Original article

Antinutrients and heavy metals in new Nigerian *Musa* hybrid peels with emphasis on utilization in livestock production

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Abstract — **Introduction**. A comparative study of antinutrients and heavy metals in the peels of five improved varieties of plantain and banana hybrids was investigated. Our aim was to provide information on plantain and banana peels that may circumvent huge losses during fruit processing by converting waste into wealth and health. **Materials and methods**. Four new plantain hybrids developed at the IITA, Nigeria, named PITA 14, PITA 17, PITA 24 and PITA 26, one cooking banana hybrid (BITA 3) and an African plantain landrace, Agbagba, were investigated. Antinutrient and heavy metal contents of the dried peels from the different cultivars were determined and the data were statistically analyzed. **Results and discussion**. The plantain hybrid PITA 14 differed significantly from other cultivars in saponin, tannin and oxalate. A significant difference was observed between PITA 17 in phytate compared with other cultivars. Cyanogenic glucosides found in PITA 17, PITA 26 and BITA 3 differed significantly from the values obtained in other cultivars. Both BITA 3 and Agbagba are significantly different from other cultivars in phenolic content, while PITA 24 and Agbagba differed significantly from other cultivars in lead. PITA 24 peels differed significantly from other cultivars in cadmium, but no significant difference was found among the different *Musa* varieties in mercury. **Conclusion**. In spite of the antinutritional properties ascribed to the various constituents investigated, the levels found in the peels of new *Musa* hybrids suggest that new varieties might not constitute a health hazard when ingested. Plantain and banana peels may be converted into livestock feeds, which will eventually provide protein and other nutrients to humans from consumption of meat and other products derived from the animals.

Nigeria / *Musa* / fruit peels / antinutritional factors / chemical composition / heavy metals / cyanogenic glucosides / health hazards

Substances antinutritionnelles et métaux lourds dans la peau des bananes de nouveaux hybrides nigérians potentiellement utilisables en production animale.

Résumé — **Introduction**. Une étude comparative des substances antinutritionnelles et des métaux lourds dans la peau de cinq variétés de plantain améliorées et hybrides de bananier a été effectuée. Notre but a été de fournir des informations sur la peau de plantains et bananes, qui pourraient limiter les énormes pertes occasionnées par la transformation des fruits en convertissant ces pertes en profits et santé. **Matériel et méthodes**. Quatre nouveaux hybrides de plantain (PITA 14, PITA 17, PITA 24 et PITA 26) développés à l'IITA, au Nigéria, un hybride de banane à cuire (BITA 3) et un plantain local africain, Agbagba, ont été évalués. La teneur en substances antinutritionnelles et en métaux lourds a été déterminée dans la peau sèche des différents cultivars et les données ont été statistiquement analysées. **Résultats et discussion**. La peau de l'hybride de plantain PITA 14 a différé de manière significative des autres cultivars en saponine, tannin et oxalate. Par rapport aux autres cultivars, PITA 17 a présenté une amélioration en phytate. Les glucosides cyanogéniques trouvés dans la peau de PITA 17, PITA 26 et BITA 3 ont différé de manière significative des valeurs obtenues dans les autres cultivars. BITA 3 et Agbagba se sont démarqués par leur teneur en phénols, alors que PITA 24 et Agbagba ont différé de manière significative des autres cultivars pour leur teneur en plomb. La peau de PITA 24 a eu la plus forte teneur en cadmium, mais aucune différence significative n'a été trouvée parmi les différentes variétés de *Musa* quant à leur teneur en mercure. **Conclusion**. Malgré les propriétés antinutritionnelles attribuées aux divers constituants étudiés, leur niveau trouvé dans la peau des fruits de nouveaux hybrides de *Musa* suggère que leur ingestion ne pourrait pas constituer un risque sanitaire. Les épluchures de plantains et de bananes peuvent être converties en aliments pour le bétail qui fourniront par la suite des protéines et d'autres éléments à l'homme par consommation de la viande et d'autres produits dérivés des animaux ainsi alimentés.

