Determination and Health Risk Assessment of Tartrazine and Sunset Yellow in Marketed Branded Soft Drinks and Food Products

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Synthetic azo dyes such as Tartrazine (E102) and Sunset Yellow FCF (E110) are extensively used in food and beverages, raising concerns about excessive intake and potential health risks, especially in children. Hence, this study determined the concentrations of Tartrazine and Sunset Yellow in commercially available soft drinks, fruit juices, and custards marketed in Nigeria using validated UV–Vis spectrophotometry. The estimated daily intake (EDI) and Hazard Quotient (HQ) were calculated for both adults and children to evaluate potential health risks. The method showed excellent linearity ($R^2 > 0.999$), good precision (RSD < 3%), satisfactory recoveries (92–105%), and low limits of detection and quantification, confirming reliability. Sunset Yellow concentrations ranged from 12.67 to 580.43 mg L^{-1}, while Tartrazine concentrations varied from 16.49 to 380.45 mg L^{-1}. Custards exhibited significantly higher dye levels compared to soft drinks and fruit juices. Health risk assessment revealed that HQ values for Tartrazine were continuously <1 throughout every sample, implying minimal danger. However, all the custard samples analysed in this work exceeded the safety threshold (HQ > 1) for Sunset Yellow in children, suggesting potential adverse health effects. Thus, the present findings highlight the critical need for more stringent controls and monitoring of synthetic dyes in locally marketed food products. Children may be at risk from intake of custards in particular, so increased monitoring is necessary to protect consumers safety.

Keywords: Tartrazine; Sunset Yellow; UV–Vis spectrophotometry; food safety; health risk assessment; custards; beverages

Introduction

In the food and beverage sector, synthetic food colouring agent is widely used to improve the visual appeal and marketability of products, particularly azo dyes such as Sunset Yellow FCF (E110) and Tartrazine (E102). These dyes are frequently found in foods, such as flavoured drinks, carbonated beverages, and powdered desserts (Adedeji *et al*., 2023; Cetinkaya *et al*., 2024; Rovina *et al*., 2016). Despite their extensive use, concerns about their possible negative health effects when consumed in excess for a long period of time still exist (Refai *et al*., 2025).

Tartrazine (Figure 1a), a lemon-yellow azo dye, has been reported to exhibit biological effects including oxidative stress, genotoxicity, hepatotoxicity, and neurotoxicity in various *in vivo* and *in vitro* studies (Visternicu *et al*., 2025; Hosieny *et al*., 2021). Although regulatory agencies, such as WHO and EFSA, have set an acceptable daily intake (ADI) of 7.5 mg/kg body weight/day for Tartrazine (WHO, 2021), weak regulatory enforcement and inadequate monitoring in many developing countries have led to its continued and sometimes excessive use in food and beverages. However, studies have revealed that consumption may exceed this limit in certain populations, especially children (Rahnama *et al*., 2022; Yousif *et al*., 2022).

Sunset Yellow (Figure 1b), another widely used synthetic dye, imparts an orange colour to food products and is permitted in many countries with an ADI of 4.0 mg/kg body weight/day (EFSA, 2009). While generally regarded as safe at low levels, studies have linked high doses of Sunset Yellow to DNA damage, intestinal inflammation, liver and kidney toxicity, and behavioural disorders in animal studies (Sultana *et al*., 2023; Hussein *et al*., 2021). The controversial Southampton study also suggested a correlation between mixtures of azo dyes including Tartrazine and Sunset Yellow which can leads to hyperactivity in children, prompting regulatory responses in the EU that require warning labels on affected products (Bravo *et al*., 2015; Kaya *et al*., 2021).

In many developing countries, including Nigeria, monitoring and regulatory enforcement of food additives remain inconsistent, and manufacturers may not always adhere to international standards (Nnaji *et al*., 2025; Omojokun, 2013). Furthermore, data on the levels of synthetic dyes in local food and drink products are limited, creating a knowledge gap regarding exposure and potential health risks. In

regions with high soft drink consumption, particularly among children and adolescents, the cumulative intake of these dyes could exceed recommended thresholds (Rahnama *et al*., 2022).

This study aims to determine the concentration of Tartrazine and Sunset Yellow in selected branded soft drinks, fruit juices and custard products available in the Nigerian market, and also to perform a health risk assessment based on estimated daily intake (EDI) and Hazard Quotient (HQ) values, in comparison with international safety limits.

