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 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.

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, zinc 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 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 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 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 METHOD

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, 120mg/kg iron, 10mg/kg copper and 90mg/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 ^{o}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

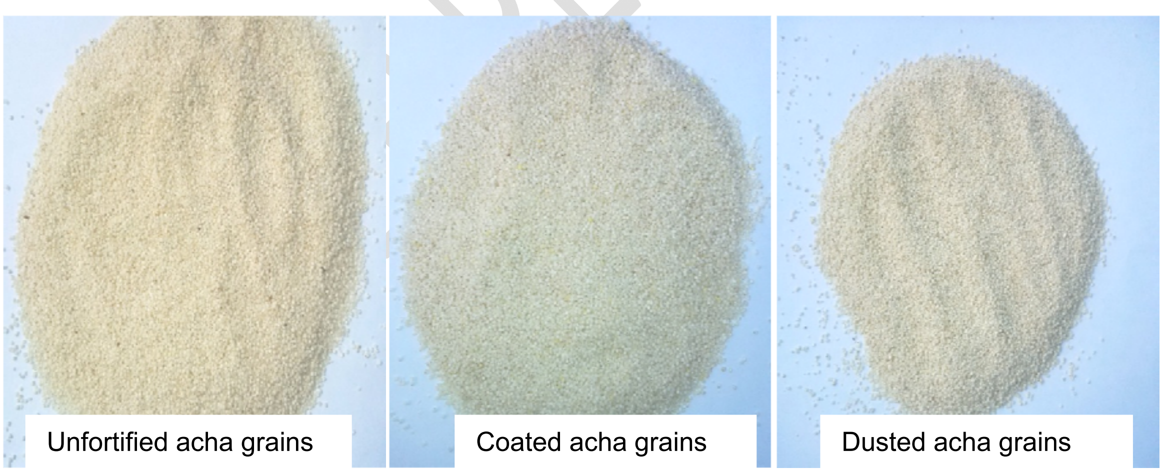
Fortified acha grains (20 g) was weighed (Mettler, Germany), and poured into 100 ml of boiling water and it was cooked for 10 minutes, allowed to cool in an air-tight container and immediately taken to the laboratory for analysis. The levels of the micronutrients of interest contained in the acha grains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

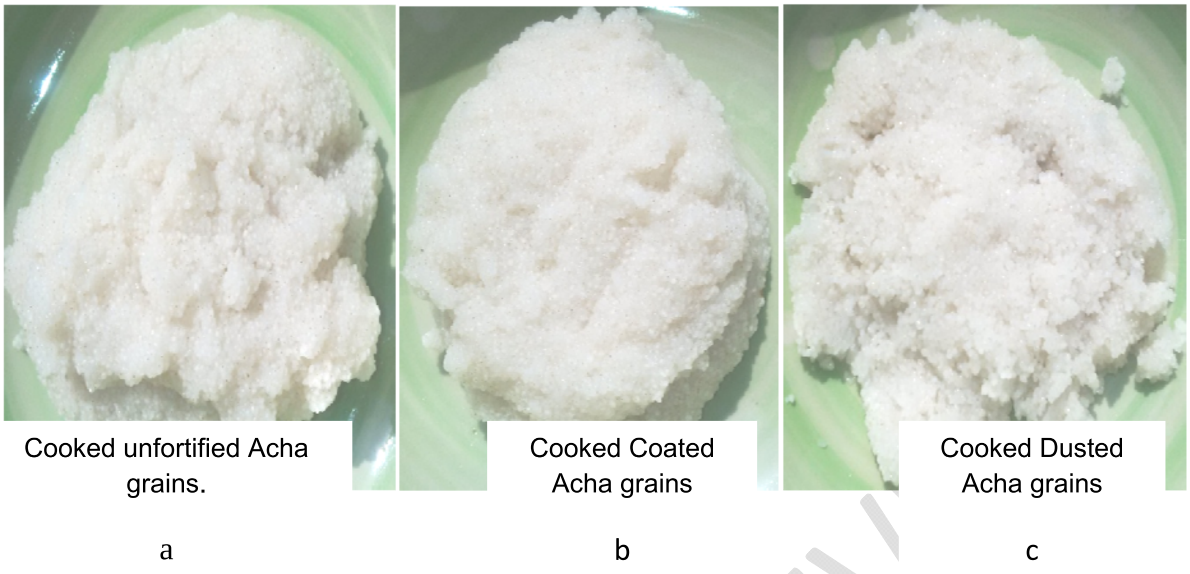


Figure 2: Acha Grains after Cooking the Unfortified grains (a), the Coated fortified grains (b) and the Dusted Fortified grains (c).

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 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

The result for analysis of vitamin A levels fortified with dusting and coating technologies as seen in table 2 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 29,909.04 IU/kg which was slightly higher than the dusted grains with a concentration of 29,673.21 IU/kg. After cooking, there was a reduction in the concentration of vitamin A. 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) Uncooked grains	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