Nigéria / *Musa* / pelure de fruits / facteur antinutritionnel / composition chimique / métal lourd / glucoside cyanogène / danger pour la santé

1. Introduction

The annual world production of plantain and banana (*Musa* spp.) is estimated at 75 Mt [1]. This includes approximately 19 Mt of peel. Dessert banana is often eaten raw when ripe, during which the fruit is peeled, and often discarded as waste. Similarly, during plantain processing, peels are usually considered as waste. Like other fruits, the peel of plantain and banana protects the edible pulp from the surrounding environment. The use of a plantain and banana pulp and peel combination in wine manufacturing has been reported [2, 3]. Rahman [4] reported on the use of whole plantain fruit, consisting of both pulp and peel, in flour production, while the peels and trunks are utilized for various agricultural purposes [5, 6]. Plantain peels are good for feeding ruminants, especially in the ripe form [7]. Ketiku [5] also reported that plantain skins are important fodder for ruminants, especially goats and sheep. One other important use of plantain peel lies in its utilization as a tenderizer for vegetables and meat when converted into powder [8]. In Uganda, banana peels are used as cattle feed and for the production of "fuel briquettes". In the Philippines, banana peels are sun-dried and further processed into chips for export to Japan and Taiwan for use as feed or fillers in chemical processing [9]. In the USA, the government has set a goal of replacing up to 30% of the nation's gasoline use with bio-fuels by 2030, and therefore bringing the cost of ethanol, the leading alternative fuel, down to $1.07 a gallon by 2012 [10]. Plantain and banana are potential bio-energy plants that could constitute a genetic recipe for producing bio-fuels.

The chemical composition of plantain peels and pulps [5, 7], and peels only [6] has been documented. Baiyeri [11] also reported on the mineral concentration of unripe and ripe plantain pulps and peels. Izonfuo and Omuaru [7] reported higher levels of some important minerals in the ripe and unripe peel of plantain compared with the pulp, which is in agreement with the report of Baiyeri [11]. Ketiku [5] reported that the peel of both ripe and unripe plantain contains higher levels of protein compared with the edible pulp, in consonance with the work of Izonfuo and Omuaru [7]. The inclusion of plantain and banana peels in the rations of goats and sheep should be encouraged to enable the animals to derive protein and other nutrients from the peel, which could have been discarded as waste. The starch content of plantain pulp is higher than that of the peel; however, higher concentrations of sugars have been reported in the peel compared with the pulp [5]. Studies have also revealed that plantain peels contain alcohol, and aromatic and phenolic compounds [1].

Unavailability of conventional ingredients is one of the major constraints to livestock production in the developing countries [12]. The concentrated feedstuffs being produced are competed for by humans and their livestock: usually the humans have to satisfy their needs, leaving the remnant for livestock. Animal scientists have increased the use of unconventional feed ingredients, notably the agro-industrial by-products and farm wastes for which humans do not compete, in livestock production to circumvent the problem of inadequacy of feeding stuffs. A need therefore exists to explore the vast under-exploited inedible portions of agricultural products, such as plantain and banana peels, to increase livestock feed. In its attempt to produce cheaper and cost-effective feeds from agro-industrial products, the federal government of Nigeria set up a task force on alternative formulations of livestock feeds [12].

