

1 **EFFECTS OF SESAME SEED ENRICHMENT ON PHYSICO-CHEMICAL AND**
2 **NUTRITIONAL CHARACTERISTICS OF FLOUR FROM TWO CULTIVARS OF**
3 **WHITE YAM (*Dioscorea rotundata* Poir)**

4
5 **ABSTRACT**

6
7 The effects of enriching two cultivars of yam (*Dioscorea rotundata* Poir) flour with sesame
8 seed (*Sesamum indicum* L) flour on their physico-chemical and nutritional characteristics
9 were studied. Yam flours were produced from *Abuja* and *Efuru* yams by parboiling at 60°C
10 for 10 minutes and left overnight, followed by sun drying for four days. Enriched yam flour
11 samples were prepared by thoroughly mixing the yam and sesame seed flour in ratios 95:5,
12 90:10, 85:15 and 80:20 respectively. Proximate, mineral and anti-nutrient content as well as
13 functional properties of enriched flours were determined using standard methods of AOAC.
14 The two yam-flour samples were low in moisture, crude protein, fat and ash content, high in
15 carbohydrate and macro minerals, while Sesame seed was very low in moisture and
16 carbohydrate, and low in crude fibre content, but very high in crude protein, fat, ash and
17 macro minerals. The moisture, crude protein, fat and fibre, ash and carbohydrate content of
18 the yams and enriched samples ranged between 11.9-13.8g, 3.3-7.5g, 0.5-13.8g, 1.6-3.0g,
19 2.0-2.6g and 61.7-78.8g/100g respectively. Addition of sesame seed flour resulted in
20 reduction in moisture and carbohydrate content and significant increase ($p=0.05$) in protein,
21 fat and ash values of enriched samples. The protein, fat and mineral content of the enriched
22 samples increased with increased level of sesame seed flour inclusion ($p=0.05$). Both yam
23 and sesame flours were low in the antinutritional factors studied. Sesame flour was high in
24 trypsin inhibitors and polyphenols. Enrichment with sesame flour resulted in further
25 reduction in the antinutritional factors content with increase in trypsin inhibitors and
26 polyphenols content of the products. *Efuru* variety flour with its enriched products had higher
27 water and oil absorption capacity, loose and packed bulk density and swelling capacity than
28 *Abuja* variety flour. Enriching yam flour with sesame flour can improve the nutrients and
29 functional properties of their products which can improve the nutritional status, health and
30 well-being of consumers.

31
32 **Key words:** Yam flour, Sesame seed flour, Anti-nutritional factors, Food enrichment,
33 Physico- chemical properties
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35

36 **INTRODUCTION**

37 Sesame (*Sesamum indicum* L.) also known as sesamum or beniseed, is a member of the
38 family *Pedaliaceae*, and one of the most ancient oilseed crops with high level of antioxidants
39 [1]. Sesame seeds are highly valued for their high content of oil, which is very resistant to
40 rancidity, and used as cooking oil. It plays important role in human nutrition, medicinal,
41 pharmaceutical, industrial and agricultural uses [2], [3].

42 Sesame foods are very healthy and are popular in culinary preparation. After the extraction of
43 its oil, the cake is mostly used as livestock feed or often as manure or the seed is ground into
44 sesame flour and added to health foods [2]. Sesame seeds contain significant amount of
45 sesamin and sesamolin, both of which have beneficial effects on serum lipid levels and liver
46 function, and give sesame seed oil a marked antioxidant activity [4]. Sesame seed also
47 contains phenolic compounds and tocopherols with antioxidant activity that have significant
48 effect on reducing blood pressure, lipid profile, degeneration of vessels and impact in
49 reducing chronic diseases [5]. The oil from sesame seed contains about 35%
50 monounsaturated fatty acids and 44% polyunsaturated fatty acids [3], [6]. In addition to being
51 a good source of oil, the seeds also contain significant amount of protein (18-25%),
52 carbohydrate (13.5%) and ash (5%) [7]. The protein of the seed has immobilized amino acid
53 profile with good nutritional value similar to soybean [8].

54 Yam, (*Dioscorea spp*); constitutes staple food that produces edible starch and is the third
55 most important tropical root crop after cassava and sweet potato [9]. *Dioscorea species* is the
56 most important food crop in West Africa, with Nigeria being the highest producer worldwide
57 (71% of the world's total production [10]; and they serve as important source of energy for
58 millions of people in Nigeria [11], [12], [13]. It has higher levels of protein and vitamins than
59 cassava [13].

60 Among the many varieties of yam species widespread through the humid tropics, White yam
61 (*Dioscorea rotundata*), Yellow yam (*D. cayensis*), Water yam (*D. alata*), Chinese yam (*D.*
62 *esculanta*), Aerial yam (*D. bulbifera*) and Trifoliate yam (*D. dumentorum*) are the most
63 economically important ones [14]. White yam (*D. rotundata*) is the most preferred yam
64 species [15]. The tubers are processed into chips, boiled yam, roasted yam, pounded yam,
65 porridge or yam flour through frying, boiling, roasting, pounding, steaming, or fermentation
66 followed by milling respectively [16]. In addition to its importance in diets, it is prominent in

67 traditional festivals, marriages, burials and indeed in almost all social, cultural and religious
68 gatherings [13].

