

CARCINOGENIC RISK ASSESSMENT OF CD, CR AND PB LEVELS IN ARTIFICIAL COLOURS AND SELECTED LOCAL FOODS AND DRINKS CONSUMED IN JALINGO, TARABA STATE.

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ABSTRACT

High consumption of street-vended foods by children at learning centres, markets, garages and other public places necessitated this research to predict the carcinogenic and non-carcinogenic effects of the commonly consumed street foods in Jalingo. Although street foods offer a great deal of advantages to food security, concerns about their health risk effects on humans are far too great to be ignored. Triplicate samples of three food colours namely Yellow, Orange and Red; four cooked foods – jellof rice, Okpa, moi-moi and Spaghetti and local drinks colours Yellow, Orange, White and Wine red were randomly collected from the surroundings of the Jalingo Main Market where food vendors hawked, and was taken to the Central laboratory, Federal University Wukari for analysis of Cd, Cr and Pb levels using the Atomic Absorption Spectrophotometry and to use the concentrations from the analysed samples to predict the potential health risk on the exposed population using the non-carcinogenic and carcinogenic risk assessment models. Results reveal significant values for non-carcinogenic risk assessment for EDI only and non-significant for THQ and HI. The carcinogenic health risk assessment reveals significant values for Pb and Cr in children and Pb (all food samples except moimoi as well as Cr in moimoi) in both children and adults, Cr (rice, DCO, DCW and DCWine red) and Cd (drink colours White and Wine Red) in adults. The high levels of Pb and Cr reflect the handling, storage, processing, cooking and preparation of the cooked foods with high levels and proximity to major roadside during drying.

Keywords: Carcinogenic health risk assessment, Food Colours, Drink Colours, Jollof Rice, Moi-moi,

INTRODUCTION

The addition of colours to foods is an age long practice which started in Egyptian cities, where candy makers around 1500 BC added natural extracts and wine to improve the appearance of their products (Maronpot *et al.*, 2020; Asif *et al.*, 2021).

Artificial food colors are synthetic dyes created through chemical processes, often derived from petroleum, and are distinct from natural food colors derived from plants or other natural sources. They are used to impart color to food products, making them more visually appealing, particularly in most street-vended products like candy, chocolates, jellies, chewing gums, beverages, baked goods, soft drinks, local drinks, and cooked food (spaghetti, Bambara pudding, bean pudding, bean cake, jollof rice, etc) (Bell 2023; Bailey 2024)

Artificial food colors are used primarily for aesthetic reasons: to enhance the color of food, make it more vibrant, and attract consumers, especially children. They can also help maintain color consistency in food products, especially when exposed to light, air, or temperature fluctuations. (Bell 2023; Bailey 2024)

Artificial food colors, while enhancing the visual appeal of food, have raised concerns about potential health risks, particularly in children. Studies have linked certain artificial dyes to hyperactivity, allergic reactions, and even potential links to cancer. (Bell 2023; Bailey 2024)

Several researches have reported the health and negative effects of these artificial food colours on humans for instance sunset yellow (E110) used in biscuits, have been found to be carcinogenic and damage kidneys and adrenals when fed to laboratory rats. (Schweiggert, 2018; Kyaw, 2019; Silva *et al.*, 2022). Others reported the presence of some toxic heavy metals in these synthetic food colours and in concentration above the permissible limits recommended by the Food and Agriculture Organization (FAO), (Aamir *et al.*, 2018; Nowreen, 2019). This indeed is a cause for alarm since children are always attracted to colourful foods and drinks and hence are at a high risk of heavy metal poisoning and any other negative effects associated with consuming synthetic food colours over a long period of time.

The focus of this research is to evaluate the carcinogenic health hazards of the selected synthetic food colours in the local cooked food and drinks commonly consumed in Jalingo metropolis.

