



A Comparative Study on the Effectiveness of Coating and Dusting Technologies on Fortification of Acha (*Digitaria exilis*) Grains

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Authors' contributions

This work was carried out in collaboration among all authors. Author CAC designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors UCC and KJC managed the analyses of the study. Author EAS managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

Background: Reports have shown that consumption of acha (*Digitaria exilis*) is beneficial to both diabetic and hypertensive patients considering its low glycaemic index, if fortified could assist to improve health and in combating hidden hunger.

Aims: This work was aimed at establishing the technology of fortifying acha (*Digitaria exilis*) grains with vitamin A, Iron, copper and zinc by comparing the effectiveness of coating and dusting technologies and analysing the vitamin A, iron, zinc and copper levels of acha grains fortified by both methods.

Methodology: Vitamin A was quantified by High Performance Liquid Chromatography (HPLC) method, while iron, zinc and copper were quantified using Atomic Absorption Spectroscopy (AAS) method.

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Results: Vitamin A was undetected in unfortified grain, but present at 29,904.18 IU/kg and 29,657.66 IU/kg in coated and dusted grains respectively. The iron content(58 mg/kg) in unfortified grain increased by 22% and 15% for coated and dusted respectively, Copper increased by 25% and 14% and Zinc by 32% and 45% with coating and dusting respectively.

Conclusion: This study suggests that coating is a more promising technology for fortifying acha grains with Vitamin A, iron and copper, which will assist in delivering these critical micronutrients in the vulnerable population and also be used as a strategy for dietary improvement.

Keywords: Acha; grains; coating; dusting; fortification; micronutrients.

1. INTRODUCTION

An alarming percentage of the world's population suffer from 'hidden hunger', the term used for micronutrient deficiencies because the symptoms often cannot be seen or felt. These deficiencies in micronutrients are widespread affecting more than a third of the world's population. Although people in all population groups may be affected, the most wide spread and severe problems are usually found in developing countries of the world particularly in many parts of Asia and sub-Saharan Africa like Nigeria where poverty, lack of access to a variety of foods, lack of knowledge of appropriate dietary practice and high incidence of infectious diseases are recurrent problems [1]. Collectively, the micronutrient deficiencies damages the immune system which increases morbidity and mortality rate, harm reproduction, retard psychomotor and cognitive development, and lower work productivity and occupational choices [2]. The three most common forms of micronutrient malnutrition include iron, vitamin A and iodine deficiencies. It is estimated that over two billion people are anaemic, two billion have inadequate iodine nutrition and 254 million preschool-aged children are vitamin A deficient [3].

Vitamin A is a vital nutrient required in small amounts by humans for the normal functioning of the visual system, for maintaining of cell functions, for growth and development, epithelial cellular integrity, immune function and reproduction [4]. Dietary requirements of vitamin A are normally provided from pre-formed vitamin A (retinol), which is present in foods of animal sources; it is also commercially produced and administered as esters such as retinyl acetate or palmitate. Provitamin A carotenoids are derived from foods of vegetable origin, which have to be converted into retinol by tissues such as the intestinal mucosa and the liver in order to be utilized by cells [5]. In commercial preparations preformed vitamin A is esterified usually with palmitic or acetic acid, to the more stable

corresponding esters. Retinyl acetate and retinyl palmitate, along with provitamin A (β -carotene), are thus the main commercial forms of vitamin A that are available for use as food fortificants. Vitamin A is more labile than its ester form, for this reason vitamin A esters are usually used for food fortification [6].

Iron is an important metal for all living things. In the human body iron is a major component of haemoglobin, which is the protein molecule in red blood cells that carries oxygen from the lungs to the tissues [7]. Iron is also an important component of various enzyme systems, such as the cytochromes, which are involved in oxidative metabolism [3]. Iron is derived from both plant and animal sources. Two iron forms that are commonly used in food fortification are ferrous (Fe^{2+}) and ferric (Fe^{3+}), because both of these species contain unfilled d orbitals, they readily form complexes with electron-rich components, yielding species that influence taste and bioavailability [8]. Iron deficiency is the most common and widespread nutritional disorder in the world, and is a public health problem in both industrialized and non-industrialized countries [9]. It is the result of a long-term negative iron balance and in its more severe stages, iron deficiency causes anaemia. Anaemia is defined as a low blood haemoglobin concentration. In underdeveloped countries, anaemia is a major contributory factor to maternal morbidity and mortality [10]. Iron deficiency is estimated to be responsible for around 50 % of all anaemia cases [11].

