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Formulation of a Ginger (*Zingiber Officinale*)-Based Energy Drink Using Tea-Derived Caffeine: A Comparative Energy Analysis

Siti Syazliana Md Saad[1], Nor Faizah Razali[1]*

[1] *Department of Chemical Engineering Technology, Faculty of Engineering Technology, Universiti Tun Hussein Onn Malaysia, Pagoh Higher Education Hub, 84600, Pagoh, Muar, Johor, Malaysia.*

*Corresponding Author: faizahr@uthm.edu.my
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Abstract

Energy drinks are one of the most consumed functional beverages among teenagers, athletes, and working adults. Commercial energy drinks are often associated with high sugar content and artificial additives that pose health concerns if consumed regularly. This paper aims to formulate a natural ginger-based energy drink enriched with caffeine extracted from green tea and black tea leaves as a healthier alternative. Caffeine was extracted using Soxhlet extraction and was incorporated into 250 mL of ginger juice. Black tea produced a higher caffeine yield (5.59%) compared to green tea (1.22%). Nutritional analysis showed that the GT1 formulation (70 mg caffeine) had the highest energy content (164.84 kcal), while all samples maintained low sugar levels (9.83 g/L). Protein, fat, and fibre contents were negligible due to the use of natural ginger juice. The findings demonstrate that ginger juice combined with naturally derived caffeine can produce a functional energy drink with lower sugar content and improved energy value. Further studies on shelf life and consumer acceptability are recommended.

1. Introduction

The increasing consumption of commercial energy drinks has raised significant health concerns due to their high sugar content and reliance on artificial caffeine and ingredients. Although these functional beverages provide a short-term stimulation and enhance alertness, excessive intake has been associated with adverse effects such as cardiovascular complications, metabolic disorders, and caffeine dependence [1]. As consumers become more health-conscious, there is a growing demand for functional beverages formulated with natural ingredients that can provide sustained energy while minimizing long-term health risks. Caffeine is the primary stimulant responsible for the ergogenic effects of energy drinks, acting by blocking adenosine receptors in the central nervous system and enhancing neurotransmitter release, which improves alertness and reduces fatigue [2]. Commercial energy drinks typically contain synthetic caffeine, which may induce rapid stimulation followed by energy crashes and undesirable physiological responses when consumed excessively [3]. In contrast, caffeine derived from natural sources is often accompanied by bioactive compounds that may modulate its absorption and physiological impact. Tea leaves (*Camellia sinensis*) are well-established natural sources of caffeine and are also rich in polyphenolic compounds, including catechins in green tea and theaflavins in black tea, which provide antioxidant and cardioprotective benefits [4].

Ginger (*Zingiber officinale*) is a functional plant ingredient extensively used in traditional medicine and food applications due to its antioxidant, anti-inflammatory, and digestive properties. Ginger contains bioactive compounds, such as gingerol and shogaol, which have been linked to improved metabolism, reduced inflammation, and enhanced vitality [5]. Ginger-based beverages have gained recognition as functional drinks because they are naturally low in fat and calories while providing beneficial micronutrients, including potassium and magnesium. However, ginger alone may not produce the immediate stimulatory effect typically associated with commercial energy drinks, particularly for individuals engaged in prolonged physical or mental activities [6].

The incorporation of naturally extracted caffeine into ginger-based beverages represents a promising strategy to enhance their energizing potential while preserving nutritional quality. Black and green tea leaves differ in their processing methods, which influence their chemical composition, caffeine content, and antioxidant profile [7]. Previous studies have reported variability in caffeine yield depending on tea type, extraction conditions, and solvent selection, with Soxhlet extraction demonstrating high efficiency for caffeine recovery from tea leaves [8]. Despite the widespread use of tea-derived caffeine, limited studies have directly compared caffeine extracted from black and green tea leaves for application in ginger-based energy drink formulations, particularly with respect to energy contribution and sugar content.

Therefore, this study aimed to develop a ginger-based energy drink fortified with natural caffeine extracted from black and green tea leaves and to compare the caffeine recovery yield, energy content, and sugar composition of the formulated beverages. By utilizing naturally derived caffeine and ginger juice, this research seeks to provide a healthier alternative to conventional energy drinks with lower sugar content and improved functional value.

