

Effect of Pretreatments and Drying Methods on The Physicochemical and Antioxidant Properties of Whole Eggplant (*Solanum aethiopicum*) Flour

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ABSTRACT: Sliced eggplant was pretreated (blanching and citric acid dip), -dried (oven and sun), then pulverized to flour. Physicochemical and antioxidant properties were evaluated using standard methods. The results showed increases in protein, moisture, fat, ash, crude fiber, and carbohydrate contents. They ranged from 7.78–8.39%, 8.90–10.14%, 4.32–5.28%, 0.77–0.91%, 10.72–13.43%, and 63.35–65.77%, respectively. Citric acid treatment and dried methods increased the minerals content for sodium (121.77–125.87 mg/100g), zinc (3.18–5.77 mg/100g), potassium (489.53–628.58 mg/100g), magnesium (68.86–75.39 mg/100g) and iron (8.91–11.82 mg/100g) than the blanched treatment. Functional properties of eggplant flour revealed that bulk density (0.42–0.50%), oil absorption capacity (0.64–4.85%), and wettability (1.43–4.35%) increased with citric acid and sun-drying method while swelling index (1.25–1.61%) and water absorption capacity (3.85–5.61%) increased with citric acid and oven drying method. Total polyphenol (26.49–29.78 mg GAE/mL), flavonoid (22.12–11.38 mg QE/mL), ABTS (52.38–61.34 Mmol/100 mL), DPPH (62.78–68.48%) and FRAP (58.67–65.36 Mmol/100mL) showed significant ($p < 0.05$) increases in citric acid and dried methods. From the results, the physicochemical and antioxidant properties of eggplant flour were positively affected by citric acid pre-treatments in sun and oven-dried methods.

Keywords: Eggplant flour; Pretreatment methods; Drying methods; Physicochemical properties; Antioxidant activity

INTRODUCTION

Eggplant (*Solanum aethiopicum*) is a vegetable that plays a vital role in human nutrition. Vegetables, in general, contain unique amounts of nutrients that are strongly linked to the protection of different health diseases (Naeem and Ugur, 2019). According to Dias (2012) and Ukom and Obi (2018), vegetables provide micronutrients, dietary fiber, and phytochemicals that are associated with improvement of gastrointestinal health, good vision, and reduced risk of heart disease, stroke, chronic diseases like diabetes, and some forms of cancer.

As an important vegetable, eggplant (*Solanum aethiopicum*) is consumed or utilized by people worldwide. It is widely utilized among the local population of Nigeria, especially in receiving visitors. Eggplant possesses 4.58 to 5.79% protein, 1.65 to 2.13% lipid, 1.78 to 1.81% crude fiber, and 11.77 to 15.42% carbohydrate (Agoreyo *et al.*, 2012). It is one of the best dietary sources of biologically active polyphenolic compounds, flavonoids, β -carotene, anthocyanin, vitamins A, C, E, and fiber (Kebede and Admassu, 2019) and provides medicinal requirements (Sanchez-Mata *et al.*, 2010; Solanke and Tawar, 2019). The phytochemical compounds have been reported in the prevention of diseases such as cancer and coronary heart disease (Yadav *et al.*, 2016). It was also reported to possess analgesic,

antipyretic, antioxidant, anti-inflammatory, anti-asthmatic, hypo-lipidemic, anti-platelet, and anaphylactic inhibitory activities (Solanke and Tawar, 2019).

Eggplant, as a vegetable, is perishable and difficult to preserve due to worm attacks and high moisture content (Deng *et al.*, 2017). Drying is one of the most common preservation methods for extending the shelf life of vegetables by reducing the water content and preventing or inactivating enzymatic-mediated deteriorative reactions (Mujumdar, 2014; Omolola *et al.*, 2017). Drying also reduces the weight and volume of vegetables with the benefits of minimizing packaging, storage, and transportation costs (Kamiloglu *et al.*, 2016).