69 White yam is low in protein and micronutrients, especially vitamins, and large quantity of
70 these micronutrients are lost during processing [17], [18]. Addition of sesame seed to yam
71 products can provide means of improving the nutrient content of the products as well as
72 nutrient intake of consumers. This study was carried out to investigate the effect of enriching
73 the flour of two cultivars of white yam (*Abuja* and *Efuru*) with sesame seeds on the physico-
74 chemical properties of the products.

75 MATERIALS AND METHODS

76 Sample Collection and Preparation

77 Two cultivars of *D. rotundata* (*Abuja* yam and *Efuru* yam) with white sesame seeds were
78 purchased from Bodija market in Ibadan, Oyo State, South-west Nigeria, Bodija market is
79 one of the largest markets for foodstuff in Ibadan, and is the major depot for raw foods from
80 different parts of the country. Hence, samples obtained from this market are representative of
81 food items from most parts of the country while the two samples were brought from Benue
82 State of Nigeria. The tubers were washed to remove the dirt and adhering sand particles,
83 rinsed with clean water at room temperature. The washed tubers were peeled with knife,
84 washed with distilled water and cut into pieces for each of the *Abuja* and *Efuru* yam, sliced
85 into cubes with dimension 1.0×1.5×1.5 cm to ensure efficient heat circulation during drying.

86 The two yam slices were washed with distilled water, weighed and parboiled at 60°C for 10
87 min, left in the warm water for 18 h, drained and sundried for 4 days separately [19], [17].

88 The different dried yam slices were milled into flour using attrition mill, the flour samples
89 were packaged in sealed transparent polythene bags and labeled as *Abuja* yam flour (AYF)
90 and *Efuru* yam flour (EYF) respectively; and stored at room temperature in a cool, dry place
91 till when needed. Similarly, the white sesame seeds were cleaned manually to remove dirt,

foreign materials, and immature and damaged seeds. The cleaned seeds were crushed into smaller particles in a glass mortar and stored in plastic bags at 40°C in an oven until when needed.

Different ratios of yam flour and sesame seed flour were formulated as follows.

Sample 1	=	95 g of <i>Abuja</i> yam flour + 5 g Sesame seed flour
Sample 2	=	90 g of <i>Abuja</i> yam flour + 10 g Sesame seed flour
Sample 3	=	85 g of <i>Abuja</i> yam flour + 15 g Sesame seed flour
Sample 4	=	80 g of <i>Abuja</i> yam flour + 20 g Sesame seed flour
Sample 5	=	95 g of <i>Efuru</i> yam flour + 5 g Sesame seed flour
Sample 6	=	90 g of <i>Efuru</i> yam flour + 10 g Sesame seed flour
Sample 7	=	85 g of <i>Efuru</i> yam flour + 15 g Sesame seed flour
Sample 8	=	80 g of <i>Efuru</i> yam flour + 20 g Sesame seed flour.

Each sample was thoroughly mixed, packed, labeled and sealed in transparent polythene bag.

All the ten labeled samples were kept at 4°C in the refrigerator in the laboratory until required for analyses [20].

Proximate analysis

The moisture content was analyzed using the Association of Official Analytical Chemists' (AOAC) approved method 967.08, crude protein by AOAC method 988.05, crude fat or ether extract, ash and crude fibre contents were determined using the AOAC methods 2003.06, 942.05 and 958.06 respectively [21]. Carbohydrate content was determined by difference and all analyses were carried out in triplicate.

Mineral analysis

The concentrations of the minerals in the yam flour, sesame flour and enriched sample flour were determined by Atomic Absorption Spectrophotometric method (AOAC, 975.11) [21].

Vanado-molybdate colorimetric method was used to determine phosphorus (AOAC, 975.16) [21]. All the measurements were made in triplicate.

Determination of anti-nutritional factors

Phytate determination

Phytate was determined by weighing 2 g of each sample into 250 ml Erlenmeyer flask. A 100ml of 2% hydrochloric acid was added to soak each sample for 3 hours. This was filtered through a double layer of filter paper. About 50ml of each filtrate was placed in a 500ml flask and 107 ml distilled water added in each case, followed by addition of 10ml of 0.3% ammonium thiocyanate (NH₄SCN) solution. The resultant solution was then titrated with standard solution of Iron (III) chloride containing 0.00195 g iron per ml till a slightly brownish-yellow colouration which persisted for 5 minutes (AOAC method 986.11) [21].

Saponin determination

Saponin content was determined using Spectrophotometric method described by Brunner, [22]. The absorbance of the sample as well as standard saponin solutions were read after colour development in a Jenway V6300 Spectrophotometer at a wavelength of 380 nm.