MATERIALS AND METHODS

Description of Study Area

Jalingo is the capital of Taraba state which is situated in the Northcentral geopolitical zone of Nigeria. Jalingo lies approximately between longitudes 11° 09'E to 11° 30'E and latitude 8° 47'N to 9° 01'N. The Local government lies in the north of Taraba state and is bounded to the north by Lau L.G.A, to the east by Yorro L.G.A, and to the south and west by Ardo-Kola L.G.A. and with

a total land mass of about 195.071 km². The estimated population of Jalingo is 241,590 inhabitants with the most prominent tribes being the Fulani and the Mumuye.

Jalingo has a tropical savannah climate marked by wet and dry seasons. The wet season begins in April and ends in October while the dry season which is characterized by the prevalence of the north-east trade wind from the Sahara Desert begins in November and ends in March. Jalingo has a mean annual rainfall of about 1200 mm and mean temperature of about 29°C and also has an average humidity level of 49%. Jalingo LGA is an urban and cosmopolitan area and has a lot of hotels, banks, restaurants, industries and both government and privately owned institutions. Farming is also very popular amongst the people of Jalingo especially at the outskirts of the LGA, with large scale cultivation of rice, melon and millet etc. Trade and transportation business also thrives well in Jalingo, there are several markets such as the Jalingo main market, kasuwan mata, Gadar Bobboji and a host of other small markets where a variety of commodities are bought and sold. A number of mineral resources such as iron ore, gemstones and graphite are also found in Jalingo (<https://www.manpower.com.ng>places>lga>jalingo>).

Description of Sampling Area

The sampling area which is Jalingo main market is located in Tukari 'A' ward, which is a very big market in Jalingo town where varieties of general goods including foods are sold. Outside the main market, there are vendors of different items which includes both food and other material items. Opposite the first gate is a taxi park which transport passengers to nearby villages like Mutumbiyu, Lankaviri, etc.

The entrances of the first and second gates harbours few food vendors who sell cooked foods such as white rice and stew, yam porridge, spaghetti jellof and moi-moi, very few of the foods here contains artificial colours. At the exit of the market are many food vendors which comprises of mainly young girls, adolescents and a few young adults within the ages of five to twenty years old. There were a total of twelve food vendors at the exit and seventeen of them by the side of the market. These girls sell a variety of cooked food such as palm oil rice, yam porridge, spaghetti jellof, spaghetti and stew, rice and stew, moi-moi, pork, etc. The foods sold here are very affordable as they can sell for as low as fifty (50) naira. Many of the food in this area contains food colours as they are brightly coloured especially the jellof spaghetti, yam porridge and jellof rice. The vendors of artificial colours used in local drinks are scattered all over the market. Coloured food are also found at places such as the Kasuwan Mata, Tashan Lau, Palace roundabout, main motor park, etc.

