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ORIGINAL ARTICLE

MINERAL ANALYSIS OF FLOUR OF YOUNG SHOOTS OF ROAN (*Borassus Aethiopum* Mart.) PRODUCED AFTER THREE DRYING MODES: FS, F40 and F50

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ABSTRACT

Introduction: The young shoots of roan are produced and consumed in Dimbokro, in central Côte d'Ivoire. However, they are delicately preserved and their nutritional value remains little explored. In this study, the product was sun and oven dried at 40°C and 50°C and then ground to produce flours with respective codes FS, F40 and F50. **Context**: In recent years, illegal gold mining has become established with unfortunate consequences for the ecosystem and agrosystems practised in the region. Also, farmers use chemicals (pesticides, fertilisers) in their plantations. **Objectives**: The general objective of this work is to evaluate the mineral composition of young shoot flours produced according to three drying methods in order to perceive the impact of illegal gold mining and agricultural practices in the Dimbokro area on the quality of the food produced. **Methods**: The samples were then subjected to analysis of their mineral composition by air-acetylene flame atomic absorption spectrometry using an AAS 20- Type VARIAN device. **Results:** This analysis revealed the significant presence of minerals essential to health such as Sodium (0.044 to 0.115 ppm), Phosphorus (0.019 to 0.021 ppm), Potassium (0.068 to 0.181 ppm), Calcium (0.110 to 0.122 ppm), Iron (0.043 to 0.069 ppm). However, this study also showed the presence of heavy metals such as lead (0.012 to 0.037 ppm), Arsenic (0.043 to 0.056 ppm), Mercury (0.076 to 0.142 ppm). **Conclusion**: We found that only mercury is the heavy metal with a hazard quotient greater than 1, which constitutes a significant health risk following the consumption of young shoots. The agro-system of young shoots of roan production and illegal gold panning in the study area should be regulated to avoid the concentration of heavy metals in consumer products.

***Mots-clés**: Borassus aethiopum, young shoots, drying, flours, mineral elements.*

1. INTRODUCTION

Borassus palm is a dioecious tree plant [1] with multiple uses, which has important socio-economic characteristics for the population. Its fruits are consumed as food or as a food supplement [2]; and other parts are used for handicrafts, pharmacopoeia, drilling, energy, fertilisation and construction [3]. In Côte d'Ivoire, the roan palm is an important resource for rural populations in the 'V' Baoulé savannah regions [1]. The sap extracted from the roan and consumed as traditional wine [4] constitutes a considerable source of income and an important social value of this plant [1]. From these mature fruits, young shoots are obtained after germination, 6 to 8 months later [5, 6], with an average of 3 shoots per fruit. Thus, a significant proportion of the fruits that fall from the tree after ripening germinate in the forest for the natural regeneration of the roan tree, while another part is regularly recovered by rural populations for food or to produce young shoots for consumption. The latter are similar to cassava roots and are consumed in cooked or roasted form. To this end, young shoots of roan tree are considered a libido enhancer and aphrodisiac for men [7, 8]. They also contain a high proportion of starch [9], estimated at 35.23g starch/100g, of which 20.27g is digestible starch per 100g of product [10]. However, in their fresh state, young shoots have an average moisture content of 52%, which favours their rotting shortly after harvest and storage [11]. This rapid deterioration makes it difficult to consume the product periodically, with considerable post-harvest loss; hence the need to process it into flour. This alternative facilitates storage and allows people to keep it longer for various uses.

Exposure to the sun is the most accessible drying technique practiced in rural areas. Although this drying technique significantly reduces water activity, it rarely results in completely dry products, especially for high-moisture commodities processed in environments where air humidity is itself high. Faced with this shortcoming, steaming is an alternative to solar drying, but with risks of degradation of the biocompounds of the product; risks directly correlated to the temperature-time pair constituting the drying schedule.

Furthermore, the department of Dimbokro is located in a gold mining area [12]. In recent years, illegal gold mining has become established with unfortunate consequences for the ecosystem and agrosystems practised in the region. Gold miners regularly use chemicals that contaminate water and food products in the mined areas. Small-scale artisanal gold mining using mercury (Hg) smelting for gold recovery has been identified as one of the biggest contributors to mercury pollution, contaminating the atmosphere, water and people [13, 14]. A study conducted on a site contaminated by mining discharges in northwest Tunisia showed significant levels of heavy metals (Zn, Cu, Cd, Pb) in the root zone of some plants, with lower concentrations found in the aerial zone [15]. Also, farmers use chemicals (pesticides, fertilisers) in their plantations. Nowadays, agricultural and industrial activities are sometimes dependent on pesticides and fertilisers that lead to contamination with heavy metals and other organic components that become pollutants for the environment. The transfer of these pollutants in agricultural products, and in particular heavy metals, represents serious public health problems [16]. They are the third source of risk for food and feed after mycotoxins and microorganisms [17]. These two (2) activities can contaminate food with heavy metals that are harmful to health. The general objective of this work is to evaluate the mineral composition of young shoot flours produced according to three drying methods in order to perceive the impact of illegal gold mining and agricultural practices in the Dimbokro area on the quality of the food produced. The young shoots flours (FS, F40 and F50) were first produced from sun and oven drying at 40°C and 50°C, respectively. Then their mineral content was assessed and daily intakes were estimated from consumption projections of these products in order to consider exposure risks regarding toxic chemical elements.