Tannin determination

Total tannin content was determined by the Spectrophotometric procedure described by Association of Official Analytical Chemists [23].

Oxalate determination

The oxalate content of the samples was determined using the AOAC method [21].

Determination of functional properties of flour

Swelling capacity determination

This was determined in accordance with the method described by Leach *et al.*, 1959 [24] with modification for small samples. A 0.1g of sample was weighed into a weighed test tube (W₁) into which 10 ml of distilled water was added and heated in a water bath at temperature of

60°C for 30 min, with constant shaking within the heating period. The mixture was cooled to room temperature and centrifuged at #5000 × g, for 15 minutes. The residue obtained after centrifuging with the water was retained and the test tube was weighed (W₂).

$$\text{Swelling of starch} = \frac{W_2 - W_1}{\text{Weight of starch}}$$

Least gelation concentration (LGC) determination

Sample of starch (2 - 18% w/v), were prepared in test tube with distilled water (5ml). The starch suspensions were mixed with Variwhirl mixer for 5 min. The test tubes were heated for 30 min at 80°C in a water bath, followed by rapid cooling under running cold tap water. The test tubes were further cooled at 4°C for 2 hrs. Least gelation concentration was determined as that concentration when the sample from the inverted test tube did not fall down or slip.

Oil and water absorption capacity determination

The Sathe *et al.*, (1959) [25] method was applied. A 5 ml of oil (Executive Chef Oil, Lever Brothers (Nigeria) Plc, Lagos, Nigeria) was added to 0.5 g of sample flour in 10 ml centrifuge tube. The mixture was stirred with glass rod to disperse the sample in oil for 30 s and centrifuged for 30 min at 35000 rpm. Then, the volume of the supernatant was recorded.

Loose and packed bulk density determination

Two grammes (2 g) of flour was weighed into a 25 ml measuring cylinder as volume **1** (V₁), the flour particles inside the cylinder was tapped several times for 10 min till a constant volume **2** (V₂) was obtained. Loose bulk density was obtained using the formula:

$$\text{Bulk Density} = \frac{\text{Weight of sample}}{\text{Volume } V_1}$$

while

$$\text{Packed bulk density} = \frac{\text{Weight of sample}}{\text{Volume } V_2}$$

Statistical analysis

Analyses were done in triplicate. Analysis of variance was performed to calculate the significant difference between means, and multiple range test (Turkeys Least Significant Difference) was conducted on the results obtained. Level of significance was set at $p>0.05$.

RESULTS AND DISCUSSIONS**Proximate composition**

The proximate composition of raw flour of the two varieties of yam, sesame seed and the enriched yam flour are presented in Tables 1a and 1b respectively. The moisture content of the two varieties of yam flour was low and very similar without significant difference ($p>0.05$). The crude protein and fat content of the flour of the two yam varieties were low, while the ash content was high, and total carbohydrate content very high compared with other tubers. *Efuru* flour was slightly but not significantly higher ($p>0.05$) in crude protein and ash values. Sesame seed flour was very low in moisture and carbohydrate content, high in crude protein and very high in fat compared with the two yam varieties. Enriching the yam flour with sesame seed flour significantly reduced the moisture and total carbohydrates content ($p=0.05$), the level of reduction increasing with the level of inclusion of the seed flour. The moisture content of all enriched samples of yam flour was lower than that of flour of the two varieties of yam, but higher than that of sesame seed flour. There were significant increase ($p=0.05$) in protein, fat and ash content of enriched samples, the value of nutrients increasing with increase in level of inclusion of sesame seed flour.

192 Table 1a: Proximate composition of *Abuja* yam, *Efuru* yam and Sesame seed flour (g/100g)

Parameter	AYF	EYF	SSF
Moisture	13.8±0.01 ^d	13.7±0.01 ^d	2.9±0.00 ^a
Crude Protein	3.3±0.00 ^c	3.5±0.01 ^d	25.9±0.00 ^b
Crude Lipid	0.5±0.18 ^b	0.5±0.00 ^b	53.0±0.02 ^d
Ash	2.0±0.00 ^d	2.2±0.01 ^a	5.7±0.00 ^b
Total Carbohydrates	80.4±0.00 ^b	80.1±0.01 ^b	12.5±0.01 ^d

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194 AYF = *Abuja* yam flour; EYF = *Efuru* yam flour, and SSF = Sesame seed flour

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212 Table 1b: Proximate composition of enriched *Abuja* and *Efuru* yam flour (g/100g dry sample)

