Original Research Article

A COMPARATIVE STUDY ON THE EFFECTIVENESS OF COATING AND DUSTING TECHNOLOGIES ON FORTIFICATION OF ACHA (*DIGITARIA EXILIS*) GRAINS.

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 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.

Results: Vitamin A was undetected in unfortified grain, but present at 29,909 IU/kg and 29,673 IU/kg in coated and dusted grains respectively. The iron content(58mg/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 aneamic, 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 esters 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 goiter, rickets, ariboflavinosis and pellagra in the United States is attributed to the consumption of foods fortified with iodine, vitamin D, vitamin B_2 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 in developing economy. 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).

2. MATERIALS AND METHOD

All chemicals and reagents used were of analytical grade. The vitamin 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. It was manually destonned by washing, sundried and packaged in a Ziploc 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 manufacturers recommendation for addition of vitamin premix, 1.25 g of premix and 5 kg of grains were weighted using a weighing balance (Mettler, Germany), the grains were damped with 5 ml of distilled water to improve adherence of the powder to the grains. After damping, the grains were mixed in a tumble mixer (Premier, Germany) and dried in an oven dryer (Xingtai, China) at a temperature of 80 ^{o}C for 5 minutes to minimize loss of the micronutrient. The dried grains were packaged in an opaque (Ziploc) storage bag and stored at room temperature.

2.2 Coating Technology

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

Procedure:

A total of 4 kg of acha grains was weighted, then 80 g of the grains was weighted out from the 4 kg grains and 1 g of premix powder 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 opaque (Ziploc) 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 vitamin A content of the acha grains were analyzed before fortification, after fortification and after cooking. The analysis was done using high-performance liquid chromatography (HPLC) 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) method AOAC (21).

2.4 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 control 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. RESULT

Photographs of the coated, dusted and unfortified grains after fortification are shown in Figure 1. The unfortified grains were whitish in colour as expected; the dusted grains were also white with a very faint colour change which can only be seen under very bright lighting while the coated grains had yellow coloured grains sparsely dispersed in the white grains. Figure 2 shows the photographs of the coated, dusted and unfortified grains after cooking. There was no colour difference between the unfortified, dusted and coated grains as they all appeared whitish in colour.

a b c

Figure 1: Acha Grains before Fortification (a) and after Fortification with the Coating Technology (b) and the Dusting Technology (c).

a b c

Figure 2: Acha Grains after Cooking the Unfortified grains (a), the Coated fortified grains (b) and the Dusted Fortified grains (c).

The HPLC analysis shows the result of the absence of vitamin A in the unfortified acha grains and the presence of vitamin A in the fortified acha grains as the grains where compared with the standard as presented in Table 1.

Table 1 Retention Time and Peak Area of Acha Grains Analyzed for the Presence of Vitamin A

	Retention time (minutes)	Area of peak (mV/s)
Standard (retinol palmitate)	6.693	54921
Dusted grains	6.610	12414
Coated grains	6.594	12311
Dusted grains (cooked)	6.548	2943
Coated grains (cooked)	6.577	4702
Unfortified grains	Nil	Nil

Result for analyzing the vitamin A level of acha grains fortified with the dusting and coating technology is presented in Table 2. The result shows the concentration of vitamin A present in the grains but the unfortified grains, both raw and cooked had no vitamin A present. The raw grains coated grains had a concentration of 29,909.04 IU/kg which is slightly higher than the dusted grains with a concentration of 29,673.21 IU/kg. After cooking there was a high reduction in the concentration of vitamin A where the coated grains had a concentration of 12,051.21 IU/kg and the dusted grains had a concentration of 7,529.19 IU/kg.

Table 2 Concentration of Vitamin A in Fortified and Unfortified Acha Grains

	Vitamin A (IU/kg)	Vitamin A (IU/kg) Cooked grains	Percentage retention (%)
Unfortified grains	Not detected	Not detected	
Coated grains	29,909.04	12,051.21	40.29
Dusted grains	29,673.21	7,529.19	25.37

After analyzing for the presence of iron, the unfortified grains had a concentration of 58.46 mg/kg, which increased after fortification to 75.8 mg/kg (22%) and 68.81 mg/kg (15%) for coated grains and dusted grains respectively. The level of zinc in unfortified acha, 21.1mg/kg increased after fortification to 38.72 mg/kg (45%) for dusted and 30.84mg/kg (32%) for coated, also the level of copper in the unfortified sample, 2.78 mg/kg increased after fortification to 3.22mg/kg (14%) for dusted and 3.72 mg/kg (25%) for coated as presented in Table 3. 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.

Table 3 Concentration of Iron, Copper and Zinc in Fortified and Unfortified Acha Grains

	MINERALS (mg/kg)		
SAMPLE	Iron (Fe)	Copper (Cu)	Zinc (Zn)
Unfortified grains	58.46 ± 3.29^{a}	2.78 ± 1.20^{a}	21.1 ± 0.50^{a}
Coated grains	75.8 ± 1.36^{c}	3.72 ± 0.32^{a}	30.84 ± 0.57^{b}
Dusted grains	68.81 ± 0.82^{b}	3.22 ± 0.8^{a}	38.72 ± 0.04^{c}

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

4. DISCUSSION

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 (22). 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 grains had yellow coloured grains slightly dispersed in the white grains, while the dusted grains had a very faint colour change which is as a result of the premix colour. The vitamin A (retinol palmitate) used in fortification is yellow in colour therefore it gives the premix its yellow colour (12). After cooking both the fortified and unfortified grains, it came out whitish or rather same colour for both the fortified and unfortified grains. This is as a result of the solubility of the premix in water because during cooking the premix on the grains is dissolved, 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). From Figure1 there was a colour change but it was so minimal that the colour change was lost after cooking as seen in Figure 2.

Analysis carried out on the grains for the concentration of vitamin A in acha grains showed that acha contained no vitamin A. The retention time of all the fortified grains are 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 shows the absence of vitamin A in the unfortified grains before and after cooking. After the analysis the concentration of vitamin A present in the fortified grains was evaluated and the coated grains had a concentration of 29,909.04 IU/kg while the dusted grains had a concentration of 29,673.21 IU/kg which were close to the recommended vitamin A fortification standard of 30,000 IU/kg (23).

After cooking, there was a decrease in vitamin A concentrations of the coated grains from 29,909.04 IU/kg to 12,051.21 IU/kg and the dusted grains reduced from 29,673.21 IU/kg to 7,529.19 IU/kg. The loss in the value of vitamin A is most-likely as a result of heat treatment effect and leaching due to cooking (24). The coated grains had a retention percentage of 40 % and the dusted grains had a retention percentage of 25 %, this 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 and can be easily removed thereby causing the dusted grains to have a lower retention percentage than that of the coated acha (25). This result agrees with the findings of Alavi *et al.* (26) who suggested that application of heat to rice fortified via coating technology recorded small loss of vitamin A compared to the dusted technology.

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. This study further presented the possibility of acha grains being a good vehicle for vitamin A and iron fortification with the coating technology being a more effective approach.

COMPETING INTERESTS

No competing interests

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