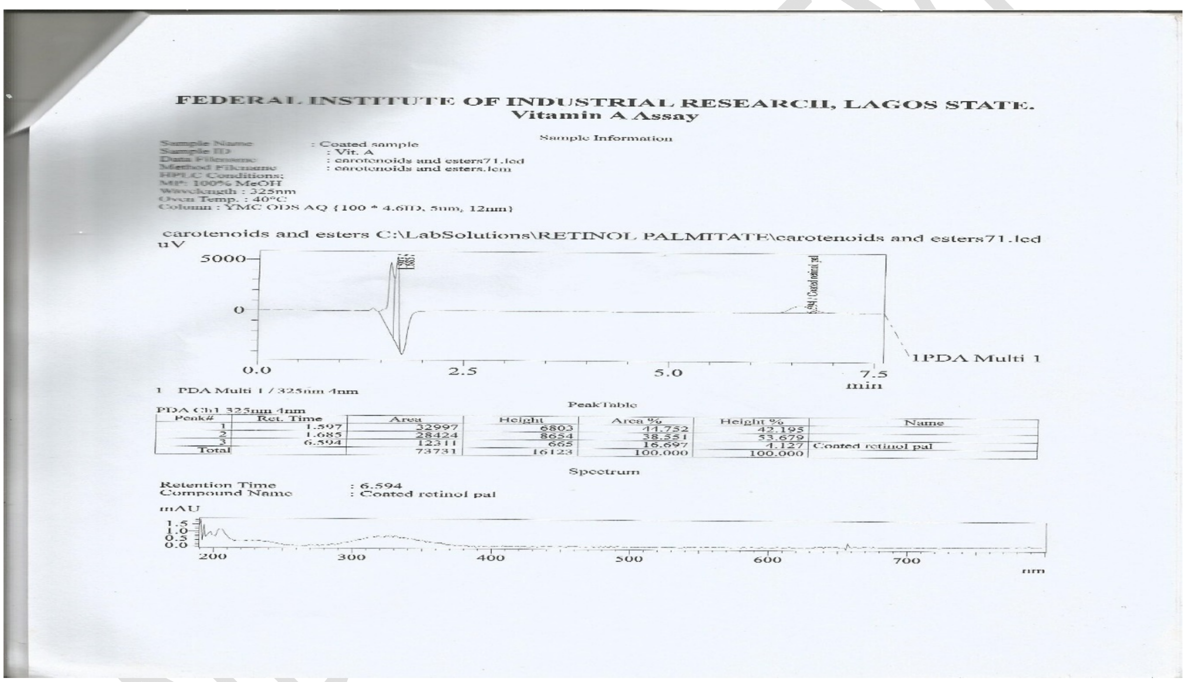
After analyzing for the presence of iron, the unfortified grains had a concentration of 58.46 mg/kg, which increased after coating to 75.8 mg/kg (22%) before cooking and slightly reduced to 73.32 (20%) after cooking, and after dusting 68.81 mg/kg (15%) was observed before cooking which slightly reduced to 66.71mg/kg (12%) after cooking. The level of zinc in unfortified acha (21.1mg/kg) increased after dusting to 38.72 mg/kg (45%) before cooking and slightly reduced to 36.85mg/kg (43%) after cooking. After coating the zinc level increased to 30.84mg/kg (32%), which reduced slightly to 30.32mg/kg (30%) after cooking, also the level of copper in the unfortified sample (2.78 mg/kg) increased after dusting to 3.22mg/kg (14%) and slightly reduced to 3.19mg/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 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)	
	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).

HPLC Chromatograms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Vitamin A Assay

Sample Information

Sample Name : Coated sample
Sample ID : Vit. A
Data Filename : carotenoids and esters71.lcd
Method Filename : carotenoids and esters.lcm
HPLC Conditions;
MP: 100% MeOH
Wavelength : 325nm
Oven Temp. : 40°C
Column : YMC ODS AQ (100 * 4.6ID, 5um, 12nm)

carotenoids and esters C:\LabSolutions\RETINOL PALMITATE\carotenoids and esters71.lcd