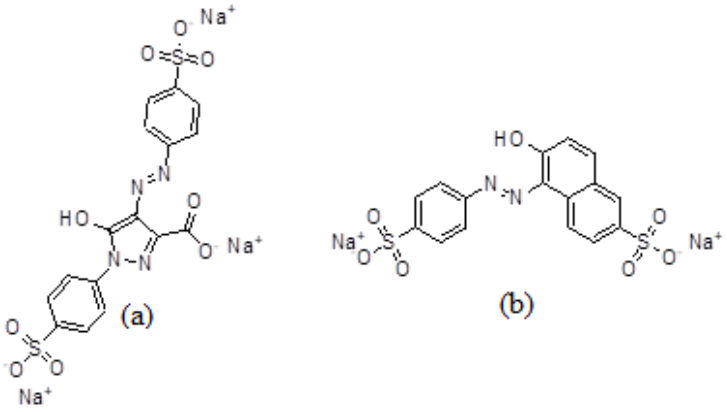


Figure 1: Structure of (a) Tartrazine and (b) Sunset Yellow

Materials and Methods

Chemicals and reagents

All reagents used were of analytical grade. Standard reference powders of Tartrazine and Sunset Yellow FCF (≥99% purity) were procured from Sigma-Aldrich (USA)**.** Distilled water**,** 0.1 M NaOH**,** and 0.1 M HCl were used for dilution and pH adjustment. All glassware was soaked overnight in 10% nitric acid, rinsed thoroughly with distilled water, and oven-dried at 105 °C before use.

Sample collection

A total of sixteen (16) samples were randomly collected from supermarkets and open markets in Ijebu-Ode, Ogun State, Nigeria, a major commercial hub in the southwestern region, to represent widely consumed soft drinks, fruit juices, and custard products. These comprised popular branded soft drinks, fruit juices, and custard powders from various commercial producers, characterized by their intense yellow colouration. The products were chosen based on consumer preference, market popularity, and label indications of colourant content.

Preparation of standard and sample solutions

As adopted from Lawal *et al.* (2021), stock solutions of 1000 mg L^{-1} Tartrazine and Sunset Yellow were prepared by dissolving 0.1 g into 100 mL volumetric flask and brought to volume with phosphate buffer solution and by shaking for complete dissolution. Working standard solutions (2–10 mg L^{-1}) were prepared by serial dilution. For soft drink and fruit juice samples, each drink was degassed by ultrasonication (Qsonica Q500 Ultrasonic Processor (Qsonica,USA)) for 10 minutes. A 10 mL aliquot was taken and diluted to 50 mL with distilled water. The solution was adjusted to neutral pH (7.0 ± 0.2), filtered through Whatman No. 1 filter paper, and stored in amber bottles until analysis while for custard powders, one gram of each powdered custard sample was accurately weighed and dissolved in 50 mL of warm distilled water, following procedures similar to those used in spectrophotometric food dye extraction studies (Akshitha *et al*., 2019). The solution was stirred for 5 minutes, cooled, and filtered to remove insoluble particles. The filtrate was used for spectrophotometric analysis.

Instrumental analysis

Quantification of Tartrazine and Sunset Yellow was performed using a UV–Visible spectrophotometer **(**Shimadzu UV-1800**)** scanned between 200–600 nm. Absorbance was recorded at 427 nm and 482 nm for Tartrazine and Sunset Yellow, respectively. Calibration curves were established from standard solutions (2 – 10.0 mg L^{-1}). The linear equations derived from the calibration plots were used to determine dye concentrations in the samples. All experimental procedures were conducted at the Chemical Sciences Laboratory, Department of Chemical Sciences, Tai Solarin Federal University of Education, Ijagun, Ogun State, Nigeria.

Method validation

Validation of the UV–Vis spectrophotometric method was carried out in accordance with the International Council for Harmonisation (ICH) guidelines (Ojha & Bhargava, 2022) and the AOAC International single

laboratory validation guidelines to ensure reliability and reproducibility of results (AOAC, 2016).

Linearity and range

The linearity of the UV–Vis spectrophotometric method was assessed by constructing calibration curves for Tartrazine and Sunset Yellow over a series of standard concentrations. Five calibration levels were prepared between the working range of 2.0 –10.0 mg L^{-1} for each of the analyte. Each solution was analysed in triplicate, and the mean absorbance was plotted against concentration. The calibration curves were evaluated by linear regression analysis using the equation of the graph where *y* represents the absorbance, *m* equivalent to slope, *x* is the concentration of the analyte, and *c* the intercept. The measurement of linearity was determined by correlation coefficient (R^2). The analytical range was defined as the interval between the lowest and highest concentrations of the calibration curve that could be measured with acceptable accuracy (recoveries 80–120%) and precision (RSD ≤ 2%).

Accuracy (recovery studies)

The accuracy of the method was assessed through recovery studies, in accordance with ICH Q2(R1) and AOAC guidelines. Pre-analyzed samples of soft drinks and food extracts were spiked with known quantities of Tartrazine and Sunset Yellow standards at three concentration levels (5, 10, and 15 mg L^{-1}) to cover the working range of the calibration curve. Each spiked sample was analyzed in triplicate using the validated spectrophotometric procedure at their respective λmax values (427 nm for tartrazine and 482 nm for sunset yellow).

