Energy Drink Ingredients and Early-Onset Cancer: A Review of Taurine, Guarana, and B Vitamin Mechanisms

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Abstract

Early-onset cancer, defined as a cancer diagnosis in individuals under 50 years of age, has increased steadily over the past few decades. This trend parallels the dramatic global rise of energy drink consumption, particularly among adolescents and young adults. While energy drinks' primary ingredients, such as glucose and caffeine, have already been well established in the literature, comparatively little attention has been directed toward lesser-studied compounds. Emerging data suggest that ingredients such as taurine, guarana, and B vitamins affect tumor cells through pathways involving proliferation, viability, and immune evasion. Moreover, the combined and potential synergistic effects among these ingredients remain largely uncharacterized. This literature review evaluates the current evidence on the individual effects of taurine, guarana, and B vitamins on cancer risk and progression, and explores potential synergistic interactions among these components that may influence carcinogenesis and tumor behavior. In the context of early-onset cancers, our review highlights gaps in the existing literature and the need for further mechanistic, epidemiologic, and clinical studies to better define the role of these ingredients in cancer development and outcomes.

Introduction

Cancer is a multifaceted disease characterized by the uncontrolled growth of abnormal cells that can spread to other parts of the body (*What Is Cancer?*, 2007). Cancer typically affects individuals aged 50 or older(Cancer Research UK, 2023). In the United States, the median age of cancer diagnosis is 67 years, meaning half of cancer diagnoses occur in people over 67 years of age (*Why Is Early-Onset Cancer On the Rise? - NCI*, 2025). However, in the past few decades, there has been a significant increase in the number of cancer cases affecting people under 50 years of age. The term early-onset cancer (EOC) refers to these cases of people developing cancer from 18 to 50 years of age (Ugai et al., 2022). EOC cases also increased by 71.9% from 1991 to 2023 (Kehm & Terry, 2025).

Currently, there is limited data regarding the cause behind this increase in cases, as there are many factors, including lifestyle and environmental exposures, and biological traits that can increase the risk of cancer. However, certain lifestyle factors greatly influence cancer prevention, treatment, and outcome. Nutrition is one such example, as it has been estimated that 25% of overall cancer cases could be prevented by diet and nutrition (Fjeldburg, 2022). Diet influences cancer primarily through body weight, inflammation, and gut immunity (Rock et al., 2020). In addition, approximately 30-35% of all cancer-related deaths are linked to diet (Narimatsu & Yaguchi, 2022).

Furthermore, one possible explanation for this rise in EOC is changes in diet and lifestyle, particularly among younger populations. At the same time, one of these multigenerational changes has been increased energy drink (ED) consumption: from 2003 to 2016, ED consumption among adolescents increased tenfold (Vercammen et al., 2019). According to the National Center for Complementary and Integrative Health (NCCIH), EDs are products that are promoted as "increasing energy and enhancing mental alertness and physical performance" (*Energy Drinks*, 2018).

Appearing first in 1949 and later becoming popular with the launch of Red Bull in 1997, EDs are now very prevalent worldwide, with an estimated lifetime prevalence of energy drink use of 54.7% (Reissig et al., 2009). Today, approximately 30-50% of young Americans consume EDs, indicating a high level of use (Alsunni, 2015). Furthermore, according to the National Center for Complementary and Integrative Health (NCCIH), almost one-third of teenagers consume energy drinks regularly (*Energy Drinks*, 2018).

EDs are marketed to increase energy, alertness, and exercise performance (Costantino et al., 2023). These EDs typically contain a combination of ingredients, including caffeine, sugars, taurine, guarana, and B vitamins(Higgins et al., 2018). While caffeine and sugar are the most widely studied components and have the most comprehensive understanding of their relationship to cancer, other commonly included ingredients have received less attention despite their potential biological effects. This review focused on taurine, guarana, and B vitamins because they are frequently included in energy drinks and are known to influence key cellular processes, including metabolism, oxidative stress, and cell signaling, which are relevant to cancer development (Hanna et al., 2022; Zeidán-Chuliá et al., 2013)

. Although there is currently limited evidence directly linking ED consumption to early-onset cancer, examining the biological effects of these individual ingredients may provide insight into possible mechanisms. By focusing on these less-studied but biologically active components, this review aims to better understand whether they could contribute to processes associated with early-onset cancer.

