# COLOUR PROFILE, FUNCTIONAL GROUPS CHARACTERISTICS AND HEAVY METALS OF RED FOOD COLOURS SOLD IN MINNA MAIN MARKET

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## ABSTRACT

*This study assessed the functional group characteristics, colour profile and heavy metal contents of eight (8) commercial red liquid food colourant samples popularly sold in Minna markets. The brands and the package information were noted and the functional groups, colour profile and heavy metals concentrations were analysed using standard methods. The FTIR spectra revealed that all the cred colourant samples exhibited aromatic ring (C=C), hydroxyl (–OH), azo (–N=N–), sulfonate (S=O) confirming their identity as a sulfonated synthetic azo dye. Weaker sulfonate groups were also identified amongst the liquid red colourants; FCRL, ACRG and (ACRL. Red liquid colourants had higher values of brightness index than the powdered sample with colourant sample ACRG having the highest brightness index (BI). Heavy metal analysis variations in the concentrations of As, Cd, and Pb and among the samples with BDRP having the highest value of lead, cadmium and arsenic at 0.013 m/kg, 0.09 mg/kg and 0.047 mg/kg respectively. Although all concentrations were below international permissible limits, the consistent presence of these metals raises concerns regarding production quality and consumer safety. The findings underscore the need for stricter quality control and regular monitoring of food colourants in Nigerian markets to mitigate potential health risks associated with its usage.*

**Keywords:** Synthetic Colours, Health, Safety, market

## 1.0 INTRODUCTION

Colour is an important component in consumer acceptance and appetizing value of foods (Dey and Negababbu, 2022). Food colours used in the food industry and domestic cooking helps improve appearance, flavour, restore natural colour lost during processing, and sustain the brands food products uniqueness. Food colours are broadly classified into natural and synthetic depending on the source. The natural food colours are derived from plant phytochemicals such as the carotenoids, betalain, anthocyanins and chlorophyll and from curcumin animal such as the cochineal extract from insects (Singh *et al*., 2023). Synthetic food colours, on the other hand, are chemically manufactured from a complex blend of metal ions, oxygen, hydrogen, carbon, nitrogen, and sulphur (Silva *et al*., 2022).

Synthetic food colours have high colour intensity, more colour stability and uniformity and are affordable. They have been increasingly used than natural food colours by food manufacturers to achieve improved food appearance (Dilrukshi *et al*., 2019). The permitted food colours shades are three and these are the red shades (Carmoisine, Ponceau 4R, Erythrosine), two yellow shades (Sunset yellow FCF, Tartrazine), two blue shades (Brilliant blue FCF, Indigo Carmine), and one green shade (Fast green FCF). However, adulterants are illegally introduced such as Sudan dye (Dey and Negababbu, 2022; Varghese and Ramamoorthy, 2023).

Safety concerns have been raised in the toxicity of synthetic colours in humans (Amchova *et al*., 2024) where there are reported symptoms of neuro-behavioural disorders, including attention deficit hyperactivity disorder (ADHD), genotoxicity, nausea and intestinal inflammation (Kong *et al*., 2021). The demand for food colours in Nigeria is experiencing steady growth due to various factors which includes expansion in food processing industries in Nigeria, increase desire towards visually appealing food products prompting the introduction of diverse food colours to the market (ANON, 2025). Also, the introduction of innovative food products is driving the demand for a diverse range of food colours in the market. At present most studies are basically on the products food colour is applied and there is dearth of information on the food colours additives functional group and heavy metals composition.

This study aims to evaluate the functional groups present in red food colours sold in Minna Metropolis and assess their levels of heavy metal contamination due to the growing trend of environmental contamination which calls for continuous monitoring of heavy metals to safeguard human health (Pecanac *et al*., 2023). This will provide essential data for regulatory bodies, the consumer protection agencies and the findings of will also contribute to the growing body of knowledge on food safety, ensuring that food colorants used in Minna, Nigeria, meet established health standards and do not pose risks to public health.

## 2.0 MATERIALS AND METHODS

### 2.1 Colour Samples Collection

Synthetic red food colours were collected from the vendors in the Minna local markets. A total of four each of the powder and liquids forms of the red colours were purchased. The synthetic red colours were selected because of the high sales volume and they represent the most commonly used food colorants in the region, typically found in local markets, grocery stores, and food processing outlets.

**Brand and Packaging**: Each sample was purchased in its entirety, including the original branded packaging. This ensures that the sample is representative of the product as sold to consumers. One exception was the "*Jawa*" brand, which was purchased from a local store and stored separately in a polyethylene bag. According to the vendor, the *Jawa* is used mostly by the meat jerky (*suya*) sellers.