There are many ways to increase micronutrient intake, thereby reducing and preventing this global prevalence of hidden hunger, this includes taking supplements regularly or through dietary measures that promote the regular consumption of micronutrient rich foods and improve their absorption in the diet. Technology is now available to improve the micronutrient content of cereal crops through selective plant breeding [12]. However, in many situations, these

interventions are either not available or inaccessible by those who need them the most. On the other hand, fortification of commonly eaten foods including cereals, offers a low-cost and simple way of delivering micronutrients to a large number of people who need them.

Food fortification is usually regarded as the deliberate addition of one or more micronutrients to particular foods, so as to increase the intake of these micronutrient(s) in order to correct or prevent a demonstrated deficiency and provide a health benefit. Food fortification which is one of the nutritional interventions used to improve micronutrients intake by the population has been successfully used in the United States for over 80 years [12]. Reduction of goitre, rickets, ariboflavinosis and pellagra in the United States is attributed to the consumption of foods fortified with iodine, vitamin D, vitamin B₂ and niacin respectively [13]. Food fortification has shown to possess many advantages; it is generally socially acceptable, it requires minimal changes in food habit, it usually costs less than 2% of the cost of the unfortified food, its delivery system is already in place and it can become sustainable [14].

Cereal grains are important food vehicles for fortification. Though several foods could be used for carrying micronutrients, high fiber cereal grains are inexpensive vehicles for providing basic nutrition to large populations [15]. Cereals are excellent vehicles because they are staple foods in many parts of the world, which are key ingredient in so many food preparations, readily available, affordable, and culturally acceptable and consumed by all age groups including infants [3]. They are mostly processed in centralized facilities with established distribution and marketing capacity [12]. Traditional African cereals which include acha, have received an increasing attention by scientists within the last decade as revealed from literature [16]. Acha (*Digitaria exilis*) is an annual cereal crop, although considered like one of the oldest West African indigenous cereals, it has for a long time been neglected by scientific research and development programs [17]. Acha is often referred to as “hungry rice” by the indigenous people of West Africa who consume this grain; however, this is a misleading term, implying that it is a ‘famine food’ consumed only during times of food scarcity. They have the potential to contribute significantly to whole grain diets, wellness and economic status improvement and play important role in food security and in

economic development. They are considered as health grains in the sense that they are often consumed whole and are gluten – free [16] and they are also valued as a weaning food because of its low bulk and high caloric density [18]. Therefore the objective of this study was to establish a more effective method for the fortification of acha grains with vitamin A, Iron, Copper and Zinc by comparing coating and dusting technologies.

2. MATERIALS AND METHODS

All chemicals and reagents used were of analytical grade. The Micronutrient premix was obtained from Biological Derivatives Onikan, Lagos Island. Other chemicals were purchased from Steeve-Moore chemicals store in Zaria, Kaduna State, Nigeria. Acha grains were purchased from Kaduna Central Market, Kaduna state of Nigeria. The grains were purchased already dehulled by pounding and winnowed to separate shaft from the grains. Stones were manually removed by washing, and then it was sundried and packaged in an airtight polythene bag.

2.1 Dusting Technology

This fortification technique used was described by USAID and carried out at the Federal Institute of Industrial Research Oshodi [19].

Procedure:

Using the manufacturer’s recommendation, 1.25g of the premix, containing 132795.10 IU/kg vitamin A palmitate, 120 mg/kg iron, 10 mg/kg copper and 90 mg/kg zinc was weighed (Mettler, Germany) damped with 1 ml of distilled water to improve adherence of the powder to the 5 kg of grains weighed using a weighing balance (Mettler, Germany). The premix-grain mixture was further mixed in a tumble mixer (Premier, Germany) and dried in an oven dryer (Xingtai, China) at a temperature of 80°C for 5 minutes to minimize loss of the micronutrient. The dried grains were packaged in an airtight polythene bag and stored at room temperature.

2.2 Coating Technology

The Coating technology used in grain fortification [19] was carried out at the Federal Institute of Industrial Research Oshodi (FIIRO).

