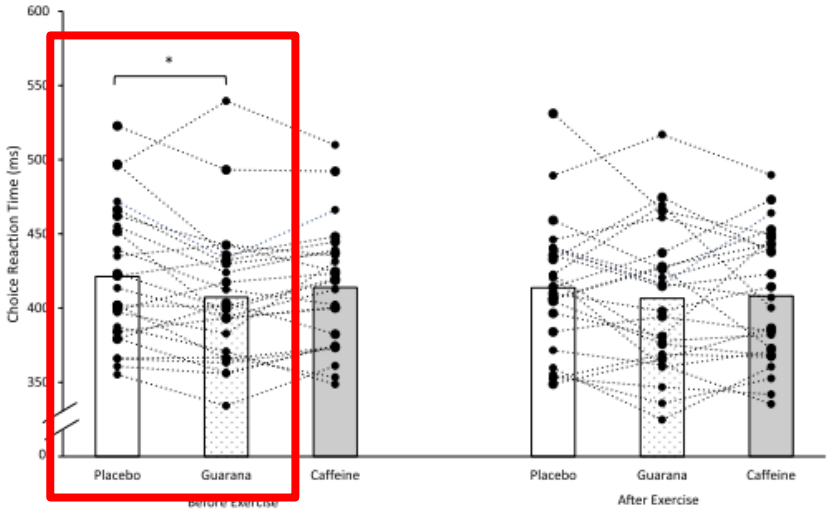

Fig. 2. Mean and individual choice reaction time (CRT) before and after exercise. *Signifies a significant difference ($P \leq 0.05$) between supplements and CRT.

Bond–Lader mood scales

Parametric assumptions were not met for alert scores; therefore, Friedman's was employed. Friedman's reported a significant increase in alert scores following guarana supplementation (63·3 (SD 13·8)) when compared with placebo (57·4 (SD 13·4)) following exercise only ($P = 0.014$). Kendall's W reported 0·097, indicating a small ES. No differences were reported between caffeine (61·2 (SD 12·8)) *v.* placebo and caffeine *v.* guarana ($P > 0.05$).

There was no significant main effect, time effect or supplement × time interaction ($P > 0.05$) for all other Bond–Lader mood scale variables (content and calm) between supplements.