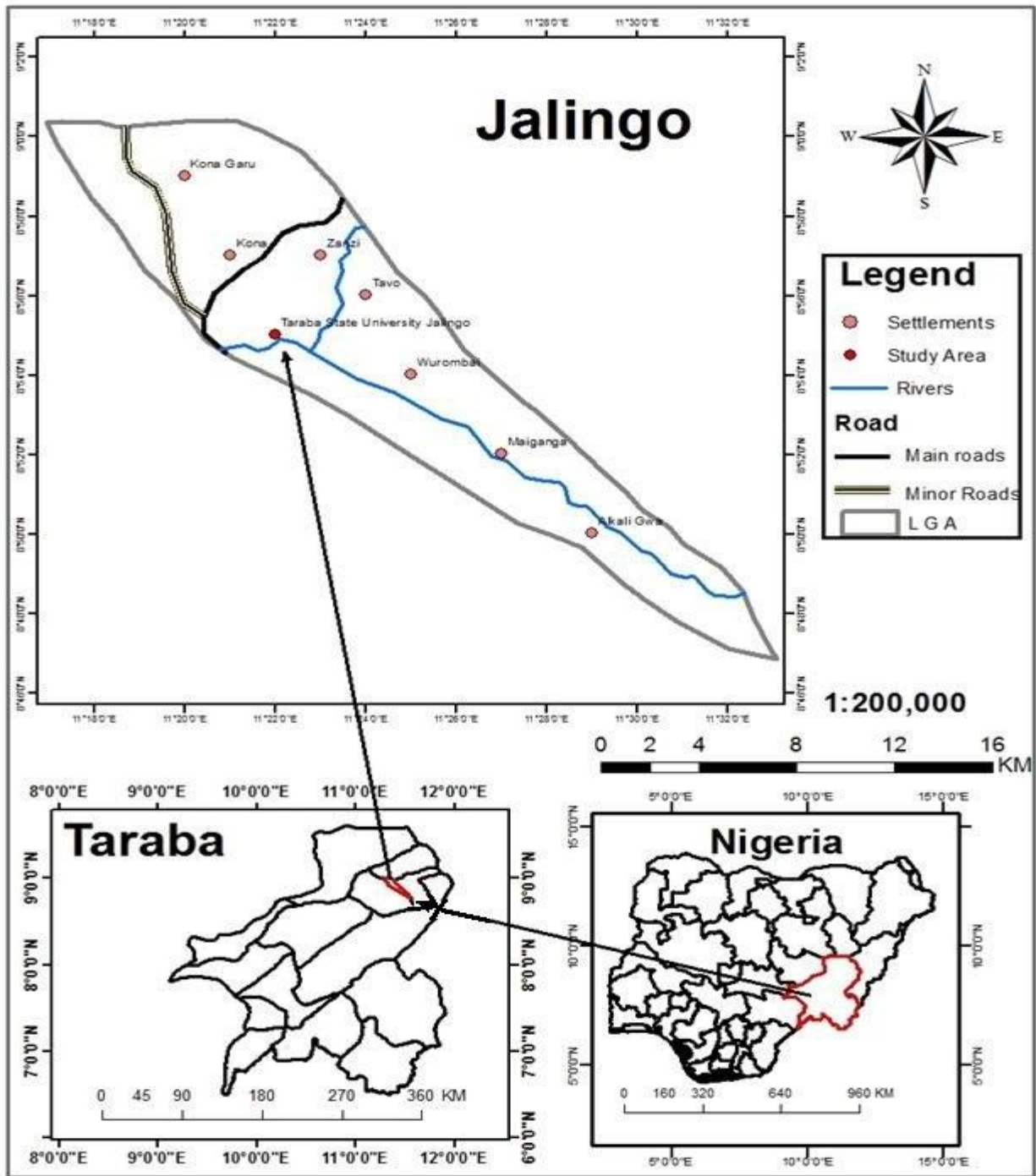


Figure 3.1. A map showing the study area. Source: Vincent *et al.*, (2020)

Sample collection and Analysis

Selected local cooked food (cooked jellof rice, moi-moi, spaghetti and okpa), drink (yellow, white, orange and wine red colours) and artificial colour (red, yellow and orange) samples commonly used by food vendors were collected from randomly selected local food vendors from Jalingo main

market in the month of June, 2023. According to food vendors, the selected cooked foods are usually enhanced by adding artificial food and drink colours to attract their customers and speed up sales on a daily basis. The artificial food colours and the drink colours are usually in powdered and liquid form respectively. A total of 33 samples in triplicates were taken to the Central Laboratory, Federal University Wukari, Taraba State for metal analysis using the Atomic absorption spectrophotometry (AAS) (Ugwu and Jeyol, 2024).

Table 1: Wavelength and Method of Validation Parameters Obtained by AAS Analysis in Artificial Colours used in Local Foods and Drinks.

