

Health Aspects Attributing to Composition of Energy Drinks and their Scope in Forensic Science: A Review

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Abstract

Energy drinks are beverages that typically contain ingredients such as caffeine, taurine, B vitamins, guarana, and other stimulants and are often carbonated. The primary active ingredient in energy drinks is caffeine. Though these drinks have been marketed as ergogenic products which can enhance physical and cognitive performances (temporary boost in energy level), results of several studies show that due to presence of high caffeine content, their excessive consumption can lead to caffeine overdose or toxicity which includes a range of adverse effects such as tachycardia, heart palpitations, high blood pressure, anxiety, dehydration, digestive issues, disrupted sleep patterns which can lead to further health risks and in severe cases, even cardiac arrhythmias or seizures. High levels of sugar and acids in these drinks even lead to dental problems. The combination of caffeine and other stimulant ingredients in energy drinks can pose a risk and can potentially lead to cardiovascular problems, hepatotoxicity, nephrotoxicity, neurotoxicity and behavioral & psychological issues. It is therefore advised that these drinks should be consumed with caution while taking certain medications or alcohol. The stimulant effects of energy drinks can interact negatively with some medications, such as certain antidepressants or stimulant medications. Combining energy drinks with alcohol can mask the depressant effects of alcohol, leading to excessive alcohol consumption and potentially risky behavior.

While energy drinks are not extensively studied within forensic science, their potential toxicity, their use as markers of consumption patterns, susceptibility to adulteration, and risk of contamination make them relevant in specific forensic contexts. Forensic analysis of energy drink ingredients can provide insights into their quality, composition, and compliance with regulatory standards. By employing scientific techniques, food forensic scientists can ensure the authenticity, safety, and compliance of energy drinks in the marketplace.

Keywords: Energy drinks; Caffeine; Additives; Forensic Science; Food Forensics.

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INTRODUCTION

Energy drinks (EDs) are ergogenic, carbonated or non-carbonated, alcoholic or non-alcoholic drinks in which caffeine/guarana, sugar or its alternatives (artificial sweeteners such as sucralose), taurine, B vitamins, minerals, amino acids and herbs or herbal extracts like ginseng^{1,2,3} are present as key ingredients in varying concentration. The

energy drinks were first introduced in the markets of Europe and Asia in 1960s.⁴ The products considered under this beverage category ranged from soft drinks to energy drinks, were highly caffeinated and soon became popular amongst the teenagers and young adults.^{5,6} The market of energy drinks has expanded exponentially since 1987 in Austria and in 1997 in the U.S. when Red Bull was introduced in the respective markets. The present paper aims to present a review of the major health concerns related to energy drinks and see its relevance in field of forensics.

METHODOLOGY

Searches were conducted using the terms *soft drink, energy drink, marketing, global market, ingredients, additives in energy drinks, athletes & energy drinks and energy drink health concerns* using databases such as Scopus, PubMed and WebMD. Internet search engines such as Google and Google Scholar were also used to locate relevant information in form of research papers. For further information related to health aspects, websites such as Science Direct and Research Gate were used and for information related to products, their concerned websites were visited.

RESULTS

Energy Drinks in global market

Marketing tactics of these products have created a strong and widespread consumer ground for these products. According to a study, worldwide market of carbonated beverages is estimated to cross the 410 billion USD figure by 2023.⁵ Ever since the launch of energy drinks in the commercial market, the sports persons have been the prime target consumers of these businesses. With the expansion and growth in this market, the prime focus has now shifted from the athletes to the teenagers and youngsters.⁷ As a result, a decline is observed in the consumption of soft drinks in many countries while on the other hand, growth is observed in the sales of EDs, especially amongst youngsters. Although exact factors behind these trends can't be marked but results of several survey based quantitative researches are indicating towards the fact that the children and youngsters cannot clearly distinguish sports or isotonic drinks from the energy drinks. Their choice of consumption is based on the tastefulness of the drink, to satiate their thirst and

to enhance their performance in sports.^{8,9,10}

Ingredients and Additives in Energy drinks

Water, sugar (artificial sweeteners or carbs in form of ribose/sucrose/fructose) and caffeine are the primary ingredients of energy drinks out of which, caffeine is the key psychoactive ingredient and in combination with sugar, it provides ergogenic effects. In addition to this, energy drinks are loaded with several other additives namely, ginseng, taurine, ginkgo biloba, milk thistle, yerba mate, glucuronolactone, L-carnitine, guarana (an alternative source of caffeine), vitamin B complexes, inositol among others, claiming to enhance energy level and cognitive power, along with other health benefits.^{11,12}

