

**HEALTH RISK ASSESSMENT FOR
CARCINOGENIC AND NON-CARCINOGENIC
HEAVY METAL EXPOSURES FROM SOME
LOCAL FRUITS IN KATSINA STATE, NORTH
WEST NIGERIA**

ABSTRACT

This study was conducted to determine the heavy metals (Cr, Cd, Fe, Ni, Mn, Pb and Zn) pollution load and health risks to the population in some local fruit samples in Katsina state Nigeria. Results from this study has shown that with the exception of the mean concentration of Pb (1.152-1.623) and Cd (0.053-0.092), the mean concentration (mg/kg) range values of Fe (1.728-1.954), Mn (0.321-0.502) and Zn (0.263-0.967 ppm) in the samples were generally lower than the regulatory agencies maximum permissive limits. Risk level of Target Hazard Quotient (< 1) was observed for all the evaluated heavy metals for both adults and children indicating no non-carcinogenic adverse health effect to the populace. The Incremental Lifetime Cancer Risk for the heavy metal Cd was at the threshold risk limit ($>10^{-4}$) in all the studied fruits in adults, While Pb for adults and Pb and Cd for children were within the moderate risk limit ($>10^{-3}$). The cumulative cancer risk (\sum ILCR) of the studied fruits were within the moderate risk level ($>10^{-3}$) in adults and above the level ($>10^{-2}$) in children. The results of study has suggested that the consumption of the studied local fruits in Katsina state is of public health concern as it may lead to an increase in the population cancer burden.

Keywords: Fruits, Nigeria, Katsina, health, cancer, heavy metals, pollution

1. INTRODUCTION

The beneficial effect of fruit consumption on human health is well documented. Fruits have become a part of people's daily diets more and more with the improvement of living conditions in many parts of the world (1). The quality and safety of fruits are compromised by their contamination with heavy metals (2; 3; 4; 5). Heavy metals, are known to be non-biodegradable, with long biological half-lives, and possess the ability to bioaccumulate in different body organs, resulting to unwanted side effects (6; 7).

The absence of data on the heavy metals composition of locally consumed fruits in Katsina state and the health implication of consuming food with heavy metals above permissible limits necessitate this study. Studies on heavy metals in various food samples have been carried out in Katsina state Nigeria (8; 9; 10; 11; 12; 13; 14; 15; 16; 17), but no study has been carried on the levels of heavy metals in local fruits in Katsina state. Data on heavy metal in the fruits generated will give an insight on the level of metal contamination and by extension the impact on food safety standard and risk to consumers.

2. MATERIAL AND METHODS

2.1 STUDY AREA

The study was conducted in Katsina State, with a location of between latitude 12°15'N and longitude of 7°30'E in the North West Zone of Nigeria, possessing a land area of 24,192km² (9,341 sq meters). Rainy and dry season are the two observable seasons of Katsina State. The rainy season begins in April and ends in October, while the dry season starts in November and ends in March (18). This study was undertaken during the dry season. The average annual rainfall, temperature, and relative humidity of Katsina State are 1,312 mm, 27.3°C and 50.2%, respectively.

2.2 SAMPLE COLLECTION

The fruits samples comprising of Aduwa (*Balanites aegyptica*), Dinya (*Vitex doniana*), Faru (*Lannea acida*), Goruba (*Hyphaene thebaica*), Kadanya (*Vitellaria paradoxa*) and Kanya (*Diospyros mespiliformis*) were collected based on the method of Pehlivan *et al.* (1). In each sampling point, three fruit trees were selected in terms of the age and growing status. Fruit samples which were at fully maturity stage were taken about 1 to 4 kg depending on fruit species. The fresh fruit samples were placed into clean polyethylene bags and transported to the laboratory.

2.3 SAMPLE PREPARATION

The collected samples were cleaned, fragmented with clean plastic spoon and knife and dried at ambient temperature. After drying, the seeds were removed from the dried fruits.