2. Literature review

2.1 Energy drinks

An energy drink is a type of functional beverage that contains stimulant compounds, which are marketed as providing mental and physical stimulation. It commonly contains caffeine, taurine, glucuronolactone, vitamins, herbal extracts, and proprietary blends [13]. In the body, energy drinks stimulate the central nervous system, temporarily boosting metabolic rate, heart rate, and blood pressure. These effects can improve reaction time, mental clarity, and physical endurance, which explains their popularity among athletes, students, and individuals with demanding lifestyles. The sugar content in many commercial energy drinks also provides a rapid but short-lived energy supply, which can aid in physical activity but may pose health risks if consumed excessively [14]. High doses of caffeine or frequent consumption may lead to adverse effects such as insomnia, jitteriness, increased anxiety, and, in some cases, cardiovascular complications.

2.2 Ginger as a Functional Ingredient in Energy Drinks

Ginger (*Zingiber officinale*) is one of the most commonly consumed dietary condiments in the world [15]. Its spicy aroma is mainly due to the presence of ketones, especially the gingerols, which appear to be the primary components of ginger studied in much of the health-related scientific research. Ginger is rich in minerals like calcium, phosphorus, and iron, and nutrients like vitamins C, thiamine, and niacin [16]. Ginger contains abundant bioactive compounds such as gingerols and shogaols with proven pharmacological effects if consumed regularly, such as helping reduce inflammation, oxidative stress, and supporting metabolic health. Ginger is usually served in both culinary and medicinal contexts, and it is also widely used in soft drinks (ginger beer, ginger ale, ginger wine, and ginger tea). According to Harfmann, ginger is showing up more and more in beverages as consumers are starting to crave spicy and exotic flavours along with many health benefits, such as anti-inflammatory properties that can provide relief for issues like muscle soreness, and also lowering blood sugar [17].

2.3 Caffeine from Tea Leaves as a Natural Energy Source

Caffeine is one of the primary active ingredients in energy drinks and is well known for enhancing mental and physical performance. Energy drinks contain caffeine, which blocks adenosine receptors in the brain, keeping consumers awake and lowering fatigue [2]. Caffeine was discovered naturally occurring in plants such as coffee beans, cacao, guarana berries, and yerba mate. Tea leaves, particularly black and green tea, are natural sources of caffeine and contain additional bioactive compounds, such as polyphenols and catechins, which significantly contribute to their health benefits. Black tea generally contains higher caffeine levels due to the fermentation process during production, while green tea retains a higher antioxidant content [18]. Compared to synthetic caffeine, tea-derived caffeine is often perceived as providing a smoother and longer-lasting energy effect, making it suitable for functional beverage applications. Incorporating caffeine extracted from tea leaves into energy drinks aligns with current trends toward natural and clean-label products [19].

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3. Methodology

In this study, caffeine was derived from two natural sources, which were dried black tea and dried green tea leaves purchased from a local herb store. The tea leaves were finely ground to enhance solvent contact during extraction. Caffeine was extracted using a Soxhlet apparatus with ethyl acetate as the solvent due to its high affinity for compounds like caffeine. The powdered samples were placed in a thimble and subjected to continuous solvent reflux, producing a caffeine-enriched extract. The solvent was subsequently removed using rotary evaporation, yielding crude caffeine with a yellowish appearance. Caffeine recovery was calculated for both tea varieties, and the extracted compounds were characterized using UV–visible spectrophotometry and melting point determination to assess purity. The extracted caffeine was then incorporated into two ginger-based energy drink formulations, one containing caffeine from black tea and the other from green tea. The beverages were prepared using ginger extract, sugar, and food-grade preservatives. Nutritional analyses focusing on sugar content and total energy were conducted, and the results were compared with a commercial energy drink (Monster Energy) to evaluate nutritional differences and potential health benefits. Statistical analysis in this study was limited due to the exploratory nature of the work and constraints in sample replication. The experiments were conducted primarily to establish formulation feasibility and comparative trends rather than to generate statistically significant outcomes. As such, inferential statistical tests, replication-based variance analysis, and error propagation analysis were not performed.