2. MATERIAL AND METHODS

2.1. Biological material

The young shoot of roan is the main biological material in this experiment. It is 8 months old.

2.2. Sampling: Samples of young shoots were purchased in three (3) markets in the town of Dimbokro. For each market, 20 kg of young shoots were purchased from three (3) vendors, making 60 kg of young shoots purchased per market. The total was 180 kg for all three markets. The young shoots were then transported to the laboratory, mixed for the different analyses.

2.3. Production of young shoots flour: The young shoots flour was obtained in several steps. First, the tubers of young shoots were peeled, washed and cut into small pieces. These pieces were then divided into three (3) batches which were dried respectively in an oven at 40°C, at 50°C and in the sun for 4 days. Finally, the dried pieces of tubers from each batch were crushed and the crushed material was sieved using a 2mm diameter sieve. Thus, three (3) types of young shoots flour were obtained: F40, F50, and FS, respectively for oven drying at 40°C, 50°C and sun drying.

2.4. Determination of minerals

The determination of minerals is carried out by atomic absorption with an air-acetylene flame AAS 20 type VARIAN. FS, F40, F50 flours are ground to 0.1mm. 0.3 g of each flour is calcined at 600°C for 5 h in a furnace until a white ash is obtained. After cooling, 5mL of 1N nitric acid was added and evaporated to dryness on a sand bath. To the residue is added 5mL of 1N hydrochloric acid and the whole is fired again at 400°C for 30 min. Once the calcined product (residue) is recovered from the oven, 10mL of 0.1N hydrochloric acid is added to the crucible to recover the product. The resulting mixture is poured directly into a 50 ml volumetric flask. The operation (washing the crucible with 10 ml of 0.1 N HCl) is repeated three times and the flask is filled to the mark. Allow to decant and take the supernatant for filtration through a 0.36 µm syringe filter. The elements contained in the solution are then determined by AAS. To avoid interference from the elements Ca, K, 5 ml of lantane chloride are added.

2.5. Estimation of mineral intake

A deterministic approach was adopted for the estimation of mineral intake. It consisted of multiplying a fixed value of dietary intake of young shoots of roan by a fixed value of minerals from the young shoots and dividing this product by the actual body weight of the individual [18,19]. The daily per capita consumption of young shoots was estimated at 500g. The intake of these minerals was calculated according to the formula:

$$AJE = (Ci \times Q)/P \quad (1)$$

Where:

AJE is the estimated daily intake of the mineral (µg/kg bw/d) by a 60 kg adult individual,
Ci: is the average concentration of the mineral (µg/kg),
Q: is the amount of flour consumed per day per capita (kg),
P: is the body weight (kg).

The **AJE** was then divided by the Tolerable Daily Intake (DJT) of these minerals to determine the hazard quotient which must be less than 1.

2.6. Statistical study

All analyses were performed in triplicate and the data processed using the Statistical Program for Social Sciences (SPSS version 20.0, SPSS for Windows, USA). For each characteristic, the results were expressed as means followed by their standard deviations as data dispersion parameters. A one-way analysis of variance (ANOVA 1) was also performed to test the effect of flour on the characteristics evaluated, at the 5% statistical significance level. For statistically different means, classification was performed with the Student-Newman-Keuls test.

3. RESULTS AND DISCUSSION

3.1 Description of minerals

The results of this study showed the presence of several minerals (Table 1) in young shoots flours. Some of them were affected by the drying temperature. Indeed, the mineral contents increased with temperature. This increase in the mineral content of the young shoot flours would be due to the effect of the heat. This can be explained by the fact that certain anti-nutritional factors interfere with the availability of minerals by complexing them in their structure, as suggested by Alonso et al., (2001) [20] and Anigo et al., (2009) [21]. The degradation of these anti-nutritional factors by heat releases these minerals into the matrix [22].

Among the minerals, we have boron, Vanadium, Chromium, Iron, and Nickel, Copper, Gold which are trace elements. Trace elements are present in very small quantities in the human body and have an essential biological function. As the body does not know how to produce them, we find them in our diet when it is healthy, and in supplements, as we have to cope with pollution, pesticides and fertilizers and stress.

