# The top five selling UK energy drinks: implications for dental and general health

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## Key points

- Compares both the potential oral and general health consequences of overuse of a selection of energy drinks which are popular in the UK.
- Suggests regular consumption of energy drinks could contribute to dental erosion and the development of obesity; Lucozade and Rockstar were found to potentially have the greatest impact on oral health and obesity.
- Suggests achieving a healthy product by reformulation is highly unlikely due to the very high initial free sugar content.
- Argues health professionals need to acknowledge the popularity of these products and help their clients to reduce their consumption.

## Abstract

**Aim** Energy drinks are widely consumed worldwide and are recognised for their adverse health effects, usually due to their high caffeine content. However, little is known about their impact on oral and general health. The aim of this investigation was to review the most popular energy drinks sold in the UK, for their possible effect on oral health and contribution to obesity.

**Materials and methods** Five drinks representing 75% of the UK energy drinks market were purposively selected (Lucozade, Red Bull, Monster, Rockstar and Relentless). pH and sugar content were measured and their ingredients reviewed in the context of oral and general health, focusing on dental caries and erosion and obesity.

**Results** All five energy drinks investigated had pH values below the critical value (5.5) associated with dental erosion; the lowest pH was 2.72 (Lucozade) and the highest was 3.37 (Monster). The drinks also contained excessive amounts of free sugars, ranging from 25.5 g (Red Bull) to 69.2 g (Rockstar). Differences in sugar content were mainly explained by portion size. Other ingredients contained within the energy drinks, caffeine and various acids, are also linked to oral and general health.

**Conclusion** Regular consumption of energy drinks could contribute to dental erosion and the development of obesity. Lucozade and Rockstar were found to potentially have the greatest impact on oral health and obesity. Achieving a healthy product by reformulation is highly unlikely due to the very high initial free sugar content. Thus, health professionals need to acknowledge the popularity of these products and help their clients to reduce their use. This is the first study which compares in detail the potential oral and general health consequences of overuse of a selection of energy drinks popular in the UK.

## Introduction

Energy drinks contain high proportions of free sugars and have a very low pH; this has implications for oral and wider public health in terms of dental caries,[1] dental erosion[2] and obesity.[3] These drinks can provide functional benefits by boosting energy and alertness, thus they are popular among athletes and students.[4] The energy drink's functionality is obtained from ingredients such as glucose, caffeine or taurine.[5] The stimulants contained within energy drinks are a cause for concern as they are associated with hypertension, anxiety and heart palpitations.[6] Energy drinks are a growing global public health problem as their popularity is increasing substantially, especially among adolescents.[7] Total sales of energy drinks have grown in the UK alone by £255 million from 2011 to 2015, giving an average increase of £51 million a year, with sales predicted to further increase in forthcoming years.[8]

The largest consumers of energy drinks in the UK are males aged 25–34, although their popularity is increasing among females, with 38% of women aged 16–44 reporting using them on at least a weekly basis. Another core consumer group of energy drinks are 18–24-year-olds, who make up the bulk of the student population; 51% drink them and 29% drink them at least once a week.[8]

Energy drinks contain free sugars and acids, hence these drinks have the ability to cause both dental caries and erosion. There is a strong relationship between eating foods high in 'free' sugars (defined as any mono or disaccharides added to a food or drink by someone, for example, a manufacturer, cook, or consumer, as well as sugars naturally found in syrups, fruit juices and honey) and dental caries.[1] Free sugars are converted by acid producing bacteria (such as *Streptococci mutans* and *Lactobacilli)* into lactic acid. The lactic acid causes demineralisation of the tooth enamel, thus causing carious lesions.[9] Many energy drinks have also been found to

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have a pH of below 5.5, which is the critical pH for the demineralisation of enamel, hence causing erosion.[2] In addition, the intake of free sugars or sugar sweetened beverages is a determinant of body weight.[3] As obesity is associated with greater risks of type 2 diabetes mellitus, hypertension, coronary artery and other diseases, the UK government focused on reducing the recommended maximum percentage energy provided by free sugars in 2015.[10]

Much of the existing literature on energy drinks relates to studies of sugar-sweetened beverages (SSBs), incorporating energy drinks as well as sports drinks and sodas[11,12,13] or single brand case studies, for example, Red Bull or Rockstar.[12,13] Further, many of the previous studies concentrate on the detrimental effects of the ingredients without considering the product as a whole and the sensory preferences of the consumers.