3.1 Extraction of Caffeine from Tea Leaves using the Soxhlet Extraction

A 100g amount of the black tea powder was accurately weighed using the analytical balance. The Soxhlet apparatus was prepared for the extraction of caffeine from the tea powder. This followed the weighing of 40g of sodium bicarbonate, a base, which was mixed with the tea powder. The powder and the base were further placed in the thimble, followed by the main chamber. The volume of 1000mL of the solvent ethyl acetate was measured and poured into a round-bottom flask attached to the Soxhlet apparatus. The Soxhlet apparatus was attached to the condenser and heated for a period of 8 hours until the solution turned brown. The bottom flask was removed, followed by connecting the equipment to a rotary evaporator for the removal of the solvent from the crude caffeine. The bottom flask of the rotary evaporator was placed in a 40°C water bath while being turned at a speed of 100rpm. The crude caffeine was transferred to a desiccator once the solvent had been removed. The process was similarly done for the green tea powder [9]. Then, the UV-Visible spectrophotometry and melting point analyses were performed in this study to confirm the presence of caffeine in the extracted samples. These methods serve as qualitative and semi-quantitative confirmation techniques and do not provide definitive purity assessment, extraction efficiency, or absolute concentration accuracy. Therefore, the results are interpreted as confirmation of caffeine presence rather than precise quantification of extraction yield or purity level.

3.2 Formulation of Ginger-based Energy Drink

The juice of fresh ginger was compounded with 70 mg of purified caffeine, 250 mg of sodium bicarbonate, glucose (5%, w/v), potassium metabisulfite (0.15%, w/v), and potassium sorbate (0.1%, w/v). Mix thoroughly by dissolving the above-mentioned substances with a small amount of distilled water to distribute evenly into 250 mL of ginger juice. A total of six samples were prepared. Of these, three samples were prepared containing 70 mg, 80 mg, and 90 mg of caffeine. These were extracted from black tea leaves, and the other three were extracted from green tea leaves. The ginger energy drinks were then placed inside sterilized glass bottles at 5°C in a refrigerator until further analysis [10].

3.3 Moisture Content

A 20 g sample was accurately weighed using an analytical balance and placed in a clean, dry, and tarred porcelain dish. The dish was placed in a hot air oven set at 100°C for a minimum of 2 hours. After the sample was allowed to cool in a dessicator, it was weighed. The process of heating, cooling, and weighing was repeated at 2-hour intervals until a constant weight was achieved, indicating the removal of moisture [10]. The moisture content was calculated using the following formula:

$$Moisture\ content\ (\%) = \frac{Weight\ loss\ of\ sample\ (g)}{Weight\ of\ the\ sample\ (g)} \times 100\% \tag{1}$$

Weight loss of sample (g) = After heating
Weight of the sample (g) = Before heating

3.4 Ash Content

The porcelain crucible was cleaned, dried in a hot air oven at 110 °C for 1 hour, and cooled in a desiccator before weighing (W1). A 5 g sample of the ginger energy drink was placed into the crucible, and the combined weight was recorded (W2). The crucible was then heated in a muffle furnace at 600 °C for 3 hours until white ash was formed. After cooling in a desiccator, the crucible was reweighed (W3) [10]. The ash content was calculated using the standard formula.

$$Ash\ content = \frac{W3 - W1\ (g)}{W2 - W1\ (g)} \times 100\% \quad (2)$$

W1 = Weight of the empty crucible (g)
W2 = Weight of the crucible + 5 g ginger-based energy drink sample
W3 = Weight of the crucible containing ash after incineration

3.5 Protein Content

The protein content was determined using the Biuret method, which involves constructing a calibration curve with Bovine Serum Albumin (BSA) standard solutions of known concentrations. The absorbance values obtained were then plotted against the concentration. The protein content of the samples was then determined by interpolating their absorbance values from the standard calibration curve [20]. The formula that was used to obtain the percentage of protein in the formulated ginger-based energy drink:

$$Protein\ content\ (\%) = \frac{Protein\ concentration\ \left(\frac{mg}{mL}\right) \times Volume\ (mL)}{Weight\ of\ the\ sample\ (mg)} \times 100\% \quad (3)$$