The boron content of flours increases with increasing drying temperature (0.138 to 0.195 ppm). The boron content of our three (3) flours is lower than that of white wheat flour (9.65 ppm). Boron is a trace element that is present throughout the body. In particular, it plays a role in the formation of bones, the manufacture of red blood cells and the cells of the immune system [23].

The vanadium content of the three (3) flours increases with increasing drying temperature (0.145 to 0.352 ppm). The vanadium content of our three flours is lower than that of radishes (79 ppm) and higher than that of carrots (0.01 ppm). Vanadium is a trace element which increases insulin sensitivity and helps to combat type 2 diabetes is involved in numerous enzymatic reactions, is involved in iron metabolism, inhibits cholesterol synthesis, helps to ensure good mineralization of bones and teeth, and helps to treat certain eating disorders [24]. The chromium content of FS, F40, F50 flours increases with increasing drying temperature (0.081 to 0.223 ppm). The content of our three (3) flours is lower than that of dried dates (0.29 ppm). Nevertheless, the contents of FS, F40, F50 flours are lower than the threshold limit set by the Chinese hygiene standard for wheat (1 ppm) [25]. The chromium content of FS (0.081 ppm) and F40 (0.089 ppm) flours is lower than that of Chinese wheat flour (0.109 ppm) [25], which in turn is lower than F50 flour (0.223 ppm). Chromium is a trace element. Chromium facilitates the action of insulin, a hormone that regulates blood sugar levels. It is thus involved in the metabolism of carbohydrates (sugars), lipids (fats) and proteins

The iron content of the three (3) flours increases with increasing drying temperature (0.043 to 0.069 ppm). The iron contents of our flours are lower than that of sweet potato flour (10.97 ppm) revealed by Ofori et al., (2016) [26]. The iron values of the three (3) flours is below the limit of 15 mg/Kg set by WHO as the limit of iron in food [27]. Iron plays an important role in the human body. The hemoglobin in the red blood cells absorbs the 70% of iron consumed. This allows oxygen to function properly. This oxygen is then transmitted to the cells. Iron is also found in the myoglobin of the muscles, which enables air to be stored. The remaining 30% of iron plays a role in activating the body's metabolisms. It contributes greatly to the production of energy and the activation of the immune system [28]. Iron deficiency anaemia affects one third of the world's population. However, excessive iron intake causes colorectal cancer [29].

The nickel content of FS, F40, F50 flours increases with increasing drying temperature (0.015 to 0.278 ppm). The nickel content of the flours is lower than that of desiccated coconut (1.36 ppm). The contents of the three (3) flours are lower than the limit set by FAO/WHO, (1984) [30] (1.63 ppm). Nickel is a trace element; it is involved in the assimilation and metabolism of iron, and seems to be essential for the action of several enzymes.

The copper content of the three flours increases with increasing drying temperature (0 to 0.858 ppm). The copper content of the flours is lower than that of taro flour (6.63 ppm) revealed by Ofori et al., (2016) [26]. This is well below the WHO limit of 40 ppm for Copper in food [27]. Copper is an "essential trace element for the functioning of the body. It is a powerful antioxidant, which helps to combat cellular stress in the event of excess oxidation problems. It allows the assimilation of iron, which itself allows the production of red blood cells. It contributes to the formation of the immune system. It plays a role in glucose metabolism. It plays a role in the regulation of neurotransmitters, as it is a cofactor in the synthesis of noradrenaline. It thus contributes to the normal functioning of the nervous system. It is involved in the synthesis of melanin and thus provides better defense against UV rays [31].

The gold content of FS, F40, F50 flours increases with increasing drying temperature (0 to 0.045 ppm). Certain foods such as potatoes and parsley draw this trace element from the soil. "Taken in the form of a trace element, gold stimulates the body's defense and adaptation capacities in the face of disturbances in the immune system. After a physical shock (fall, surgery) or psychological shock (depression, nightmares, loss of vitality, repeated infections), it strengthens immunity and helps to fight against stress. "This natural doping agent owes its anti-fatigue and anti-stress properties to its capacity to activate the functioning of the adrenal glands and, therefore, to stimulate the release of cortisol [32]. Our study also showed the presence of macroelements (mineral salts) such as sodium, magnesium, phosphorus, potassium, calcium. The sodium content of the three flours increases with increasing drying temperature (0.044 to 0.115 ppm). The Sodium content of the flours is lower than that of soy sauce (62600 ppm). Sodium plays an important physiological role in humans at several levels, as it is involved in: controlling the volume of the extracellular medium (which refers to the body's fluid balance), maintaining the electrochemical gradient of cells, transmission of nerve impulses, muscle contraction, and intestinal absorption of certain nutrients [33]. With its low sodium content, the flour of young shoots of roan could be used as food without any apprehension of health risk for people suffering from high blood pressure.