To our knowledge, this is the first study which compares in detail the potential health consequences of overuse of a selection of energy drinks popular in the UK. The aim of this study was to investigate the five top-selling energy drinks in the UK, measuring their individual ingredients and pH, relating this to the evidence base of possible health effects.

## Materials and methods

The top five energy drinks, according to MINTEL's 2016 UK review of the market, were purposively selected for this study.[8] These five drinks represent over three quarters of the UK market as outlined in Table 1.

One variety (original flavour, or if this was unavailable the first available flavour) of each of the energy drink brands were purchased from a major online UK supermarket in November 2016. The drinks were then analysed for their pH and sugar content using the standard methodologies described below. The ingredients as declared on the product labels were noted.

The drink samples at room temperature were decanted into five separate glasses, each with a column length of 10 cm. The drinks had not been previously opened, in case the loss of carbon dioxide affected the drinks' pH.[14] The pH was analysed using a Testo 206-pH2 (Testo AG, Germany) pH meter.

The sugar content of the same drink samples was then measured using a CETI DIGIT 0 32 ATC sugar pocket refractometer (Medline Scientific, Oxfordshire, UK). The refractometer uses Brix as a measurement; the percentage of total solids in solution, in grams of solute/100 g of solution (g/g).[15] A 1 ml sample of the drink at room temperature was transferred using a pipette onto the refractometer, following the manufacturer's instructions. An average of three readings were taken for each drink, for both pH and sugar analysis. Both the pH meter and the refractometer were washed thoroughly with clean water after each use to prevent any cross contamination and dried to prevent any dilution of the samples.

Each drink's primary packaging was reviewed and the ingredients list recorded as they appeared on each label.[16] The sugar content, based on refractometry and label declaration, was calculated using the can/bottle as the serving size. This was compared against national guidelines on free sugar intake and UK food-based dietary guidelines.[10,17]

**Table 1 UK market share of energy drinks**

| Product | Manufacturer | UK market share (%) |
|---|---|---|
| Lucozade Energy | Lucozade Ribena Suntory Ltd, Uxbridge, UK | 29 |
| Red Bull | Red Bull GmbH, Fuschl am See, Austria | 24 |
| Monster Energy | Monster Beverage Corporation, Corona, California | 12 |
| Rockstar | A.G. Barr PLC, Cumbernauld, Scotland | 6 |
| Relentless | The Coca-Cola Company, Atlanta, Georgia | 5 |