Parameter	Moisture	Crude Protein	Crude Lipid	Ash	Total Carbohydrates
Sample 1	12.3±0.06 ^d	6.7±0.02 ^d	13.4±0.01 ^b	2.3±0.01 ^a	65.3±0.01 ^a
2	12.3±0.01 ^d	6.8±0.03 ^a	13.4±0.01 ^c	2.4±0.01 ^c	65.0±0.01 ^b
3	12.2±0.01 ^d	6.9±0.03 ^b	13.5±0.04 ^a	2.4±0.01 ^b	65.0±0.01 ^d
4	12.0±0.01 ^b	7.1±0.08 ^d	13.5±0.04 ^b	2.5±0.01 ^b	64.9±0.01 ^d
5	12.3±0.00 ^a	6.9±0.00 ^b	13.5±0.00 ^a	2.4±0.01 ^c	64.9±0.01 ^b
6	12.2±0.01 ^b	7.1±0.00 ^d	13.6±0.00 ^b	2.4±0.01 ^c	64.7±0.01 ^a
7	12.1±0.01 ^b	7.3±0.01 ^b	13.7±0.00 ^a	2.5±0.01 ^d	64.4±0.01 ^b
8	11.9±0.01 ^a	7.5±0.01 ^c	13.8±0.01 ^d	2.6±0.00 ^a	64.2±0.01 ^a

213	Sample 1	=	95 g of <i>Abuja</i> yam flour + 5 g Sesame seed flour
214	Sample 2	=	90 g of <i>Abuja</i> yam flour + 10 g Sesame seed flour
215	Sample 3	=	85 g of <i>Abuja</i> yam flour + 15 g Sesame seed flour
216	Sample 4	=	80 g of <i>Abuja</i> yam flour + 20 g Sesame seed flour
217	Sample 5	=	95 g of <i>Efuru</i> yam flour + 5 g Sesame seed flour
218	Sample 6	=	90 g of <i>Efuru</i> yam flour + 10 g Sesame seed flour
219	Sample 7	=	85 g of <i>Efuru</i> yam flour + 15 g Sesame seed flour
220	Sample 8	=	80 g of <i>Efuru</i> yam flour + 20 g Sesame seed flour

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222 The two yam flours were low in moisture content (Table 1(a)). Low moisture content of the
 223 two yam flour is indicative of its long shelf life, as it has been reported that low moisture
 224 content reduces microbial spoilage of food products [26]. The value obtained for moisture
 225 content of flour in this study were higher than the range of 3.33 – 6.42% reported for banana
 226 – sesame seed blend [27].

The protein and fat values of the yam flour were low. This is in line with the finding of Adepoju [17] that raw yam is low in both protein and fat content. The high ash content of the two yam flour was suggestive of high mineral content, especially macro-minerals. The result obtained here is in agreement with the reported ash values of some processed white yam products [17].

The value obtained for sesame seed flour proximate composition in this study is at variance with the one in the literature [28]. The difference in value is believed to be due to yearly, seasonal and geographic variation, as both samples were obtained from different geographic locations and years.

Addition of sesame seed flour to yam flours improved the nutrient content of the products (Table 1(b)). The observed increase is believed to be due to the high nutrient content of sesame seed ([28], [29], [30]). However, the addition resulted in reduction of total carbohydrate content. The reduction is believed to have resulted in low carbohydrate and high protein and fat contents of the seeds [28].

Mineral composition

The mineral content of the flour of the two varieties of yam, sesame seed and enriched yam flour are presented in Tables 2(a) and (b). The yam varieties were high in potassium, calcium, magnesium and phosphorus, moderate in iron, and zinc, but very low in manganese and copper content (Table 2(a)). The *Efuru* yam flour was not significantly higher ($p=0.05$) in minerals than that of *Abuja* yam flour. Sesame seed flour was very high in all the macro-minerals studied. Enriching the yam flour with sesame flour resulted in significant increase in all the minerals, especially the macro-minerals.

Table 2a: Mineral composition of *Abuja* yam, *Efuru* yam and Sesame seed flour (mg/100g)

Parameter	AYF	EYF	SSF
Potassium	215.00±0.01 ^d	217.00±0.02 ^d	1234.70±0.00 ^c
Sodium	57.67±0.02 ^a	60.00±0.02 ^b	587.00±0.06 ^d
Calcium	137.00±0.05 ^c	136.00±0.04 ^c	1160.10±0.04 ^a
Magnesium	274.00±0.01 ^b	277.00±0.05 ^d	393.60±0.05 ^d
Phosphorus	226.00±0.02 ^d	228.00±0.02 ^a	480.40±0.02 ^b
Iron	3.13±0.01 ^d	3.10±0.01 ^b	9.26±0.03 ^c
Zinc	1.87±0.01 ^d	1.86±0.01 ^a	3.38±0.01 ^d
Manganese	0.43±0.01 ^c	0.40±0.00 ^d	0.76±0.01 ^a
Copper	0.29±0.01 ^a	0.29±0.02 ^c	0.48±0.03 ^b

The yam flour had good potassium and sodium ratio for balancing the intra and extracellular fluid of the body. Sesame flour is a very good source of these minerals (Table 2(a)). A 100 g sample of sesame flour can meet more than half of daily requirements of the macro-minerals and zinc.