Taurine

Taurine (2-aminoethanesulfonic acid) is a semi-essential amino acid found in animal and human tissues, including brain, heart, and skeletal muscle tissues (Santulli et al., 2023). In the daily diet, taurine is commonly found in seafood, including shellfish, scallops, and octopus (Ujong, 2026). In the body, taurine plays diverse physiological roles. Taurine is an antioxidant that protects cells from damage and may reduce the risk of cancer in healthy individuals (Surai et al., 2019). Taurine helps regulate cell volume and stabilize the cell membrane through osmoregulation. In addition, taurine can increase cellular antioxidant defense in response to inflammation, leading to anti-inflammatory effects (Seidel et al., 2019).

In energy drinks, taurine is one of the main compounds marketed to boost physical and cognitive performance (Deng et al., 2025). Taurine also plays an important role in maintaining proper muscle function and is known to balance and support energy metabolism and production in the body (Wen et al., 2019). For these benefits, taurine is commonly found in energy drinks to support athletic performance and recovery. However, interestingly, studies examining taurine's role in cancer have produced mixed results. Previous studies show that taurine induces apoptosis, reduces cell proliferation, inhibits cancer invasion and metastasis, and that its effects on cancer are dose-dependent. In colon cancer models, Zhang et al. demonstrated that taurine can induce apoptosis and reduce cell proliferation in colorectal cancer cells, regardless of p53 mutational status, via upregulation of the p53-upregulated modulator of apoptosis (PUMA) (X. Zhang et al., 2014). Similarly, Wang et al. (2020) demonstrated that taurine significantly reduced the number and size of colorectal tumors in an ulcerative colitis (UC)-associated colorectal cancer mouse model (G. Wang et al., 2020). Taurine-treated mice had decreased Ki-67 expression (a cellular marker for proliferation), increased apoptosis, and upregulation of the tumor suppressor PTEN (phosphatase and tensin homolog) gene. In breast cancer models, taurine is also associated with reduced lung metastatic burden by upregulating PTEN (Lin et al.,

2024). In both *in vitro* and mouse lung cancer models, taurine slowed cancer growth in a dose-dependent manner, with higher concentrations associated with slower proliferation (Tu et al., 2018).

However, more recent studies also show that taurine has pro-tumorigenic effects via the SLC6A6 protein. In one study of gastric cancer, cancer cells extract taurine from the environment via the SLC6A6 membrane protein, also known as the taurine transporter (TauT), which is responsible for cellular taurine uptake. However, T cells (immune cells) also rely on taurine to survive and function as effective killers. Cancer cells can outcompete T cells by overexpressing SLC6A6, causing T cells to become dysfunctional and die, ultimately leading to immune exhaustion (Cao et al., 2024). This study shows that taurine not only impacts the tumor but also the surrounding tumor immune microenvironment. In patients with breast cancer, those with excess taurine in the blood had enhanced tumor growth, as SLC6A6 overexpression drives tumor progression in vivo and accelerates proliferation in vitro. In addition, taurine's antioxidant properties were found to neutralize the tumor's oxidative stress through SLC6A6, promoting its survival (Cai et al., 2026). This study shows negative, dose-dependent effects of taurine on cancer and suggests that targeting the specific protein may help in cancer treatment, since patients with higher Slc6a6 (the taurine transporter) protein levels had worse outcomes than those with lower levels. In a recent study in *Nature*, Sharma et al. (2025) found that leukemia stem cells take up taurine through the SLC6A6 protein, which activates the mTOR pathway (a master regulator of metabolism) and triggers glycolysis in leukemia stem cells, leading to rapid cell proliferation (Sharma et al., 2025). Furthermore, blocking CDO1 (an enzyme that drives taurine production) impaired leukemia stem cell growth and improved survival in the mouse model. This study demonstrates the potential of targeting the CDO1 protein in cancer treatment to improve outcomes. This study suggests that taurine is linked to carcinogenesis; therefore, taurine at the high concentrations found in energy drinks could contribute to EOC in younger adults.