Procedure:

Using the manufacturer’s recommendation, a total of 4 kg of acha grains was weighed, then 80 g of the grains was weighted out from the 4 kg grains and 1 g of the same premix powder used in the Dusting technology was also weighted using a weighing balance (Mettler, Germany), the 80 g grains were coated with the 1 g premix in a coating machine (Noah, China) using 1 ml of 96% absolute ethanol which enabled the premix to stick to the grains. After coating the coated grains were mixed with the remains from the initial 4 kg grains at a ratio of 1:200 in a box mixer (Patissier, China). The fortified grains were packaged in an airtight polythene bag and stored at room temperature.

2.3 Cooking of Acha Sample

Fortified acha grains (20 g) was weighed (Mettler, Germany), and poured into 100 ml of boiling water and it was cooked for 10 minutes, allowed to cool in an air-tight container and immediately taken to the laboratory for analysis. The levels of the micronutrients of interest contained in the acha grains were ascertained before fortification, after fortification and after cooking. The analysis of vitamin A was done using high-performance liquid chromatography (HPLC Hitachi Elite LaChrom L-220) method of retinol determination as described in AOAC [20]. The determination of mineral content (Fe, Zn and Cu) was done using atomic absorption spectrophotometer, (AAS Perkin Elmer AAnalyst 400) method AOAC [21].

2.4 Sensory Evaluation of Colour, According to Method by Bayarri et al. [22]

A 20-member panel was constituted who had experience in colour observation, who also exhibited normal colour vision as confirmed with a Farnsworth-munsell 100-Hue Test. Sensory evaluation sessions were performed in a standardised test room [23]. All colours in the chart as shown in Fig. 1, were identified and named before the acha samples were matched for colour change identification

2.5 Statistical Analysis

The data was analyzed using two way analysis of variance (ANOVA). Followed by Tukey’s multiple comparison post hoc tests, to compare the level of significance between standard and experimental groups. Values of P less than 0.05 (P < 0.05) were considered significant. The results were expressed as mean ± standard deviation (SD) except where otherwise stated.

3. RESULTS

With reference to Fig. 1, the panellists observed and recorded 100% closet mix colour for unfortified acha grains, which indicated that the colour of sample before fortification was closet mix. (Fig. 2) and after fortification, the grains showed noticeable colour changes of which coated samples was observed and recorded by panellists at 99% master mix and 1% closet mix while dusted grains showed 98% and 2%,

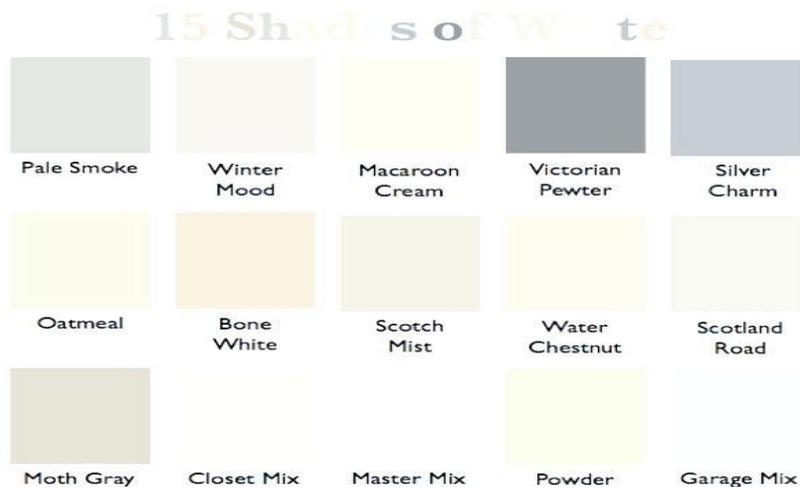


Fig. 1. Colour chart reflecting various shades of white used for identification

(Source: <http://www.pinterest.com>)