267 Table 2(b): Mineral composition of enriched *Abuja* and *Efuru* yam flour (mg/100g)

Sample	1	2	3	4	5	6	7	8
K	346.30 ±0.06 ^a	359.40 ±0.04 ^a	396.70 ±0.03 ^a	413.00 ±0.02 ^c	305.00 ±0.02 ^b	358.30 ±0.01 ^c	399.70 ±0.05 ^b	415.00 ±0.02 ^c
Na	127.30 ±0.10 ^b	154.00 ±0.02 ^c	173.00 ±0.01 ^d	187.70 ±0.01 ^a	130.00 ±0.01 ^a	157.00 ±0.02 ^a	175.70 ±0.02 ^a	190.30 ±0.04 ^b
Ca	290.30 ±0.06 ^c	305.30 ±0.05 ^d	336.30 ±0.01 ^c	354.30 ±0.04 ^b	291.70 ±0.04 ^d	309.00 ±0.02 ^a	340.00 ±0.04 ^c	359.30 ±0.02 ^d
Mg	296.00 ±0.02 ^d	310.70 ±0.04 ^a	323.00 ±0.02 ^d	337.30 ±0.05 ^b	300.70 ±0.06 ^a	311.70 ±0.04 ^c	324.70 ±0.02 ^b	340.30 ±0.05 ^c
P	270.70 ±0.04 ^a	287.30 ±0.02 ^b	302.30 ±0.05 ^b	315.30 ±0.02 ^d	274.00 ±0.02 ^c	290.30 ±0.00 ^d	305.70 ±0.02 ^d	316.70 ±0.04 ^a
Fe	3.20 ±0.01 ^c	3.20 ±0.04 ^b	3.24 ±0.02 ^c	3.27 ±0.01 ^a	3.20 ±0.01 ^b	3.21 ±0.01 ^a	3.24 ±0.01 ^a	3.27 ±0.04 ^a
Zn	1.92 ±0.01 ^a	1.97 ±0.01 ^a	1.99 ±0.01 ^a	2.02 ±0.02 ^c	2.00 ±0.01 ^c	1.97 ±0.01 ^b	2.00 ±0.01 ^c	2.02 ±0.01 ^b
Mn	0.45 ±0.01 ^d	0.48 ±0.03 ^b	0.47 ±0.01 ^d	0.50 ±0.01 ^a	0.45 ±0.01 ^b	0.49 ±0.02 ^c	0.48 ±0.01 ^a	0.50 ±0.00 ^d
Cu	0.35 ±0.01 ^b	0.34 ±0.01 ^d	0.37 ±0.00 ^c	0.39 ±0.04 ^d	0.31 ±0.00 ^a	0.34 ±0.00 ^d	0.37 ±0.00 ^b	0.39 ±0.01 ^a

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269 The mineral content of the enriched samples increased with the level of inclusion of sesame
 270 seed flour. The increase in essential minerals content of enriched samples can be attributed to
 271 the fact that sesame seed is a good source of protein. Studies have reported that legumes and
 272 nut seeds are good sources of protein and minerals, and that these seeds are usually consumed

in many parts of the developing countries, particularly where animal proteins are scarce or very expensive [31], [32].

Anti-nutritional and antioxidant composition

The anti-nutritional factors and antioxidant properties of the yam flours and enriched samples are presented in Tables 3. The two yam cultivars were very low in antinutritional factors, reducing power and polyphenols, while sesame seed had significantly higher ($p=0.05$) values of the anti-nutrients. Likewise, sesame seed contained significantly higher values of trypsin inhibitors, reducing power and polyphenols ($p=0.05$). The level of anti-nutritional factors in the sesame seed influenced the amount of trypsin inhibitors and antioxidant properties of the enriched samples (Table 3). However, the trypsin inhibitors concentration can be eliminated or reduced to tolerable level through processing methods like roasting, fermentation, soaking etc ([33], [34], [35], [36]). The enriched flour samples will undergo processing before they are being consumed. Hence, the enriched flours are safe for consumption.

The presence of high quantity of polyphenols is an indication of good antioxidant properties of sesame seed, as well as the enriched products.

Table 3: Anti-nutrient and anti-oxidant content of *Abuja*, *Efuru*, Sesame seed and enriched flour