Health Aspects related to Energy drinks

Since energy drinks are marketed highlighting their cognition enhancement and physical health boosting ability, they have become popular among the adolescents and athletes and their consumption rate has increased over the past decade.¹³ Physical workout trainers prioritize EDs as it is believed by them that these drinks have advancement in terms of nutritional, pharmacological and psychological indices and would result into increased efficiency of the workout and accelerate the post-workout recovery.^{14,15}

The relation between energy drink uptake and the performance of athletes has been established for various sports like American football and soccer^{16,17,18}, athletics^{19,20,21} volleyball²² and handball.²³ Though ED might serve as athletic performance enhancing dietary supplement but only when it is consumed in small portions. Caffeine and taurine are the most extensively studied ingredients and they are known to be the primary elements that provide ergogenic effect to the energy drinks.^{24,25,26}

Although these drinks claim to improve the physical and mental performance, the research results, except for caffeine, however, either don't support the claim or it is difficult to prove their claim after analysis of the energy drink samples.²⁷ The results from multiple studies have indicated that controlled consumption of these drinks in moderate dosage would result in beneficial effects like improved athletic performance during endurance and explosive activities by showing ergogenic effects. However, in spite of the positive results due to consumption of such drinks in controlled quantity, the myriad of health problems including various cardiovascular and neurological

disorders resulting from regular, uncontrolled and/or longtime consumption of these drinks cannot be avoided due to the presence of high caffeine and sugar content in them.^{8,13}

Health impact of caffeine and sugar

Consumption of ED raises the possibility of caffeine toxicity and other negative effects due to the known and unknown pharmacology of the ingredients of EDs. Tachycardia, vomiting, cardiac arrhythmias, seizures, and even death can result from caffeine intoxication. Obesity and dental enamel degradation brought on by the EDs' acidity are two additional health issues associated with their use.²⁸⁻³² In one of the case studies, seizure activity was reported in a patient who had recently started consuming these drinks in high quantity. The research showed how people with low seizure verges might risk themselves to higher seizure susceptibility if they would be exposed to high amounts of caffeine.³² The dose triggering the seizures amongst the pediatric and non-pediatric patients could vary from as low as 480 mg of caffeine (present in a single can of ED of some brands) to several cans in a single day.³⁰

Relation of energy drinks with substance abuse and its impact on health

Adolescent users' increased risk-taking behaviours, impaired driving, and greater use of other illegal substances have all been linked to their caffeine and ethanol consumption as per results of various studies. Several studies have shown that drinking alcohol combined with energy drinks causes different subjective states from drinking alcohol alone, including increased stimulation and increased desire to drink. When mixers are artificially sweetened, or lack sucrose, which decreases the pace of alcohol's gastric emptying, caffeine's impact on intoxication may be most noticeable.²⁸ In a case study acute renal failure was reported in a teenager who consumed energy drinks with vodka.²⁹

A study's results show relation of regular consumption of EDs with various behavioural issues like getting anger issues, smoking, and substance abuse including alcohol consumption, violating traffic rules³³, reduced sleep, disturbed sleep pattern and other mental developmental problems.³⁴ In a study conducted on Australian consumers, 87% of the participants who consumed EDs along with other substances for recreational purposes showed up with adverse health

symptoms. Most commonly reported symptoms were tremors, distress, heart palpitations and disturbed gastrointestinal tract. 21 participants showed signs of severe cardiac or neurological noxiousness, including seizures, hallucinations, cardiac arrhythmias or cardiac ischaemia. 128 participants (out of which 57 only consumed EDs) had to be hospitalized.³

