

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

4
5 **ABSTRACT**

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

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

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

14 **Results:** Vitamin A was undetected in unfortified grain, but present at 29,909 IU/kg and 29,673 IU/kg in
15 coated and dusted grains respectively. The iron content(58mg/kg) in unfortified grain increased by 22%
16 and 15% for coated and dusted respectively, Copper increased by 25% and 14% and Zinc by 32% and
17 45% with coating and dusting respectively.

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

21
22 **Keywords:** Acha, grains, coating, dusting, fortification, micronutrients
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25 **1. INTRODUCTION**

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

38 Vitamin A is a vital nutrient required in small amounts by humans for the normal functioning of the visual
39 system, for maintaining of cell functions, for growth and development, epithelial cellular integrity, immune
40 function and reproduction (4). Dietary requirements of vitamin A are normally provided from pre-formed

41 vitamin A (retinol), which is present in foods of animal sources; it is also commercially produced and
42 administered as esters such as retinyl acetate or palmitate. Provitamin A carotenoids are derived from
43 foods of vegetable origin, which have to be converted into retinol by tissues such as the intestinal mucosa
44 and the liver in order to be utilized by cells (5). In commercial preparations preformed vitamin A is
45 esterified usually with palmitic or acetic acid, to the more stable corresponding esters. Retinyl acetate and
46 retinyl palmitate, along with provitamin A (β -carotene), are thus the main commercial forms of vitamin A
47 that are available for use as food fortificants. Vitamin A is more labile than its esters form, for this reason
48 vitamin A esters are usually used for food fortification (6).

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

61 There are many ways to increase micronutrient intake, thereby reducing and preventing this global
62 prevalence of hidden hunger, this includes taking supplements regularly or through dietary measures that
63 promote the regular consumption of micronutrient rich foods and improve their absorption in the diet.
64 Technology is now available to improve the micronutrient content of cereal crops through selective plant
65 breeding (12). However, in many situations these interventions are either not available or inaccessible by
66 those who need them the most. On the other hand fortification of commonly eaten foods, including
67 cereals, offers a low-cost and simple way of delivering micronutrients to a large number of people who
68 need them.

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

78 Cereal grains are important food vehicles for fortification. Though several foods could be used for carrying
79 micronutrients, high fiber cereal grains are inexpensive vehicles for providing basic nutrition to large
80 populations (15). Cereals are excellent vehicles because they are staple foods in many parts of the world,
81 which are key ingredient in so many food preparations, readily available, affordable, and culturally
82 acceptable and consumed by all age groups including infants (3). They are mostly processed in
83 centralized facilities with established distribution and marketing capacity (12). Traditional African cereals
84 which include acha, have received an increasing attention by scientists within the last decade as revealed
85 from literature (16). Acha (*Digitaria exilis*) is an annual cereal crop, although considered like one of the
86 oldest West African indigenous cereals, it has for a long time been neglected by scientific research and

87 development programs (17). Acha is often referred to as “hungry rice” by the indigenous people of West
88 Africa who consume this grain; however, this is a misleading term, implying that it is a ‘famine food’
89 consumed only during times of food scarcity. They have the potential to contribute significantly to whole
90 grain diets, wellness and economic status improvement and play important role in food security in
91 developing economy. They are considered as health grains in the sense that they are often consumed
92 whole and are gluten – free (16) and they are also valued as a weaning food because of its low bulk and
93 high caloric density (18).

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95 **2. MATERIALS AND METHOD**

96 All chemicals and reagents used were of analytical grade. The vitamin premix was obtained from
97 Biological Derivatives Onikan, Lagos Island. Other chemicals were purchased from Steeve-Moore
98 chemicals store in Zaria, Kaduna State, Nigeria. Acha grains were purchased from Kaduna Central
99 Market, Kaduna state of Nigeria. The grains were purchased already dehulled by pounding and winnowed
100 to separate shaft from the grains. It was manually destonned by washing, sundried and packaged in a
101 **Ziploc** bag.

102 **2.1 Dusting Technology**

103 This fortification technique used was described by USAID and carried out at the Federal Institute of
104 Industrial Research Oshodi (19).

105 **Procedure:**

106 Using the manufacturers recommendation for addition of vitamin premix, 1.25 g of premix and 5 kg of
107 grains were **weighted** using a weighing balance (Mettler, Germany), the grains were damped with 5 ml of
108 distilled water to improve adherence of the powder to the grains. After damping, the grains were mixed in
109 a tumble mixer (Premier, Germany) and dried in an oven dryer (Xingtai, China) at a temperature of 80°C
110 for 5 minutes to minimize loss of the micronutrient. The dried grains were packaged in an opaque (**Ziploc**)
111 storage bag and stored at room temperature.

112 **2.2 Coating Technology**

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

115 **Procedure:**

116 A total of 4 kg of acha grains was weighted, then 80 g of the grains was weighted out from the 4 kg grains
117 and 1 g of premix powder was also **weighted** using a weighing balance (Mettler, Germany), the 80 g
118 grains were coated with the 1 g premix in a coating machine (Noah, China) using 1 ml of 96 % absolute
119 ethanol which enabled the premix to stick to the grains. After coating the coated grains were mixed with
120 the remains from the initial 4 kg grains at a ratio of 1:200 in a box mixer (Patisier, China). The fortified
121 grains were packaged in an opaque (**Ziploc**) bag and stored at room temperature.