Sample	Phytate %	Oxalate %	Saponins %	Tannins %	T. I (TIU/mg)	R P	T P (mg/GAE/g)
AYF	0.03± 0.00 ^b	0.01± 0.00 ^d	0.09± 0.00 ^a	0.00± 0.00 ^a	0.13± 0.01 ^b	0.33± 0.00 ^c	9.31± 0.07 ^d
EYF	0.02± 0.00 ^d	0.01± 0.00 ^b	0.08± 0.00 ^c	0.00± 0.00 ^a	0.09± 0.00 ^d	0.34± 0.00 ^b	9.38± 0.01 ^a
SSF	0.35± 0.00 ^d	0.19± 0.00 ^a	0.22± 0.00 ^b	0.00± 0.00 ^b	19.37± 0.01 ^c	0.83± 0.00 ^d	25.34± 0.01 ^c
1	0.07± 0.00 ^d	0.04± 0.00 ^a	0.10± 0.00 ^b	0.01± 0.00 ^b	0.66± 0.01 ^b	0.36± 0.00 ^c	11.02± 0.00 ^d
2	0.09± 0.00 ^a	0.05± 0.00 ^d	0.11± 0.00 ^d	0.01± 0.00 ^a	0.81± 0.01 ^c	0.38± 0.00 ^c	11.51± 0.00 ^a
3	0.09± 0.00 ^b	0.06± 0.00 ^a	0.11± 0.00 ^b	0.01± 0.00 ^b	1.13± 0.01 ^c	0.40± 0.00 ^a	11.86± 0.01 ^d
4	0.10± 0.00 ^a	0.07± 0.00 ^b	0.13± 0.00 ^c	0.01± 0.00 ^d	1.40± 0.00 ^d	0.43± 0.00 ^b	12.12± 0.00 ^c
5	0.07± 0.00 ^a	0.04± 0.00 ^a	0.10± 0.00 ^c	0.10± 0.00 ^d	0.60± 0.01 ^c	0.83± 0.00 ^a	25.34± 0.01 ^c
6	0.08± 0.00 ^a	0.05± 0.00 ^b	0.11± 0.00 ^c	0.01± 0.00 ^c	0.75± 0.00 ^d	0.40± 0.00 ^b	11.19± 0.00 ^a
7	0.09± 0.00 ^b	0.05± 0.00 ^a	0.12± 0.00 ^a	0.01± 0.00 ^c	1.09± 0.00 ^b	0.41± 0.00 ^a	11.96± 0.00 ^b
8	0.00± 0.00 ^b	0.07± 0.00 ^a	0.13± 0.00 ^d	0.01± 0.00 ^b	1.34± 0.00 ^c	0.43± 0.00 ^d	12.21± 0.01 ^a

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303 AYF = Abuja yam Flour; EYF = Efuru yam flour; SSF = Sesame seed flour

304 T. I. = Trypsin Inhibitor; R. P. = Reducing power; T. P. = Total Polyphenols

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306 **Functional properties**

The functional properties of the yam flours and enriched samples are as presented in Table 4. The loose bulk density ranged from 0.49 g/ml in raw flour of the two varieties of yam and 0.51 g/ml in sesame seed and in the mixtures above 5% proportion while in the packed bulk density, the range was between 0.51 g/ml – 0.54 g/ml. The water absorption capacity was higher in *Efuru* yam flour than in *Abuja* yam flour as well as its enriched sample. The Water Absorption Capacity values of the yam flour and enriched samples were comparatively lower than the value of *Cassia fistula* seed flour reported by Akinyede and Amoo, (2009) [37]. The swelling capacity of the two varieties of yam was higher than the sesame seed with a slight increase with the % increase of sesame seed flour. However, the swelling capacity of the fortified yam flour was significantly lower than both the *Abuja* and *Efuru* yam flours. The least gelation concentration of the enriched yam flour also increased with successive increase in the amount of sesame seed flour though the raw yam flour had higher values when compared with sesame seed flour. The high gelation value implies that the diet would require more energy consumption to cook, and hence, the gel strength of the diets would be weak and undesirable [38].

334 Table 4: Physico-chemical properties of *Abuja*, *Efuru*, Sesame seed and enriched flour

Sample	LBD (g/ml)	PBD (g/ml)	WAC (g/100g)	OAC (g/100g)	SC (g/g)	LG
AYF	0.49± 0.00 ^b	0.51± 0.00 ^a	127.00± 0.00 ^d	96.00± 0.00 ^b	18.26± 0.00 ^d	21.24± 0.00 ^b
EYF	0.49± 0.00 ^a	0.51± 0.00 ^d	130.00± 0.71 ^d	101.00± 0.71 ^b	18.31± 0.01 ^a	21.18± 0.01 ^b
SSF	0.51± 0.00 ^a	0.54± 0.00 ^d	118.00± 0.71 ^c	80.00± 0.00 ^a	11.64± 7.07 ^d	13.38± 0.00 ^a
1	0.49± 0.00 ^c	0.52± 0.00 ^b	123.00± 7.07 ^d	86.00± 1.02 ^c	12.03± 0.00 ^d	13.70± 7.07 ^d
2	0.50± 0.00 ^b	0.52± 0.00 ^c	131.00± 1.44 ^b	98.00± 1.41 ^b	12.47± 0.00 ^a	13.92± 0.00 ^b
3	0.51± 0.00 ^d	0.53± 0.00 ^b	136.00± 0.00 ^b	98.00± 1.41 ^b	12.49± 0.00 ^a	14.15± 0.00 ^c
4	0.51± 0.00 ^a	0.53± 0.00 ^d	141.00± 0.00 ^a	105.00± 0.00 ^d	12.69± 0.00 ^d	14.26± 0.00 ^d
5	0.49± 0.00 ^b	0.52± 0.00 ^a	126.00± 0.71 ^d	88.00± 0.71 ^b	12.05± 0.00 ^d	13.71± 0.01 ^d
6	0.50± 0.00 ^d	0.52± 0.00 ^d	134.00± 0.71 ^d	94.00± 0.00 ^b	12.30± 0.00 ^c	13.95± 0.01 ^c
7	0.51± 0.00 ^c	0.53± 0.00 ^b	138.00± 0.71 ^a	100.00± 0.71 ^d	12.51± 0.01 ^a	14.17± 0.00 ^a
8	<u>0.51±</u> <u>0.00^d</u>	<u>0.53±</u> <u>0.00^b</u>	<u>143.00±</u> <u>0.71^b</u>	<u>108.00±</u> <u>0.71^d</u>	<u>14.28±</u> <u>0.01</u>	<u>14.28±</u> <u>0.01</u>