However, drying may negatively affect the physicochemical and antioxidant properties of vegetables depending on the drying method. For example, antioxidant contents (total polyphenol and DPPH scavenging activity) were shown to be higher in the cabinet than the sun-drying method for potato peel composite cake (Akter *et al.*, 2023). However, pretreatment with citric acid and blanching methods was shown to obtain the shortest drying times on Amasya red apples (Doymaz, 2010), hence higher physicochemical and antioxidant properties. Therefore, eggplants and other vegetables can also be subjected to physical or chemical pretreatments like blanching and organic acids. These



Figure 1. Pretreated whole eggplant and flour

treatments also inactivate catalase enzymatic actions, enhance preservation, and improve the color quality of vegetables (Yu *et al.*, 2017). When pretreated and dried, the eggplant can be made into flour and put to functional uses in food systems with improved qualities of physicochemical and antioxidant properties.

About four groups of *Solanum* species are well-known and cultivated in many geographical zones of the world. They include Gilo, Kumba, Shum, and Aculeatum groups, of which the first three are the most important in Africa and they are produced for their fruits (Gilo and Kumba), especially in the humid zone of West Africa while Shum is cultivated for its leaves in the savannah area (Dauda *et al.*, 2005, Horna and Gruere, 2006). Although no official figures are recorded for eggplant production in Nigeria, the crop has a wide distribution as a garden crop (Dauda *et al.*, 2005). However, the global production of garden egg was 49.4 million tons in 2023 (FAOSTAT, 2015) of which 57% of this production output comes from China, while India produced 27% (FAOSTAT, 2015).

Eggplants remain a source of income for women and many rural dwellers (Nwodo *et al.*, 2013). Many varieties of these eggplants are produced yearly without preservation and end-product uses. This results in income and postharvest losses to farmers. Processing eggplant into flour will go a long way to prevent losses and support functional end uses and/or value addition to foods. Aside from this, there is a dearth of information on the effect of pre-treatment and drying on the physicochemical and antioxidant properties of eggplant flour. Therefore, this study was aimed at evaluating the effect of pre-treatment (blanching and citric acid) and drying (sun and oven) methods on the physicochemical and antioxidant properties of dehydrated eggplant flour.

MATERIALS AND METHOD

Source of raw materials

The eggplant (*Solanum aethiopicum*) grows in sunny, fertile, and well-drained soil for optimum productivity. The eggplants used for this study were bought at full-grown size and physiological maturity from Ariaria market, Aba, Abia State, Nigeria. All reagents and equipment for analysis were obtained from the Biochemistry laboratory, National Root Crop Research Institute, Umudike, Abia State, Nigeria.

Samples preparation

Pretreatment and production of Eggplant flour

Two pre-treatments were used in eggplant (*Solanum aethiopicum*) preparation as modified from the method of Combo *et al.* (2020). The eggplants were washed in potable water and then sliced, followed immediately by hot water blanching (98 °C, 5 min) and citric acid dip (2% concentration, 5 min). It was then oven-dried (55 °C, 24 h) and sun-dried over a shade for 36 h. The eggplant samples were divided into four: citric acid sun-dried (CS), citric acid oven-dried (CO), blanched sun-dried (BS), and blanched oven-dried (BO), respectively. It was milled and sieved into flour (500 μ) and stored appropriately for further analysis (Figure 1).

Determination of the proximate composition of eggplant flour

The proximate analysis: moisture, crude fiber, crude fat, crude protein, ash content, and carbohydrate of eggplant flour were determined according to AOAC (2010) standard methods.

Determination of minerals content of the eggplant flour

The method of AOAC (2010) was used. A solution of the ash sample was dissolved in a drop of trioxonitrate (V)

Table 1. Effect of pretreatment and drying on the proximate composition of eggplant flour (%dw)

Sample	Moisture content	Ash	Crude protein	Fat	Crude fiber	Carbohydrate
CS	9.27 ± 0.04 ^c	4.50 ± 0.03 ^c	8.39 ± 0.02 ^a	0.83 ± 0.01 ^b	11.76 ± 0.06 ^{ab}	65.25 ± 0.16 ^{ab}
CO	8.90 ± 0.08 ^d	5.28 ± 0.03 ^a	8.14 ± 0.02 ^b	0.91 ± 0.01 ^a	13.43 ± 1.38 ^a	63.35 ± 1.40 ^b
BS	10.14 ± 0.03 ^a	4.32 ± 0.04 ^d	7.91 ± 0.02 ^c	0.81 ± 0.01 ^b	11.49 ± 0.01 ^{ab}	65.33 ± 0.11 ^{ab}
BO	9.84 ± 0.02 ^b	5.14 ± 0.02 ^b	7.78 ± 0.03 ^d	0.77 ± 0.01 ^c	10.72 ± 0.06 ^b	65.77 ± 0.08 ^a

Note: a-d means that different superscripts within the same column are significantly different ($p < 0.05$). Where CS: Citric acid and sun-dried treated eggplant flour; CO: Citric acid and oven-dried treated eggplant flour; BS: Blanched and sun-dried treated eggplant flour; BO: Blanched and oven-dried treated eggplant flour

acid and made up to 50 ml with deionized water. Fe, Mg, and Zn were analyzed using the atomic absorption spectrophotometer, while Na and K were analyzed using the flame photometer.