**Fig. 1 pH values of the top five selling energy drinks in the UK**

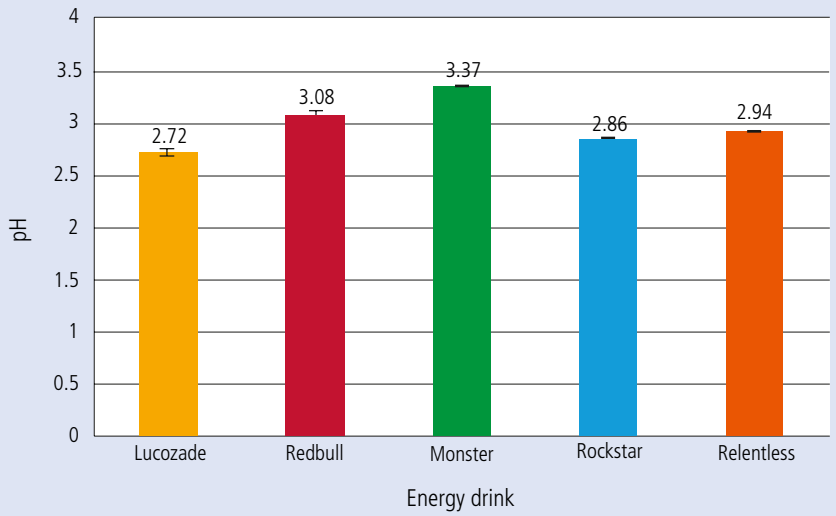


**Fig. 2 Free sugar content per 100 ml of the top five selling energy drinks in the UK**

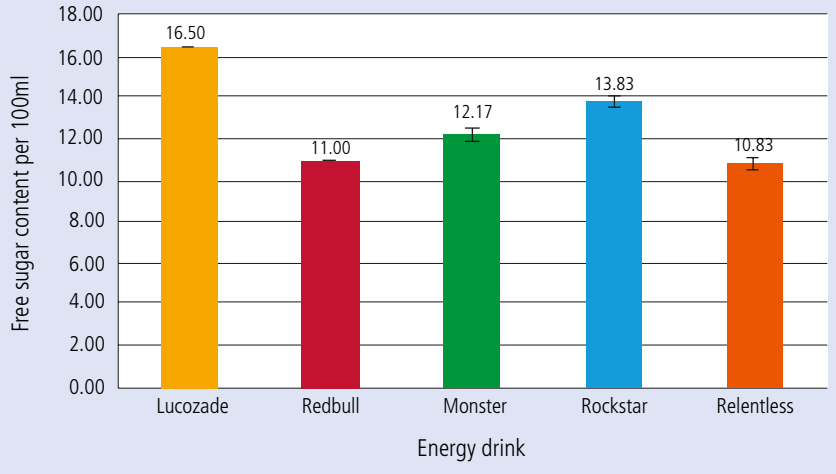

**Table 2 Sugar content, energy and percentage of daily sugar recommendation per serving of energy drink**

| Energy drink | Sugar (g)/100 ml | Serving size (ml) | Sugar (g)/serving size (ml) | % of daily sugar recommendation* |
|---|---|---|---|---|
| Lucozade | 16.5 | 380 | 62.7 | 170 |
| Red Bull | 11.0 | 250 | 25.5 | 69 |
| Monster | 12.2 | 500 | 60.9 | 165 |
| Rockstar | 13.8 | 500 | 69.2 | 187 |
| Relentless | 10.8 | 500 | 54.2 | 146 |

*5% of daily energy intake calculated for a 19–24-year-old male (2,772 kcal, SACN, 2011)

**Table 3 Ingredients of selected energy drinks and ingredients which impact dental and general health**

| Energy drink | Ingredient list | Ingredients regarded as impacting dental and general health |
|---|---|---|
| Lucozade Energy (Original) | Carbonated water, glucose syrup (25%), acids (citric acid, lactic acid), flavouring, preservatives (potassium sorbate, sodium bisulphite), caffeine, antioxidant (ascorbic acid), colours (sunset yellow, Ponceau 4R) | Carbonated water<br>Glucose syrup<br>Citric acid<br>Lactic acid<br>Caffeine<br>Ascorbic acid |
| Red Bull (Original) | Water, sucrose, glucose, acidifier citric acid, carbon dioxide, taurine (0.4%), acidity regulator (sodium carbonates, magnesium carbonate), caffeine (0.03%), vitamins (niacin, pantothenic acid, B6, B12), flavourings, colourings (caramel, riboflavin) | Sucrose<br>Glucose<br>Citric acid<br>Carbon dioxide (carbonated water)<br>Caffeine |
| Monster Energy (Original) | Carbonated water, sucrose, glucose syrup, acid (citric acid), natural flavourings, taurine (0.4%), acidity regulator (sodium citrate), panax ginseng root extract (0.08%), l-carnitine l-tartrate (0.04%), caffeine (0.03%), preservatives (sorbic acid, benzoic acid), colour (anthocyanins), vitamins (B2, B3, B6, B12), sodium chloride, D-glucuronolactone, guarana seed extract (0.002%), inositol, sweetener (sucralose) | Carbonated water<br>Sucrose<br>Glucose syrup<br>Citric acid<br>Caffeine<br>Sucralose |
| Rockstar (Blueberry + Pomegranate + Acai) | Carbonated water, sugar, black carrot concentrate, acids (citric acid, lactic acid, malic acid), flavouring, green tea extract, caffeine (0.03%), antioxidant (ascorbic acid), taurine (0.02%), acidity regulator (potassium phosphate) guarana extract (0.01%), vitamins (niacin, B6, E) | Carbonated water<br>Sugar<br>Citric acid<br>Lactic acid<br>Malic acid<br>Caffeine<br>Ascorbic acid |
| Relentless (Original) | Carbonated water, sucrose, acid (citric acid), taurine (0.4%), acidity regulator (sodium citrate), preservatives (potassium sorbate, sodium benzoate), colour (caramel E150d), flavourings, caffeine (0.03%), vitamins (B3, B5, B6, B12), guarana seed extract (0.002%) | Carbonated water<br>Sucrose<br>Citric acid<br>Caffeine |