Overall, current evidence on taurine is mixed, with potential for both anti-tumor and pro-tumor effects reported, highlighting the need for further research. However, these pro-tumor effects are from newer studies, which may lend increasing support to taurine's pro-tumorigenic role.

Guarana

Guarana extract is derived from the seeds of *Paullinia cupana*, a plant native to South America. This extract has one of the highest caffeine concentrations among plants, even higher than that of coffee beans. According to the Memorial Sloan Kettering Cancer Center, guarana is also marketed as a stimulant that alleviates fatigue and may improve cognitive performance and reduce mental fatigue in adults (Memorial Sloan Kettering Cancer Center, 2022). Furthermore, certain compounds in guarana may slow caffeine absorption, with some studies suggesting a more sustained stimulant effect than that of coffee (Moustakas et al., 2015). In addition, guarana has been reported to have a variety of health benefits, including anti-inflammatory, antioxidant, and stimulating properties, and, most significantly, anti-cancer properties (Torres et al., 2022). Guarana has anti-inflammatory effects, as it has been found to inhibit pro-inflammatory signaling molecules. Guarana also has strong antioxidant properties, not only from caffeine but also from its tannins (protective compounds), which are highly effective at preventing cellular damage and may reduce cancer risk (Machado et al., 2021). These benefits ultimately make guarana a popular ingredient in energy drinks.

In the context of cancer, guarana has been studied primarily for the management of cancer-related fatigue and in preclinical antitumor studies. Based on existing data, guarana has antitumor activity by reducing cell proliferation, tumor size, and cell viability and, when used with chemotherapeutic agents, can strongly affect cancer cells.

In breast cancer cell lines, guarana inhibited both the mTOR and MAPK pathways (cell growth pathways), reducing cell proliferation and decreasing colony formation. In colorectal cancer cell lines, guarana only inhibited the mTOR pathway. These results indicate that guarana's effects on cancer cell pathways vary by cancer type. However, guarana did not affect normal, healthy cells, suggesting it selectively targets cancer cells rather than being generally toxic, and thus potentially acting as an anti-cancer agent (Cadoná et al., 2016). In a mouse model of lung cancer, guarana reduced tumor size by 68.6% compared with the control by decreasing cell proliferation and increasing apoptosis in tumor cells (Fukumasu et al., 2008). This study shows that guarana combats cancer progression by inhibiting cancer cell growth and increasing cancer cell death.

Many studies have examined the effects of guarana in combination with chemotherapy. In the breast cancer cell line MCF-7, guarana had an antiproliferative effect at higher doses (5 and 10 μg/mL) and significantly improved chemotherapy. Specifically, guarana combined with chemotherapy significantly reduced cell growth, with cell viability decreasing by more than 40% compared with chemo alone after 72 hours (Hertz et al., 2015). In the colorectal cancer cell line HT-29, guarana decreased cell proliferation at every concentration tested and, when combined with oxaliplatin, a standard chemotherapy drug, boosted the drug's potency. In addition, at the highest dose tested (100 ug/mL), guarana decreased cell viability as effectively as oxaliplatin. Guarana's anti-tumor properties stem from its apoptotic ability to upregulate the p53 protein (Cadoná et al., 2016). These studies demonstrate the potential of combined guarana and chemotherapeutic agents in cancer research. In addition, these results illustrate that guarana's anti-tumor effects are dose-dependent, with better outcomes correlating with higher doses.