Determination of vitamin contents of eggplant flour

The vitamin A content of eggplant flour was determined using the method described by Delia *et al.* (2004). The eggplant flour was extracted with cold acetone and then partitioned with petroleum ether. The aqueous phase after partitioning was discarded and the petroleum ether phase was washed thrice to remove residual acetone. It was then passed through a funnel containing anhydrous sodium sulfate to remove residual water and the absorbance was read at 450 nm using a spectrophotometer. Vitamin A was calculated using 12 µg β-carotene as 1 µg retinol activity equivalents.

$$\beta\text{-carotene content (mg/g)} = \frac{A \times \text{Volume (ml)} \times 10^4 \times df}{A^{1\% \text{ cm}} \times \text{weight of sample}}$$

Where

A : Absorbance,

Volume : Total volume of extract

$A^{1\% \text{ cm}}$: Absorbance Coefficient of β-carotene in petroleum ether (2592).

By multiplying the result with 100, the carotenoid content in µg/100g was obtained. Thiamine (Vitamin B₁), riboflavin (Vitamin B₂), niacin (Vitamin B₃), and Vitamin C contents were determined by the spectrophotometric method described by Onwuka (2005), while vitamin E was determined by (AOAC, 2010). Vitamin content was expressed as mg/g dry weight.

Determination of the functional properties of eggplant flour

The swelling index was determined according to the methods as described by Tester and Morrison (1990). The bulk density, water absorption capacity (WAC), oil absorption capacity (OAC), and wettability were determined by the method described by Onwuka (2005).

Determination of antioxidant and antioxidant activity of eggplant flour

The total phenol content (TPC) in each extract was determined using the Folin-ciocalteu method described by Quy *et al.* (2014). The total flavonoid content of the eggplant flour was determined using a slightly modified method reported by Bao *et al.* (2015).

The DPPH (2,2-Diphenyl-1-picrylhydrazyl) was determined using the method described by Katalinic *et al.* (2006). The FRAP assay was determined following the method described by Moharram and Youssef (2014), while ABTS was determined by the method described by Stratil *et al.* (2006)

Statistical analysis

All experimental data were analyzed using the SPSS version 22.0 software and were expressed as mean ± SD (standard deviation). One-way analyses of variance (ANOVA) were carried out. The Duncan Multiple Range Test (DMRT) methods were used to compare the means of experimental data at 95% confidence interval.

RESULT AND DISCUSSION

Effect of pretreatment and drying on the proximate composition of eggplant flour

Flour from pretreated and dried eggplant was evaluated for its proximate composition. Generally, pretreatment of vegetables has been reported to induce some levels of physical and biochemical modifications, leading to nutritional, textural, and sensorial changes. Pretreatment also brings about the destruction of microorganisms and inactivation of enzymes and anti-nutritional factors in vegetables (Palermo *et al.*, 2014). The effects of pretreatment of vegetables can enhance their digestibility and nutrient bioavailability. The whole and pretreated dried eggplant flour are shown in Fig 1 and the proximate values are presented in Table 1.

The results showed significant differences ($p < 0.05$) in line with the treatment variables. CO revealed higher retention of ash (5.28%), fat (0.91%), fiber (13.43%), and

Table 2. Effect of pretreatment and drying on the mineral composition of eggplant flour (mg/100gdw)

Powder sample	Fe	Zn	Na	K	Mg
CS	11.32 ± 0.11 ^b	4.84 ± 0.02 ^b	124.87 ± 0.04 ^b	628.58 ± 0.18 ^a	75.39 ± 0.13 ^a
CO	11.82 ± 0.05 ^a	5.77 ± 0.01 ^a	125.87 ± 0.04 ^a	614.62 ± 43.98 ^a	72.53 ± 0.11 ^b
BS	9.58 ± 0.03 ^c	3.62 ± 0.03 ^c	122.77 ± 0.04 ^c	583.56 ± 0.06 ^a	72.53 ± 0.11 ^b
BO	8.91 ± 0.01 ^d	3.18 ± 0.03 ^d	121.77 ± 0.04 ^d	489.53 ± 0.11 ^b	68.86 ± 0.08 ^c