The percentage recovery was calculated using the equation (1):

$$\text{Recovery } (\%) = \frac{(C_{found} - C_{original})}{C_{added}} \times \frac{100}{1} \qquad (1)$$

Where, C_{found} = concentration measured after spiking (mg L^{-1}), $C_{original}$ = concentration of the unspiked sample (mg L^{-1}), and C_{added}= known concentration of the standard added (mg L^{-1}).

Precision

The precision of the method was evaluated to determine the closeness of agreement among independent measurements under specified conditions. It was assessed at two levels: repeatability (intra-day precision) and intermediate precision (inter-day precision), in accordance with established validation guidelines. Three quality-control (QC) concentrations low QC (LQC, 2 mg L^{-1}), middle QC (MQC, 5 mg L^{-1}), and high QC (HQC, 10 mg L^{-1}) within the working range were prepared independently from the calibration standards. For matrix precision, pre-analyzed beverage and food extracts were spiked at the same three QC levels and processed as samples. For each dye and QC level, six independent preparations (n = 6) were analyzed within a single day under identical conditions to assess intra-day precision (repeatability). The same QC protocol was repeated on three separate days, at least 24 hours apart, to evaluate inter-day precision (intermediate precision).

Precision was expressed as the percentage relative standard deviation (%RSD) of replicate measurements, and values of ≤5% RSD were considered acceptable, consistent with AOAC (AOAC, 2016) and ICH validation criteria (ICH, 2005). The precisions were calculated using the equation (2):

$$\%RSD = \frac{SD}{\bar{x}} \times \frac{100}{1} \qquad (2)$$

Where, SD = standard deviation, $\bar{x}$ = mean concentration and RSD = relative standard deviation

Limit of detection (LOD) and quantification (LOQ)

The sensitivity of the UV–Vis spectrophotometric method was evaluated by determining the limit of detection (LOD) and the limit of quantification (LOQ) in accordance with ICH Q2(R1) guidelines (ICH, 2005) and AOAC recommendations . The LOD and LOQ were calculated from the standard deviation of the blank response (σ) and the slope of the calibration curve (S) using the equations (3) and (4):

$$LOD = \frac{3.3 \times \sigma}{SL} \qquad (3)$$

$$LOQ = \frac{3.3 \times \sigma}{SL} \qquad (4)$$

:

Where**,** σ = standard deviation of replicate blank absorbance measurements (n = 10), SL = slope of the calibration curve for each dye.

Health risk assessment

To evaluate potential health risks, the Estimated Daily Intake (EDI), expressed in mg/kg body weight/day) and Hazard Quotient (HQ) were calculated using equations (5) and (6) (Refai *et al*., 2025).

$$EDI = \frac{(C \times D)}{BW} \qquad (5)$$

Where:

C = concentration of dye in product (mg L^{-1} or mg kg^{-1}),

D = daily consumption of product (1.0 L/day for soft drinks/fruit juice (non alcoholic flavoured drinks), 100 g/day for custard; 0.6 L/day and 50 g/day for children. These values were adapted from previous dietary exposure studies on beverage and food consumption patterns (Singh *et al*., 2015; EFSA, 2011)

BW = average body weight (60 kg for adults, 25 kg for children).

$$HQ = \frac{EDI}{ADI} \qquad (6)$$

With ADIs based on FAO/WHO guidelines

Where:

ADI = Acceptable Daily Intake (7.5 mg kg^{-1} bw day^{-1} for Tartrazine; 4 mg kg^{-1} bw day^{-1} for Sunset Yellow).

HQ values ≥ 1 indicate potential health risks, while HQ <1 suggests acceptable safety margins.

Quality control and assurance

All measurements were performed in triplicate**.** Reagent blanks, method blanks, and spiked samples were used to assess contamination and recovery. Calibration standards were freshly prepared for each batch. Instrument performance was verified daily using quality control samples.