Element	Wavelength (nm)	R ² Value	Calibration Range	Slit Setting	Max current	P/N
Cd	228.8nm	0.9975	1-1200	7	10mA	4108
Cr	357.9nm	0.9980	1-1200	7	20mA	4112
Pb	217.0nm	0.9935	1-1200	7	15mA	4129

Health Risk Assessment

The risk assessment factors and values were estimated according to Ugwu and Jeyol 2024. The health risk assessment of each contaminant is based on the estimation of the risk level and is classified as carcinogenic or non-carcinogenic health hazards (Wongsasuluk *et al.*, 2014). The potential health risks of heavy metal consumption have been assessed using different models (Wongsasuluk *et al.*, 2014; Tefera and Teklewold, 2021).

Carcinogenic Risk Assessment

Carcinogenic risk (CR) indicates an incremental probability of an individual to develop cancer over a lifetime due to exposure to a potential carcinogen(s). This was calculated using the formula; $CR = CSF \times EDI$eq (4)

where, CSF which is the carcinogenic slope factor is the risk produced over a lifetime exposure of 1mg/kg BW/day and it is specific to a particular contaminant. The CSF values of Cd, Cr, and Pb are 0.01, 0.5 and 0.38 mg/kg/day, respectively (Gebeyehu and Bayissa, 2020). EDI is the estimated daily intake of heavy metals. For single and multi-carcinogenic metals, the permissible limits are 10^{-6} and $< 10^{-4}$, respectively (Tepanosyan *et al.*, 2017).

$$EDI = (C \text{ metal} \times IR) / BW \dots \dots \dots \text{eq (1)}$$

Where, **EDI** is the estimated daily intake of metal,

C metal (mg/kg) is the mean concentration of heavy metal in the samples, **IR** which is the ingestion rate is the average daily consumption of the colour additives (gram/day/person), **BW** is the average body weight (Kg) (Amer, 2019). The ingestion rate of colour additives in food is assumed to be 7g/day/person. The average body weight for adult was 60.0 kg (Meseret, 2020).

THQ: (target hazard quotient) predicts safety risk assessment. It describes the non-carcinogenic risks of long-term exposure to contaminants as seen in Eq (2). (Gebeyehu and Bayissa, 2020).

$$THQ = (Efr \times ED \times FIR \times C / RfDo \times BW \times ATn) \times 10^{-3} \dots \dots \dots \text{eq (2)}$$

Where,

Ef = exposure frequency (208 days/year);

Ed = exposure duration 60years

Fir = food ingestion rate

Cf = concentration of heavy metals

RfDo = reference dose, it is specific to the heavy metals under investigation (mg/kg/day). The RfD values for Cd, Cr and Pb are 0.001, 0.003 and 0.004mg/kg/day, respectively

Bw = body weight (60kg)

ATn = average exposure time for non-carcinogen ($Efr \times Ed = 208 \text{ days} \times 60 \text{ years}$)

10^{-3} = unit conversion factor. (Deka *et al.*, 2023).

THQ ≥ 1 indicates a non-carcinogenic health risk effect on the exposed population while a THQ < 1 shows that the consumers are safe.

HI (health index): The HI is used to estimate the cumulative health risk to human through the exposure of more than one contaminant. As shown in Eq. (3), HI is the sum of the total hazard quotients of all heavy metals in the samples.

HI= THQ(Cd) + THQ(Cr) + THQ(Pb) eq (3)

HI values ≥ 1 indicates that the population are exposed to adverse health effects while HI < 1 means the population is unlikely to experience adverse health effect (Ghasemidehkordi, 2018; Mohammadi, 2019).

RESULTS AND DISCUSSION

Non-Carcinogenic Health Risk Assessments

The non-carcinogenic health risk assessment factors of the expected daily intake (EDI), the target hazard quotient (THQ) and the health index (HI) values are shown in Tables 1, 2 and 3. The EDI was significant (greater than 1 = >1) for Pb in the cooked foods, local drinks and the artificial colours in both adults and children. The EDI value was higher in children than in the adults. This reflects a potential health risk threats to the consumers especially children. The THQ and HI were non- significant (< 1) in all the food, local drinks and artificial colours samples in both adults and children (Tables 2 and 3). This indicates that the consumers are safe.

