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Research Article

The Hidden Table Salt in Synthetic Food Coloring Materials

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Abstract

The purpose of the research was to investigate the presence of hidden table salt (sodium chloride, NaCl) in seven synthetic food colors (saffron yellow, apple green, lemon yellow, orange red, tomato red, raspberry red 1, and raspberry red 2) commonly used in Zanzibar. The samples were collected from Mwanakwerekwe and Darajani Zanzibar. The analysis involved sodium (Na), potassium (K), magnesium (Mg), calcium (Ca), aluminium (Al), and chloride (Cl) in food colors which were analyzed by an Energy Dispersive X-Ray Fluorescence (EDXRF) technique with a Rigaku NEX CG EDXRF model spectrometer. The concentrations of elements in food colouring material were then compared with Food and Agriculture Organization/World Health Organization (FAO/WHO) safe limits. Remarkably, the levels of Na in all samples were higher than safe limits. The maximum detected levels of K, Mg and Ca were also higher than safe limits. Nevertheless, the standard safe limits of Al and Cl are currently not yet in the list of FAO neither in WHO. The percentage composition of Na, Cl, Ca, Mg, K, and Al are found to be 59.1%, 37.6%, 1.0%, 1.0%, 0.7% and 0.7% respectively. Thus the study suggests that a large proportion of food color is in the form of sodium and chloride, which signifies the elemental composition of the table salt (NaCl) which serves as the base in the food coloring matter. The high concentrations of sodium and chloride should be noted precautiously for the consumers with dietary salt restrictions. Excessive intake of sodium could trigger major risks for high blood pressure, which in turn associated with several health complications including an increased risk of cardiovascular diseases such as heart disease and stroke.

Keywords: Table salt; Food color; Dietary sodium; High blood pressure; Stroke

Introduction

Food coloring materials are extensively utilized in the food industry to enhance the visual appeal of products, making them more attractive to consumers [1]. These additives are primarily valued for their ability to impart vibrant colors, thereby increasing the marketability of various food items [2]. However, beyond their intended function, food colorants may contain several elements that are not immediately apparent, raising concern about their potential impact on public health [3]. Among these hidden components, sodium chloride, commonly known as table salt, is particularly noteworthy due to its association with various health risks [4]. Yet sodium and chloride are not the only elements presents in these additives, other elements including K, Mg, and Rb. Ca, strontium (Sr), Al, iron (Fe), silicon (Si), phosphorous (P), sulphur (S) and many others may also found in varying concentrations [5]. The presence of sodium chloride in food colorants is of particular concern given the established link between excessive sodium intake and the presence of hypertension, cardiovascular diseases and other related health conditions [5]. Sodium helps regulate fluid balance in the body, although consuming too much sodium make the body to retain more water in order to balance sodium levels in the blood stream, this in turn increases the volume of blood leading to higher pressure on blood vessel walls, which raises blood pressure [10].

The chronic hypertension caused by high sodium intake increases the risk of cardiovascular diseases, including heart attack, stroke and heart failure [11]. In many regions, dietary salt consumption already exceeds recommended levels, and the unrecognized contribution of food colorants to overall sodium intake could exacerbate this public health issue [6].

Furthermore, the presence of other elements such as heavy metals like uranium and essential minerals like calcium, iron and zinc in these colorants adds an additional layer of complexity [7]. While essential minerals are necessary for maintaining bodily functions, their presence in unregulated amounts can lead to imbalances and interfere with metabolic processes [8]. On the other hand heavy metals are toxic even at low concentrations and pose the long-term health consequences [9].

This study aims to comprehensively investigate the presence and concentration of sodium chloride alongside the four other elements K, Mg, Ca, and Al in various food coloring materials that are commonly used in Zanzibar. Ultimately, this study is aiming at contributing to the broader discourse on food safety and public health by providing actionable insights that can help mitigate the risks associated with the use of food colorants.

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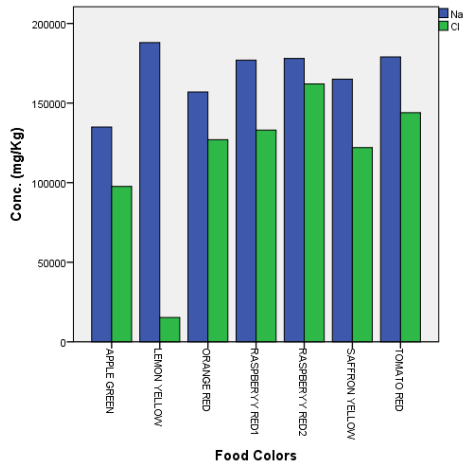

Figure 1: Level of sodium and chloride in food color samples.