The potassium content of the three flours increases with increasing drying temperature (0.068 to 0.181 ppm). The same is true for magnesium, which increases from 0 to 0.243 ppm. Potassium is a mineral that increases cardiovascular well-being, as does magnesium, which is recommended for the prevention of certain complications of myocardial infarction [34, 35]. The potassium content of the flours is lower than that of pistachios (10200ppm). The magnesium content of the flours is lower than that of almonds (2355ppm). There is no significant difference between the calcium contents of FS, F40, F50 flours. The same is true for the phosphorus content of the three flours. The overall averages for calcium and phosphorus are respectively 0.115 ppm and 0.02 ppm at the 5% threshold. The calcium content of the flours is lower than that of the rice (100 ppm) The phosphorus content of the flours is lower than that of brown rice (2350 ppm) A diet rich in calcium and phosphorus is a factor in the prevention of osteoporosis and also a factor in reducing the risk of high blood pressure, colon cancer and prostate cancer [36].

In contrast to the minerals described above, the presence of metals such as lead, antimony, barium, mercury, tin and arsenic in the three flours may present risks for the population consuming these flours. For this reason, for the different minerals and metals we will calculate the hazard quotient (AJE/DJT) which must be less than 1. The amount of lead in our three flours (0.012 to 0.037 ppm) is much lower than the amounts of lead detected in wheat flour manufactured in Ghana and Turkey (0.22 ppm and 0.34 ppm) revealed by Doe et al., 2013 [37]. The lead content of our flours is below the limit defined by the Codex Alimentarius [38] for tubers (0.1 ppm). Lead has no known physiological role in humans: its presence in the body always indicates contamination. It can be incorporated by the digestive, respiratory or blood route between the mother and the fetus. It is then distributed in the blood, soft tissues, and especially in the skeleton (94%) where it progressively accumulates and remains stored for a very long time (half-life greater than 10 years). Lead can cause kidney masses, affect cognitive development and can lead to cardiovascular disease in adults [39].

Antimony is an endocrine disruptor, according to a WHO report, interfering with our body's hormones, leading to serious health problems, such as prostate cancer in men, developmental disorders of the nervous system and growth of sexual organs in children, hormonal imbalances and thyroid cancer. Antimony is in low proportion in our flours (0.01 to 0.05 ppm). The levels of Barium naturally present in the environment are very low. Large amounts of barium can only be found in soils and foods such as nuts, algae, fish and some plants. The amount of barium that is detected in food or water is generally not high enough to become a health concern. Barium is only present in F40 and F50 flours. It is present at low levels (0.085 ppm). The mercury content of our flours (0.076 to 0.142 ppm) is higher than the mercury content of wheat flour from China (0.0017 ppm) revealed by Lei et al., (2015) [25]. Mercury is considered by WHO as one of the top ten chemicals or group of chemicals of public health concern. Mercury can have toxic effects on the nervous, digestive and immune systems, as well as on the lungs, kidneys, skin and eyes [18]. The amount of mercury in FS (0.076 ppm) and F40 (0.077 ppm) flours is below the codex alimentarus [38] threshold limit for food salt (0.1 ppm). The F50 flour (0.142 ppm) is above the threshold limit.

Tin is mainly used in various organic substances. Tin-organic bonds are the most dangerous forms of tin for humans. Despite the danger, these products are used in a large number of industries such as the paint and plastics industry and in agriculture (pesticides). The number of applications of organic substances with tin is constantly increasing despite the fact that the consequences of tin poisoning are known. The long-term effects are: depression, liver damage, immune system dysfunction. Tin is only present in F50 flour in a small proportion (0.07 ppm), it is well below the maximum threshold recommended by the Codex Alimentarius [38] (50 to 250 ppm). The arsenic present in our flours (0.043 to 0.056 ppm) is higher than the arsenic present in Chinese wheat flour (0.028 ppm) revealed by Lei et al., (2015) [25]. Arsenic is also considered toxic. Ingestion of arsenic leads to gastrointestinal symptoms, cardiovascular system disorders and nervous system functions. Long-term exposure to arsenic is linked to an increased risk of cancer [40]. Arsenic is present in our flours in low proportions (0.043 to 0.056 ppm), below the limit recommended by the codex alimentarus [38] (0.1 to 0.5 ppm). Chemical fertilisers and pesticides contain several types of heavy metals [41], in particular arsenic in phosphate fertilisers, whose prolonged use with herbicides and insecticides can cause an accumulation of arsenic [42].

Table 1: the average concentrations of minerals in FS, F40 and F50 flours.