A published study states that high caffeine consumption, usually if taken along with the additives (whose safety profile is not known), should be put under immediate and exhaustive research to check whether it is safe for consumption for children and young population.³⁴

Health Impact of other Ingredients of Energy drink

In a study, the putative effects of EDs were studied and it was concluded through that study that these beverages contained many ingredients that were less studied and unregulated and possessed no therapeutic value. Instead, considering the toxicity reports owing to the consumption, it presents an alarming picture of myriads of serious adverse health effects that these EDs are potent of delivering.¹

There is either fickle or no experimental evidence indicating that by adding glucuronolactone, glucose, multivitamins, yerba mate, ginseng, carnitine or guaraná to an ED containing caffeine would result in enhancement in physical and mental performance. The ergogenic effects and solely be credited to the presence of caffeine alone in those EDs.²⁶

Caffeine and taurine are considered to have synergic effects on each other and could also generate positive inotropic effect.³⁵ It was found in the study that when caffeine is taken in combination with taurine, they show in-vitro physiological effects on the intra-cellular calcium levels of vascular smooth muscles which leads to cardiac hypertrophy and congestive heart failure and the patients had high concentrations of caffeine and taurine in their cardiac tissues.¹³ In another controlled research study in 2010, the participants (young adults) consumed sugar free EDs that had high concentration of taurine (1g) and glucuronolactone (0.6g) and low caffeine concentration (0.08g). The results showed substantial surge in mean arterial pressure and aggregation of platelets. Also, a significant decline was noted in their endothelial function.³⁶

The researchers and health experts are alarmed

about the high quantity of Vitamin B6 present in many of these drinks. Neuropathic conditions have been reported in patients since as early as 1983. These patients reported consumption of 2 to 6 gm pyridoxine (Vitamin B6) on daily basis.³⁷ Later researches have also confirmed neurotoxicity due to consumption of vitamin B6, however, the results reveal that the toxic effects can be seen by per day consumption of small doses as low as 50 milligrams.^{38,39,40}

Involvement of energy drinks in Forensics

EDs can indeed play a role in food forensics investigations. Food forensics involves the scientific analysis of food and beverage products to determine their authenticity, safety, quality, and compliance with regulations. These drinks, like any other food or beverage product, can be subjected to various forensic techniques to gather information and evidence. They may be considered relevant in food forensics falling under following scope:

- **Ingredient analysis:** EDs often contain a variety of ingredients and analyzing the composition and concentration of these ingredients can help determine if the ED matches its label claims or if any adulteration has occurred.
- **Contaminant detection:** EDs may be screened for contaminants like heavy metals, pesticides, mycotoxins, or microbial pathogens. These analyses help ensure the safety and compliance of the product and identify any potential sources of contamination.
- **Authentication:** Food forensics aims to authenticate food and beverage products to verify their origin and quality. EDs can be subjected to techniques like stable isotope analysis or trace element analysis to determine their authenticity, including verifying the origin of specific ingredients or detecting counterfeit products.
- **Packaging Analysis:** ED packaging, such as cans or bottles, can provide valuable forensic evidence. Investigators can examine the packaging for tampering, counterfeit labels, or other signs of adulteration.
- **Toxicology and Adverse Reactions:** In cases where EDs are suspected to cause adverse health effects, forensic toxicology can analyze the drink's components, such as caffeine or other stimulants, to assess their potential contribution to the observed symptoms. Also,

there are chances of presence of a potential source of bacterial or chemical contamination which can be identified.

EDs may also have a scope in food forensics, which is the application of scientific techniques to investigate food related crimes, fraud, or contamination. In this context, EDs may be of interest due to their potential for adulteration or mislabeling. For example, EDs may contain undeclared ingredients, such as prescription drugs, which can have serious health consequences for consumers. In such cases, food forensic scientists can use various analytical techniques to identify and quantify the presence of such ingredients, thereby helping to protect public health. EDs may also be relevant in food fraud or consumer fraud investigations, where they could be substituted for other products or used to create counterfeit versions of legitimate products. For example, these drinks could be used to simulate the color, texture, or taste of other beverages, or to dilute more expensive ingredients.