Overall, current studies highlight guarana's cancer-specific anti-tumor effects and its potential relevance to cancer treatment in combination with chemotherapy drugs, which warrants further investigation.

B-Vitamins

B Vitamins are a group of 8 water-soluble vitamins that are necessary for the body. However, most B vitamins cannot be stored in large quantities and require regular dietary intake, except B12, which the liver can store for several years (Hanna et al., 2022). B vitamins are found in animal protein, vegetables, dairy products, and grains. In the body, B vitamins primarily help with cellular metabolism, energy production, red blood cell production, and nervous system regulation (O'Leary & Samman, 2010). Commonly found B vitamins in energy drinks include B3 (Niacin), B5 (Pantothenic Acid), B6, B9 (folic acid), and B12. However, most energy drinks contain amounts of vitamin B that exceed the recommended daily value (Jagim et al., 2022). Energy drink companies include B vitamins for their supposed exercise benefits, such as providing an "energy boost," because B vitamins are associated with the conversion of food into ATP (Adenosine Triphosphate), the primary cellular energy molecule (Hanna et al., 2022). However, substantial evidence that B vitamins enhance performance is lacking (Higgins et al., 2018).

Cancer studies involving B vitamins are also increasing, creating a complex relationship between cancer and B vitamins. In a study involving a wide range of female cancer patients,

specifically breast cancer, the synergistic supplementation of vitamin B6, folic acid, and B12 did not have a significant effect on cancer mortality (S. M. Zhang et al., 2008).

Most studies examine the effects of B vitamins on colorectal cancer, often using meta-analysis, such as Zhang et al.'s study, which concluded that B vitamins generally did not affect cancer incidence or mortality (S.-L. Zhang et al., 2016). However, Sun et al.'s study found that B vitamins may have anti-tumor effects, with B3 (niacin) and B9 (folic acid) as the main drivers (Sun et al., 2026). In addition, high vitamin B levels were associated with a reduced risk of colorectal cancer (X.-L. Wang et al., 2025). These meta-analyses show that B vitamins are associated with reduced cancer risk. I*n vivo* studies show that B vitamins are associated with apoptosis, suppression of tumor growth and invasiveness, and a stronger immune response. In triple-negative breast cancer, vitamin B3 led to apoptosis and suppressed tumor growth and invasiveness in both breast cancer stem cells and a mouse model (Jung et al., 2022). In a colon cancer model, Kuo et al. found that folic acid (B9) reduced tumor size and prolonged lifespan through the p53 protein (Kuo et al., 2015). Based on these meta-analyses and *in vivo* studies, B vitamins may have anti-tumor effects.

However, some studies have linked B vitamins to cancer. Similar to the anti-tumor studies, there are many meta-analyses on the effect of B vitamins on cancer, specifically against colorectal cancer. In one study, the treatment of folic acid (B9) and vitamin B12 saw an increase in lung cancer incidence and caused patient mortality (Ebbing et al., 2009). One study examined the effect of B vitamins on lung cancer and found that vitamin B6, specifically, was associated with lung cancer risk based on blood samples (Johanasson, 2010). One study examined genetically predisposed individuals with genes associated with high levels of folic acid, B6, and B12 and found that high vitamin B6 levels were associated with colorectal cancer (Yuan et al., 2021). Additionally, in *vitro* and mouse models, vitamin B3 protected pancreatic cancer cells by reducing oxidative stress, suppressing DNA damage, and blocking apoptosis, all of which reduced chemotherapy efficacy (Nakazzi et al., 2026). Furthermore, in a mouse model of breast cancer, a high folic acid diet was associated with enhanced tumor growth (Hansen et al., 2017). Overall, these contrasting studies do not establish a clear relationship between B vitamins and cancer, ultimately demonstrating a need for a better understanding of B vitamins and cancer, considering their relevance in EDs and supplements. However, this relationship might depend on dosage, B vitamin type, and cancer type, given the anti-tumor and pro-tumor effects of B vitamins.