122 **2.3 Cooking of Acha Sample**

123 Fortified acha grains (20 g) was weighed (Mettler, Germany), and poured into 100 ml of boiling water and
124 it was cooked for 10 minutes, allowed to cool in an air-tight container and immediately taken to the
125 laboratory for analysis.

126 The vitamin A content of the acha grains were analyzed before fortification, after fortification and after
127 cooking. The analysis was done using high-performance liquid chromatography (HPLC) method of retinol
128 determination as described in AOAC (20). The determination of mineral content (Fe, Zn and Cu) was
129 done using atomic absorption spectrophotometer, (AAS) method AOAC (21).

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131 **2.4 Statistical analysis**

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

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138 **3. RESULT**

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



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



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

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

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160 **Table 1** Retention Time and Peak Area of Acha Grains Analyzed for the Presence of
 161 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

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163 Result for analyzing the vitamin A level of acha grains fortified with the dusting and coating technology is
 164 presented in Table 2. The result shows the concentration of vitamin A present in the grains but the
 165 unfortified grains, both raw and cooked had no vitamin A present. The **raw grains coated grains** had a
 166 concentration of 29,909.04 IU/kg which is slightly higher than the dusted grains with a concentration of
 167 29,673.21 IU/kg. After cooking there was a high reduction in the concentration of vitamin A where the
 168 coated grains had a concentration of 12,051.21 IU/kg and the dusted grains had a concentration of
 169 7,529.19 IU/kg.

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171 **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

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173 After analyzing for the presence of iron, the unfortified grains had a concentration of 58.46 mg/kg, which
 174 increased after fortification to 75.8 mg/kg (22%) and 68.81 mg/kg (15%) for coated grains and dusted
 175 grains respectively. The level of zinc in unfortified acha, 21.1mg/kg increased after fortification to 38.72
 176 mg/kg (45%) for dusted and 30.84mg/kg (32%) for coated, also the level of copper in the unfortified
 177 sample, 2.78 mg/kg increased after fortification to 3.22mg/kg (14%) for dusted and 3.72 mg/kg (25%) for
 178 coated as presented in Table 3. Fortification significantly ($p < 0.05$) increased the iron content of the acha
 179 grains with the coated grains recording the highest increase. There was a slight but not significant
 180 ($p < 0.05$) increase in copper content of the acha grains while there was a significant ($p < 0.05$) increase in
 181 the zinc content of the dusted grains when compared with the unfortified and the coated grains.

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

SAMPLE	MINERALS (mg/kg)		
	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

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

186 **4. DISCUSSION**

187 Food fortification has been used to correct or prevent widespread nutrient intake shortfalls and associated
188 deficiencies to balance the total nutrient profile of a diet, to restore nutrients lost in processing or to
189 appeal to consumers looking to supplement their diet (22). Acha (*Digitaria exilis*) is one of the most
190 nutritious African cereals, but it is deficient in some essential minerals and vitamins which include vitamin
191 A.

192 After fortification, the coated grains had yellow coloured grains slightly dispersed in the white grains, while
193 the dusted grains had a very faint colour change which is as a result of the premix colour. The vitamin A
194 (retinol palmitate) used in fortification is yellow in colour therefore it gives the premix its yellow colour (12).
195 After cooking both the fortified and unfortified grains, it came out whitish or rather same colour for both
196 the fortified and unfortified grains. This is as a result of the solubility of the premix in water because during
197 cooking the premix on the grains is dissolved, which is then absorbed by the grains. The ability for any
198 cereal to be an agent of fortification depends on its ability to carry the fortificant without changing its
199 properties and even if there is a change it should be minimal so it does not affect the consumer (12).
200 From Figure1 there was a colour change but it was so minimal that the colour change was lost after
201 cooking as seen in Figure 2.

202 Analysis carried out on the grains for the concentration of vitamin A in acha grains showed that acha
203 contained no vitamin A. The retention time of all the fortified grains are very close to that of the standard,
204 this signifies the presence of vitamin A before and after cooking except for the unfortified grains which
205 had no retention time; this shows the absence of vitamin A in the unfortified grains before and after
206 cooking. After the analysis the concentration of vitamin A present in the fortified grains was evaluated and
207 the coated grains had a concentration of 29,909.04 IU/kg while the dusted grains had a concentration of
208 29,673.21 IU/kg which were close to the recommended vitamin A fortification standard of 30,000 IU/kg
209 (23).

210 After cooking, there was a decrease in vitamin A concentrations of the coated grains from 29,909.04
211 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
212 in the value of vitamin A is most-likely as a result of heat treatment effect and leaching due to cooking
213 (24). The coated grains had a retention percentage of 40 % and the dusted grains had a retention
214 percentage of 25 %, this indicates the efficiency of the coating technology over the dusting technology
215 because the added nutrient, being on the surface of the acha grains in the dusted fortified acha and can
216 be easily removed thereby causing the dusted grains to have a lower retention percentage than that of
217 the coated acha (25). This result agrees with the findings of Alavi *et al.* (26) who suggested that
218 application of heat to rice fortified via coating technology recorded small loss of vitamin A compared to the
219 dusted technology.

220 **5. CONCLUSION**

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

227 **COMPETING INTERESTS**

228 No competing interests

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