335

336 Where:

337 **LBD** = Loose Bulk Density, **WAC** = Water absorption Capacity, **OAC** = Oil Absorption

338 Capacity, **SC** = Swelling Capacity, **PBD** = Packed Bulk Density, **LGC** = Least Gelation

339 Concentration, **AYF** = Efuru Yam Flour, **SSF** = Sesame Seed Flour

340

CONCLUSION

Enriching yam flours with sesame seed flour significantly improves the proximate mineral composition and the functional properties of the flours of two cultivars of yam studied. Including sesame seed flour in yam flour can improve nutrient intakes, dietary diversity and contribute substantially to meeting nutritional needs of consumers when consumed along other food sources, thereby improving the nutritional and health status of consumers.

REFERENCES

1. Abou-Gharbia HA, Shahidi F. Effects of processing on oxidative stability of sesame oil extracted from intact seeds. *J. Amer. Oil Chem. Soc.* 1997;74:215-221.
2. El Khier MKS, Ishag KEA, Yagoub AEA. Chemical Composition and Oil Characteristics of Sesame Seed Cultivars grown in Sudan. *Research J. of Agriculture and Biological Sci.* 2008;4(6):761-766.
3. Ghandi AP. Simplified process for the production of sesame seed (*Sesamum indicum* L) butter and its nutritional profile. *Asian J. Food Agro-Ind.* 2009; 2(01):24-27.
4. Crews C, Hough P, Godward J, Brereton P, Lees M, Guiet S, Winkelmann W. Quantitation of the main constituents of some authentic grape-seed oils of different origin. *J. Agric. Food Chem.* 2006;54:6261-6265.
5. Jannat B, Oveisi MR, Sadeghi N, Hajimahmoodi M, Behzad M, Choopankari E, Behfar AA. Effects of roasting temperature and time on healthy nutraceuticals of antioxidants and total phenolic content in Iranian Sesame seeds (*Sesamum indicum* L). *Iran J. Environ. Health. Sci. Eng.* 2010;7(1):97-102.
6. Hansen R; 2011. Sesame profile. Available at: [http://www.agmrc.org/commodities/products/grain oilseeds/sesame profile.cfm](http://www.agmrc.org/commodities/products/grain%20oilseeds/sesame%20profile.cfm).
7. Borchani C, Besbes S, Blecker CH, Attia H. Chemical Characteristics and Oxidative stability of Sesame Seed, Sesame Paste and Olive Oils. *J. Agri. Sci. Tech.* 2010;12:585-596.
8. NAERLS; 2010. Beniseed production and utilization in Nigeria. Extension Bulletin No 154, Horticulture (5). Available at: www.naerls.gov.ng/extmat/bulletins/Beniseed.pdf.
9. Fu Y, Huang P, Chu C. Use of continuous bubble separation process of separating and recovering starch and mucilage from yam (*Dioscorea pseudojaponica yamamoto*). *LWT-Food Science and Technology.* 2005;38(7):735-744.
10. BBC News; 2010. Celebrating Nigeria's Yummy Yam. BBC News Africa (Southern Nigeria). September, 2010.
11. Osunde ZD. Minimizing post harvest losses in yam (*Dioscorea spp*) treatment and techniques. In G. L. Robertson and J. R. Lupein (eds), using Food Science and Technology to improve Nutrition and Promote National Development. Canada International Union of Food Science and Technology. 2008.
12. Reuben J, Barau AD. Resource use efficiency in Yam production in Taraba State, Nigeria. *J. of Agricultural Science.* 2012;3(2):71-77.