Parameters	FS	F40	F50	General Average	P-value
Boron (ppm)	0.138±0.01^{a}	0.195±0.005^{b}	0.264±0.004^{c}		0.000
Sodium (ppm)	0.044±0.001^{a}	0.075±0.004^{b}	0.115±0.004^{c}		0.000
Magnesium (ppm)	0^{a}	0.000002^{a}	0.243±0.018^{b}		0.000
Phosphorus (ppm)	0.019±0.005^{a}	0.020±0.006^{a}	0.021±0.003^{a}	0.02	0.892
Potassium (ppm)	0.068±0.009^{a}	0.120±0.004^{b}	0.181±0.01^{c}		0.000
Calcium (ppm)	0.110±0.007^{a}	0.112±0.006^{a}	0.122±0.003^{a}	0.115	0.082
Vanadium (ppm)	0.145±0.003^{a}	0.224±0.005^{b}	0.352±0.008^{c}		0.000
Chromium (ppm)	0.081±0.006^{a}	0.089±0.004^{a}	0.223±0.003^{b}		0.000
Manganese (ppm)	Not present	Not present	Not present		
Iron (ppm)	0.043±0.006^{a}	0.062±0.004^{b}	0.069±0.004^{b}		0.002
Nickel (ppm)	0.015±0.004^{a}	0.102±0.006^{b}	0.278±0.003^{c}		0.000
Copper (ppm)	0^{a}	0.382±0.002^{b}	0.850±0.004^{c}		0.000
Zinc (ppm)	Not present	Not present	Not present		
Molybdenum (ppm)	Not present	Not present	Not present		
Silver (ppm)	Not present	Not present	Not present		
Gold (ppm)	0^{a}	0^{a}	0.045±0.004^{b}		0,000
Aluminium (ppm)	Not present	Not present	Not present		
Titanium (ppm)	Not present	Not present	Not present		
Arsenic (ppm)	0.043±0.004^{a}	0.043±0.004^{a}	0.056±0.003^{b}		0.007
Cadmium (ppm)	Not present	Not present	Not present		
Etain (ppm)	0^{a}	0^{a}	0.071±0.004^{b}		0.000
Antimoine (ppm)	0.013±0.003^{a}	0.026±0.005^{b}	0.051±0.004^{c}		0.000
Baryum (ppm)	0^{a}	0.085±0.004^{b}	0.085±0.003^{b}		0,000
Mercure (ppm)	0.076±0.007^{a}	0.078±0.004^{a}	0.142±0.004^{b}		0,000
Plomb (ppm)	0.012±0.003^{a}	0.037±0.003^{b}	0.037±0.002^{b}		0,000

Per line, values followed by different superscript letters are statistically different at 5%. **P-value**: value of the statistical probability test. With a < b<c; **P value** < 0.05 (5%) so the difference is significant.

3.2 Evaluation of the estimated daily intake of mineral elements and the risk of exposure from the consumption of FS, F40, F50 flours (Tables 2, 3, 4)

For FS, F40, F50 flours, all estimated boron intakes (1.15 µg/Kgbw/d; 1.625 µg/Kgbw/d; 2.2 µg/Kgbw/d) in this study are below the tolerable daily intake (DJT) set by the European Food Safety Agency (EFSA, 2006) [43] which is 167 µg/Kgbw/d. Furthermore, the hazard quotients calculated from this DJT and the estimated intakes are all less than 1. In addition, the hazard quotients calculated from this DJT and the estimated intakes are all less than 1. This situation indicates that the consumption of the boron-containing FS, F40, F50 flours in this study does not endanger the health of consumers.

All estimated intakes of sodium (0.367 µg/Kgbw/d; 0.625 µg/Kgbw/d; 0.958 µg/Kgbw/d) in this study are below the Tolerable Daily Intake (DJT) set by Whelton et al., (2012) [44]; Coqswel et al., (2012) [45] which is 38333 µg/Kgbw/d. In addition, the hazard quotients calculated from this DJT and the estimated intakes are all below 1. In addition, the hazard quotients calculated from this DJT and the estimated intakes are all less than 1. This indicates that the consumption of the sodium-containing FS, F40, F50 flours in this study does not endanger the health of consumers.

For all three flours, all estimated daily magnesium intakes (0 µg/Kgbw/d; 1.667*10-5 µg/Kgbw/d; 2.025 µg/Kgbw/d in this study) are lower than the Tolerable Daily Intake (DJT) set by the European Food Safety Agency (EFSA, 2006) [43] which is 41667 µg/Kgbw/d. In addition, the hazard quotients calculated from this DJT and the estimated intakes are all lower than 1. In addition, the hazard quotients calculated from this DJT and the estimated intakes are all less than 1. This study indicates that the consumption of flours containing magnesium does not endanger the health of consumers.