Children are at the risk of heavy metal poisoning because they are naturally attracted to colourful food products. The consumption of Pb above permissible limits damages the central nervous system especially in developing children and foetuses and also causes nephropathies, alterations of the gastrointestinal tract and Alzheimer's disease (Fathabad *et al.*, 2018; Paz *et al.*, 2019). Prolonged consumption of Pb may also increase red blood cell fragility and kidney tubular cells and it could also result to the impairment of the hearing process (Maigari *et al.*, 2016).

Table 1: Estimated daily intake (EDI) for adults and children

Samples	EDI for adults			EDI for children		
	Cd	Cr	Pb	Cd	Cr	Pb
FSS	0.0011	0.0014	0.0430	0.0035	0.0044	0.1290
FSM	0.0000	0.0000	0.0001	0.0000	0.0000	0.0005
FSR	0.0043	0.0087	0.1110	0.0131	0.0262	0.3328
FSO	0.0010	0.0007	0.2257	0.0031	0.0021	0.6772
FCR	0.0026	0.0002	0.1090	0.0080	0.0007	0.3293
FCY	0.0007	0.0008	0.0710	0.0021	0.0024	0.2124
FCO	0.0014	0.0005	0.0650	0.0042	0.0017	0.9142
DCY	0.0130	0.0010	0.1830	0.0407	0.0055	0.5513
DCO	0.0050	0.0080	0.1640	0.0166	0.0240	0.4939
DCW	0.0030	0.0020	0.1690	0.0093	0.0074	0.5087
DCwine red	0.0030	0.0040	0.0760	0.0093	0.0148	0.2294

Key: FSS = food sample spaghetti; FSM = food sample moi-moi; FSR = food sample rice; FSO = food sample Okpa; FCR = food colour red; FCY= food colour yellow; FCO= food colour orange; DCY = Drink colour yellow; DCO = drink colour orange; DCW = Drink colour white; DCWred = Drink colour wine red

Provisional tolerable daily intake (PTDI) Cd = 0.025mg/kg for adults and children, World Health Organization (WHO, 2021); Cr = 0.3mg/kg for adults and 0.0521mg/kg for children (European Food Safety Authority EFSA, 2014); U.S. FDA Interim safe intake for Pb = 12.5µg or 0.0125mg/kg/day for adult (Flannery *et al.*, 2020) and 2.2µg/day or 0.0022mg/kg/day for children (Flannery and Middleton, 2022). The bolded figures mean significant values.

Table 2: Non-carcinogenic health risk assessment using THQ

Samples	THQ for adults			THQ for children		
	Cd	Cr	Pb	Cd	Cr	Pb
FSS	0.0012	0.0005	0.0107	0.0035	0.0015	0.0323
FSM	0.0000	0.0000	0.0000	0.0000	0.0076	0.0001
FSR	0.0043	0.0029	0.0277	0.0131	0.0088	0.0832
FSO	0.0010	0.0002	0.0478	0.0031	0.0007	0.1693
FCR	0.0026	0.0001	0.0274	0.0080	0.0002	0.0823
FCY	0.0007	0.0003	0.0177	0.0021	0.0008	0.0531
FCO	0.0014	0.0002	0.0162	0.0042	0.0006	0.0486
DCY	0.0136	0.0006	0.0459	0.0407	0.0019	0.1378
DCO	0.0056	0.0027	0.0412	0.0166	0.0080	0.1235
DCW	0.0031	0.0008	0.0424	0.0093	0.0025	0.1272
DCwine red	0.0031	0.0016	0.0191	0.0093	0.0049	0.0574

Key: FSS = food sample spaghetti; FSM = food sample moi-moi; FSR = food sample rice; FSO = food sample Okpa; FCR = food colour red; FCY= food colour yellow; FCO= food colour orange; DCY = Drink colour yellow; DCO = drink colour orange; DCW = Drink colour white; DCWred = Drink colour wine red.