1 PDA Multi 1 / 325nm 4nm

PeakTable

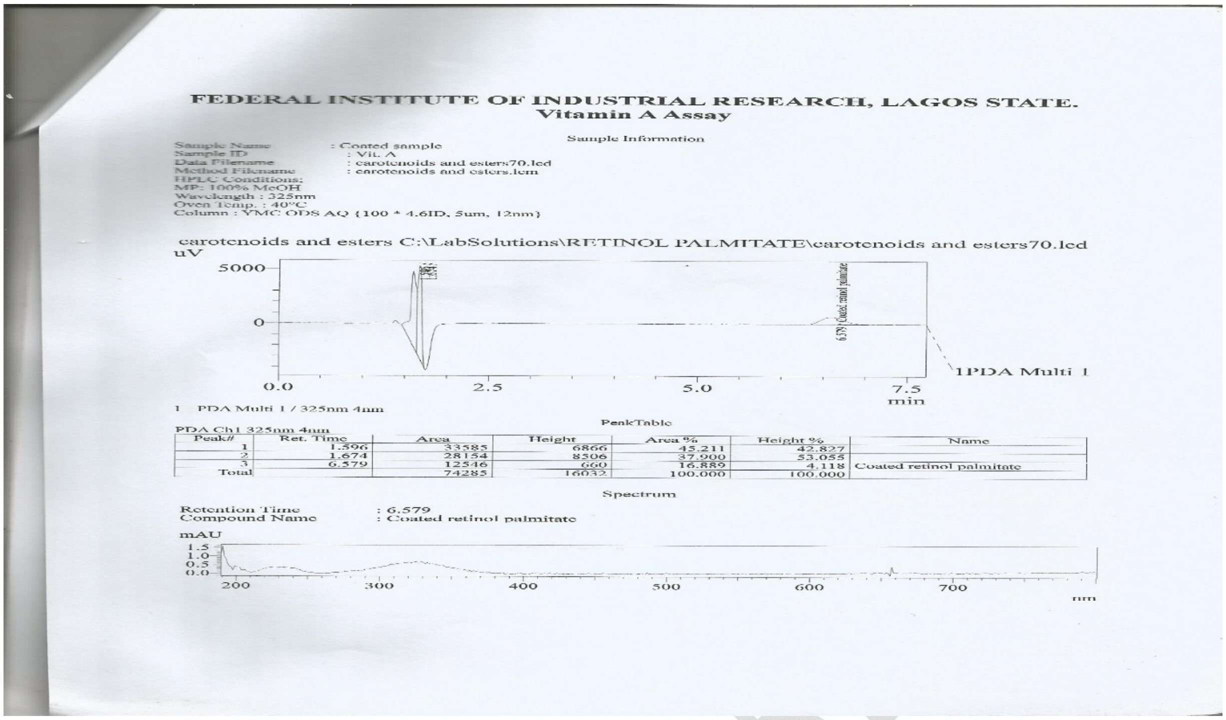
PDA Ch1 325nm 4nm

Peak#	Ret. Time	Area	Height	Area %	Height %	Name
1	1.597	32997	6803	44.752	42.195	
2	1.685	28424	8654	38.551	53.679	
3	6.594	12311	665	16.697	4.127	Coated retinol pal
Total		73731	16123	100.000	100.000	

Spectrum

Retention Time : 6.594
Compound Name : Coated retinol pal

a. Coated Retinyl palmitate before cooking (1st)



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Vitamin A Assay

Sample Information

Sample Name : Coated sample
Sample ID : Vit. A
Data Filename : carotenoids and esters70.lcd
Method Filename : carotenoids and esters.lcm
HPLC Conditions:
MP: 100% MeOH
Wavelength : 325nm
Oven Temp. : 40°C
Column : YMC ODS AQ {100 * 4.6ID, 5um, 12nm}

carotenoids and esters C:\LabSolutions\RETINOL PALMITATE\carotenoids and esters70.lcd

1 PDA Multi 1 / 325nm 4nm

PeakTable

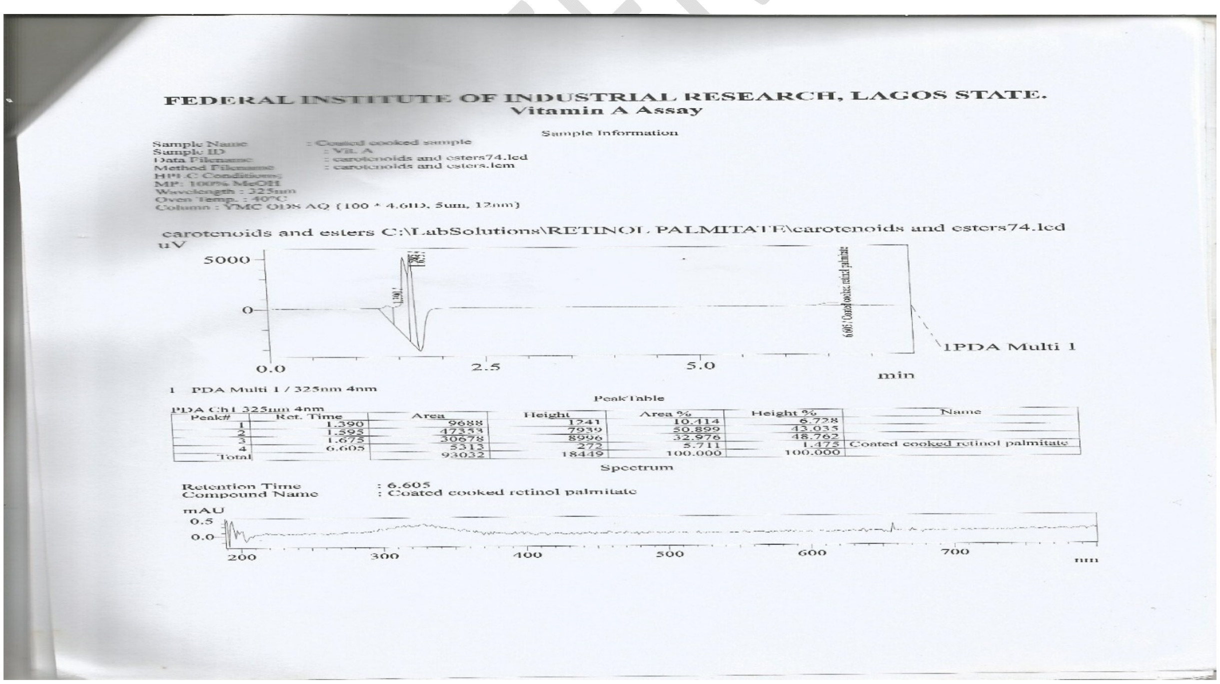
PDA Ch1 325nm 4nm

Peak#	Ret. Time	Area	Height	Area %	Height %	Name
1	1.596	33585	6866	45.211	42.827	
2	1.674	28154	8506	37.900	53.055	
3	6.579	12546	660	16.889	4.118	Coated retinol palmitate
Total		74285	16032	100.000	100.000	

Spectrum

Retention Time : 6.579
Compound Name : Coated retinol palmitate

b. Coated Retinyl palmitate before cooking (2nd)



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Vitamin A Assay

Sample Information

Sample Name : Coated cooked sample
Sample ID : Vit. A
Data Filename : carotenoids and esters74.lcd
Method Filename : carotenoids and esters.lcm
HPLC Conditions:
MP: 100% MeOH
Wavelength : 325nm
Oven Temp. : 40°C
Column : YMC ODS AQ {100 * 4.6ID, 5um, 12nm}

carotenoids and esters C:\LabSolutions\RETINOL PALMITATE\carotenoids and esters74.lcd