For all three flours, all estimated daily phosphorus intakes (0.158 µg/Kgbw/d; 0.167 µg/Kgbw/d; 0.175 µg/Kgbw/d) in this study are lower than the Tolerable Daily Intake (DJT) set by the European Food Safety Agency (EFSA, 2006) [43], which is 50,000 µg/Kgbw/d. In addition, the hazard quotients calculated from this DJT and the estimated intakes are all lower than 1. In addition, the hazard quotients calculated from this DJT and the estimated intakes are all below 1. This study indicates that the consumption of phosphorus-containing flours does not endanger the health of consumers.

For FS, F40, F50 flours, all the estimated daily intakes of potassium (0.567 µg/Kgbpc/d; 1 µg/Kgbpc/d; 1.508 µg/Kgbpc/d) in this study are lower than the Tolerable Daily Intake (DJT) [46] which is 61667 µg/Kgbpc/d. In addition, the hazard quotients calculated from this DJT and the estimated intakes are all lower than 1. In addition, the hazard quotients calculated from this DJT and the estimated intakes are all less than 1. This study indicates that the consumption of flours containing potassium does not endanger the health of consumers. For all three flours, all estimated daily intakes of calcium (0.917 µg/Kgbw/d; 0.933 µg/Kgbw/d; 1.017 µg/Kgbw/d) in this study are below the tolerable daily intake (DJT) set by the European Food Safety Agency (EFSA, 2015) [47] and NNR, (2012) [46] which is 41667 µg/Kgbw/d. Furthermore, the hazard quotients calculated from this DJT, and the estimated intakes are all below 1. In addition, the hazard quotients calculated from this DJT and the estimated intakes are all less than 1. This study indicates that the consumption of calcium-containing flours does not endanger the health of consumers.

For FS, F40, F50 flours, all the estimated daily intakes of vanadium (1.208 µg/Kgbw/d; 1.867 µg/Kgbw/d; 2.933 µg/Kgbw/d) in this study are lower than the Tolerable Daily Intake (DJT) [48] which is 30 µg/Kgbw/d. Moreover, the hazard quotients calculated from this DJT and the estimated intakes are all lower than 1. In addition, the hazard quotients calculated from this DJT and the estimated intakes are all less than 1. This study indicates that the consumption of vanadium-containing flours does not endanger the health of consumers. For all three flours, all estimated daily intakes of chromium (0.675 µg/Kgbw/d; 0.702 µg/Kgbw/d; 1.858 µg/Kgbw/d) in this study are below the tolerable daily intake (DJT) set by the European Food Safety Agency (EFSA, 2014) [49], which is 300 µg/Kgbw/d. In addition, the hazard quotients calculated from this DJT and the estimated intakes are all below 1. In addition, the hazard quotients calculated from this DJT and the estimated intakes are all less than 1. This study indicates that the consumption of chromium-containing flours does not endanger the health of consumers.