**Table 1. Components listing on the red colours samples**

| Sample | Form | Label Information | Images |
|---|---|---|---|
| EBRP | Powder | Excellent Blend Red-Velvet Colour Powder. Ingredients: E129 & E110 Direction for use: For Red-Velvet Cakes. For 250 grams Flour, add 1 level of teaspoon of excellent blend red velvet powder to your milk, water, egg, and mix as usual |   |
| UNRP | Powder | None |   |

| | | | |
|---|---|---|---|
| JWRP | Powder | JAWA |   |
| BDRP | Powder | New Improved Bakers Delight Red Velvet Powder.<br>Ingredient: Made from approved pure edible colours E1248 E110<br>Description: specially formulated to colour red-Velvet cakes and icing for better taste. Can also be used in other food products.<br>Uses: For Red velvet cakes Direction for use: For 250 grams, add 1 level of teaspoon of excellent and red velvet powder to your milk, water, egg, and mixture |   |
| ACRL | Liquid | Acabado Red Velvet (Liquid Colour) (NAFDAC Reg No.: A8-0562L)<br>Ingredients: Concentrated colour for colouring Food, Drinks etc |   |
| ACRG | Gel | Acabado Colour (Gel) (NAFDAC Reg No.: A8-0562l)<br>Ingredients: Humectant, gelling Agent, Colours.<br>Direction: Add to cream, Marzipan, pastes, Drinks, etc. as desired |   |
| FCR | Liquid | Foster Clark's Red (NAFDAC Reg No. D1-526)<br>Ingredients – Water, Colours (E122, E110), Acidity, E330, Preservative E211.<br>**Nb**: This material may be having a negative effect on activity and concentration in children. Alcohol free. |   |
| DRL | Liquid | No information |   |

**Geographic Representation**: The selection process aimed to capture a broad and representative sample of red food colorants as it is most used across different settings (baking, cooking, and local food processing) in Minna Metropolis.

## 2.2 Analyses

### Functional Group Determination

The functional group characteristics of the liquid food colour samples were determined using Fourier Transform Infrared (FTIR) Spectroscopy (Shimadzu IRTracer-100). Each food colour sample (5g) was mixed with KBr pellets and analysed in FTIR spectra range 4000–450 cm-1 and a resolution of 4 cm-1 by spreading food colour on a glass slides (Katayama and Kandori, 2015). The liquid red colour samples were dried before analysis.

### Determination of Colour Profile

The colour characteristics (L*, a*, b*) of the liquid and gel food colour samples were determined using a digital colorimeter (Chroma Meter, Konica Minolta CR-400) following the AOAC (2020) method. Measurements were taken in triplicates at room temperature, and the instrument was calibrated against a white reference tile (L* = 97.83, a* = -0.43, b* = 1.98). L* = lightness (0 = black, 100 = white) a* = redness (+) to greenness (−) b* = yellowness (+) to blueness (−). Brightness Index was calculated using equation = $BI = \sqrt{(L^2 + a^2 + b^2)}$

### Determination of Heavy Metals

The concentrations of selected heavy metals lead, cadmium, arsenic, and mercury in the liquid food colour samples were determined using Atomic Absorption Spectrophotometry (AAS). Essentially, 1 g of the food colour sample each was digested with 15 ml mixture of concentrated nitric acid ($HNO_3$) and perchloric acid ($HClO_4$) in a 3:1 ratio at 200 oC on a hot plate until clear solution was achieved. The digested sample was allowed to cool, filtered and diluted to a 100 ml with distilled water before metal determination. The absorbance of each metal ion was measured at its characteristic wavelength using the atomic absorption spectroscopy (AAS) instrument, and concentrations were calculated by comparison with standard calibration curves. The results were expressed in milligrams per kilogram (mg/kg) and compared with permissible limits set by FAO/WHO (2019) and NAFDAC (2021) for food additives.

## 3.0 RESULTS AND DISCUSSION

Evaluation of different food colours labels revealed many inaccuracies, with missing basic product information and application being the most common issue. Absence of obligatory statement on the product's labels that the synthetic food colours can have adverse effect on activity and attention in children. This fault concern all the products, with exception of sample FCRL.

## 3.1 Functional Group Characteristic of the Red Colourants Samples

Table 1 shows the functional group and peaks identified for the various colourants and Fig 1 -2 shows the superimposed graph of the functional groups. For clarity, the FTIR spectra (Fig 1) shows the powdered colourants samples; Excellent Blend Red-Velvet Powder (EBRP), New Improved Baker's Delight Red UNR Powder (UNRP), Jawa Red Powder (JWRP), Velvet Powder (BDRP). While FTIR spectra (Fig 2) shows the water based, and in liquid form colours ; FCRL (Foster Clark red), ACRL (Acarbado Red), DRSL (Dee real berry), and ACRG (Acarbado red colour gel) which is more gel-like.