Combined Effects of Energy Drinks

Studying ED ingredients provides a better understanding of EDs based on the ingredients' separate mechanisms; however, it does not establish how they behave when consumed together, as they typically are in a single beverage. Direct evidence on ingredient combinations and cancer-relevant outcomes is limited to a small number of studies, summarized critically below.

One study tested the effects of two commercial energy beverages on normal cell cultures, including mesenchymal (connective tissue) cells, epithelial (lining), and neuronal cells (Doyle et al., 2012). Mesenchymal and epithelial cells showed a dose-dependent delay in regeneration, which the researchers attributed to slower cell proliferation. Notably, the energy drink treatment showed a longer delay than the caffeine, taurine, and glucose treatment, indicating that these three ingredients alone could not replicate the effects of the whole beverage. This suggests that other ingredients or synergistic interactions among many

compounds were responsible for the more pronounced effect, implying that studies isolating individual ingredients may underestimate the full health impact of EDs.

Another study examined the effects of caffeine, taurine, and guarana, both individually and in combination, on human neuronal cells (Zeidán-Chuliá et al., 2013). All three ingredients showed dose-dependent antioxidant effects. When combined, they reduced superoxide dismutase, a natural enzyme in cellular metabolism that, when dysregulated, can lead to DNA damage and increased cancer risk, more than either ingredient alone, suggesting a synergistic antioxidant effect. In addition, guarana induced apoptosis in these cells, but when combined with taurine, the apoptotic effect was reduced. This synergistic effect matters because increased apoptosis in normal cells could disrupt tissue maintenance.

Together, these two studies highlight a critical gap in the current literature. Most research examines ED ingredients in isolation, but these studies suggest that ingredient interactions can amplify or suppress biological effects in ways that are difficult to predict, providing a better understanding of these synergistic effects at the cellular level. Whether these combined effects ultimately increase or decrease cancer risk remains unclear, but the possibility that ED ingredients interact synergistically warrants further investigation.