Every part of plantain and banana, except the roots and suckers, can be and has been used to feed livestock in various parts of the world [12]. For fresh green plantain or banana, the best way of feeding them to ruminants is to chop the fruits and sprinkle some salt on the slices, since Musa spp. fruits are low in the inorganic nutrients. Clavijo *et al.* [13] reported that gestating sows fed on a banana plus supplement diet performed better than those on the control diet, gaining significantly more weight during gestation and producing heavier piglets at birth. The use of dried, milled banana in livestock feed enables it to be incorporated into diets at much higher levels than those obtained using fresh banana. In another study, Fetuga *et al.* [14] reported on the use of plantain peels, yellow maize, maize cobs and yam peels for feeding pigs. Göhl [15] reported that banana leaves could be used as emergency feed for ruminants, but that the digestibility decreased as the level of banana leaves increased in the ration. The author therefore recommended that no more than 10% of the grain of poultry diets should be replaced by banana meal because high levels of banana meal depress the growth rate and reduce feed efficiency. In addition, banana pseudostems could be fed fresh, but chopped, ensiled pseudostems enriched with readily fermentable carbohydrates is the best way of feeding them to ruminants. Dehydrated, green, milled banana has been successfully utilized as a source of starch in the preparation of calf feeds and specifically in the manufacture of milk replacers [16]. Chenost *et al.* [17] carried out digestibility trials on goats and reported that, when banana and forages were blended, the dry matter and digestible organic matter rose sharply as the content of bananas increased in the ration from 0–20%. Similarly, Geoffroy and Chenost [18] reported that replacement of cereals with banana meal and banana silage in a concentrated diet resulted in increased dry matter intake, significantly higher milk yield and better weight gains. Viswanathan *et al.* [19] reported that feeding of sheep with banana stalk does not have a detrimental effect on the health of the animals, although the daily live-weight gains were low. Successful inclusion of up to 7.5% of dried plantain peels in maize used for broiler diets has also been reported [20], beyond which it is detrimental. It has been well established that the greatest limitation to using banana as a feed for ruminants is the lack of fermentable nitrogen, and hence banana diets must always be supplemented with a source of nitrogen such as urea [21]. The most common non-essential but nutritionally important minerals, as far as toxicity is concerned, are lead, mercury, arsenic and chromium [22]. Cadmium is an extremely toxic metal commonly found in industrial workplaces, particularly where any ore is being processed or smelted. These elements, also known as heavy metals, and some other trace elements and antinutrients found in foods are toxic when ingested in quantities above critical amounts [22].

In spite of their nutritional composition and extensive reports on the composition and uses of plantain and banana peels, their potential in livestock production is yet to be fully explored. Investigations into the antinutritional factors and heavy metal constituents of new plantain and banana hybrid peels were therefore undertaken as a renewed effort to promote their application in livestock production. To the authors' knowledge, there are no published reports on the antinutrient and heavy metal contents of new *Musa* hybrids developed at the International Institute of Tropical Agriculture (IITA).

2. Materials and methods

2.1. Collection of samples

Five new *Musa* hybrids developed at the IITA, Nigeria, named either PITA (Plantain International Institute of Tropical Agriculture) or BITA (Banana International Institute of Tropical Agriculture) were investigated. The cultivars included four plantain hybrids (PITA 14, PITA 17, PITA 24 and PITA 26) and one cooking banana hybrid (BITA 3), with an African plantain landrace, Agbagba, as control. Green (unripe) fruit samples were obtained from the experimental station of the IITA, High Rainfall Station, Onne Agroecology, located at lat. 04° 43' N, long. 07° 01' E and 10 m alt., near Port Harcourt, Nigeria. Three representative fruit samples were collected from the second hand from the proximal end of the bunch, following the recommendation of Baiyeri and Ortiz [23]. The same day, the bunch was harvested.

2.2. Preparation of samples

Fruit samples were washed and peeled manually with a stainless steel kitchen knife and the peels sliced longitudinally. Peel samples were cut into small sizes, then placed in petri dishes and covered with filter paper to prevent contamination. Samples were dried in a Forced-Air Moisture Extraction Plus II oven (Sanyo Gallenkamp PLC, United Kingdom), at 65 °C for about 48 h, and they were milled with a stainless steel Kenwood Chef Blender, Model KM001 (0067078) series.

2.3. Analytical procedures

The antinutrient content and heavy metals in the banana peel flour were determined using AOAC [24] procedures. All chemical analyses were performed in the Plant Anatomy & Physiology Research Laboratory, Faculty of Science, University of Port Harcourt, Herbarium, Port Harcourt, Nigeria.