**Table 1. Identified functional group in the various red colourants**

| Sample | No. of Peaks Identified | Frequency (cm-3) |
|---|---|---|
| **EBRP** | 5 | 3400 (s), 2920 (m), 1620 (s), 1515 (m), 1180 (w) |
| UNRP | 5 | 3395 (s), 2900 (m), 1625 (s), 1505 (m), 1190 (w) |
| JWRP | 5 | 3410 (s), 2930 (m), 1610 (s), 1525 (m), 1175 (w) |
| BDRP | 5 | 3380 (s), 2950 (m), 1605 (s), 1540 (m), 1200 (w) |
| ACRL | 4 | 1615.80 (m), 1595.30 (w), 1041.79 (w), 802.75 (m), 650–720 (b, s) |
| FCRL | 5 | 1617.66 (m), 1591.57 (w), 1030.60 (vw), 650–750 (b, s) |
| ACRG | 5 | 1617.66 (s), 1503.98 (w), 1025.01 (vs), 834.92 (m), 650–720 (b, s) |
| DRSL | 5 | 1615.80 (m), 1591.57 (w), 1060.42 (w), 834.92 (m), 650–720 (b, s) |

*s – strong, m – medium, w – weak,* vw = very weak, vs = very strong, b = broad

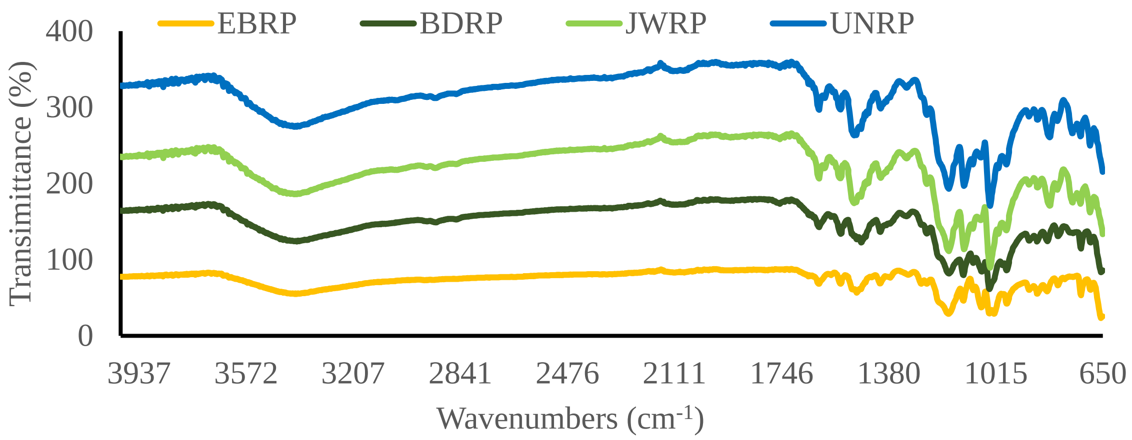


**Figure 1.** Superimposed functional group characteristics of EBRP, BDRP, JWRP and UNRP red colourants samples

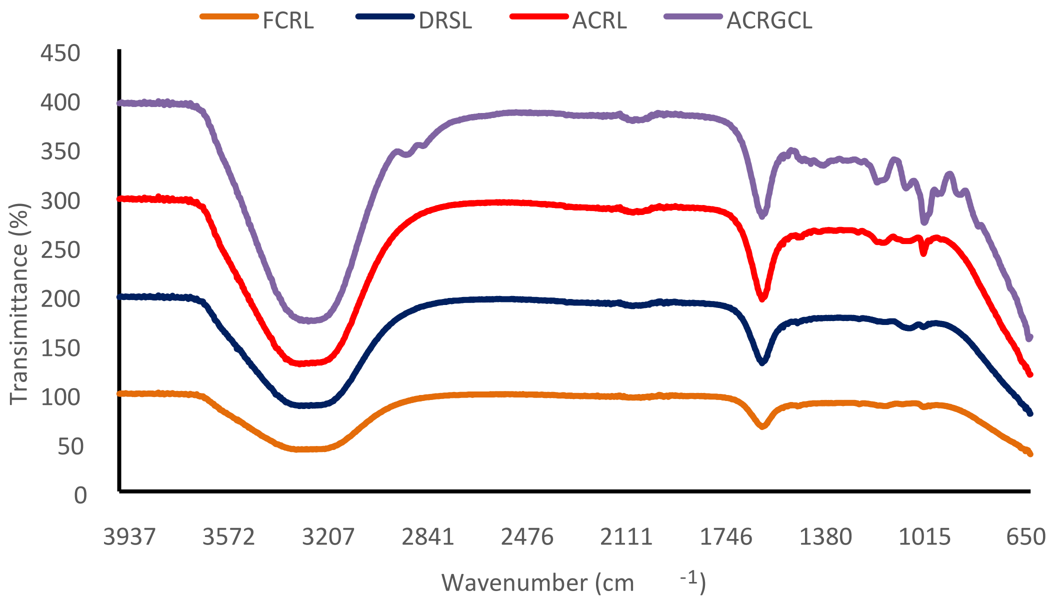


**Figure 2.** Functional group characteristics of FCRL, DRSL, ACRL and ACRG red colourants

A clear absorption bands in the FTIR spectra of the red food was observed which are aligned with the functional groups of most important of synthetic azo dyes. The largest peaks were at 3400 cm -1 (O -H stretching), 2920 -2950 cm -1 (C -H stretching), 1600 -1625 cm -1 (aromatic C=C and azo -N=N -stretching), and 1180 -1200 cm -1 (S=O stretching) and this was found amongst the powdered red colourant samples. Essentially, the powdered red colourants showed a strong peak at the hydroxyl and amine region of 3380-3410 cm-1. Many food colours contain naphthol rings that facilitates solubility and colour stabilization (Gräb and Geidel, 2019). In addition, it was also observed that there is a consistent pattern between EBRP and UNRP with the possibility of having the same chemical backbone of a common red.

Also, for the liquid red colourants (ACRL, FCRL, ACRG and DRSL) samples' broad absorption bands were mainly in the 650–750 $cm^{-1}$ region, attributed to aromatic C–H out-of-plane bending vibrations, confirming the presence of aromatic ring structures. The azo dyes were in These spectral characteristics prove the existence of aromatic azo compounds containing sulfonate groups, which is expected in the chemical profile of typical synthetic food dyes (Malviya *et al*., 2023; Bingol *et al*., 2010). This observation aligns with Clarke and Davies