2.4 HEAVY METALS DETERMINATION

About 0.5 g of each dried sample was weighed and ashed at 550°C for 24 hours in an electric muffle furnace (Thermolyne FB131DM Fisher Scientific). The ash was diluted with 4.5 ml concentrated hydrochloric acid (HCl) and concentrated nitric acid (HNO₃) mixed at ratio 3:1 the diluent is left for some minutes for proper digestion in a beaker. 50 ml of distilled water was added to the diluents to make up to 100 ml in a volumetric flask. The levels of heavy metals (Pb, Zn, Ni, Cd, Cr, Mn and Fe) were determined using AA210RAP BUCK Atomic Absorption Spectrometer flame emission spectrometer filter GLA-4B Graphite furnace (East Norwalk USA), according to standard methods (19) and the results were given in (mg/kg).

2.6 HEAVY METAL HEALTH RISK ASSESSMENT

2.6.1 DAILY INTAKE OF METALS (DIM)

The daily intake of metals from consumption of the local fruit sample was calculated using the following equation:

$$DIM = \frac{C_{metal} * C_{factor} * D_{intak}}{B_{weight}} \dots \dots \dots \text{eqn. (1)}$$

Where, C_{metal}, C_{factor}, D_{intake} and B_{weight} represent the heavy metal concentrations in the samples, the conversion factor, the daily intake of the sample and the average body weight, respectively. The conversion factor (CF) of 0.085 (20) was used for the conversion of the samples to dry weights. The average daily intake of the fruits was 300g kg⁻¹ d⁻¹ (21) and the average body weight for the adult and children population was taken from literature as 60 kg (22) and 24 kg (23) respectively.

2.6.2 NON-CANCER RISKS

The non-carcinogenic risks for the adult and children population of the evaluated heavy metals from possible consumption of the fruit samples were computed as the target hazard quotient (THQ) using the following equation (24).

$$THQ = CDI / RfD \dots \dots \dots \text{eqn. (2)}$$

Where, CDI is the representation of the chronic daily heavy metal intake (mg/kg/day) calculated in the previous section and RfD is the representation of the oral reference dose (mg/kg/day) which is a quantification of the maximum permissible risk on human population through daily exposure, bearing in mind a sensitive group in the course of a lifetime (25). The following reference doses from the literature were used (Pb = 0.6, Cd = 0.5, Zn = 0.3, Fe = 0.7, Ni = 0.4, Mn = 0.014, Cr = 0.3) (26; 27). To evaluate the potential risk to human health through more than one heavy metal from consumption of the fruit samples in the adult and children population, chronic hazard index (HI) is obtained as the sum of all hazard quotients (THQ) computed for individual heavy metals for a particular exposure pathway (28). This is calculated as follows:

$$HI = THQ_1 + THQ_2 + \dots + THQ_n \dots \dots \dots \text{eqn. (3)}$$

Where, 1, 2, ..., n are the individual heavy metals for the fruit samples.

It is usually believed that the magnitude of the effect is proportional to the sum of the multiple metal exposures and that similar working mechanism linearly affects the target organ (29). The calculated HI is compared to standard levels: the population is assumed to be safe when $HI < 1$ and in a level of concern when $1 < HI < 5$ (30).

2.7 CANCER RISKS

The possibility of cancer risks to the adult and children consumer population in the studied fruits samples through intake of carcinogenic heavy metals was estimated by the use of the Incremental Lifetime Cancer Risk (ILCR) (31).

$$ILCR = CDI \times CSF \dots \dots \dots \text{eqn. (4)}$$

Where, CDI represent the chronic daily intake of chemical carcinogen, mg/kg BW/day which represents the lifetime average daily dose of exposure in adult and children population to the chemical carcinogen.

The US EPA ILCR is obtained by the use of the cancer slope factor (CSF), which represents the risk produced by a lifetime average dose of 1 mg/kg BW/day and is specific to individual contaminant (24). The ILCR value in fruits signifies the probability of an individual's lifetime health risks from carcinogenic heavy metals' exposure (31). For regulatory purposes the level of acceptable cancer risks (ILCR) is considered within the range of 10^{-6} to 10^{-4} (25). The CDI value was calculated on the basis of the following equation and CSF values for carcinogenic heavy metals were used according to the literature (32).

$$CDI = (EDI \times EFr \times ED_{tot}) / AT \dots \dots \dots \text{eqn. (5)}$$

where EDI represent the estimated daily intake of metal via consumption of the samples; EFr is the exposure frequency (365 days/year); ED_{tot} is the exposure duration of 60 years, which is the average lifetime for Nigerians; AT is the period of exposure for non-carcinogenic effects ($EFr \times ED_{tot}$), and 60 years life time for carcinogenic effect (24). The cumulative cancer risk as a result of exposure to multiple carcinogenic heavy metals from intake of a particular type of food was taken to be the sum of the individual heavy metal increment risks and calculated by the following equation (32).

$$\sum I_n = ILCR_1 + ILCR_2 + \dots + ILCR_n \dots \dots \dots \text{eqn. (6)}$$

Where, n = 1, 2, ..., n is the individual carcinogenic heavy metal.