3.6 Fat Content

A 50 mL sample of the ginger-based energy drink was diluted with 50 mL of distilled water and transferred to a separating funnel. Heptane was added, and the mixture was gently shaken for 2–3 minutes with periodic venting to release pressure. The mixture was allowed to stand for 10–15 minutes to allow phase separation. The aqueous layer was drained, and the organic layer containing the extracted fat was collected. The extraction was repeated 2–3 times using fresh solvent, and the organic extracts were combined. The solvent was evaporated using a water bath, and the remaining fat residue was cooled in a desiccator and weighed. The total fat content was calculated based on the residue weight [10].

$$Crude\ Fat\ \% = \frac{Weight\ of\ fat\ residue\ (g)}{Weight\ of\ sample\ (g)} \times 100\% \quad (4)$$

3.7 Fibre Content

A 100 mL sample of the ginger energy drink was evaporated to dryness to obtain a solid residue. If required, the residue was defatted using a Soxhlet extractor with heptane and weighed. The residue was then boiled with 150 mL of 1.25% sulfuric acid for 30 minutes, filtered, and washed with hot distilled water. The solid residue was subsequently boiled with 150 mL of 1.25% sodium hydroxide for another 30 minutes, followed by filtration and thorough washing until free of alkali. The residue was dried in a hot air oven at 105 °C to constant weight and weighed. It was then ashed in a muffle furnace at 600 °C for 1–2 hours, cooled in a desiccator, and reweighed. Crude fibre content was determined from the difference between the dried residue and ash weight [10].

$$Crude\ Fibre\ \% = \frac{Weight\ before\ ignition\ (g) - weight\ after\ ignition\ (g)}{weight\ of\ initial\ sample\ (g)} \times 100\% \quad (5)$$

3.8 Carbohydrate Content

The carbohydrate content in the ginger-based energy drink was calculated by using the "by difference" method [21]. The formula is as follows:

$$Carbohydrate\% = 100\% - (Moisture + Ash + Protein + Fat + Fibre) \quad (6)$$

3.9 Energy Content

The energy content was calculated based on the micronutrient composition of the nutrient, including protein, carbohydrate, and fat contents. The energy value was computed using the conventional conversion factors of 4 kcal/g for protein, 4 kcal/g for carbohydrates, and 9 9kcal/g for fat, as stated in the following formula [22]:

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$$Energy\ value = \frac{4kcal}{g} Protein + \frac{4kcal}{g} carbohydrate + \frac{9kcal}{g} fat \quad (7)$$

3.10 Sugar Content

Sugar content in the ginger energy drink was determined using the phenol–sulfuric acid colorimetric method. Sucrose standard solutions of known concentrations were prepared, and the energy drink sample was diluted to fall within the standard range. Aliquots of 2 mL of each standard, sample, and distilled water (blank) were transferred into labelled test tubes. Each tube was treated with hydrochloric acid and heated in a boiling water bath for 10 minutes to hydrolyze sucrose, then cooled and neutralized with sodium hydroxide. Phenol solution was added, and the mixtures were reheated to develop colour. After cooling, absorbance was measured at 490 nm using a UV–Vis spectrophotometer. A calibration curve was constructed from the standards, and the sugar concentration of the sample was determined accordingly [23].

$$Sugar\ \% = \frac{Sugar\ concentration\ \left(\frac{mg}{mL}\right) \times Volume\ (mL)}{Weight\ of\ sample\ (mg)} \times 100\% \quad (8)$$