(2019), with slight differences between samples in the azo and sulfonate peaks may be due to variations in formulation or dye purity or adulteration associated with different manufacturing origin. On the other hand, Benkhaya *et al*. (2020), reported that peaks at 1600- 1625 cm-1, 1500-1540 cm-1 and broad peaks 650-750 cm-1 which are also found in both food grade and common textiles dyes could suggest a mix of industrial grade colours used in textile. Furthermore, the FTIR findings indicate that red colourants available in the Minna markets are of synthetic azo dye category, which includes aromatic rings, azo connections, hydroxyl groups and sulfonate functional groups. These structural characteristics do not only determine the colour intensity and stability, but they also have toxicological implications because azo and sulfonate groups may interact with metal ions or present reactive intermediates during metabolic degradation, which could be dangerous to the health (Onakpa *et al*., 2018; Oloruntoba *et al*., 2024).

## 3.2 Colour characteristics of the colour samples

Table 2 shows the result of the colour profile amongst the samples collected. These parameters provide an objective quantitative measure of the visual appearance and colour intensity of the samples, which are critical indicators of product quality, consumer perception, acceptance and purchase. Low colour values for L* (7.55 and 17.46) indicating a high pigmentation of synthetic dyes in the powdered colour samples EBRP, UNRP, JWRP and BDRP. Red colour sample EBRP the lowest at 7.55 while ACRL had the highest value of L*at 50.13. the lower the L* value the darker the shade of red in the samples. The a* values was the lowest in colour sample BDRP at 34.80. This value tends towards the green axis and indicates low redness. The sample ACRG had the highest value of a* signifying high redness. This implies that these samples possess stronger red chromophores, possibly due to the presence of synthetic azo compounds with conjugated double bonds, as previously confirmed through FTIR analysis. The high a* values also correspond with the presence of aromatic and azo functional groups, which contribute to vivid colour expression in synthetic dyes (Neri-Numa *et al*., 2020). The b* was the lowest at UNRP signifying a more bluish range. Red colour sample FCRL was the highest. These values could possibly dictate their marketability, consumers preference and usage. The observed differences in the colour values reflects variations in dye formulation, concentration, or solvent composition (Carvalho *et al*., 2019). The a* values, which represent the degree of redness, were notably positive across all samples, confirming that all tested liquid colourants were dominantly red in hue. The brightness index (BI) ranged between 50.30 to 80.29 with BDRP the lowest and ACRG the highest.