1 PDA Multi 1 / 325nm 4nm

PeakTable

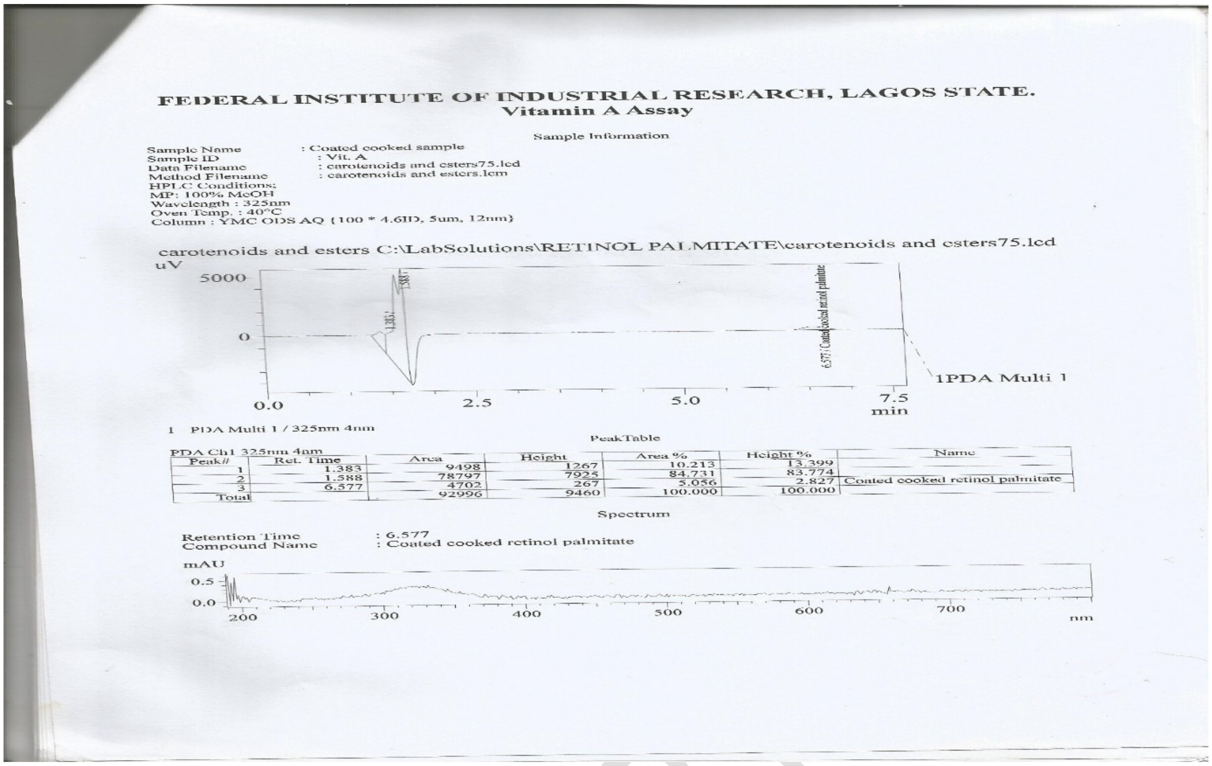
PDA Ch1 325nm 4nm

Peak#	Ret. Time	Area	Height	Area %	Height %	Name
1	1.390	9688	1241	10.414	6.728	
2	1.595	47353	7939	50.899	43.035	
3	1.675	30678	8996	32.976	48.762	
4	6.605	5313	272	5.711	1.475	Coated cooked retinol palmitate
Total		93032	18449	100.000	100.000	

Spectrum

Retention Time : 6.605
Compound Name : Coated cooked retinol palmitate

c. Coated Retinyl palmitate after cooking (1st)



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Vitamin A Assay

Sample Information

Sample Name : Coated cooked sample
Sample ID : Vit. A
Data Filename : carotenoids and esters75.lcd
Method Filename : carotenoids and esters.lcm
HPLC Conditions;
MP: 100% MeOH
Wavelength : 325nm
Oven Temp. : 40°C
Column : YMC ODS AQ {100 * 4.6ID, 5um, 12nm}