13. Omojola JT, Ugwumba COA, Chidebelu SAND. Economic Efficiency and returns to scale of Yam production in Southwest Nigeria. *Inter. J. of Agric. Innovations and Research*. 2014;2(6):900-904.
14. Ike PC, Inoni OE. Determinants of yam production and economic efficiency among small holder farmers in South-eastern, Nigeria. *Journal of Central European Agriculture*. 2006;7(2):337-342.
15. Djeri B, Tchobo PF, Adjrah, Y, Karou, DS, Ameyapoh Y, Soumanou, MM, Souza C. Nutritional potential of yam chips (*Dioscorea cayenensis* and *Dioscorea rotundata* Poir) obtained using two methods of production in Togo. *African Journal of Food Science*. 2015;9(5):278-284.
16. Iwuoha CI. Comparative evaluation of physicochemical qualities of flours from steam-processed yam tubers. *J. Food Chem*. 2004;85:541-551.
17. Adepoju OT. Effects of processing methods on nutrient retention and contribution of white yam (*Dioscorea rotundata*) products to nutrient intake of Nigerians. *African J Food Sci*. 2012;6(6):163-167.
18. Adepoju OT, Boyejo O, Adeniji PO. Effects of processing methods on nutrient and antinutrient composition of yellow yam (*Dioscorea cayenensis*) products. *Food Chemistry*. 2018;238:160–165.
19. Ihekoronye IA, Ngoddy PO. Integrated Food Science and Technology for the Tropics. Macmillan Educ. Ltd, London and Oxford. 1985;1st edn:pp. 44-46, 160-162.
20. Ojiako OA, Igwe CU. Nutritional and Antinutritional compositions of *Cleome ruidosperma*, *Lagenaria siceraria* and *Cucurbita maxima* seeds from Nigeria. *J.Med Food*. 2007;10:735-738.
21. AOAC. Official methods of analysis. 17th edition. Association of Official Analytical Chemists. Washington D. C., USA; 2005.
22. Brunner JH. Direct Spectrophotometer determination of Saponin. *Anal. Chem*.1984;34: 1314-1326.
23. AOAC. Official methods of analysis. 14th edition. Association of Official Analytical Chemists. Arlington VA; 1984.
24. Leach HW, McGowen LD, Schoch TJ. Structure of the starch granule. Swelling and solubility patterns of various starches. *Cereal Chem*. 1959;36:534.
25. Sathe SK, Deshpande SS, Salunkhe DK. Functional properties of winged bean (*Psophocarpus tetragonolobus*) proteins. *J. Food Sci*. 1959;47:503-506.
26. Ouilly JT, Bazongo P, Bougma A, Kabore' N, Lykke AM, Oue' draogo A, Bassole' IHN. Chemical composition, physicochemical characteristics and nutritional value of *Lannea kerstingii* seeds and seed oil. *J. of Analytical methods in Chemistry* 2017; 1-6.
27. Zebib H, Bultosa G, Abera S. Physico-chemical and sensory properties of Banana flour - sesame paste blends. *International Journal of Scientific and Research Publications*. 2015;5(4):1-9.
28. Bamigboye AY, Okafor AC, Adepoju OT. Proximate and mineral composition of whole and dehulled Nigeria sesame seed. *Afr. J. of Food Science and Tech*. 2010;1(3):071-075.
29. Abu-Jdayil B, Al-Malah K, Asoud H. Rheological characterization of milled sesame (*tehineh*). *Food Hydrocolloids*. 2002;16(1):55-61.
30. Gharehyakheh S, Tavakolipour H. Rheological properties of sesame paste (Ardeh) with different concentration of honey. *Annals of Biological Research*. 2013;4:196-199.
31. Brough SH, Azam-Ali SN, Taylor AJ. The potentials of Bambara groundnut (*Vigna subterranean*) in vegetable milk production and basic milk protein functionality systems. *Food Chem*. 1993;47:277-283.

- 432 32. Lalude LO, Fashakin JB. Development and Nutritional Assessment of a weaning food
433 from Sorghum and Oil-seeds. *Pakistan J. Nut.* 2006;5(3):257-260.
- 434 33. Leiner IE. Implications of antinutritional components in soyabean foods. *Crit.*
435 *Rev. Food Sci Nutr.* 1994;34:31-67.
- 436 34. Vasconcelos IM, Siebra EA, Mala AA, Moreira RA, Neto AF, Campelo GJA, Oliveira
437 JTA. Composition, toxic and antinutritional factors of newly developed cultivars of
438 Brazilian soybean (*Glycine max*). *J. Sci. Food Agric.* 1997;75:419-426.
- 439 35. Agbede JO, Aletor VA. Comparative evaluation of weaning foods from *Gliricidia* and
440 *Leucaena* leaf protein concentrates and some commercial brands in Nigeria.
441 *J.Sci.Food Agric.* 2003;84:21-30.
- 442 36. Bamigboye AY, Adepoju OT. Effects of processing methods on nutritive values of
443 Ekuru from two cultivars of beans (*Vigna unguiculata* and *Vigna angustifoliata*).
444 *African J. of Biotechnology*. 2015;14(21):1790-1795.
- 445 37. Akinyede AI, Amoo IA. Chemical and functional properties of full fat and defatted
446 Cassia fistula seed flours. *Pak. J. Nutr.* 2009;8:765-769.
- 447 38. Enujiugha VN. Supplementation of ogi, a maize-based infant weaning food
448 with African oil bean (*Pentaclethra macrophylla benth*) seed. *J.Food Agric. Environ.*
449 2006;4(2):34-38.