A standard cup of coffee contains 80 mg of caffeine in it whereas the caffeine concentration ranges from 50 mg to as high as 505 mg in a single serving can of an ED.⁴¹ Along with caffeine, several other bioactive compounds are found in form of additives in them. Despite its well established adverse effects on health, the US FDA (the United States Food and Drug Administration) has not mandated the mentioning of high caffeine warning on the ED cans, nor has it limited the quantity of caffeine in these drinks.⁴² In India, as of September 2021, the Food Safety and Standards Authority of India has set the permissible caffeine content window for caffeinated drinks (including EDs) to be 145 ppm - 300 ppm. The problem not only exists with the content of caffeine and sugar in the ED but also with the other additives added to them. EDs are somewhat considered to be functional food loaded with dietary supplements such as ginseng, guarana, taurine, yerba mate, etc. These beverages are diligently promoted amongst population as ergogenic and mind stimulating drinks but don't display all the ingredients of the product or in some cases, their quantity on product's label.⁴³ The issue that arises here is of probable consumer fraud where if the claims made by the product are actually delivered to the consumer in virtue of the additives present in the drink or are all the ingredients mentioned on the product label actually present in the drink or is there any hidden ingredient present in the drink whose information has not been revealed on the product label and whether these

drinks are fit for prolonged consumption or not. This has drawn attention of scientists, healthcare professionals and regulatory bodies to review the effects of ingredients other than caffeine present in the EDs and prove/disapprove the claims made by the brands.²⁶

EDs are not universally banned, but there have been instances where certain countries or jurisdictions have banned or restricted their sale or consumption.¹ The World Anti-Doping Agency (WADA) prohibits the use of certain stimulants, including caffeine, in high doses, though not banning their use outright. The National Collegiate Athletic Association (NCAA) has placed restrictions on the sale and distribution of EDs at its events and student-athletes may not consume them during competition or practice. The NCAA also recommends that student athletes limit their caffeine intake to no more than 400 mg per day. The International Olympic Committee (IOC) does not have a specific ban on EDs, but it does prohibit the use of certain stimulants, including caffeine, in high doses. Athletes are subject to drug testing and may be penalized if they are found to have used prohibited substances, including stimulants. This subject matter can be taken under scope of forensics when dope test requirement arises.

EDs can have a potential scope in forensic science when it comes to toxicology and postmortem analysis. Forensic toxicologists may be interested in EDs when their consumption leads to adverse health effects. A study reported in 2012 mentions the probable health issues such as nervous or hepatic damage, related to consumption of these drinks which contain caffeine in excessive quantity, along with other ingredients.³⁴ In addition to their potential toxicity, EDs may also be relevant in forensic investigations as a marker of consumption patterns. For example, the presence of energy drinks at a crime scene could provide valuable information about the lifestyle, habits, and behaviors of the individuals involved. Overall, while the scope of energy drinks in forensic science is not extensive, their potential toxicological effects and their use as markers of consumption patterns make them relevant to certain areas of forensic investigation.

CONCLUSION

EDs often contain bioactive compounds other than caffeine. It is important to note that while these drinks can have potential health risks, they

are generally considered safe for most people when consumed in moderation. However, certain populations, such as children, pregnant women, and individuals with underlying health conditions, may be more susceptible to adverse effects and should use caution when consuming energy drinks. The increased cases of caffeine toxicity amongst young population resulting from excessive consumption of ED demand regulation and reviewing of their labelling and sales.³ The exploration of the comparative effects of acute and chronic ingestion of the ingredients in EDs other than caffeine need to be done.⁴⁴

Although a few studies supported the contribution of glucose and extract of guarana in enhancing physical performance and mental alertness but majority of the studies credit the contribution to caffeine present in the EDs.²⁶ This further creates a requirement for well planned, placebo-controlled, randomized studies by the researchers across the globe in order to give a reality check to the consumers for the claims made for EDs.

The scope of EDs in food forensics includes the detection of adulteration, mislabeling, and fraud, as well as potential contamination issues. The use of analytical techniques and forensic science can help to identify such issues and protect public health. The scope of EDs in food forensics must be explored further to ensure public health and to formulate stringent laws that would prevent consumer fraud.

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