1 PDA Multi 1 / 325nm 4nm

PeakTable

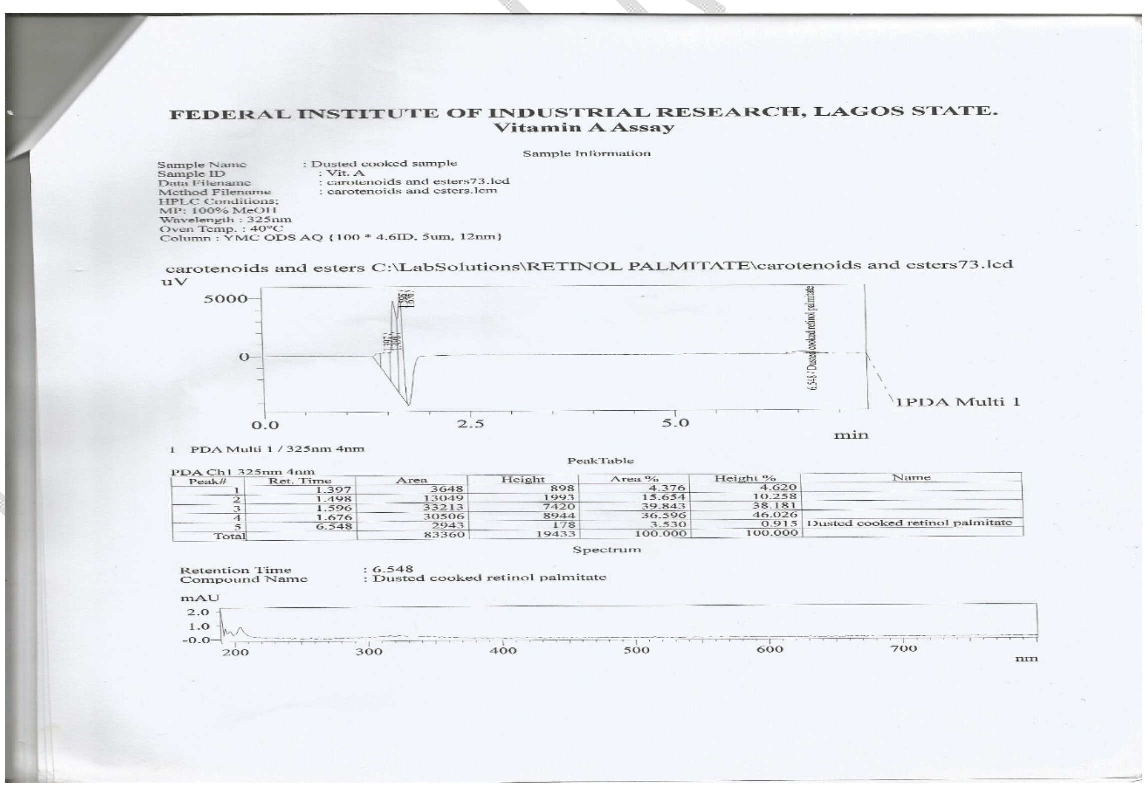
PDA Ch1 325nm 4nm

Peak#	Ret. Time	Area	Height	Area %	Height %	Name
1	1.383	9498	1267	10.213	13.399	
2	1.588	78797	7925	84.731	83.774	
3	6.577	4702	267	5.056	2.827	Coated cooked retinol palmitate
Total		92996	9460	100.000	100.000	

Spectrum

Retention Time : 6.577
Compound Name : Coated cooked retinol palmitate

d. Coated Retinyl palmitate after cooking (2nd)



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Vitamin A Assay

Sample Information

Sample Name : Dusted cooked sample
Sample ID : Vit. A
Data Filename : carotenoids and esters73.lcd
Method Filename : carotenoids and esters.lcm
HPLC Conditions;
MP: 100% MeOH
Wavelength : 325nm
Oven Temp. : 40°C
Column : YMC ODS AQ {100 * 4.6ID, 5um, 12nm}

1 PDA Multi 1 / 325nm 4nm

PeakTable

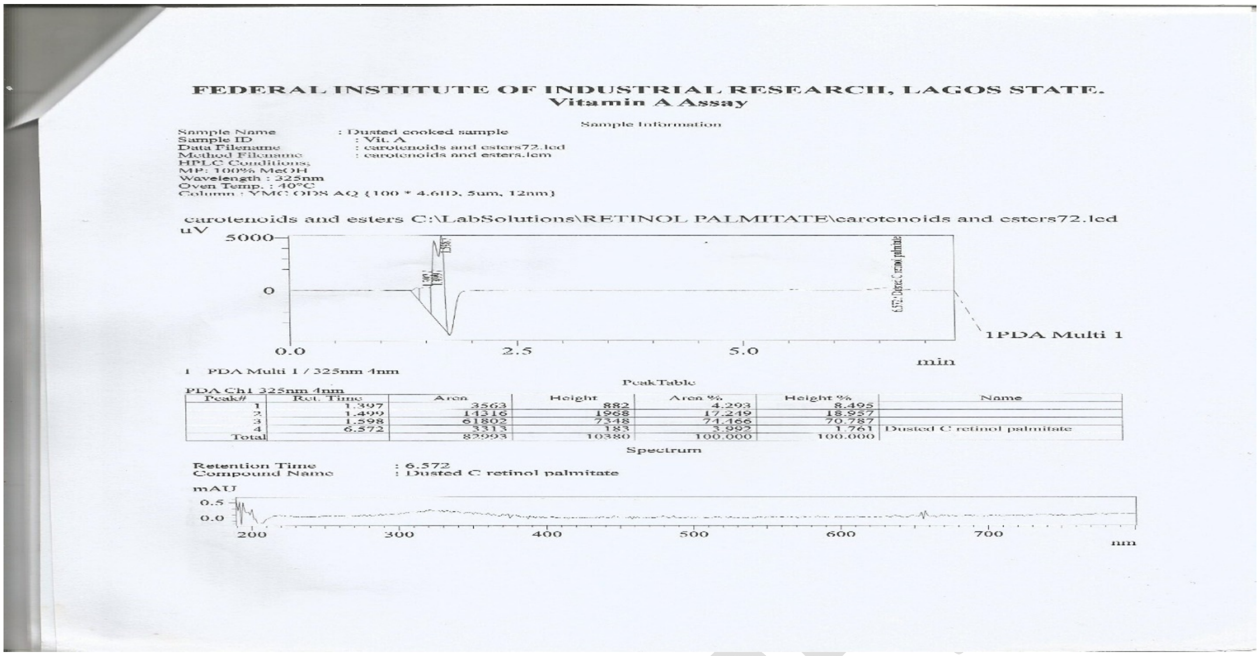
PDA Ch1 325nm 4nm

Peak#	Ret. Time	Area	Height	Area %	Height %	Name
1	1.397	3648	898	4.376	4.620	
2	1.498	13049	1993	15.654	10.258	
3	1.596	33213	7420	39.843	38.181	
4	1.676	30506	8944	36.596	46.026	
5	6.548	2943	178	3.530	0.915	Dusted cooked retinol palmitate
Total		83360	19433	100.000	100.000	