2.4. Data analyses

The data generated were analyzed using the Statistical Analysis Systems (SAS) version 9.1 [25] software package. Significance of treatment means was tested at the 5% probability level using Duncan's New Multiple Range Test (DNMRT).

3. Results and discussion

3.1. Antinutrients

The saponin, tannin and oxalate contents in the peel of PITA 14 were significantly ($p < 0.05$) higher compared with those obtained in other cultivars (*table I*). The phytate content in the peel of PITA 17 was significantly ($p < 0.05$) the highest compared with other cultivars. Cyanogenic glucoside contents found in BITA 3, PITA 17 and PITA 26 peels were significantly higher ($p < 0.05$) compared with values obtained in other cultivars. The mean phenolic contents observed in both BITA 3 and Agbagba peels were significantly higher ($p < 0.05$) compared with the values found in the other cultivars.

The lead contents of PITA 24 and Agbagba peels were significantly higher ($p < 0.05$) compared with those of the other cultivars (*table II*). Similarly, the cadmium content of PITA 24 peels was significantly ($p < 0.05$) the highest, but no significant difference ($p < 0.05$) was found among the different *Musa* varieties in mercury contents.

This study revealed that plantain and banana peels had higher levels of antinutrients than those reported by Adeniji *et al.* [26] for the antinutrients and heavy metals in plantain and banana flour of pulp. Even though anti-nutritional properties have been ascribed to saponins, they are harmless when ingested by chicks, rats and mice at 0.5% to 3% of the diet because neither saponins nor sapogenins were found in the blood of chicks, rats and mice kept on a diet containing 20% soybean meal [27]. Suffice to say that saponins are not absorbed, but remain intact until they leave the intestine. The Merck Index [28] also reported that saponins are practically non-toxic to humans when taken orally. They are known to have a number of advantages, of which the most interesting is that they can lower plasma cholesterol concentrations [29, 30]. Food rich in saponins may reduce the effect

Table I.
Antinutrients (%) measured in dried plantain and banana peel at harvest (Nigeria).

Cultivar	Saponin	Tannin	Oxalate	Phytate	Cyanogenic glucosides	Phenolic compound
AGBAGBA	3.0 f	9.8 e	0.35 e	0.28 e	0.22 c	0.124 a
BITA 3	6.2 e	10.8 d	0.66 b	0.38 c	0.65 a	0.124 a
PITA 14	26.5 a	12.0 a	0.73 a	0.28 e	0.25 b	0.123 b
PITA 17	7.6 d	11.0 c	0.47 c	0.62 a	0.65 a	0.119 c
PITA 24	24.6 b	11.8 b	0.22 f	0.39 b	0.25 b	0.119 c
PITA 26	21.3 c	8.4 f	0.42 d	0.32 d	0.65 a	0.113 d

Values in the same column with different letters are significantly different at $p < 0.05$.

of heart disease [31, 32]. There is therefore a need to identify actual and potential sources of dietary saponins. For instance, the bitter taste of oil bean seed is due partly to saponin glycoside [33]. Sirtori *et al.* [34] associated soybean saponins with the lowering of serum cholesterol, and Oakenful *et al.* [29] showed that saponins were hypocholesterolaemic. These findings suggest that food containing saponins could be beneficial to humans.

The presence of antinutrients in the human diet prevents the digestion, availability and assimilation of food substances, depending on their concentration [35–37]. Specifically, oxalate at high concentrations is known to strongly chelate with dietary calcium and other divalent metals [38], thereby making the complexed calcium unavailable for absorption. Like oxalates, tannins also form complexes with proteins, divalent metals, cellulose, hemicellulose, pectin and other carbohydrates [39]. Tannins therefore reduce the availability of these nutrients. Elemo *et al.* [40] reported 0.021% tannins in sheanut, which is far lower than those obtained in this present research. The tannin levels found in our study may therefore be regarded as high concentrations and thus can be assumed to be toxic. Processing should be carefully carried out to reduce the levels in the peels prior to utilization.