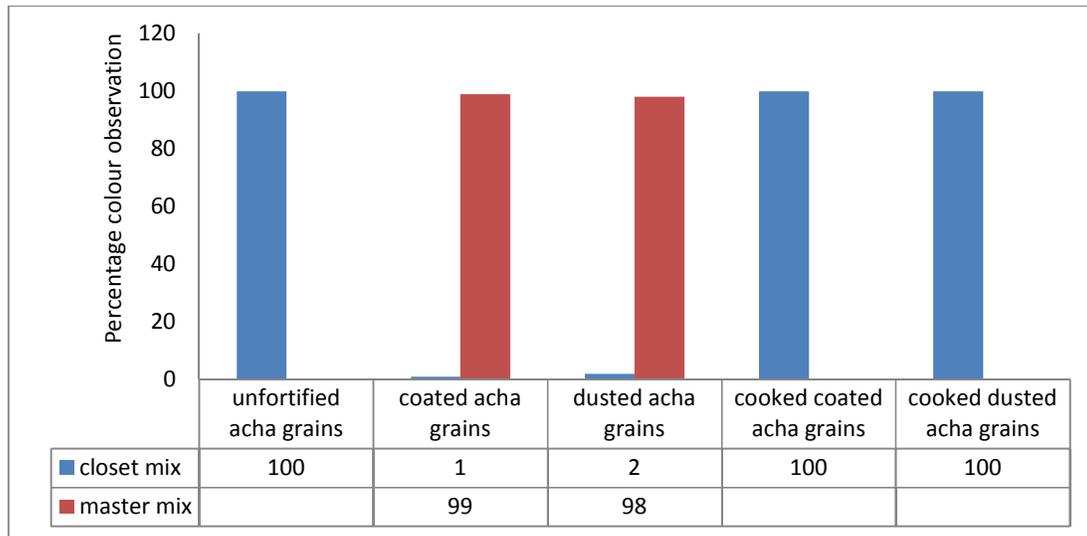


Fig. 2. Percentage colour changes as recorded by panellists

Table 1. Concentration of vitamin A in fortified and unfortified acha grains

	Vitamin A (IU/kg) uncooked grains	Vitamin A (IU/kg) cooked grains	Percentage retention (%)
Unfortified grains	Not detected ^a	Not detected ^a	0.0
Coated grains	29,904.18 ± 23.18 ^c	12,038.48 ± 72.12 ^c	40.18
Dusted grains	29,657.66 ± 68.11 ^b	7,532.47 ± 52.50 ^b	25.06

Table 2. Concentration of iron, copper and zinc in fortified and unfortified acha grains

Sample	Minerals (mg/kg)					
	Iron (Fe)		Copper (Cu)		Zinc (Zn)	
	Before cooking	After cooking	Before cooking	After cooking	Before cooking	After cooking
Unfortified grains	58.46±3.29 ^a	55.98±3.21 ^a	2.78±1.20 ^a	2.68±1.10 ^a	21.1±0.50 ^a	20.57±0.20 ^a
Coated grains	75.80±1.36 ^c	73.32±1.23 ^c	3.72±0.32 ^a	3.63± 0.31 ^a	30.84±0.57 ^b	30.32±0.62 ^b
Dusted grains	68.81±0.82 ^b	66.71±0.85 ^b	3.22±0.80 ^a	3.19± 0.70 ^a	38.72±0.04 ^c	36.85±0.05 ^c

Values are mean ± S.D of three determinations. Values with different superscripts down the column are significantly different ($p < 0.05$)

master mix and closet mix colours respectively as shown in Fig. 2. After cooking, both coated and dusted acha grains recorded 100% closet mix colouration, which indicated that the initial colour (closet mix) of the acha samples before fortification was completely restored after cooking.

3.1 Vitamin A Level in Fortified and Unfortified Acha Grains

The HPLC analysis result confirmed the absence of vitamin A in the unfortified acha grains and the presence of vitamin A in the fortified acha grains as the grains were compared with the

standard as presented in Table 1. shown in Table 1.