Statistical analysis

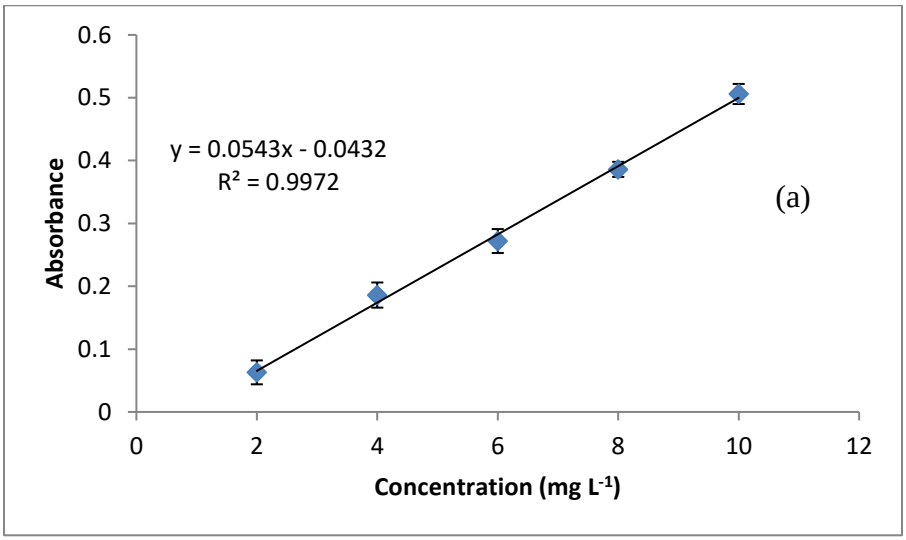
All experimental data were expressed as mean ± standard deviation (SD) of at least three independent measurements. Calibration data were subjected to linear regression analysis to obtain the slope, intercept, and correlation coefficient (R^2) values for each analyte. All statistical analyses were performed using SPSS version 26 (IBM Corp., Armonk, NY, USA) and Microsoft Excel 365.

Results and Discussion

Validation

Linearity and range

Figures 2a and 2b revealed that the calibration curves for both Sunset Yellow and Tartrazine gave satisfactory linearity within the studied concentration range of 2–10 mg L^{-1}. The high correlation coefficients (R^2 > 0.98) confirm the method's suitability for quantitative analysis of these dyes. These results are consistent with other studies that shown high linearity for synthetic azo dyes using UV-Vis spectrophotometry (Marahel, 2022; Ali *et al*., 2020; Asadollahi *et al*., 2022). These findings showed that the present technique yields accurate calibration curves, ensuring precision in the subsequent quantification of food and beverage samples.



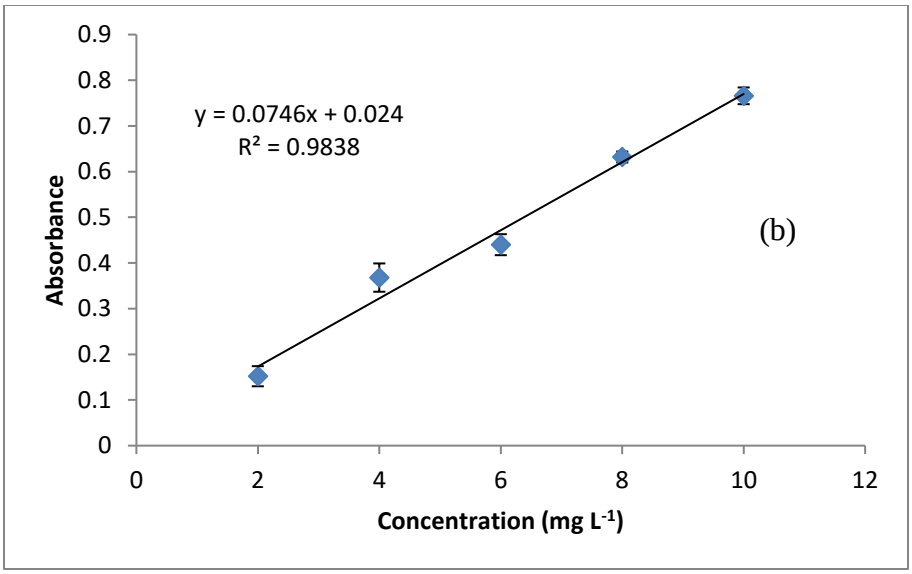


Figure 2: Standard calibration curve for (a) Sunset Yellow and (b) Tartrazine

Accuracy

As presented in Table 1, the recovery results for both dyes were within 97–99%, with RSD values below 3%, confirming the high accuracy and reliability of the method for quantitative analysis of Tartrazine and Sunset Yellow in soft drinks and food products. The present results are consistent with the recommendations of the International Council for Harmonisation (ICH Q2(R1), 2005), which suggest that recovery values between 95–105% are generally acceptable for accuracy validation in analytical procedures. The present recovery values align with those reported in previous studies. For instance, Kumar *et al*. (2021) validated a spectrophotometric method for synthetic food dyes and reported recovery in the range of 96–102%. Similarly, Van Staden et al. (2022) obtained recoveries between 97–101% for Tartrazine and Sunset Yellow in soft drink samples using a spectrofluorimetric method. More recently, Gürkan *et al*. (2023) recorded recoveries of 98–103% using a chemometric-assisted spectrophotometric technique, further supporting the reliability and accuracy of the analytical approach employed in this study.. Thus, the recovery studies indicate that the proposed UV–Vis spectrophotometric method is accurate and suitable for routine determination of Tartrazine and Sunset Yellow in commercial food and beverage samples.