## Results

pH values of the selected energy drinks ranged from 2.72 for Lucozade Energy to 3.37 for Monster Energy. All five drinks were more acidic than the critical pH value recognised as contributing to dental erosion (pH 5.5) (Fig. 1). The free sugar content of the drinks ranged from 10.83 g/100 ml for Relentless to 16.5 g/100 ml for Lucozade Energy (Fig. 2). Table 2 highlights the free sugar content of the drinks per serving size and relates this to current UK nutritional recommendations.[10]

The serving size of the selected drinks varied from 250 ml (Red Bull) to 500 ml (Monster, Rockstar, Relentless) (Table 2). All of the single-serving sizes, except Red Bull, exceeded the 37 g maximum daily recommendation for free sugar intake among males aged 19–24.[10] The smaller Red Bull serving size was the only factor contributing to its lower sugar content; even so, one can a day would provide more than two thirds of the recommended free sugar intake. Rockstar had the highest free sugar content with 69.2 g per serving, 187% of the daily maximum recommendation.

Table 3 provides the ingredients list of each of the energy drinks, as transcribed from the label. The ingredients which have been evidenced as having detrimental effects on oral and/or wider public health are indicated. Carbonated water was the main constituent of all the drinks surveyed. Free sugars were the second largest component; predominantly sucrose and/or glucose. Citric, malic and/or lactic acid was present in all the energy drinks for flavouring. Rockstar contained all three, Lucozade contained two (lactic and citric acid), while Monster, Red Bull and Relentless contained only citric acid. Acids were also present in smaller quantities as a preservative (ascorbic, benzoic and sorbic acid).

All the drinks contained the stimulant caffeine and the content was indicated on all but Lucozade Energy as 0.03%. Lucozade did not declare the caffeine percentage. Other stimulants included guarana extract, in three products and ginseng root extract, in one product (Table 3). Other ingredients were present as preservatives (potassium sorbate, sodium bisulphite), acidity regulators (for example, sodium carbonate, sodium citrate), vitamins (for example, B vitamins and in the case of Rockstar, vitamin E) and colours (for example, caramel, riboflavin, sunset yellow, Ponceau 4R, anthocyanins, black carrot concentrate).

## Discussion

The results from this study are unusual as the energy drinks surveyed constituted a single-serving, unlike other studies of high fat, salt and sugar (HFSS) products, where individually consumed portion sizes could vary from recommendations on the packet; breakfast cereals, for example, commonly state 30 g as a portion size.[18,19] The energy drinks were sold to be drunk as 'one drink', the serving size though ranged from 250–500 ml.

Irrespective of the serving size, the sugar content exceeds present dietary recommendations, of no more than 5% of energy from free sugars.[10,20] The new recommendations for free sugar consumption are based on a maximum percentage of total energy, but this varies according to age, gender, weight and physical activity. The sugar in grams per serving ranged from 26 g

(6.5 tsps) to 69 g (17 tsps). NHS Choices advise that adults should have no more than 30 g of free sugars a day and children aged 7–10 should have no more than 24 g.[21] A single-serving of Red Bull energy drink could give an average adult nearly all their free sugar allocation whereas Lucozade, Monster or RockStar could give over twice the allocation in a single-serving. For children aged 7–10, a single-serving of each of the drinks provides in excess of their daily maximum for free sugar, with most providing more than double. Rockstar with a sugar content of 69.2 g per serving provides almost treble their maximum daily allowance.

Glucose syrups, an ingredient in three of the drinks, have a high viscosity, which can hinder their clearance from the mouth meaning teeth are exposed to sugar and acidic conditions for a longer period of time.[22,23] Furthermore, the constituents of the glucose syrup, various starch sources, commonly potatoes or corn, can vary[24] and this too can affect acid production in the mouth[24] which can further promote dental caries and erosion.