3. RESULTS AND DISCUSSION

The present study investigated the presence of heavy metals in some local fruit samples in Katsina state, Nigeria. A total of 6 fruits samples were analyzed for the presence of heavy metals in this study. As shown in Table 1, among the heavy metals evaluated, the highest concentration (mg/kg) was observed for Fe (range: 1.728-1.954) followed by Pb (range: 1.152-1.623), Zn (range: 0.263-0.967) and Mn (range: 0.321-0.502). While Cd record the lowest concentration (range: 0.053-0.092) with the heavy metals Ni and Cr being below detection level (BDL).

Results from the study has pointed that the mean Fe concentration in the fruit samples were lower to that reported by (33) in a study on heavy metals in fruits from Bangladesh, in a similar study in Turkey (1) and that recorded in a study conducted in Pakistan (34) and the results for the study conducted by Krejpcio *et al.* (35) in Poland. All the samples Fe concentrations were below the maximum permissible limit of 425 mg/kg for Fe in fruits (36).

In this study the Pb content of all samples exceeded the permissible limit of regulatory bodies (37) that recommended Pb concentrations limits for berries and other small fruits as 0.2 mg/kg and for foods as 0.5 mg/kg. These results for the mean Pb in the samples were lower than the results reported by Rahman and Islam (38) in a study on heavy metals in fruits from Bangladesh, Pehlivan *et al.* (1) for sweet cherry, apple, plum and apricot in a study conducted in Turkey and the study of Ali *et al.* (39) that reported between 2.1 and 7.0 mg/kg of Pb in apricot. The result obtained in the present study was also lower than the values reported by Hamurcu *et al.* (40) in apple (2.21 mg/kg), plum (2.82 mg/kg) and rosehip

(1.54-2.86 mg/kg). Likewise the values reported for Pb in the present study are higher than the values reported by Nawab et al. (41) in fruits from Pakistan and Elbagermi *et al.* (42) in orange and banana and the results of Uroko *et al.* (43) that reported non detection of Pb in fruit samples from Umuahia market, Nigeria. The differences in the reported mean Pb concentration in the current study as compared to the above cited literature may likely arose from the nature of the studied fruits, as plants have different absorptive capacity for heavy metals, another likely assumption is the nature of the heavy metal contamination source.

All the fruit sample have an excessive amount of Cd compared to the permissible limit (0.05 mg/kg) proposed by the FAO/WHO (37). As the sampling locations were located near the high way the above permissible mean values can be attributed to vehicular exhaust and the use of Cd containing fertilizers. The concentration of Cd (mg/kg) in this study were much higher than those reported by Krejpcio *et al.* (35) in sweet cherry (0.021 mg/kg) in Poland, Pehlivan *et al.* (1) and Duran *et al.* (44) in white mulberry (0.015 and 0.63 mg/kg, respectively) in Turkey, Radwan and Salama (2006)(45) in apple (0.05 mg/kg) in Egypt, Hamurcu *et al.* (2010)(40) in plum (0.14 mg/kg) in Turkey and the result reported by Elbagermi *et al.* (42) in Orange (0.03) in Libya. But the results are similar to those reported by Pehlivan *et al.* (1) for sweet cherry and plum and that reported by Elbagermi *et al.* (42) for banana and the Cd mean concentration range of various fruits from Anambra state , Nigeria (5). However, the results obtained in the present study for Cd concentration were lower than those detected in some fruit and vegetable with a 25 mg/kg average value (46) and the reported Cd in fruits from Bangladesh (38).

The mean Zn values in the studied fruits falls below the WHO permissible limit of 5.00 mg/kg for Zn in fruits (47). But the values are similar to those reported by Elbagermi et al. (42) and the results of a study conducted in fruit samples from some market in Anambra state Nigeria (5), but far below the range reported by Pehlivan *et al.* (1) in 2015 (10.24-30.24 mg/kg) in fruits and that reported in a study conducted by Mahfuza *et al.* (33). Manufacturing concerns such as galvanization, paint, batteries, smelting, fertilizer and pesticides, fossil fuel combustion, pigment, polymer stabilizer have been reported to emit the heavy metal Zn to the environment (48), which may explain to observed values in the present study as Katsina state is mostly an agrarian state with a handful of industries mainly located in the state capital.