Table 1: The results of Accuracy (recovery studies) of Sunset yellow and Tartrazine

Dye	Spiked conc. (mg L^{-1})	Measured conc. (mg L^{-1})	Recovery (%)	RSD (%)
Sunset Yellow	2	1.94	97.00	2.40
	5	4.88	97.60	1.80
	10	9.81	98.10	1.50
Tartrazine	2	1.96	98.00	2.10
	5	4.92	98.40	1.70
	10	9.89	98.90	1.30

Precision

According to Tables 2(a) and 2(b), all intra-day %RSDs ≤ 2.1% and inter-day %RSDs ≤ 3.3%, comfortably met the ≤ 5% acceptance criterion for UV–Vis methods in food matrices. Variability was slightly higher in inter-day (as expected), but no meaningful drift was observed across days, indicating robust method performance under routine conditions. These precision characteristics, together with the previously established linearity, support reliable quantification of Tartrazine and Sunset Yellow across the working range in soft drinks and processed foods.

Table 2(a): The results of Intra-day (repeatability)

Analyte	Nominal (mg L^{-1})	Mean found (mg L^{-1})	SD (mg L^{-1})	%RSD
Sunset Yellow	2	1.98	0.040	2.02
	5	5.04	0.090	1.79
	10	9.95	0.200	2.01
Tartrazine	2	2.02	0.030	1.49
	5	4.94	0.070	1.42
	10	10.08	0.180	1.79

Table 2(b): The results of Inter-day (intermediate precision)

Analyte	Nominal (mg L^{-1})	Overall mean (mg L^{-1})	Overall %RSD
Sunset Yellow	2	1.99	2.80
	5	5.02	3.10
	10	9.97	3.30
Tartrazine	2	2.01	2.40
	5	4.97	2.60
	10	10.03	2.90

One-way ANOVA shown in Table 3 was performed to evaluate whether there was a significant day-to-day variation in inter-day precision results. For both Tartrazine and Sunset Yellow (Due to their similarity, the ANOVA table is not shown), ANOVA showed no significant difference ($p > 0.05$) among the means obtained on different days, confirming that day-to-day variability did not significantly affect quantitation. These findings indicate that the developed UV-Vis spectrophotometric method provides reliable repeatability and reproducibility. In other words, the mean values of the three groups are statistically the same. The inter-day precision studies indicate that the method produces consistent results across the three days tested The low intra-day variability suggests stable instrument performance and operator consistency, while the non-significant inter-day variation confirms robustness over multiple days. These results are consistent with previous method validation studies for food dyes, where intra- and inter-day %RSD values remained within the 5% acceptance limit (Kumar *et al*., 2021; Alarfaj *et al*., 2020).

Table 3: Results of one- way ANOVA of inter-day precision (Tartrazine)

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	0.045741	2	0.02287	0.001954	0.998048	3.402826
Within Groups	280.8877	24	11.70365			
Total	280.9334	26				

LOD and LOQ

The sensitivity of the developed UV–Vis spectrophotometric method for the determination of Tartrazine and Sunset Yellow was evaluated by calculating the LOD and LOQ. The LODs for Tartrazine and Sunset Yellow were found to be approximately 0.12 and 0.15 mg L^{-1}, respectively, while the LOQs were 0.40 and 0.50 mg L^{-1}, respectively. These values demonstrate the high sensitivity of the proposed method, enabling detection of the dyes at concentrations well below the maximum permissible levels set by regulatory agencies such as the European Food Safety Authority (EFSA, 2014) and the U.S. Food and Drug Administration (FDA, 2018). Comparable studies have reported LOD and LOQ values in the same range, supporting the reliability of the present method (de Oliveira *et al.*, 2024; Alp *et al*., 2018). The low LOD and LOQ values indicate that the method is sufficiently sensitive for monitoring trace levels of Tartrazine and Sunset Yellow in complex food and beverage matrices.