Spectrum

Retention Time : 6.548
Compound Name : Dusted cooked retinol palmitate

e. Dusted Retinyl palmitate after cooking (1st)



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Vitamin A Assay

Sample Information

Sample Name : Dusted cooked sample
Sample ID : Vit. A
Data Filename : carotenoids and esters72.lcd
Method Filename : carotenoids and esters.lcm
HPLC Conditions;
MP: 100% MeOH
Wavelength : 325nm
Oven Temp. : 40°C
Column : YMC ODS AQ {100 * 4.6ID, 5um, 12nm}

carotenoids and esters C:\LabSolutions\RETINOL PALMITATE\carotenoids and esters72.lcd

1 PDA Multi 1 / 325nm 4nm

PeakTable

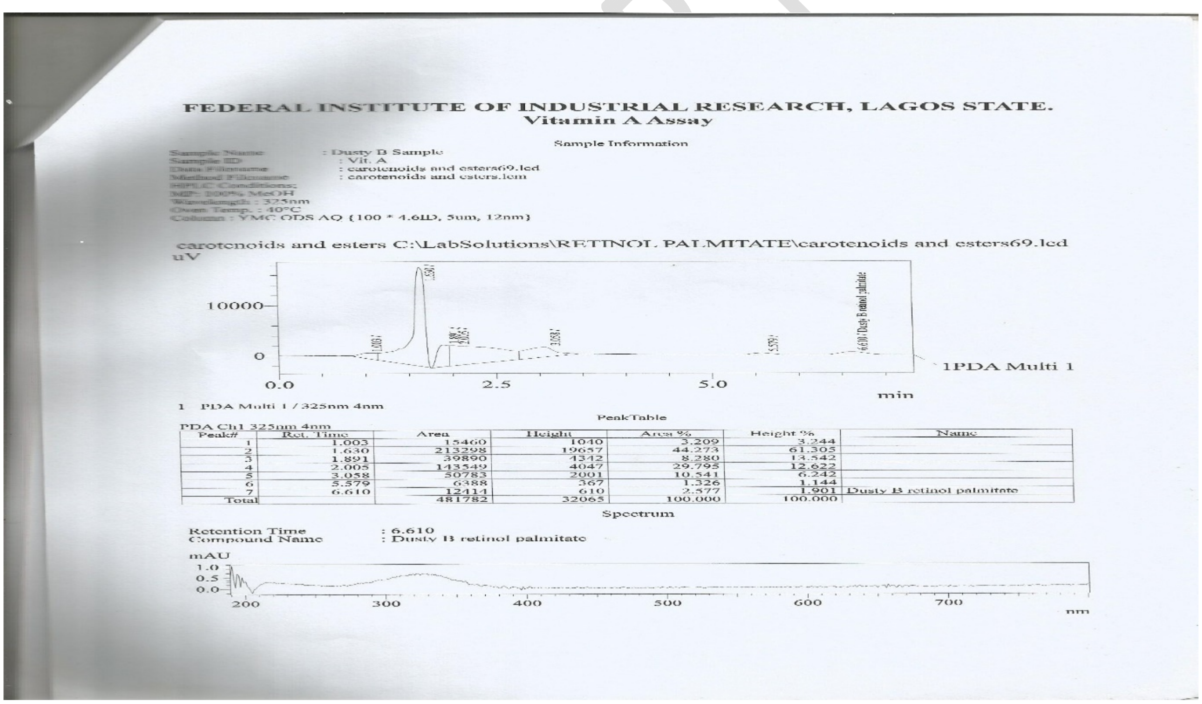
PDA Ch1 325nm 4nm

Peak#	Ret. Time	Area	Height	Area %	Height %	Name
1	1.397	3563	882	4.293	8.495	
2	1.499	14316	1968	17.249	18.957	
3	1.598	61802	7348	74.466	70.787	
4	6.572	3313	183	3.992	1.761	Dusted C retinol palmitate
Total		82993	10380	100.000	100.000	

Spectrum

Retention Time : 6.572
Compound Name : Dusted C retinol palmitate

f. Dusted Retinyl palmitate after cooking (2nd)



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Vitamin A Assay

Sample Information

Sample Name : Dusty B Sample
Sample ID : Vit. A
Data Filename : carotenoids and esters69.lcd
Method Filename : carotenoids and esters.lcm
HPLC Conditions;
MP: 100% MeOH
Wavelength : 325nm
Oven Temp. : 40°C
Column : YMC ODS AQ {100 * 4.6ID, 5um, 12nm}

carotenoids and esters C:\LabSolutions\RETINOL PALMITATE\carotenoids and esters69.lcd