**Table 2. Colour profile of the red food colourants samples**

| Colour Samples | L* | a* | b* | BI |
|---|---|---|---|---|
| EBRP | 7.55 (0.07) | 50.99 (0.18) | 13.59 (0.11) | 53.33 (0.05) |
| UNRP | 10.66 (0.05) | 54.41 (0.15) | 2.49 (0.08) | 55.54(0.07) |
| JWRP | 15.58 (0.08) | 56.81 (0.21) | 31.66 (0.17) | 66.95(0.11) |
| BDRP | 17.46 (0.12) | 34.80 (0.10) | 31.84 (0.14) | 50.30(0.10) |
| ACRL | 50.13 (0.10) | 54.80 (0.18) | 30.33 (0.14) | 79.04(0.10) |
| ACRG | 47.82 (0.22) | 59.31 (0.16) | 28.52 (0.19) | 80.29(0.08) |
| FCRL | 42.35 (0.15) | 55.82 (0.09) | 32.44 (0.10) | 76.61(0.15) |
| DRSL | 45.56 (0.18) | 57.11 (0.11) | 29.60 (0.13) | 76.43(0.14) |

### 3.3 Heavy Metals Content of Red Food Colourants Samples

The results of the heavy metal analysis are presented in Table 3 The lead, cadmium and arsenic concentration ranged from 0.06 to 0.013 mg/kg, 0.041 to 0.090 mg/kg and 0.02 to 0.047 mg/kg respectively. It was observed that the red colourants in powdered form had more concentration of the heavy metals compared with water based red colourants. This could probably be due to concentration effect. The values for the heavy metals analysed in this study are lower than the FAO/WHO (2019) and SON/NAFDAC permissible maximum limit which represents the allowable amount of food additives (JECFA, 2020). Nevertheless, cadmium is a toxic element with a high bio-accumulative capacity and even low doses of it may cause kidney and bone diseases with a long period of consumption. The presence of arsenic in any concentration remains undesirable, as chronic exposure can lead to dermatological, neurological, and carcinogenic effects (Godwill *et al*., 2015). Also, lead exposure has accounted for 1.5 million

**Table 3. Heavy metals concentration (mg/kg) of colour samples**

| Colour Samples | Lead | Cadmium | Arsenic |
|---|---|---|---|
| EBRP | 0.120 (0.001) | 0.082 (0.001) | 0.041 (0.001) |
| UNRP | 0.095 (0.001) | 0.068(0.0010 | 0.033 (0.001) |
| JWRP | 0.110 (0.001) | 0.075 (0.001) | 0.038 (0.001) |
| BDRP | 0.130(0.001) | 0.090(0.001) | 0.047 (0.001) |
| ACRL | 0.08 (0.001) | 0.054 (0.00) | 0.027 (0.001) |
| ACRG | 0.06 (0.001) | 0.044 (0.00) | 0.022 (0.001) |
| FCRL | 0.06 (0.001) | 0.041 (0.00) | 0.020 (0.001) |
| DRSL | 0.07 (0.00) | 0.049 (0.00) | 0.024 (0.001) |
| | **Limits** | | |
| WHO | 2.0 | 0.5 | 1.0 |
| SON/NAFDAC | 1.0 | 0.3 | 0.5 |

WHO= World Health Organization, NAFDAC= National Agency for Food and Drugs Administration and Control, and SON= Standard Organization of Nigeria

Deaths globally in 2021 and its neuro-toxicity particularly in young children have been reported (Scutarașu and Trincă, 2023). Though the heavy metals are not exceeding safety levels in this study, persistent food intake of various sources may increase the accumulated dietary intake of these heavy metals. The detection of these heavy metals in all samples suggests contamination which may have originated during manufacturing, particularly from pigments or stabilizers containing trace. This observation aligns with findings from Ibrahim *et al*. (2024), who reported sub-limit contamination in of some heavy metals in food-grade colorants sold across Nigerian markets. However, studies by Malviya *et al*. (2023), reported lower values for lead (0.018 mg/kg) and cadmium (0.030 mg/kg) in sweet colours.

## 4.0 CONCLUSION

This study highlights the diversity of red colourants samples commonly sold in Major markets in Minna. These colourants used in food preparation products possess functional group properties of azo dyes found in synthetic dyes and industrial dyes. The heavy-metals (As, Cd, Pb) contents remained within the internationally established safety levels. However, most of these synthetic red colours do not have enough information with respect to the usage and this raises serious concern over the safety of habitual consumption of foods such as cakes, sweets and other confectionery in which these products are being applied.

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