THQ ≤ 1 means there is no significant health risk while THQ > 1 means the health risk is significant.

Table 3: Non-carcinogenic health risk assessment using Health Index

Samples	HI for adults	HI for children
FSS	0.0124	0.0371
FSM	0.0000	0.0077
FSR	0.0346	0.1050
FSO	0.0490	0.1731
FCR	0.0302	0.0911
FCY	0.0187	0.0560
FCO	0.0178	0.0532
DCY	0.0601	0.1803
DCO	0.0495	0.1480
DCW	0.0463	0.1387
DCwine red	0.0238	0.0714

Key: FSS = food sample spaghetti; FSM = food sample moi-moi; FSR = food sample rice; FSO = food sample Okpa; FCR = food colour red; FCY= food colour yellow; FCO= food colour orange; DCY = Drink colour yellow; DCO = drink colour orange; DCW = Drink colour white; DCWred = Drink colour wine red.

HI \leq 1 shows the consumers are safe while a **HI $>$ 1** portends a potential threat to the consumers.

Carcinogenic Health Risk Assessments

The computed values of CR for Cd, Cr and Pb due to exposure from the ingestion of artificial food colours for both adult and children are presented in Tables 4 and 5. The carcinogenic health risk assessments was significant for Cd in DCW and DCWine red in drinks; Cr in rice, DCO, DCW and DCWine red and for Pb in all the samples analysed in the present study except moimoi for adults (Table 4). Cadmium (Cd) and lead (Pb) are metals that have no biological role in humans and all of their perceptible effects are toxic (Satarug *et al.*, 2017). Cd and Pb are two of ten chemicals listed by the World Health Organization (WHO) as environmental pollutants of major public health concern (WHO, 2020). USEPA recommended the permissible level for cancer risk to be less than or about 1 chance in 1,000,000 people in a lifetime exposure ($CR < 10^{-6}$) and this value is considered negligible. Threshold risk limit ($CR > 10^{-4}$) is a chance of cancer risk for 1 in 10,000. However, values of CR lying between 10^{-6} and 10^{-4} are considered as acceptable range. Moderate risk level ($CR > 10^{-3}$) and ($CR > 10^{-2}$) that is about 1 in 1,000 and 1 in 100 respectively are considered unacceptable and the health safety of the public is of great concern. In this present study, the values of cancer risk (CR) for adults showed that Cd was within the acceptable range except for DCW and DCWine red which was 3×10^{-3} for both samples respectively, which fell in

the unacceptable range. Cr ranged from 0 to 7×10^{-4} and was within the unacceptable range in rice, DCO, DCW and DCwine red. The cancer risk for Pb were all within the unacceptable range except for moi-moi which was within the acceptable range.

In the children, the carcinogenic health risk assessment was higher in all the food samples for Pb and Cr, except Cr in moi-moi (Table 5). The estimated CR for children has Cd within the acceptable range in all the samples, Cr fell within the unacceptable range except for FCR and FCO that were within the acceptable range. Pb was within the unacceptable range in all the samples except for moi-moi which was within the permissible range. Ekhatior *et al.*, (2017) reported cancer risk for Pb and Cd above the acceptable range for both adults and children. The findings of this study revealed that the public health concern and the risk to cancer indicate that the toxic metals Pb and Cr have carcinogenic risk through consumption of artificial food colours for both adult and children.

The cancer risk (CR) of Cd, Cr and Pb were estimated for both adults and children as shown in Tables 4 and 5 respectively. For adults, the estimated cancer risk for Cd, Cr and Pb ranged from 0 to 7×10^{-6} , 0 to 7×10^{-4} and 1.63×10^{-2} to 3.8×10^{-5} respectively. For children, the estimated cancer risk for Cd, Cr and Pb ranged from 0 to 9.3×10^{-5} , 0 to 8.5×10^{-4} and 1.3×10^{-1} to 1.9×10^{-4} respectively. Pb cancer risk values fell within the unacceptable limits for both adult and children, followed by Cr and Cd. $Pb > Cr > Cd$.