1 PDA Multi 1 / 325nm 4nm

PeakTable

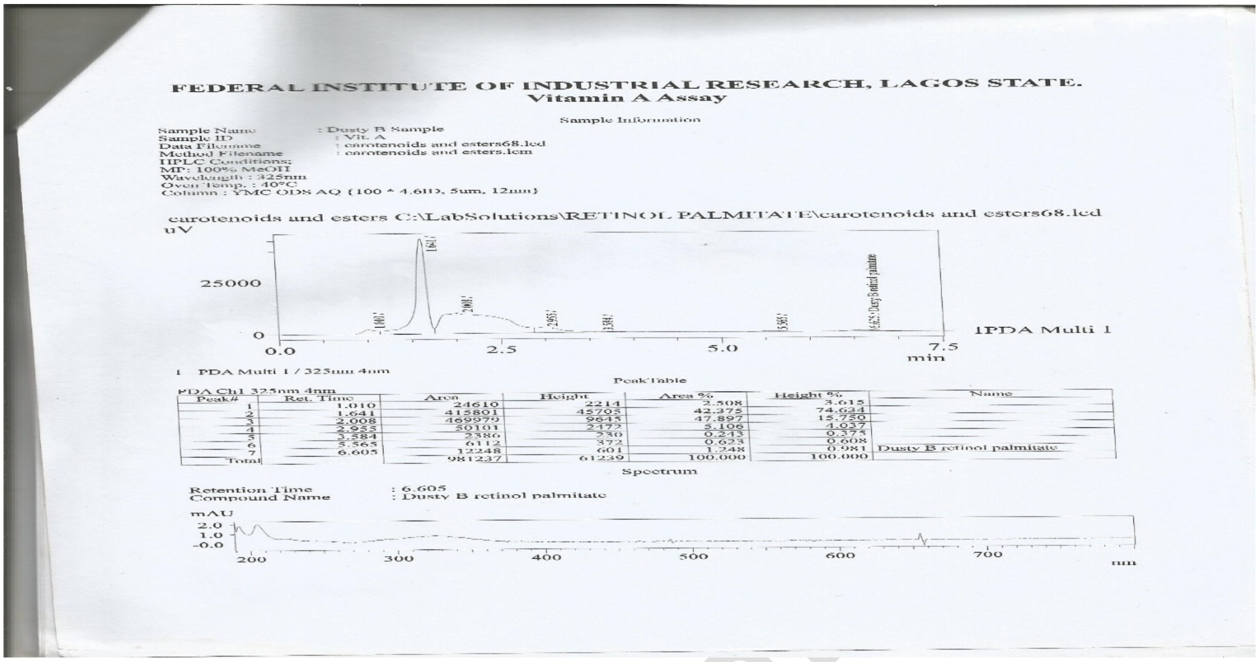
PDA Ch1 325nm 4nm

Peak#	Ret. Time	Area	Height	Area %	Height %	Name
1	1.003	15460	1040	3.209	3.244	
2	1.630	213298	19657	44.273	61.305	
3	1.891	39890	4342	8.280	13.542	
4	2.005	143549	4047	29.795	12.622	
5	3.058	50783	2001	10.541	6.242	
6	5.579	6388	367	1.326	1.144	
7	6.610	12414	610	2.577	1.901	Dusty B retinol palmitate
Total		481782	32065	100.000	100.000	

Spectrum

Retention Time : 6.610
Compound Name : Dusty B retinol palmitate

g. Dusted Retinyl palmitate before cooking (1st)



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Vitamin A Assay

Sample Information

Sample Name : Dusty B Sample
Sample ID : Vit. A
Data Filename : carotenoids and esters68.lcd
Method Filename : carotenoids and esters.lcm
HPLC Conditions;
MP: 100% MeOH
Wavelength : 325nm
Oven Temp. : 40°C
Column : YMC ODS AQ (100 * 4.6ID, 5um, 12nm)

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1 PDA Multi 1 / 325nm 4nm

PeakTable

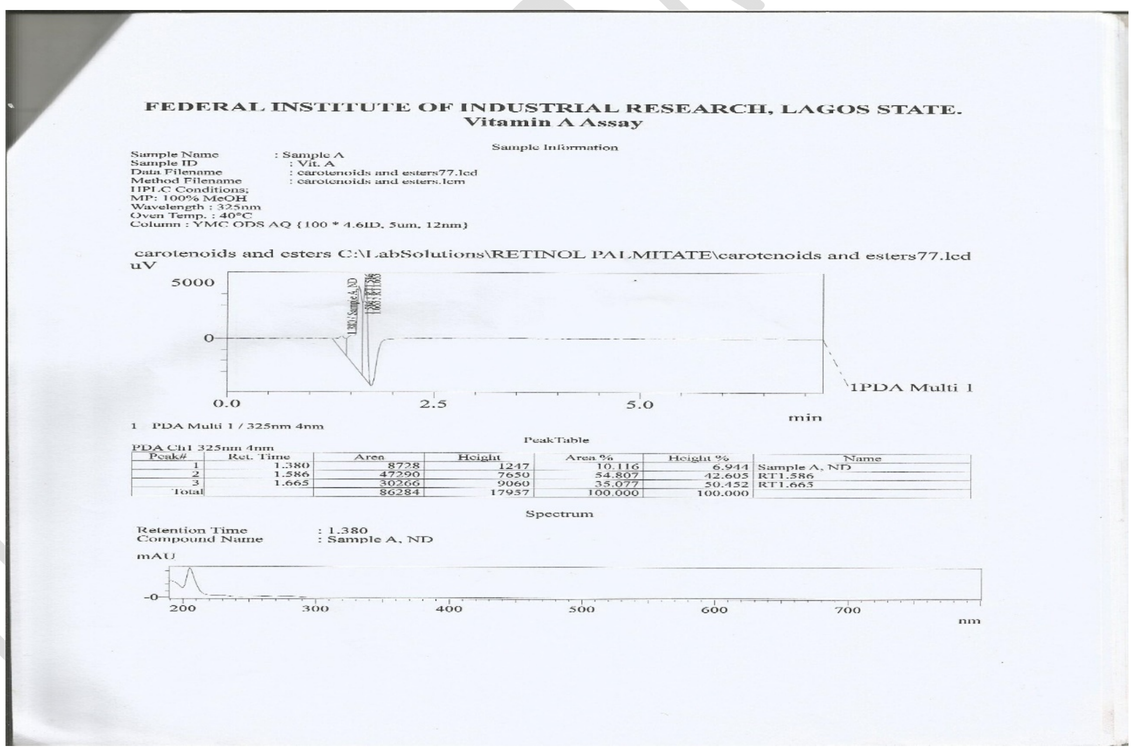
PDA Ch1 325nm 4nm

Peak#	Ret. Time	Area	Height	Area %	Height %	Name
1	1.010	24610	2214	2.508	3.615	
2	1.641	415801	45705	42.375	74.634	
3	2.008	469979	9645	47.897	15.750	
4	2.955	50101	2472	5.106	4.037	
5	3.584	2386	230	0.243	0.375	
6	5.565	6112	372	0.623	0.608	
7	6.605	12248	601	1.248	0.981	Dusty B retinol palmitate
Total		981237	61239	100.000	100.000	