4. Results and Discussion

This study compared natural caffeine extracted from green tea leaves and black tea leaves and developed a low-calorie ginger-based energy drink. Caffeine extraction was carried out using the Soxhlet method. The presence of caffeine in the extracts was confirmed using UV-Visible spectrophotometry and melting point analysis. A ginger-based energy drink was formulated by adding the extracted caffeine, glucose, and preservative. The energy content of the formulated drinks was estimated based on proximate composition analysis, including protein, carbohydrate, fibre, and fat content. Samples containing caffeine from green tea leaves were labelled A1 (70 mg), A2 (80 mg), and A3 (90 mg), while samples containing caffeine from black tea leaves were labelled B1 (70 mg), B2 (80 mg), and B3 (90 mg). Monster Energy Drink was used as a reference sample. The energy values reported in this study were calculated using Atwater factors and were not determined by direct calorimetric measurement. Therefore, the reported values represent estimated theoretical energy content and do not indicate physiological or functional energy effects. Differences in calculated energy values should be interpreted descriptively, as factors such as glycaemic response and caffeine stimulation were not evaluated. This study also did not involve sensory evaluation, shelf life, pH stability, or consumer acceptability. Therefore, the results of the taste, storage, and microbial safety cannot be drawn. It is recommended that the above tests be conducted in the future to determine the commercial viability of the ginger-based energy drink.

4.1 Extraction of Caffeine from Tea Leaves using the Soxhlet Extraction

The caffeine extraction results obtained in this study are considered semi-quantitative, as the methodology was designed primarily to demonstrate successful extraction and comparative trends between black and green tea leaves rather than precise efficiency determination. The caffeine yield obtained from 100 g of tea leaves showed a clear difference between tea types. Black tea leaves produced a higher caffeine yield (5.59%) compared to green tea leaves (1.55%), as illustrated in Fig. 1. This difference was observed despite both samples being extracted under identical Soxhlet extraction conditions using ethyl acetate as the solvent. The results are consistent with findings reported by Kamaludin et al. (2025) [11], who demonstrated that ethyl acetate effectively extracts caffeine from tea leaves, with black tea yielding higher caffeine content than green tea. These findings confirm that black tea inherently contains a higher caffeine concentration and is more efficient for caffeine recovery using solvent-based extraction methods.

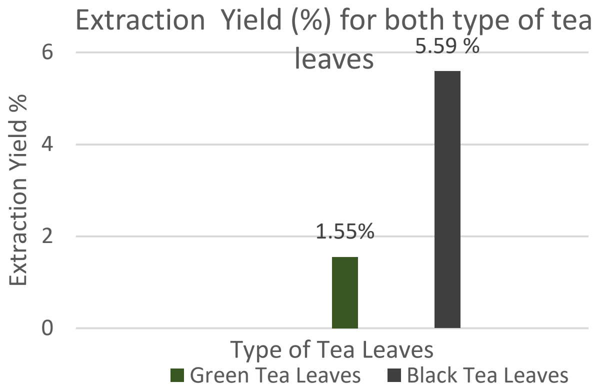

Fig. 1: Caffeine yield (%) of green tea leaves and black tea leaves after extraction.

4.2 Energy Content

The energy content results show in Fig.2 that the formulated ginger-based energy drinks were able to provide sufficient energy despite having low sugar levels. Differences in calculated energy content among the formulations were mainly influenced by variations in carbohydrate concentration and formulation composition, as caffeine does not contribute to caloric value. Although caffeine extraction from black tea resulted in a higher yield, the energy drink formulated with caffeine from green tea produced a higher overall energy content. This suggests that the energy performance of the drink is not solely dependent on the caffeine yield, but also on the characteristics of the caffeine source used in the formulation. The higher calculated energy content observed in the green tea–based formulation may be attributed to the presence of additional bioactive compounds, such as catechins and polyphenols [12], which are known to support energy metabolism. When combined with ginger juice, which has natural stimulatory and thermogenic properties, these compounds may enhance the overall energy effect of the drink. The negligible amounts of protein, fat, and fibre further confirm that the energy contribution mainly originated from glucose supplementation, caffeine, and the natural bioactive compounds present in ginger juice. This highlights the potential of the formulated drink to deliver functional energy while minimizing excessive sugar intake. This supports the study's objective of developing a functional energy drink that balances energy performance with reduced health risks associated with high sugar and synthetic additives.