The result for analysis of vitamin A levels fortified with dusting and coating technologies as seen in Table 1 shows the concentration of vitamin A present in the grains but the unfortified grains, both uncooked and cooked had no vitamin A present. The uncooked coated grains had a concentration of 29,904.18 ± 23.18 IU/kg which was slightly higher than the dusted grains with a concentration of 29,657.66 ± 68.11 IU/kg. After cooking, there was a reduction in the concentration of vitamin A. The coated grains had a concentration of 12,038.48 ± 72.12 IU/kg

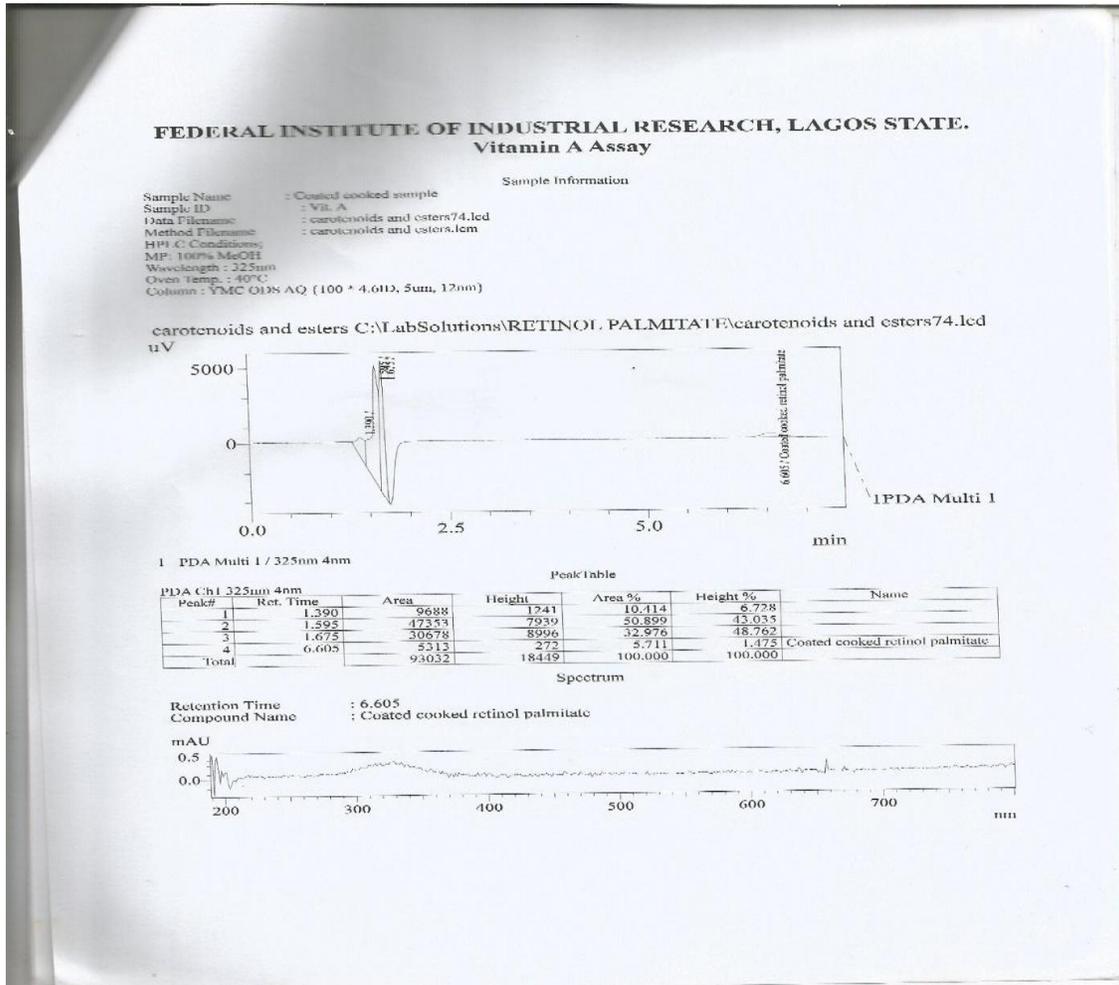
and the dusted grains had a concentration of $7,532.47 \pm 52.50$ IU/kg.