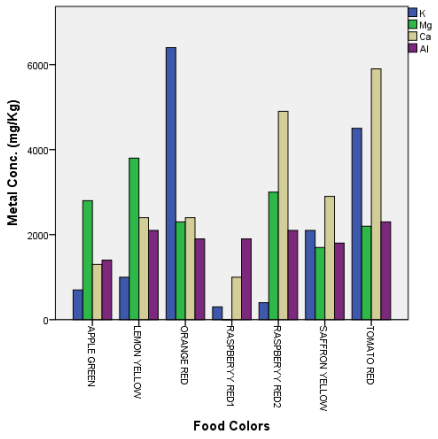

Figure 2: Level of K, Mg, Ca and Al in food color samples.

Materials and Methods

Sampling

Seven samples of food coloring were meticulously gathered from different vendors operating within Zanzibar's bustling Mwanakwerekwe and Darajani Markets, each sample exclusively in powder form. These samples encompassed a spectrum of vibrant hues: saffron yellow, apple green, lemon yellow, orange red, tomato red, raspberry red 1, and raspberry red 2. Notably, six of these samples were distinctively branded products, reflecting a variety of commercial sources and likely differing in formulation and origin. In contrast, one sample stood unbranded, potentially indicating a local or less widely recognized source within the market landscape. This diverse collection provides a snapshot of the availability and diversity of food coloring options within these vibrant market places.

Labeling of Samples

After gathering these seven samples from two distinct markets, they were transported to the Chemical and Environmental Laboratory at the Africa Minerals and Geosciences Centre (AMGC) in Tanzania for chemical analysis. Each sample was carefully labeled to facilitate clear interpretation of the test results, following the labeling scheme outlined in the table 1.

Table 1: Labelling of Food Colour in Samples.

Serial No	Food Coloring Sample	Codes
1	Apple Green	AG
2	Raspberry Red1	RR1
3	Lemon Yellow	LY
4	Orange Red	OR
5	Raspberry Red2	RR2
6	Saffron Yellow	SY
7	Tomato Red	TR

Table 2: Concentration of Elements in Food Coloring Samples.

Sample	Element Conc. (mg/Kg)					
	Na	K	Mg	Ca	Al	Cl
AG	135000	700	2800	1300	1400	97600
RR1	177000	300	BDL	1000	1900	133000
LY	188000	1000	3800	2400	2100	15300
OR	157000	6400	2300	2400	1900	127000
RR2	178000	400	3000	4900	2100	162000
SY	165000	2100	1700	2900	1800	122000
TR	179000	4500	2200	5900	2300	144000

BDL: Below Detection Limit

Descriptive Statistics of the Results

The general summary for descriptive statistics were shown in the Table 3.

The data presents the concentrations of various elements found in a sample, alongside their respective WHO standards and references. Sodium (Na) levels range from 135,000 to 188,000 mg/kg with a mean of 168,429 mg/kg, which is significantly above the WHO standard of 250 mg/kg. Potassium (K) concentrations span from 300 to 6,400 mg/kg, averaging 2,200 mg/kg, which is below the WHO standard of 3,500 mg/kg. Magnesium (Mg) ranges from below detection limit (BDL) to 3,800 mg/kg, with a mean of 2,257 mg/kg, surpassing the WHO standard of 400 mg/kg. Calcium (Ca) varies from 1,000 to 5,900 mg/kg, with an average of 2,971 mg/kg, which is below the WHO standard of 1,300 mg/kg. Aluminum (Al) levels range from 1,400 to 2,300 mg/kg, averaging 1,928.57 mg/kg, with no WHO standard available. Iron (Fe) concentrations range from 28 to 75 mg/kg with a mean of 50.14 mg/kg, surpassing the WHO standard of 19.6 mg/kg. Chlorine (Cl) concentrations range from 15,300 to 162,000 mg/kg, averaging 114,414.29 mg/kg, with no WHO standard provided. Overall, many of the measured elements exceed the WHO standards, particularly sodium, magnesium, and potassium, which could indicate potential concerns regarding their levels in the sample (Table 3).

Chronological Order of Elements Levels in Analyzed Food Colors

The actual trend of Na, K, Mg, Ca, Al and Cl concentration in decreasing order as observed in seven food coloring samples are summarized in Table 4.

Table 3: Descriptive Statistics of the Results.