Table 4: Carcinogenic Risk Assessment for Adults

Samples	Cd	Cr	Pb
FSS	1.1×10^{-5}	7×10^{-4}	1.63×10^{-2}
FSM	0	0	3.8×10^{-5}
FSR	4.3×10^{-5}	4.35×10^{-3}	4.2×10^{-2}
FSO	1×10^{-5}	3.5×10^{-4}	8.5×10^{-2}
FCR	2.6×10^{-5}	1×10^{-4}	4.1×10^{-2}
FCY	7×10^{-6}	4×10^{-4}	2.7×10^{-2}
FCO	1.4×10^{-5}	2.5×10^{-4}	2.5×10^{-2}
DCY	1.3×10^{-4}	5×10^{-4}	6.9×10^{-2}
DCO	5×10^{-5}	4×10^{-3}	6.2×10^{-2}
DCW	3×10^{-3}	1×10^{-3}	6.4×10^{-2}
DCwine red	3×10^{-3}	2×10^{-3}	2.8×10^{-2}

Key: FSS = food sample spaghetti; FSM = food sample moi-moi; FSR = food sample rice; FSO = food sample Okpa; FCR = food colour red; FCY= food colour yellow; FCO= food colour orange; DCY = Drink colour yellow; DCO = drink colour orange; DCW = Drink colour white; DCWred =

Drink colour wine red

Cd = Cadmium; Cr = chromium, Pb = Lead. The bolded figures are above the acceptable limit, 1×10^{-4} to 1×10^{-6} .

Table 5: Carcinogenic Risk Assessment for Children

Samples	Cd	Cr	Pb
FSS	3.5×10^{-5}	2.2×10^{-3}	4.9×10^{-2}
FSM	0	0	1.9×10^{-4}
FSR	1.3×10^{-4}	1.3×10^{-2}	1.3×10^{-1}
FSO	3.1×10^{-5}	1.1×10^{-3}	2.6×10^{-1}
FCR	8×10^{-5}	3.5×10^{-4}	1.3×10^{-1}
FCY	2.1×10^{-5}	1.2×10^{-3}	8.1×10^{-2}
FCO	4.2×10^{-5}	8.5×10^{-4}	7.4×10^{-2}
DCY	4.1×10^{-4}	2.7×10^{-3}	2.1×10^{-1}
DCO	1.6×10^{-4}	1.2×10^{-2}	2×10^{-1}
DCW	9.3×10^{-5}	3.7×10^{-3}	1.9×10^{-1}
DCwine red	9.3×10^{-5}	7.4×10^{-3}	8.7×10^{-2}

Key: FSS = food sample spaghetti; FSM = food sample moi-moi; FSR = food sample rice; FSO = food sample Okpa; FCR = food colour red; FCY= food colour yellow; FCO= food colour orange; DCY = Drink colour yellow; DCO = drink colour orange; DCW = Drink colour white; DCWred = Drink colour wine red

Cd = Cadmium; Cr = chromium, Pb = Lead. The bolded figures are above the acceptable limit, 1×10^{-4} to 1×10^{-6} .

CONCLUSION

The findings of this study shows that the Pb level was high across all the samples and it is a major cause for health concern since Pb has no biological function in the body. Although the mean Cd and Cr values were within the permissible limits as well as the THQ and HI values which were less than 1, the carcinogenic risk implies that there is a potential threat to the food safety, health and wellbeing of consumers of these colours in food and drink samples at Jalingo. The findings of this study therefore provided baseline data on the concentration of Cd, Cr and Pb in artificial food

and drink colours and local foods containing artificial colours implying potential carcinogenic health risk in Jalingo, Taraba state.

CONFLICT OF INTEREST

The authors declared that there is no conflict of interest

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