3.2 Mineral Elements Levels in Fortified and Unfortified Acha Grains

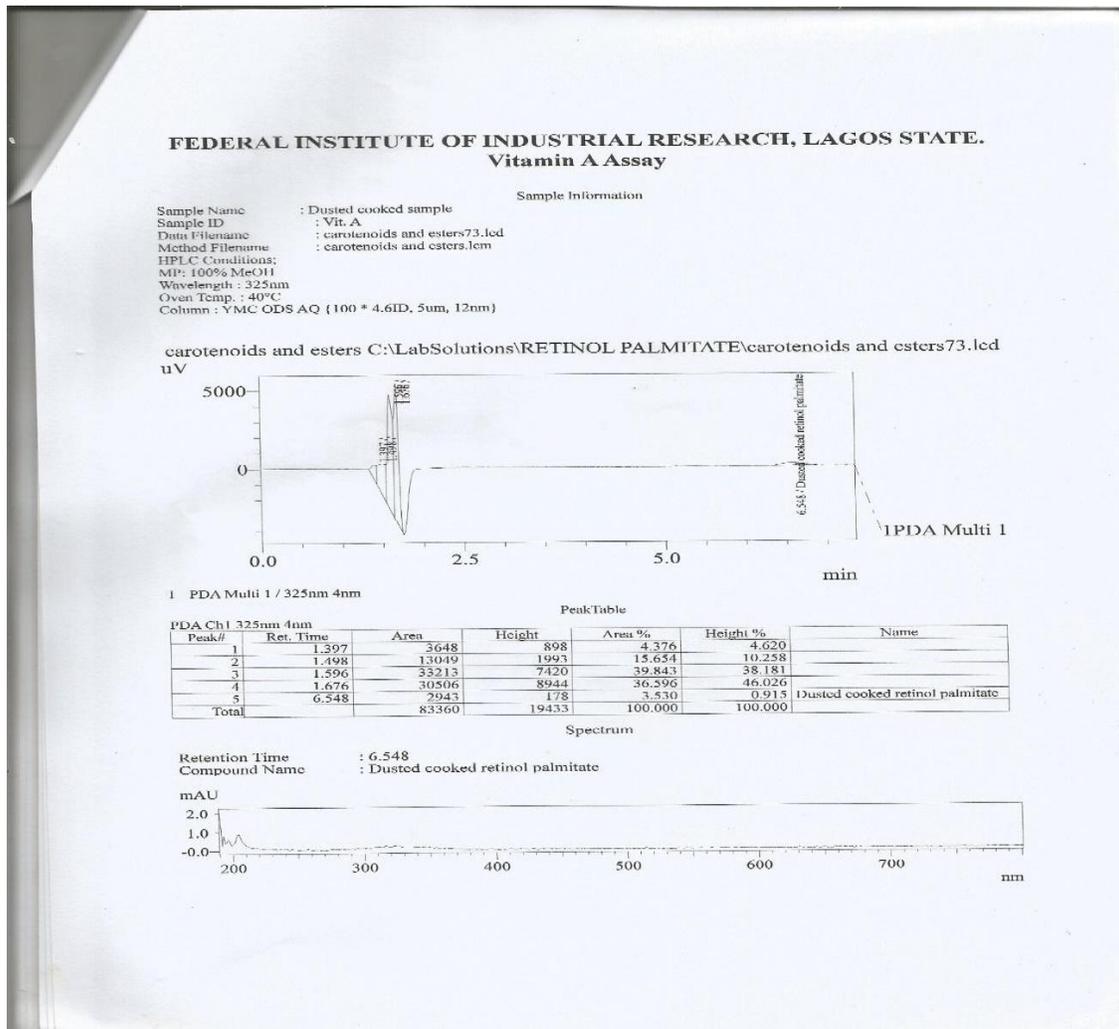
After analyzing for the presence of iron, the unfortified grains had a concentration of 58.46 mg/kg, which increased after coating to 75.8 mg/kg (22%) before cooking and slightly reduced to 73.32 (20%) after cooking, and after dusting 68.81 mg/kg (15%) was observed before cooking which slightly reduced to 66.71 mg/kg (12%) after cooking. The level of zinc in unfortified acha (21.1 mg/kg) increased after dusting to 38.72 mg/kg (45%) before cooking and slightly reduced to 36.85 mg/kg (43%) after cooking. After coating

the zinc level increased to 30.84 mg/kg (32%), which reduced slightly to 30.32 mg/kg (30%) after cooking, also the level of copper in the unfortified sample (2.78 mg/kg) increased after dusting to 3.22 mg/kg (14%) and slightly reduced to 3.19 mg/kg (13%) after cooking. 3.72 mg/kg (25%) was observed for coated grains which slightly reduced to 3.63mg/kg (23%) after cooking as presented in Table 2. Fortification significantly ($p < 0.05$) increased the iron content of the acha grains with the coated grains recording the highest increase. There was a slight but not significant ($p < 0.05$) increase in copper content of the acha grains while there was a significant ($p < 0.05$) increase in the zinc content of the dusted grains when compared with the unfortified and the coated grains.