Spectrum

Retention Time : 6.605
Compound Name : Dusty B retinol palmitate

h. Dusted Retinyl palmitate before cooking (2nd)



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Vitamin A Assay

Sample Information

Sample Name : Sample A
Sample ID : Vit. A
Data Filename : carotenoids and esters77.lcd
Method Filename : carotenoids and esters.lcm
HPLC Conditions;
MP: 100% MeOH
Wavelength : 325nm
Oven Temp. : 40°C
Column : YMC ODS AQ (100 * 4.6ID, 5um, 12nm)

carotenoids and esters C:\LabSolutions\RETINOL PALMITATE\carotenoids and esters77.lcd

1 PDA Multi 1 / 325nm 4nm

PeakTable

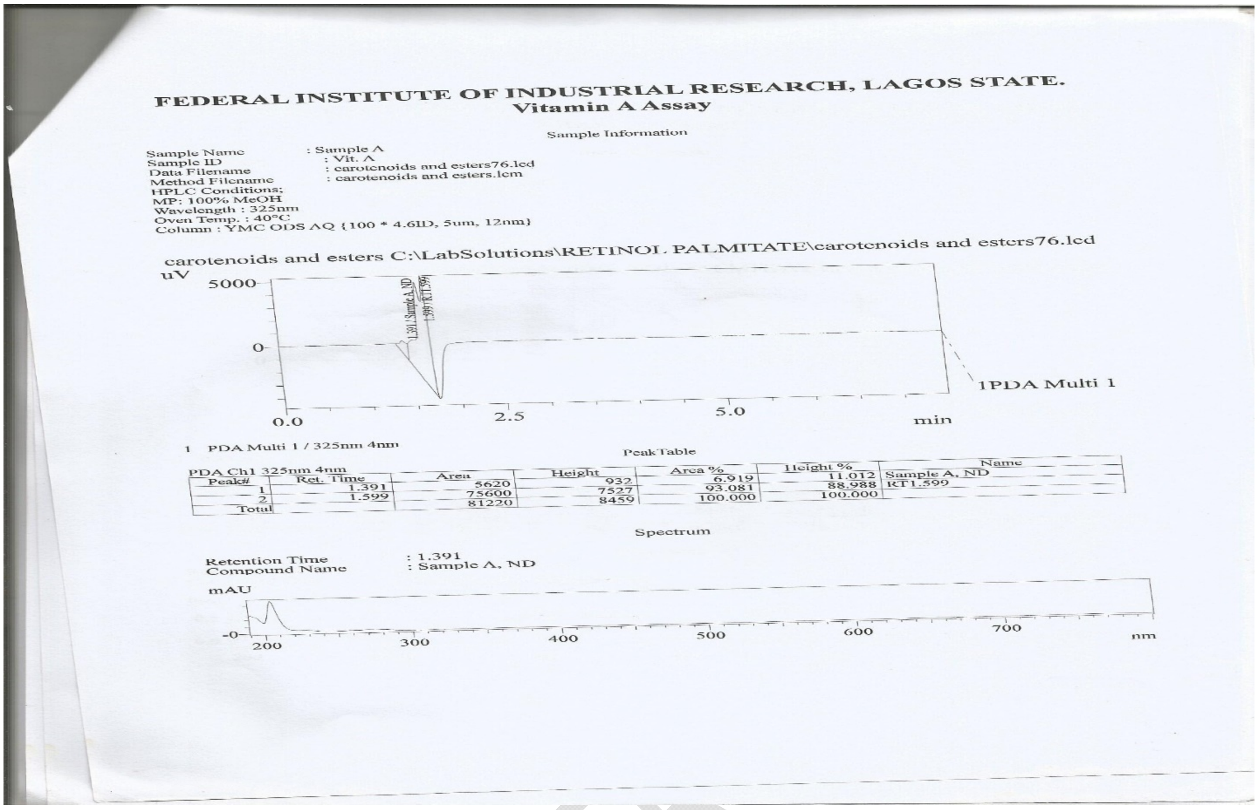
PDA Ch1 325nm 4nm

Peak#	Ret. Time	Area	Height	Area %	Height %	Name
1	1.380	8728	1247	10.116	6.944	Sample A, ND
2	1.586	47290	7650	54.807	42.605	RT1.586
3	1.665	30266	9060	35.077	50.452	RT1.665
Total		86284	17957	100.000	100.000	

Spectrum

Retention Time : 1.380
Compound Name : Sample A, ND

i. Unfortified sample (1st)



j. Unfortified sample (2nd)

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 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). 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 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 (23).

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. For vitamin A, the coated grains had a retention percentage of 40 % and the dusted grains had a retention percentage of 25 %, 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 (24). This result agrees with the findings of Alavi *et al.* (25) 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 (26).

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

No competing interests

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