For FS, F40, F50 flours, all the estimated daily intakes of iron (0.358 µg/Kgbw/d; 0.517 µg/Kgbw/d; 0.575 µg/Kgbw/d) in this study are lower than the Tolerable Daily Intake (DJT) [50] which is 750 µg/Kgbw/d. In addition, the hazard quotients calculated from this DJT and the estimated intakes are all lower than 1. In addition, the hazard quotients calculated from this DJT and the estimated intakes are all less than 1. This study indicates that the consumption of iron-containing flours does not endanger the health of consumers. For all three flours, all estimated daily intakes of nickel (0.125 µg/Kgbw/d; 0.85 µg/Kgbw/d; 2.317 µg/Kgbw/d) in this study are below the tolerable daily intake (DJT) set by the European Food Safety Agency (EFSA, 2020) [49] which is 13 µg/Kgbw/d. Furthermore, the hazard quotients calculated from this DJT and estimated intakes are all below 1. In addition, the hazard quotients calculated from this DJT and the estimated intakes are all less than 1. This study indicates that the consumption of nickel-containing flours does not endanger the health of consumers. For FS, F40, F50 flours, all the estimated daily copper intakes (0 µg/Kgbw/d; 3.183 µg/Kgbw/d; 7.083 µg/Kgbw/d) in this study are below the tolerable daily intake (DJT) [43] which is 83 µg/Kgbw/d. Moreover, the hazard quotients calculated from this DJT and the estimated intakes are all below 1. In addition, the hazard quotients calculated from this DJT and the estimated intakes are all less than 1. This study indicates that the consumption of copper-containing flours does not endanger the health of consumers.
For all three flours, all estimated daily arsenic intakes (0.358 µg/Kgbw/d; 0.358 µg/Kgbw/d; 0.467 µg/Kgbw/d) in this study are lower than the Tolerable Daily Intake (DJT) set by the Joint Expert Committee on Food Additives (JECFA, 2022) [51], which is 3,000 µg/Kgbw/d. In addition, the hazard quotients calculated from this DJT and the estimated intakes are all lower than 1. In addition, the hazard quotients calculated from this DJT and the estimated intakes are all less than 1. This study indicates that the consumption of arsenic-containing flours does not endanger the health of consumers. For FS, F40, F50 flours, all the estimated daily intakes of tin (0 µg/Kgbw/d; 0 µg/Kgbw/d; 0.592 µg/Kgbw/d) in this study are lower than the Tolerable Daily Intake (DJT) [52] which is 220 µg/Kgbw/d. Moreover, the hazard quotients calculated from this DJT and the estimated intakes are all lower than 1. In addition, the hazard quotients calculated from this DJT and the estimated intakes are all less than 1. This study indicates that the consumption of tin-containing flours does not endanger the health of consumers. For all three flours, all estimated daily intakes of antimony (0.108 µg/Kgbw/d; 0.217 µg/Kgbw/d; 0.425 µg/Kgbw/d) in this study are lower than the Tolerable Daily Intake (DJT) set by the Swiss Federal Office of Public Health, (2007) [53] which is 6 µg/Kgbw/d. Furthermore, the hazard quotients calculated from this DJT and the estimated intakes are all lower than 1. In addition, the hazard quotients calculated from this DJT and the estimated intakes are all below 1. This study indicates that the consumption of antimony-containing flours does not endanger the health of consumers. For FS, F40, F50 flours, all the estimated daily intakes of barium (0 µg/Kgbw/d; 0.708 µg/Kgbw/d; 0.708 µg/Kgbw/d) in this study are lower than the Tolerable Daily Intake (DJT) [54] which is 80 µg/Kgbw/d. Moreover, the hazard quotients calculated from this DJT and the estimated intakes are all lower than 1. In addition, the hazard quotients calculated from this DJT and the estimated intakes are all less than 1. This study indicates that the consumption of barium-containing flours does not endanger the health of consumers. For all three flours, all the estimated daily intakes of mercury (0.633 µg/Kgbw/d; 0.65 µg/Kgbw/d; 1.183 µg/Kgbw/d) in this study are above the tolerable daily intake (DJT) [55, 56], which is 0.23 µg/Kgbw/d. For mercury, the hazard quotients calculated from this DJT and the estimated intakes are all greater than 1 (these quotients are 2.75, 2.83 and 5.14 respectively for FS, F40 and F50 flours). This study indicates that the consumption of the three flours endangers the health of consumers with regard to mercury. For FS, F40, F50 flours, all the estimated daily lead intakes (0.1 µg/Kgbw/d; 0.308 µg/Kgbw/d; 0.308 µg/Kgbw/d) in this study are lower than the Tolerable Daily Intake (DJT) [56, 57], which is 3.6 µg/Kgbw/d. Moreover, the hazard quotients calculated from this DJT and the estimated intakes are all lower than 1. In addition, the hazard quotients calculated from this DJT and the estimated intakes are all less than 1. This study indicates that the consumption of flour does not endanger the health of consumers with regard to lead.

3.2.1 For FS flour

Table 2: Daily Mineral Intake and Risk of Exposure from Consumption of FS Flour.

Element	Boron	Na	Mg	P	k	Ca	Vanadium	Fe	Nickel	Cu
Average concentration (µg/kg)	138	44	0	19	68	110	145	43	15	0
Quantity of flour consumed/day (kg)	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
AJE(µg/kgbw/d)	1.15	0.367	0	0.158	0.567	0.917	1.208	0.358	0.125	0
DJT(µg/kgbw/d)	167	38333	41667	50000	61667	41667	30	750	13	83
AJE/DJT	0.007	$9.6*10^{-6}$	0	$3.16*10^{-6}$	$8.4*10^{-6}$	$2.2*10^{-5}$	0.04	$4.77*10^{-4}$	$9.6*10^{-3}$	0

* Ivorin adult, 60 kg. ***DJT**: Tolerable Daily Intake. ***AJE** : Estimated Daily Intake ; **Na** : sodium ; **P** : phophorus ; **K** : potassium ; **Ca** : calcium ; **Fe** : Iron ; **Cu** : copper

Table 2 (continued): Daily Mineral Intake and Risk of Exposure from Consumption of FS Flour.

Element	Arsenic	Tin	Antimony	Barium	Mercury	Chromium	Lead
Avearge concentration (µg/kg)	43	0	13	0	76	81	12
Quantity of flour consumed/day (kg)	0.5	0.5	0.5	0.5	0.5	0.5	0.5
AJE(µg/kgbw/d)	0.358	0	0.108	0	0.633	0.675	0.1
DJT(µg/kgbw/d)	3000	220	6	80	0.23	300	3.6
AJE/DJT	$1.19*10^{-4}$	0	0.018	0	2.75	0.002	0.028

* Ivorian adult, de 60 kg. ***DJT**: Tolerable Daily Intake. ***AJE**: Estimated Daily Intake.