Levels of sunset yellow and tartrazine in commercial samples

The concentrations of Sunset Yellow and Tartrazine in the analyzed soft drinks, fruit juices, and custard samples are presented in Table 4. A clear distinction in dye levels was observed among the three categories of the products. Soft drink samples (A–D) contained Sunset Yellow in the range of 12.67–98.42 mg L^{-1} and Tartrazine between 16.49–48.25 mg L^{-1}. The highest Sunset Yellow concentration was found in Sample D (98.42 mg L^{-1}), whereas the lowest was found in Sample C (12.67 mg L^{-1}). Similarly, Tartrazine levels were highest in Sample A (48.25 mg L^{-1}) and lowest in

Sample C (16.49 mg L^{-1}). These results suggest that soft drinks contribute moderate levels of synthetic dyes, possibly to enhance visual appeal. Fruit juice samples (E–H) exhibited Sunset Yellow levels ranging from 32.00–54.94 mg L^{-1}, while Tartrazine concentrations were between 20.24–36.60 mg L^{-1}. Compared to soft drinks, the concentrations in fruit juices were generally lower and more evenly distributed. This indicates a more controlled use of dyes in fruit-based beverages, potentially reflecting regulatory compliance or deliberate moderation to maintain a "natural" perception of juice products. Custard samples (I–P) contained markedly higher concentrations of both dyes. Sunset Yellow levels ranged from 389.19–580.43 mg L^{-1}, while Tartrazine ranged from 198.42–380.45 mg L^{-1}. The highest Sunset Yellow content was found in Sample J (580.43 mg L^{-1}), while Sample M showed the lowest (389.19 mg L^{-1}). For Tartrazine, the highest concentration was in Sample L (380.45 mg L^{-1}) and the lowest in Sample P (198.42 mg L^{-1}). The substantially elevated levels in custards, relative to beverages, may be due to their thicker consistency and higher requirement for intense colouration. Across all product categories, Sunset Yellow concentrations consistently exceeded those of Tartrazine. This observation suggests a formulation preference for Sunset Yellow, possibly due to its stronger color intensity and stability in acidic and neutral matrices. However, the high levels detected in custards raise concerns regarding cumulative dietary exposure, especially for children who frequently consume such products. When compared with the permissible limits set by international food safety agencies, such as the Joint FAO/WHO Expert Committee on Food Additives (JECFA) (FAO/WHO, 2017) and the European Food Safety Authority (EFSA, 2009), the concentrations of tartrazine and Sunset Yellow in soft drinks and fruit juices were within the maximum allowable limits of 100 mg/L (Codex Alimentarius, 2019). However, in the custard samples, the concentrations were relatively higher than expected, raising potential concerns if such beverages are consumed frequently. These findings are consistent with those of Ihediohanm *et al*. (2014) and Lawal *et al*. (2024), who reported similar elevated dye levels in plantain chips commonly sold within south eastern Nigeria and beverages consumed in Katsina metropolice in Nigeria respectively, both exceeding international safety recommendations. Conversely, studies from the Middle East (e.g. El-Wahab & Moram, 2013; Zahedi *et al*., 2020) reported much lower dye concentrations, reflecting stricter compliance with regulatory limits in those regions. According to Mindang *et al*. (2022), prolonged consumption of beverages containing high levels of synthetic dyes has been associated with hyperactivity in children, allergic reactions, and potential genotoxicity. While the present study did not exceed international limits in most cases, the cumulative risk from frequent intake of multiple coloured products may surpass the safe threshold, thus justifying the need for continuous monitoring and stricter regulatory enforcement**.**

Table 4: Concentration of Sunset Yellow and Tartrazine in samples analysed

s/no	Sample	Sunset Yellow (mg/unit) ± SD	Tartrazine (mg/unit) ± SD
1	Sample A (soft drinks)	87.99 ± 2.10	48.25 ± 4.21
2	Sample B (soft drinks)	73.81 ± 3.21	37.67 ± 3.20
3	Sample C (soft drinks)	12.67 ± 1.98	16.49 ± 2.92
4	Sample D (soft drinks)	98.42 ± 4.20	28.42 ± 1.02
5	Sample E (fruit juice)	32.00 ± 0.98	36.60 ± 0.54
6	Sample F (fruit juice)	47.29 ± 2.62	32.03 ± 0.98
7	Sample G (fruit juice)	54.94 ± 0.94	28.42 ± 2.10
8	Sample H (fruit juice)	37.82 ± 1.22	20.24 ± 2.98
9	Sample I (Custards)	469.76 ± 4.25	355.23 ± 4.32
10	Sample J (Custards)	580.43± 6.54	280.40 ± 5.23
11	Sample K (Custards)	398.46 ± 2.45	274.42 ± 2.43
12	Sample L (Custards)	420.34 ± 2.12	380.45 ± 1.98
13	Sample M (Custards)	389.19 ± 3.21	285.42 ± 3.56
14	Sample N (Custards)	426.54 ± 0.98	240.42 ± 2.98
15	Sample O (Custards)	540.42 ± 2.84	360.75 ± 1.89
16	Sample P (Custards)	432.74 ± 3.21	198.42 ± 4.23

Soft drink (mg/L), fruit juice (mg/L) and Custard (mg/kg)