The oxalate levels shown in this present study are much lower in comparison with the estimated threshold of oxalate toxicity in humans [(2 to 5) $g \cdot 100\ g^{-1}$ daily] as given by Munro and Basir [41]. This therefore suggests that consumers of plantain, banana and their derived hybrids, including the peel, stand no risk of oxalate toxicity. One advantage of high concentrations of oxalate in plants, however, is that it deters herbivores from feeding on such plants [37, 42].

Phytate occurs in soybeans and most soybean products to the extent of 1.0% to 1.5% of the dry weight [43, 44]. Bioavailability of iron, zinc and calcium for humans is a crucial factor since their absorption from plant food is often low, which is mainly due to the presence of phytic acid [45]. The phytate content of plantain and banana peels as shown in our study is much lower than these values. Elemo *et al.* [40] earlier reported a lower value of 0.145% of phytic acid in sheanut. A substantial decrease in phytin in edible parts of food crops could improve iron, zinc and calcium availability to the consumer [46]. Much of the phosphorus in soybean is unavailable because it is tied up in the phytate molecule (40% to 60%), and phytate chelates with di- and trivalent metals, such as calcium, magnesium, zinc and iron to form poorly soluble compounds that are not easily absorbed from the intestine [27]. Investigations carried out *in vivo* and *in vitro* have demonstrated anti-cancer (both preventive and therapeutic) properties of phytic acid [47].

Olusi and Oke [48] administered several times the lethal dose of cyanide as KCN to experimental animals with no necrosis, necrobiosis or other cellular or tissue damage, most of the glucoside being excreted intact in the urine as inert substances. Krebs [49] also reported that most of the glucosides are excreted unchanged in urine and faeces and thus present no toxic problems, and this has been confirmed by the work of Matsumoto *et al.* [50]. The lethal dose of hydrocyanate is believed to be about 60 $mg \cdot day^{-1}$ in an adult man [51]. Tichy [52] observed that the fatal dose of cyanogenic glycoside in food is 50 $mg \cdot day^{-1}$, while another study suggested a level of 10–20 mg·100 g in foods for safety [53]. In our study, the 0.216% to 0.648% cyanogenic glucoside obtained in plantain and banana peels may be toxic. Ihekoronye and Ngoddy

Table II.
Heavy metals ($\mu g \cdot g^{-1}$) measured in dried plantain and banana peel at harvest (Nigeria). Mercury content is inferior to 0.01 $\mu g \cdot g^{-1}$ in all the samples.

Cultivars	Lead	Cadmium
AGBAGBA	0.70 a	0.04 d
BITA 3	0.66 b	0.05 c
PITA 14	0.46 e	0.05 c
PITA 17	0.56 d	0.05 c
PITA 24	0.70 a	0.07 a
PITA 26	0.65 c	0.06 b

Values in the same column with different letters are significantly different at $p < 0.05$.

[54] reported that the high prussic acid, linamarin and lotaustralin content of most cassava cultivars implies that elaborate processing is required before consumption. Adequate heat treatment could inactivate various antinutrients in foods, and therefore detoxify them.