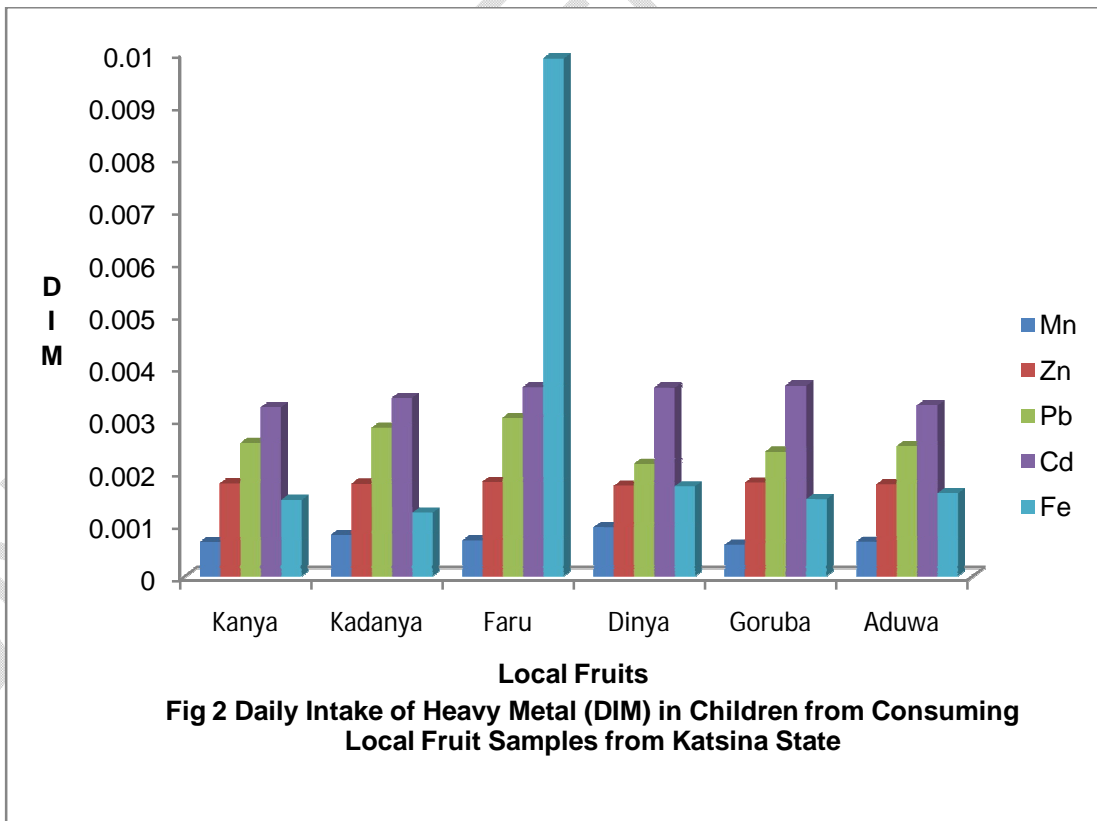
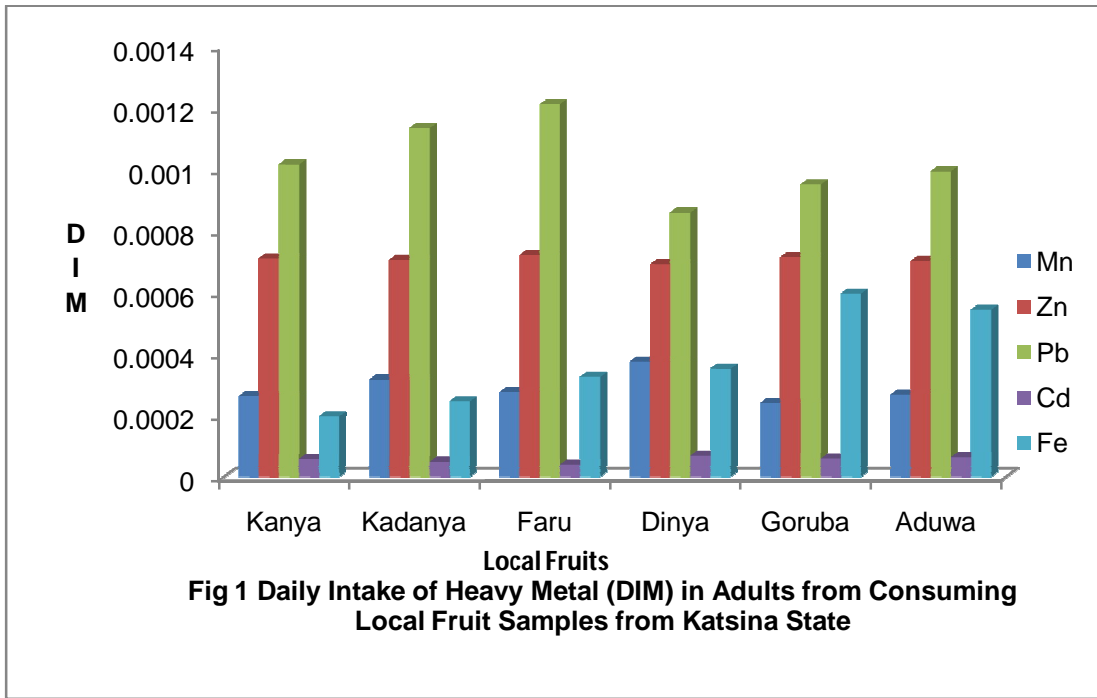
In the present work, Mn content of fruit samples is lower to that reported in fruits from Turkey (1) and Poland (35).