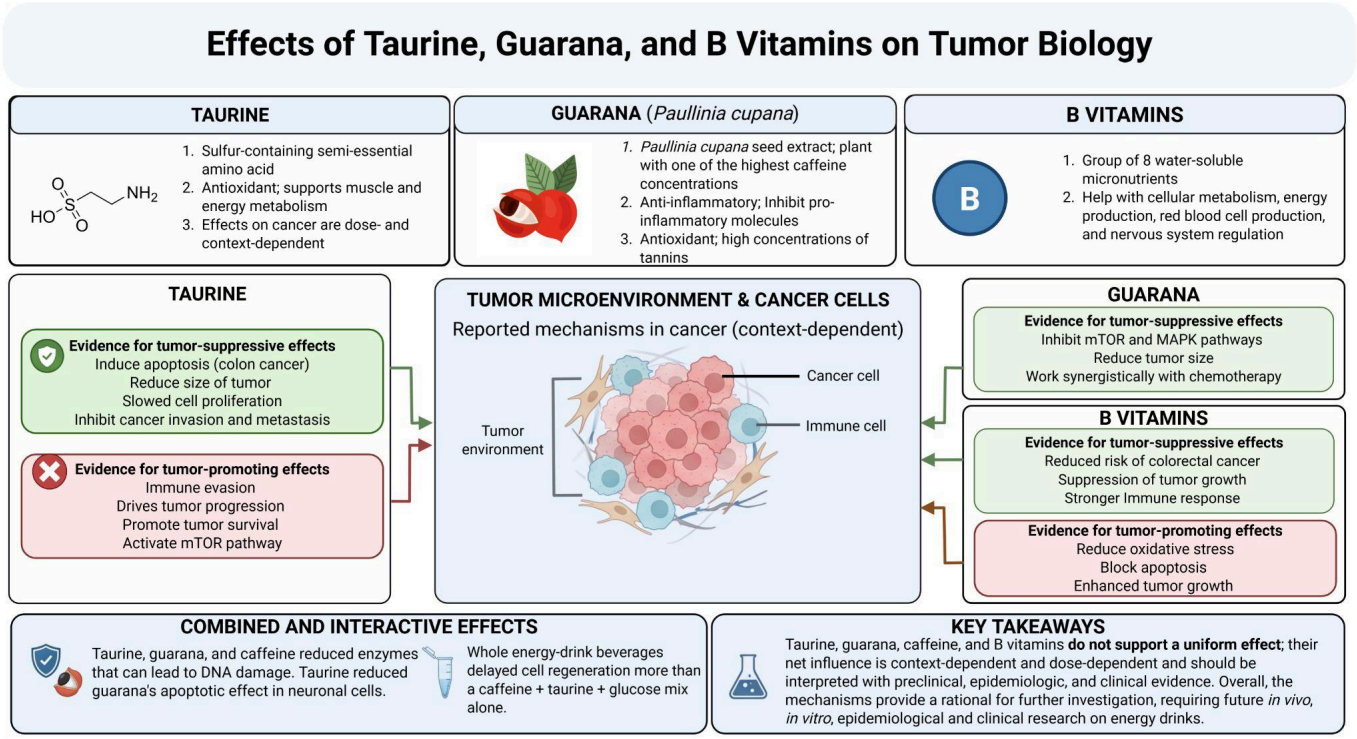

Figure 1. Effect of Taurine, Guarana, and B Vitamins on Tumor Biology. Image from BioRender

Conclusion

The global increase in EOC has intensified efforts to identify modifiable environmental and lifestyle factors that may contribute to carcinogenesis. EDs have emerged in popularity because of their rising rates of ED consumption among adolescents and young adults; however, there is a lack of studies examining the long-term effects of ED consumption, especially on cancer, considering the increase in EOC. Rather than implicating EDs as direct carcinogens,

this review highlights these lesser-known ingredients and their mechanisms with tumors, such as tumor progression, immune regulation, oxidative stress, and cellular metabolism.

Current evidence reveals that taurine, guarana, and B vitamins each have complex, context-dependent relationships with cancer (Fig 1). Taurine shows the most conflicting pattern, with older studies suggesting antitumor properties and more recent evidence pointing to pro-tumor effects mediated by the SLC6A6 taurine transporter, promoting tumor growth and immune evasion. Meanwhile, evidence for guarana remains limited, though its potential antitumor properties warrant further investigation, particularly its ability to selectively target cancer cells and its promising synergistic effects with chemotherapy. B vitamins exhibit the most nuanced relationship, with pro-tumor or anti-tumor effects depending on dosage, vitamin type, and cancer type. These findings suggest that the biological effects of ED ingredients cannot be generalized and instead depend on a variety of factors.

However, these ED ingredients are rarely consumed individually; they are typically taken in combination. The review suggests that ED ingredients consumed together may behave differently than individual ingredients studied in isolation, with synergistic interactions that can suppress effects, underscoring the importance of studying these ED ingredients in combination.

While a direct link between ED consumption and early-onset cancer has not been established, the mechanisms identified in the review provide a rationale for further investigation. Given that ED consumption is highest among adolescents and young adults, the identified evidence might explain why this is the same demographic driving the rise in early-onset cancer, which is of concern. Future in vivo, in vitro, and epidemiological research on ED is crucial for understanding its potential role in increasing the incidence of early-onset cancer and for developing prevention strategies. Once we better understand the effects of EDs on health, as well as how individual ingredients and their combined effects interact with the tumor and the tumor microenvironment, this knowledge will be crucial for informing future public health recommendations, regulatory policies, and evidence-based nutritional guidance.

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