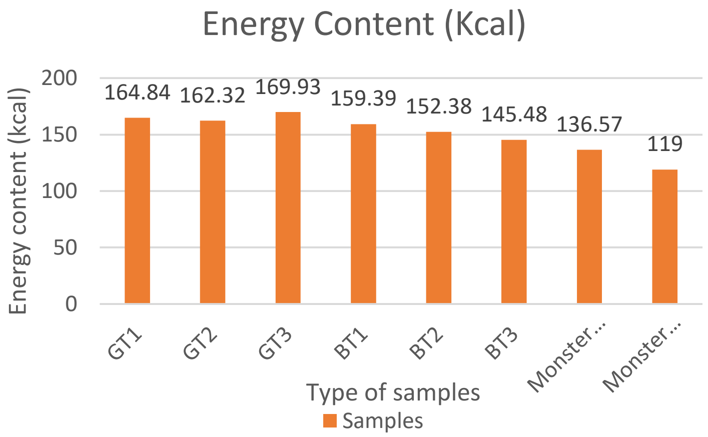

***Fig. 2*:** Bar chart of total energy value in prepared energy drinks

4.3 Sugar

The sugar content of the ginger-based energy drink that contains caffeine from green tea leaves (GT1) and black tea (BT1), and to compare with the commercial energy drink (Monster Energy Drink), as shown in Table 1 below. The sugar content of each sample was calculated and tabulated in percentage (%) in Table 1 below.

Table 1: Concentration of sugar in prepared energy drink samples

Sample	Concentration (g/L)

GT1	9.83
BT1	8.17
Monster Energy Drink	10.17

The sugar concentration in the formulated ginger energy drinks GT1 and BT1, as compared to a commercial energy drink, is shown in Table 4.1. GT1, BT1, and the commercial energy drink were found to have sugar concentrations of 9.83 g/L, 8.17 g/L, and a slightly higher concentration of 10.17 g/L for Monster Energy Drink. Although nutrition labels suggest that commercial energy drinks tend to have higher sugar concentration levels, the decreased levels found in the experiment may be due to various factors, including dilution, matrix interference, and the use of the phenol-sulfuric acid method, which determines the total rather than the individual sugar concentration levels. Despite this, there appears to be validity in the comparative analysis, given that all three were measured in the same manner. It is shown that the sugar concentration levels in the formulated ginger energy drinks were lower compared to those of the commercial energy drink based on analytical determination, thus portraying a less sweet composition. It is suggested that the higher concentration in GT1 compared to BT1 might be due to the varying material compositions, particularly polyphenol concentration, in green tea, black tea, or both extracts [12]. It is thereby concluded that the ginger energy drink possesses the advantage of being less sweet compared to commercial energy drinks.

5. Conclusion

This research has shown the viability and the possibility of developing a low-sugar energy drink with ginger and naturally extracted caffeine from black and green tea leaves. Caffeine was extracted using the Soxhlet apparatus and was confirmed to be present in the tea leaves. Caffeine was then added to the energy drinks, and the energy and sugar values were determined for the formulated drinks using proximate analysis and calculated energy values. The results have shown that there are observable differences in the calculated energy values and the amount of sugar present in the formulated energy drinks, with the energy drinks formulated with the use of green tea having lower amounts of sugar. This research has shown the possibilities and the viability for developing energy drinks with the use of naturally extracted caffeine and ginger, and it can be noted that this research was conducted at the undergraduate level, and further research will have to be conducted for the validation and commercialization potential of the product.

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Conflict of Interest

Authors declare that there is no conflict of interest regarding the publication of the paper.

Author Contribution

This journal requires that all authors take public responsibility for the content of the work submitted for review. The contributions of all authors must be described in the following manner:

The authors confirm contribution to the paper as follows: ***study conception and design:*** *Siti Syazliana Md Saad, Nor Faizah Razali;* ***data collection:*** *Siti Syazliana Md Saad;* ***analysis and interpretation of results:*** *Siti Syazliana Md Saad, Nor Faizah Razali;* ***draft manuscript preparation:*** *Siti Syazliana Md Saad. All authors reviewed the results and approved the final version of the manuscript.*

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