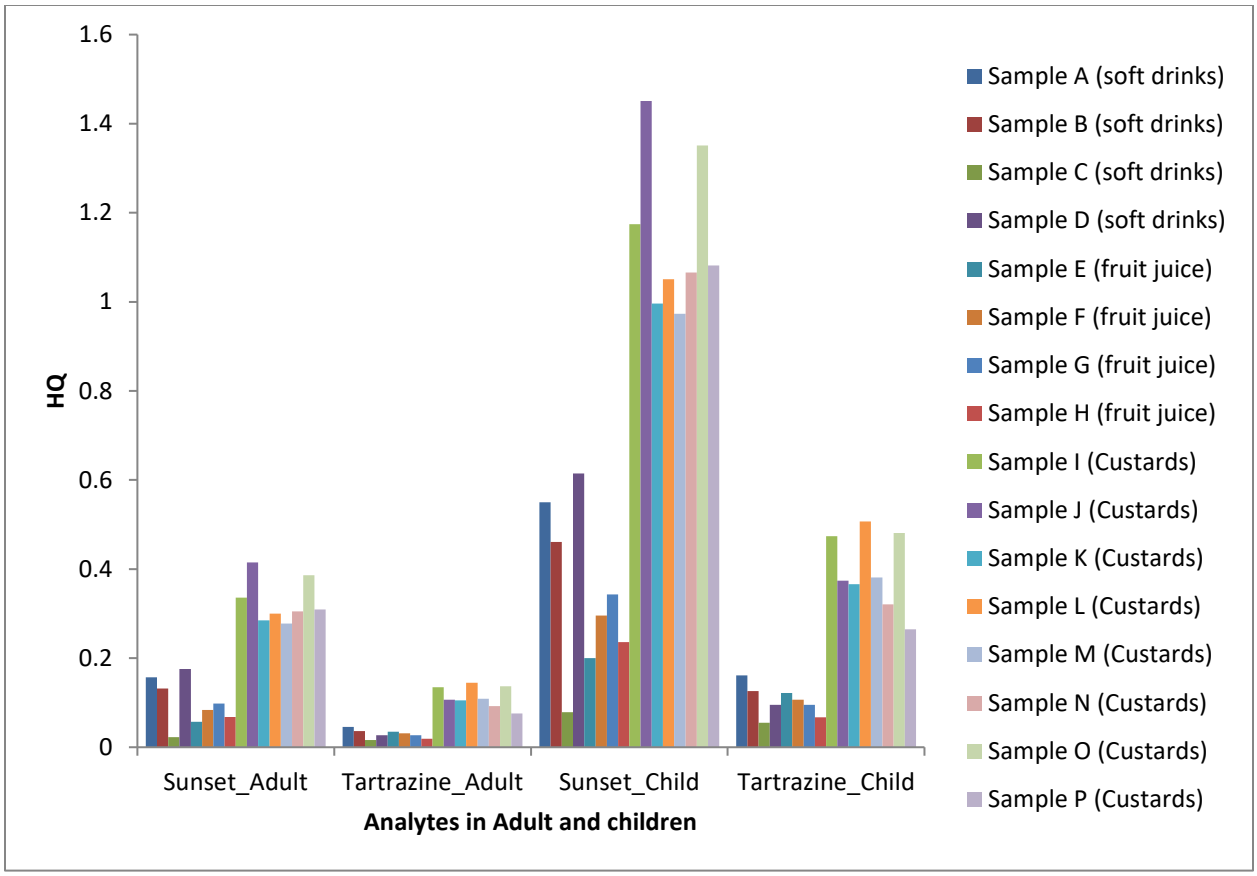


Figure 3: Hazard quotient (HQ) values of Sunset Yellow and Tartrazine in adults and children from soft drinks, fruit juices, and custard samples