3.2.2. For F40 flour

Table 3: Daily Mineral Intake and Risk of Exposure from Consumption of F40 Flour.

Element	Boron	Na	Mg	P	k	Ca	Vanadium	Fe	Nickel	Cu
Average concentration (µg/kg)	195	75	2.10^{-3}	20	120	112	224	62	102	382
Quantity of flour consumed/day (kg)	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
AJE(µg/kgbw/d)	1.625	0.625	$1.667.10^{-5}$	0.167	1	0.933	1.867	0.517	0.85	3.183
DJT(µg/kgbw/d)	167	38333	41667	50000	61667	41667	30	750	13	83
AJE/DJT	0.0097	$1.63*10^{-5}$	$4*10^{-10}$	$3.34*10^{-6}$	$1.62*10^{-5}$	$2.24*10^{-5}$	0.06	$6.8*10^{-4}$	0.065	0.038

* Ivorian adult, 60 kg. ***DJT**: Tolerable Daily Intake. ***AJE** : Estimated Daily Intake; **Na** : sodium ; **P** : phophorus ; **K** : potassium ; **Ca** : calcium ; **Fe** : iron ; **Cu** : copper.

Table 3 (continued): Daily Mineral Intake and Risk of Exposure from Consumption of F40 Flour.

Element	Arsenic	Tin	Antimony	Barium	Mercury	Chromium	Lead
Average concentration (µg/kg)	43	0	26	85	78	89	37
Quantity of flour consumed/day (kg)	0.5	0.5	0.5	0.5	0.5	0.5	0.5
AJE(µg/kgbw/d)	0.358	0	0.217	0.708	0.65	0.742	0.308
DJT(µg/kgbw/d)	3000	220	6	80	0.23	300	3.6
AJE/DJT	0.00012	0	0.036	0.0088	2.83	0.0025	0.085

* Ivorian adult, de 60 kg. ***DJT**: Tolerable Daily Intake. ***AJE**: Estimated Daily Intake.

3.2.3. For F50 flour

Table 4: Daily Mineral Intake and Risk of Exposure from Consumption of F50 Flour.

Element	Boron	Na	Mg	P	k	Ca	Vanadium	Fe	Nickel	Cu
Average concentration(µg/kg)	264	115	243	21	181	122	352	69	278	850
Quantity of flour consumed/day (kg)	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
AJE(µg/kgbw/d)	2.2	0.958	2.025	0.175	1.508	1.017	2.933	0.575	2.317	7.083
DJT(µg/kgbw/d)	167	38333	41667	50000	61667	41667	30	750	13	83
AJE/DJT	0.013	$2.5*10^{-5}$	$4.86*10^{-5}$	$3.5*10^{-6}$	$2.44*10^{-5}$	$2.44*10^{-5}$	0.098	$7.7*10^{-4}$	0.178	0.085

* Ivorian adult, de 60 kg. ***DJT**: Tolerable Daily Intake. ***AJE**: Estimated Daily Intake; **Na**: Sodium ; **P** : Phophorus ; **K**: Potassium ; **Ca**: Calcium ; **Fe**: Iron ; **Cu**: Copper.

Table 4 (continued): Daily Mineral Intake and Risk of Exposure from Consumption of F50 Flour.

Element	Arsenic	Tin	Antimony	Barium	Mercury	Chromium	Lead
Average concentration (µg/kg)	56	71	51	85	142	223	37
Quantity of flour consumed/day (kg)	0.5	0.5	0.5	0.5	0.5	0.5	0.5
AJE(µg/kgbw/d)	0.467	0.592	0.425	0.708	1.183	1.858	0.308
DJT(µg/kgbw/d)	3000	220	6	80	0.23	300	3.6
AJE/DJT	$1.56*10^{-4}$	0.003	0.07	0.009	5.14	0.0062	0.085

***** Ivorian adult, de 60 kg. ***DJT**: Tolerable Daily Intake. ***AJE**: Estimated Daily Intake.

4. CONCLUSION

This study showed that FS, F40, F50 flours from young shoots of roan from Dimbokro contain trace elements and macroelements that are beneficial to the population. Unfortunately, they also contain heavy metals that can be harmful to local populations. Arsenic, lead, tin, barium and antimony have a hazard quotient of less than 1. Only mercury has a hazard quotient of more than 1. The different flours FS, F40, F50 therefore would present a risk of exposure to mercury. However, lead may present a risk through bioaccumulation. It is therefore advisable to stop illegal gold panning or to move it away from areas where young shoots are grown. Pesticides and chemical fertilisers should also be used with great care. It would be desirable to study the minerals in young shoots zone by zone in order to establish a real map of contaminated zones.

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