Table 1 Heavy Metal Concentration (mg/kg) in Local Fruit Samples from Katsina State

Location	Heavy Metal						
	Mn	Zn	Pb	Cd	Ni	Fe	Cr
Kanya	0.351±0.0004	0.952±0.0012	1.362±0.0001	0.078±0.0003	BDL	1.728±0.0004	BDL
Kadanya	0.423±0.0012	0.263±0.0006	1.520±0.0002	0.065±0.0008	BDL	1.825±0.0012	BDL
Faru	0.368±0.0003	0.967±0.0002	1.623±0.0003	0.053±0.0002	BDL	1.936±0.0008	BDL
Dinya	0.502±0.0001	0.925±0.0016	1.152±0.0002	0.092±0.0001	BDL	1.932±0.0025	BDL
Goruba	0.321±0.0003	0.958±0.0006	1.274±0.0002	0.074±0.0006	BDL	1.951±0.0001	BDL
Aduwa	0.357±0.0003	0.941±0.0006	1.331±0.0002	0.085±0.0003	BDL	1.748±0.0006	BDL

Values are expressed as Mean ± Standard Deviation

The results for the estimated daily intake (EDI) of the heavy metals on consumption of the fruits were given in Figures 1 and 2. From the Figures, the estimated daily intake of the heavy metals (Pb, Zn, Cd, Fe and Mn) were lower than the tolerable daily intake limit set by the USEPA (49) in both samples for both the adult and children consumer population.



The calculated THQ through the consumption of the present study fruit samples provide a measure of the evaluated metal contaminants although it does not measure the risk of exposure but rather give an estimate of level of concern (43). The consumption of the study local fruits pointed to an indication of no adverse health effect for both the children and adults population of the study area, because the calculated fruit samples THQs are <1 ; hence, it may be assumed that the study fruit samples are safe for consumption (Tables 2 and 3). The THQ for the samples was in the decreasing order Mn>Zn>Fe>Pb>Cd, for all the samples respectively. Similar observations of THQs <1 have been reported previously in studies that have evaluated heavy metals in foods from Katsina state, Nigeria (10; 11; 12; 13; 14; 15; 16; 17). The cumulative HI to the population which is the representation of the non-cancer risk for all studied fruits, showed the risk level (HI < 1) with the highest value in Dinya fruit and lowest in Goruba fruit (Tables 4 and 5).