The only artificial sweetener, sucralose (Splenda), was present in Monster Energy. Sucralose is a non-fermentable, non-caloric sugar substitute,[25] with lower cariogenic properties than sugar.[26,27] A study by Mandel and Grotz[28] found that sucralose in its pure form was non-cariogenic, while research by Giacaman *et al.*,[29] indicated sucralose caused enamel demineralisation and loss of enamel hardness but to a far less degree than sucrose. However, the presence of sucralose in this drink was in addition to over 60 g of free sugar per 500 ml portion, which would not result in any appreciable reduction of either calories or cariogenic/erosive potential. Furthermore, its use is just promulgating the existence of a sweet tooth.[30]

In this study, all the energy drinks were well below the critical pH value of 5.5, known to cause dental erosion or dissolution of enamel.[31] Additionally, they were all more acidic than orange juice (pH of 3.75), sports drinks (pH of 3.78) and on a par with cola (pH of 2.74).[32] The reason for their low pH is the addition of a number of different ingredients. Carbon dioxide or carbonated water were ingredients in all of the drinks studied. All of the energy drinks were fizzy, unlike sports drinks where many are available in a still, non-carbonated form.[9] When carbon dioxide ($CO_{2)}$ is added to an aqueous solution, it dissociates into carbonic acid (H2CO3) by mixing with water (H2O), thus making the solution more acidic.[14] A study by Abraham *et al.*[33] found that carbonic acid significantly reduced the microhardness of dentine, which is essential for the support of enamel.

Acids, such as citric, lactic and malic were prominent in the drinks studied. These are added by manufacturers as both flavourings and preservatives with the result of further lowering the pH.[28] Bacteria and moulds struggle to survive in such acidic conditions, thus the addition of acids to energy drinks to prolong the shelf life.[34] Although deemed as safe to deliver this technological function by the EU and other regulatory bodies,[35] these acids have consistently been found to decrease enamel hardness and cause demineralisation of the teeth.[36,37,38]

Ascorbic acid (vitamin C), added by the manufacturers of Lucozade Energy and Rockstar, presents a paradox in regards to oral health. Its deficiency can lead to the development of scurvy which can severely effect gum health, potentially leading to the loss of teeth,[39] while as an acid it can cause dental erosion.[40] However, apart from cases of severe malnutrition, scurvy is virtually unheard of in the UK.[41]

Caffeine is widely recognised as having adverse health effects such as increasing blood pressure and exacerbating insomnia.[6,7] There is some emerging evidence that sugar-sweetened beverages (SSBs) with caffeine seem to be more cariogenic and erosive when compared with those without,[42] this is thought to be due to the diminishing effect caffeine has on salivary flow. Salivary flow plays a vital role in maintaining oral health as it can neutralise and clear dietary acids as well as washing away residue and acting as a lubricant.[43]

All the energy drinks studied have the potential to be detrimental to oral health. It should be noted that only one sample of each energy drink was used in this study. However, internal quality control at each company means that the individual samples are unlikely to differ from one another.[44] In addition, while there are other factors that can influence energy drinks' effects on oral health and obesity such as the duration, quantity and frequency of consumption, these were not investigated. It is of concern that products like energy drinks are used as additions to people's normal diets as opposed to replacing other foods. Thus, increasing total energy intake, which could lead to being overweight or obese, and exposure to highly cariogenic/erosive ingredients, detrimental to oral health.[45]

## Conclusion

All five of the energy drinks tested have the ability to negatively impact upon oral health and cause unwanted weight gain, with Lucozade and Rockstar being the most potentially detrimental. The study indicates that a number of ingredients contribute to the potential adverse effects on oral and wider health.

The fact that energy drinks are so popular but so far away from present dietary recommendations on free sugars indicates that they should have no part in a healthy diet. This justifies further the decision for a UK excise duty on sugar-sweetened beverages, including energy drinks, brought into effect in April 2018.[46] Other possible public health measures that could be considered include setting a maximum limit for caffeine per serving of any energy drink; restricting sales of energy drinks to children and adolescents; and consideration of industry wide standards for responsible marketing of energy drinks, including ensuring that the risks associated with energy drink consumption are well known.[47,48]

Manufacturers have started to reformulate, voluntarily, in preparation for the sugar levy. However, because these drinks are starting at such a high sugar content, accompanied by supersized portions, achieving a healthy product by reformulation is highly unlikely. In addition, market reports indicate that the largest consumers of these drinks are the least likely to select low or no sugar versions.[9] Health professionals need to acknowledge the popularity of these products and help their clients to reduce their use; they could be well placed to screen for dangerous energy drink consumption, both alone and with alcohol.

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