Health risk assessment of tartrazine and sunset yellow

The Estimated Daily Intake (EDI) values of Sunset Yellow and Tartrazine across beverages (soft drinks and fruit juices) and custard samples, as shown in Table 5, showed marked variation depending on concentration and ingestion rate. In adults, EDIs of Sunset Yellow ranged from 0.09 to 1.658 mg/kg bw/day, while tartrazine ranged from 0.118 to 1.087 mg/kg bw/day. In children, EDIs were consistently higher due to their lower average body weight, with Sunset Yellow ranging from 0.317 to 5.804 mg/kg bw/day and Tartrazine from 0.412 to 3.804 mg/kg bw/day. The non-carcinogenic risk posed by Tartrazine and Sunset Yellow was assessed using the Hazard Quotient (HQ) approach. The HQ values, derived from the ratio of the estimated daily intake (EDI) to the acceptable daily intake (ADI), are summarized in Figure 3. For adults, all HQ values for both dyes were below 1, ranging between 0.016 and 0.415, indicating no significant risk under normal consumption levels. However, among children, several samples, particularly custards containing Sunset Yellow, exceeded the safety threshold (HQ > 1), suggesting a potential health risk in frequent or high consumption, whereas soft drinks and fruit juices posed no significant risk (HQ < 1). The elevated HQ values for children observed in this study are consistent with the findings of Refai et al. (2025), who found HQ values of approximately 1.48 for Sunset Yellow in powdered beverages consumed by 3-year-olds, underscoring the heightened vulnerability of younger consumers and the need for regulatory attention. When stratified by food category, soft drinks and fruit juices generally remained within acceptable limits for both age groups, indicating the absence of non-carcinogenic health risks, whereas custards consistently exhibited the highest HQ values, with all samples exceeding HQ = 1 in children for Sunset Yellow. This indicates that custard consumption poses a potential chronic health risk for children, especially considering cumulative exposure. The HQ values for Tartrazine were generally below 1 for all the analyzed samples, indicating no significant non-carcinogenic risk. This outcome may be attributed to several factors. First, manufacturers often prefer the more intense and stable colouration of Sunset Yellow, which leads to its higher inclusion in food formulations compared with Tartrazine (Carocho *et al.*, 2015). Consequently, the concentrations of tartrazine measured in soft drinks, fruit juices, and custards were

consistently lower, thereby reducing the estimated daily intake (EDI). Second, tartrazine has a relatively higher acceptable daily intake (ADI) of 7.5 mg/kg bw/day, as established by JECFA and EFSA, compared with 4.0 mg/kg bw/day for sunset yellow (EFSA, 2009; EFSA, 2014; JECFA, 2017). This higher threshold allows greater tolerance before health concerns arise, which further explains the consistently lower HQ values for tartrazine. Together, these factors suggest that, despite its widespread use, Tartrazine poses a comparatively lower dietary risk in the studied food and beverage samples (Mpountoukas et al., 2010). The present study's finding that children's HQ values approach or exceed the safety threshold aligns with global evidence. Refai *et al*. (2025) reported comparable age-specific exposure risks, reinforcing the validity of using differential body-weight and consumption assumptions in exposure assessment. Similarly, previous studies (Mishra *et al*., 2021; Kaur & Kaur, 2022) have emphasized that children face higher exposure risks due to their distinct dietary patterns and lower body weights. Collectively, these findings underscore the urgent need for stricter monitoring of azo dye concentrations in processed foodsparticularly in custards and confectionery products, where excessive additive use is prevalent.

Table 5: The Estimated Daily Intake (EDI) **values of Sunset Yellow *and* Tartrazine in the samples**

Sample	EDI Adult		EDI Children	
	Sunset Yellow	**Tartrazine**	**Sunset Yellow**	**Tartrazine**
Sample A (soft drinks)	0.628	0.345	2.200	1.206
Sample B (soft drinks)	0.527	0.269	1.845	0.942
Sample C (soft drinks)	0.09	0.118	0.317	0.412
Sample D (soft drinks)	0.703	0.203	2.46	0.71
Sample E (fruit juice)	0.229	0.261	0.8	0.915
Sample F (fruit juice)	0.338	0.229	1.182	0.801
Sample G (fruit juice)	0.392	0.203	1.374	0.71
Sample H (fruit juice)	0.27	0.145	0.946	0.506
Sample I (Custards)	1.342	1.015	4.698	3.552
Sample J (Custards)	1.658	0.801	5.804	2.804
Sample K (Custards)	1.138	0.784	3.985	2.744
Sample L (Custards)	1.201	1.087	4.203	3.804
Sample M (Custards)	1.112	0.815	3.892	2.854
Sample N (Custards)	1.219	0.687	4.265	2.404
Sample O (Custards)	1.544	1.031	5.404	3.608
Sample P (Custards)	1.236	0.567	4.327	1.984

(mg/kg bw/day)

Conclusion

In this study, the two most widely used synthetic azo dyes, Tartrazine and Sunset Yellow, commonly present in commercially available soft drinks, fruit juices, and custards, were systematically quantified to determine their concentration levels, and their potential health risks to adults and children were critically evaluated. The outcomes of this study revealed that the concentrations of both dyes in several samples were within the permissible limits set by international food safety authorities, yet certain products approached or exceeded these thresholds, particularly when assessed against the higher consumption rates typical among children. The calculated EDI and HQ values highlighted that while adults generally remain within acceptable safety margins, children face a relatively greater risk of potential health effects due to lower body weights and higher intake frequencies. The findings underscore the importance of continuous monitoring of artificial colourants in processed foods and beverages, especially those targeted toward children. Regulatory agencies must ensure stricter compliance with allowable concentration limits, while manufacturers should explore the incorporation of natural and safer alternatives to synthetic dyes. This study ultimately provides critical evidence to guide policymakers, food producers, and public health

authorities in reducing exposure risks and safeguarding consumer health.

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