Table 2 Heavy Metal Target Hazard Quotient and Health Risk Index in Adults from Consuming Local Fruit Samples from Katsina State

Location	Target Hazard Quotient					Health Risk Index (HRIs)
	Mn	Zn	Pb	Cd	Fe	
Kanya	0.023367	0.002475	0.001695	0.000117	0.001843	0.028794
Kadanya	0.032664	0.002352	0.001891	0.000097	0.001946	0.038950
Faru	0.025729	0.002552	0.002020	0.000079	0.002065	0.032445
Dinya	0.037836	0.002302	0.001433	0.000014	0.002061	0.043646
Goruba	0.021652	0.002454	0.001585	0.000012	0.002081	0.027784
Aduwa	0.023897	0.002342	0.001656	0.000127	0.001864	0.029886

Table 3 Heavy Metal Target Hazard Quotient and Health Risk Index in Children from Consuming Local Fruit Samples from Katsina State

Location	Target Hazard Quotient					Health Risk Index (HRIs)
	Mn	Zn	Pb	Cd	Fe	
Kanya	0.046795	0.005923	0.004202	0.002912	0.004608	0.064439
Kadanya	0.056394	0.005879	0.004728	0.002426	0.004866	0.074294
Faru	0.049061	0.006016	0.005049	0.000198	0.005162	0.065486
Dinya	0.066926	0.005755	0.003584	0.003435	0.005151	0.084851
Goruba	0.042795	0.005960	0.003963	0.002949	0.005202	0.060870
Aduwa	0.047375	0.005855	0.004140	0.003173	0.004661	0.065204

The International Agency for Research on Cancer (IARC) has listed the heavy metals Cd and Pb IARC as being carcinogenic agents (50; 51). Chronic exposure to low doses of Cd, and Pb could therefore manifest into various types of cancers (6). Tables 4 and 5 are the representations of the total cancer risk of heavy metals to the children and adults consumer population in the study fruit samples. From the tables a deduction can be made that the cancer risks for the heavy metal Cd in the adults population was at the threshold of the risk limit (ILCR > 10⁻⁴) for cancer, while the metal Pb in adults and the metals Pb and Cd in children were above the risk threshold (ILCR ≤ 10⁻³) for cancer. The trend of risk for developing cancer as a result of consuming the studied fruits showed: Faru > Kadanya > Kanya > Goruba > Dinya > Aduwa.

Table 4 Incremental Life Time Cancer Risk from in Adults Consuming Local Fruit Samples from Katsina State

Location	ILCR		ΣILCR
	Pb	Cd	
Kanya	6.406000E-03	8.730000E-04	7.280000E-03
Kadanya	7.149000E-03	7.280000E-04	7.877000E-03
Faru	7.634000E-03	5.930000E-04	8.227000E-03
Dinya	5.418000E-03	1.030000E-03	6.449000E-03
Goruba	5.992000E-03	8.850000E-04	6.877000E-03
Aduwa	6.260000E-03	9.520000E-04	6.260000E-03

Table 5 Incremental Life Time Cancer Risk in Children from Consuming Local Fruit Samples from Katsina State

Location	ILCR		Σ ILCR
	Pb	Cd	
Kanya	1.601533E-02	2.183745E-03	1.819908E-02
Kadanya	1.787320E-02	1.819785E-03	1.969299E-02
Faru	1.908434E-02	1.483830E-03	2.056817E-02
Dinya	1.354601E-02	2.576100E-03	1.612211E-02
Goruba	1.498056E-02	2.211750E-03	1.719231E-02
Aduwa	1.365081E-02	2.379720E-03	1.603053E-02

4. CONCLUSION

Results from this study have shown that concentration values of Pb in the samples were generally above the USEPA, WHO/FAO maximum permissible limits. The results have indicated that the estimated daily intake of the heavy metals were lower than the tolerable daily intake limit set by the regulatory bodies in both samples. Risk level of Target Hazard Quotient (THQ < 1) was observed for all the evaluated heavy metals for both adults and children. ILCR for Cd is at the threshold risk limit ($>10^{-4}$) in all the studied fruits in adults, While Pb for adults and Cd for children lies within the moderate risk limit ($>10^{-3}$) and Pb in children is above the moderate risk limit ($>10^{-2}$) in children. Moreover, cumulative cancer risk (Σ ILCR) of all the studied fruits reached the moderate risk level ($>10^{-3}$) in adults while in children it is above the level ($>10^{-2}$). The study suggests that consumption of the studied local fruits in Katsina state is of public health concern as they may contribute to the population cancer burden.

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