3.2. Heavy metals

The heavy metal contents of plantain and banana hybrid peels are in consonance with the 0.01 $mg \cdot kg^{-1}$ to 0.006 $mg \cdot kg^{-1}$ lead, cadmium, mercury and chromium levels reported in some seafoods [55] in Rivers State waters in Nigeria. However, these new data are higher than those reported in plantain and banana flour [26]. Lead concentrations ranging from 1.2–7.4 $\mu g \cdot g^{-1}$ and 1.1–2.6 $\mu g \cdot g^{-1}$ have been reported in cassava roots and cocoyam (corm) obtained from some oil-prospecting locations in Rivers State [56]. Lead concentrations ranging from 2.9–9.1 $\mu g \cdot g^{-1}$, 2.4–8.6 $\mu g \cdot g^{-1}$ and 2.0–7.6 $\mu g \cdot g^{-1}$ in okra, pumpkin leaves and waterleaf were obtained from six oil-prospecting locations in Rivers State [56]. Lead concentrations found in the new *Musa* hybrid peels were much lower than these values. The heavy metal contents of the new *Musa* hybrid peels are very low, especially mercury. Rahman *et al.* [57] reported that no ill or toxic effects could be observed in chicks fed with flour from unpeeled green plantains. In addition, no mortality occurred during the experiment, and organoleptic tests revealed no differences in the color or flavor of the meat produced. The FAO/WHO [58] assessed the risk posed by lead to the health of infants and children and established a Provisional Tolerable Weekly Intake (PTWI) of 25 $\mu g \cdot kg^{-1}$ body weight for this population group and also extended to people in all age groups. The recommended Provisional Tolerable Weekly Intake of cadmium is 7 $\mu g \cdot kg^{-1}$ body weight, while a dietary limit of 1.6 $\mu g \cdot kg^{-1}$ body weight per week for methyl mercury is recommended in order to sufficiently protect the developing fetus [59]. This suggests that plantain and banana peels are safe for livestock production considering the values of lead, mercury and cadmium obtained in the present research.

4. Conclusion

This new study was realized to unveil the antinutrient and heavy metal concentrations in some new *Musa* hybrid peels with emphasis on their utilization in livestock production. The concentration of antinutrients and heavy metals found in the new plantain and banana hybrid peels may be considered safe for use in livestock production. However, reduction of antinutrients is an important step to enhance nutritional qualities, and increase palatability and digestibility of foods, which could be accomplished through different hydrothermal treatments. Application of plantain and banana peels as composite ingredients in the formulation of safe and cost-effective meal for livestock production is therefore recommended.

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Sustancias antinutricionales y metales pesados en la piel de los bananos de nuevos híbridos nigerianos potencialmente utilizables en producción animal.

Resumen — **Introducción**. Se efectuó un estudio comparativo de las sustancias antinutricionales y de los metales pesados en la piel de cinco variedades mejoradas de llantén y de híbrido de banano. Nuestro objetivo pretendió proporcionar las informaciones sobre la piel de llantenes y bananos, que podrían limitar las enormes pérdidas ocasionadas por la transformación de los frutos, convirtiendo dichas pérdidas en beneficios y en salud. **Material y métodos**. Se evaluaron cuatro nuevos híbridos de llantenes (PITA 14, PITA 17, PITA 24 y PITA 26) desarrollados en el IITA, en Nigeria, un híbrido de banano para cocinar (BITA 3) y un llantén local africano, Agbagba. Se determinaron el contenido de sustancias antinutricionales y de metales pesados en la piel seca de los diferentes cultivares; y, se analizaron estadísticamente los datos obtenidos. **Resultados y discusión**. La piel del híbrido de llantén PITA 14 difirió de modo significativo de los otros cultivares en saponina, tanina y oxilato. Con relación a los otros cultivares, PITA 17 presentó una mejora en fitato. Los glucósidos cianogénicos encontrados en la piel de PITA 17, PITA 26 y BITA 3 difirieron de manera significativa de los valores obtenidos en los otros cultivares. BITA 3 y Agbagba se demarcaron por su contenido en fenoles, mientras que PITA 24 y Agbagba difirieron significativamente de los otros cultivares por su contenido en plomo. La piel de PITA 24 tuvo más contenido en cadmio, pero no se encontró ninguna diferencia significativa entre las diferentes variedades de *Musa* en cuanto a su contenido en mercurio. **Conclusión**. A pesar de las propiedades antinutricionales atribuidas a los diversos constituyentes estudiados, su nivel encontrado en la piel de los frutos de nuevos híbridos de *Musa* sugiere que su ingestión no constituiría un riesgo saludable. Las cáscaras de los llantenes y de los bananos pueden transformarse en alimentos de ganado que después proporcionarán las proteínas y otros elementos para el hombre, mediante el consumo de la carne y de otros productos derivados de los animales alimentados de este modo.

Nigeria / *Musa* / piel de frutas / factores antinutricionales / composición química / metales pesados / glucósidos cianogénicos / peligro para la salud