HPLC Chromatograms



a. Coated Retinyl palmitate after cooking



b. Dusted Retinyl palmitate after cooking

4. DISCUSSION

Food fortification is safe and cost effective in the prevention of micronutrient deficiencies and has been widely practiced in developed countries for more than a century. It could be seen as a small investment that can help supplement the overall response to malnutrition in large populations [24].

Food fortification has been used to correct or prevent widespread nutrient intake shortfalls and associated deficiencies to balance the total nutrient profile of a diet, to restore nutrients lost in processing or to appeal to consumers looking to supplement their diet [25]. Acha (*Digitaria exilis*) is one of the most nutritious African cereals, but it is deficient in some

essential minerals and vitamins which include vitamin A.

After fortification, the coated and dusted grains showed very noticeable colour changes which could be as a result of the premix colour. The vitamin A (retinol palmitate) used in fortification is yellow in colour and could possibly be the cause of the colour changes observed [12]. After cooking, colour reversal was observed for both coated and dusted grains as the initial colour of unfortified sample was restored. This is as a result of the solubility of the premix in water and its quick dissolution on heating, which is then absorbed by the grains. The ability for any cereal to be an agent of fortification depends on its ability to carry the fortificant without changing its properties and even if there is a change it should

be minimal so it does not affect the consumer [12].

Analysis carried out to determine the levels of the micronutrients of interest showed that unfortified acha contained no vitamin A, but contained iron, copper and zinc. The retention time of vitamin A in all the fortified grains were very close to that of the standard, this signifies the presence of vitamin A before and after cooking except for the unfortified grains which had no retention time; this confirmed the absence of vitamin A in the unfortified grains before and after cooking. All amounts of micronutrient (Vitamin A, Iron, Copper, zinc) used in fortification were in accordance with recommended micronutrient fortification standard [26].

After fortification, the iron content in unfortified grain increased by 22% and 15% for coated and dusted respectively, Copper increased by 25% and 14% while Zinc increased by 32% and 45% with coating and dusting respectively. The presence of zinc in higher amounts as fortified by dusting could be due to the combined electrostatic force of binding introduced during the process and the very high bioavailability of zinc [27]. Also the use of ethanol in the coating technology could affect the retention and bioavailability of zinc, which is in accordance with the findings of Fairweather. Tait et al. [28] who observed an adverse effect of ethanol and alcoholic beverages on zinc retention and bioavailability. A similar study by Alavi et al. [29] recorded a higher zinc content by dusting technology when compared with coating technology in fortification of rice. For vitamin A, the coated grains had a retention percentage of 40.18% and the dusted grains had a retention percentage of 25.06%, although dusting technology proved to be more effective for zinc fortification, yet the observed increase for vitamin A, Copper and Iron indicates the efficiency of the coating technology over the dusting technology because the added nutrient, being on the surface of the acha grains in the dusted fortified acha can be easily removed thereby causing the dusted grains to have a lower retention percentage than that of the coated acha [27]. This result agrees with the findings of Owen and McLintire [30] and Steele [31] who suggested that application of heat to rice fortified via coating technology recorded minimal loss of micronutrient compared to the dusted technology. After cooking, there was a decrease in the levels of all the fortified micronutrients. The observed decrease in micronutrient level was most-likely as a result of

heat treatment and leaching due to cooking. Observations and reports on similar effect of heat treatment on micronutrient levels were made by Oghbaei and Prakash [32], Cubadda et al. [33] and Prodanov et al. [34].

5. CONCLUSION

Like other emerging ancient grains, Acha (*Digitaria exilis*) is known for its excellent culinary and nutritional properties and its potentials in new product development, as they are believed to represent the highest quality of vitamins, minerals, fibre and amino acids. The dusting and coating technology proved to be efficient in the fortification of acha grains due to the fact that the physical properties of the grains were not altered, although coating was seen to be a more promising technology for fortifying acha grains with Vitamin A, iron and copper. This study further presented the possibility of acha grains being a good vehicle for vitamin A, iron, zinc and copper fortification with the coating technology being a more effective approach.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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