Element	Min conc.	Max conc.	Mean	WHO Standard	Reference
Na	135000	188000	168428.57	250	Rasheed *et al.* 2020 [12]
K	300	6400	2200.00	3500	Nantel and Tontisirin 2001 [13]
Mg	BDL	3800	2257.14	400	Puscion-Jackubik *et al.* 2021 [14]
Ca	1000	5900	2971.43	1300	Nantel and Tontisirin 2001 [13]
Al	1400	2300	1928.57	NF	NF
Cl	15300	162000	114414.29	NF	NF

NF: Not Found

Table 4: Trend of Na, K, Mg, Ca, Al and Cl in Food Colors.

Element	Trend of Metal Composition in Descending Order
Na	LY > TR > RR2 > RR1 > SY > OR > AG
K	OR> TR > SY > LY > AG > RR1 > RR2
Ca	TR > RR2 > SY >LY = OR >AG > RR1
Mg	LY > RR2 >AG > OR >TR > SY > RR1
Al	TR > LY = RR2 > RR1 = OR > SY > AG
Cl	RR2 > TR > RR1 > OR > SY > AG > LY

Table 5: The percentage composition of each element in food colors.

Sample	Percentage composition of element (%)					
	Na	K	Mg	Ca	Al	Cl
AG	56.5	0.2	1.2	0.5	0.6	40.9
RR1	56.5	0.1	BDL	0.3	0.6	42.5
LY	88.4	0.5	1.8	1.1	1.0	7.2
OR	52.9	2.2	0.8	0.8	0.6	42.8
RR2	50.8	0.1	0.9	1.4	0.6	46.2
SY	55.8	0.7	0.6	1.0	0.6	41.3
TR	53.0	1.3	0.7	1.7	0.7	42.6
Average %	59.1	0.7	1.0	1.0	0.7	37.6

Percentage Composition of Analyzed Elements

The table 5 presents the percentage composition of each element for all samples analyzed.

Na and Cl Levels in Food Colors

Both Sodium and Chloride show high concentrations across all samples, with notable variations. The lowest concentration of sodium was detected in AG whereas the highest concentration was detected in LY, in contrast chloride showing highest concentration in RR1 and lowest concentration in SY as seen in Figure 1.

The presence of sodium and chloride in food colors, is a subject of considerable importance due to their impact on health and product quality. But the presence of high levels of sodium and chloride lead to various health implications. Excessive sodium intake is a major risk factor for hypertension (high blood pressure), which in turn is associated with an increased risk of cardiovascular diseases, including heart disease and stroke. Sodium contributes to fluid retention, leading to edema (swelling) and potentially straining renal function as the kidneys work to excrete the surplus. Long-term consumption of high-sodium foods can exacerbate kidney disease and other related health issues.

On the other hand, Elevated chloride levels can also have health implications, particularly concerning the body's acid-base balance. Chloride, along with sodium, plays a critical role in maintaining this balance; excessive chloride can disrupt this equilibrium, leading to metabolic acidosis. High chloride levels may also contribute to dehydration by altering electrolyte balance, which can affect overall bodily functions and health.

K, Mg, Ca and Al in Food Colors

The analysis of the nutrient data reveals significant variability in mineral concentrations among the food coloring samples. Lemon Yellow stands out with the highest magnesium (3800 mg/Kg) and calcium (2400 mg/Kg) levels, indicating its potential for superior health benefits. In contrast, Raspberry Red1 has no detectable magnesium, which may limit its nutritional value. Orange Red shows the highest potassium content (6400 mg/Kg), which could be advantageous for maintaining electrolyte balance. Meanwhile, Tomato Red and Raspberry Red2 both demonstrate high calcium levels (5900 mg/Kg and 4900 mg/Kg, respectively), suggesting they could contribute to bone health. The presence of aluminum across the samples varies, with Raspberry Red1 containing the most (1900 mg/Kg) as seen in figure 2.

Conclusions

From the observations of present study, it may be concluded that almost all analysed food colors contains high level of sodium and chloride as compared with other analzed elements (K, Ca, Mg and Al). The percentage composition of Na, Cl, Ca, Mg, K and Al are 59.1, 37.6, 1.0, 1.0, 0.7 and 0.7% respectively. The significant levels of both sodium (59.1%) and chloride (37.6%) suggest that a large proportion of food color is in the form of sodium chloride (NaCl) which serves as the base or carrier in the color mixture. The high concentration of sodium chloride should be noted especially for consumers with dietary sodium restrictions. The lower percentages of calcium (Ca), magnesium (Mg), potassium (K) and aluminium (Al) indicates they are likely minor additives or incidental components.

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