Note: a-d means with different superscripts within the same column are significantly different ($p < 0.05$). Where CS: Citric acid and sun-dried treated eggplant flour; CO: Citric acid and oven-dried treated eggplant flour; BS: Blanched and sun dried treated eggplant flour; BO: Blanched and oven dried treated eggplant flour.

protein (8.14%) contents when compared to other treatments. This was followed by

the fat (0.83%), fiber (11.76%), and protein (8.39%) contents of CS eggplant flour. BS (10.14%) and BO (9.84%) eggplant flour exhibited higher moisture content than CO and CS eggplant flour. BO eggplant flour showed lower values of protein (7.78%), fat (0.77%), and fiber (10.72%) than other treatments. Overall, citric acid treatment (sun and oven-dried) gave a mean higher retention of ash (3.2%), protein (5.1%), fat (9.2%), and crude fiber (11.8%) over the blanched (sun and oven-dried) samples, respectively. Comparing with composite values of eggplant in literature, Uthumporn *et al.* (2016) exhibited the range values of moisture (8.47–9.45 g/100g), ash (8.14–8.73 g/100g), fat (0.88–5.18 g/100g), protein (12.98–15.75 g/100g), crude fiber (13.19–19.00 g/100g), and carbohydrate (62.73–68.02 g/100g) in eggplant flour, respectively. Agoreyo *et al.* (2012) reported lower proximate values as against the higher values shown by Combo *et al.* (2020) when compared with this study. Moisture content is an index of food stability (Offor, 2015). Therefore, the range of 8.90 to 10.14% moisture obtained in this study may not result to increase microbial and biochemical deterioration of eggplant flour during storage (Miranda *et al.*, 2009). The moisture content in sun dried method was less than 11%, which may have resulted from hot weather and a windy environment during the processing period at an ambient temperature of 28–30 °C. This action was also reported by Bechoff *et al.* (2009) on the sun-drying treatment of orange-fleshed sweet potato. Oven drying posited a greater concentration of ash content. The same trend was observed by Ndife *et al.* (2019) on pre-treatment of some eggplant flour. The high protein and fiber contents of eggplant flour can be used to supplement foods with low protein and fiber contents.

Effect of pretreatment and drying on minerals composition of eggplant flour

A significant difference ($p < 0.05$) revealing the effect of pretreatment in the mineral concentration of the eggplant flour is shown in Table 2. The results exhibited high and varied concentrations of Fe, Zn, and K in the eggplant flour, especially in citric acid pre-treatment. It was

observed that CO treatment obtained higher Fe (11.82 mg/100g), Zn (5.77 mg/100g), Na (125.87 mg/100g), and K (614.62 mg/100g) than other treatments. This was followed by the mineral concentrations of CS samples, namely, Fe (11.32 mg/100g), Zn (4.84 mg/100g), Na (124.87 mg/100g), and K (628.58 mg/100g). It was noted that pretreatment with citric acid had the advantage of the shortest drying time (Doymaz, 2010). Hence, a shorter reaction time and better retention and preservation of some minerals in the citric acid pretreated eggplant, and without the possibility of lixiviation phenomenon as in the blanching pretreatment.

Blanching had a lower effect on the mineral retention of the eggplant flour. The results also showed that BS flour retained more minerals than BO flour, which ranged from 9.58 to 8.91 mg/100g (Fe), 3.62 to 3.18 mg/100g (Zn), 122.77 to 121.77 mg/100g (Na), and 583.56 to 489.53 mg/100g (K). Some of these mineral values are slightly lower than those reported by Ndife *et al.* (2019). Eggplant flour can be seen as a rich source of some essential minerals (Fe, Zn, K) that are basic for physiological requirements and maintenance of immune competence in the human body. Eggplant flour may be classified as possessing functional properties for the overall well-being of the consumer. Iron is an important mineral in the diet for the prevention of anemia and other related diseases. The recommended daily allowance (RDA) of iron for men (19 years and older) and girls and women (11–50 years old) are 8 and 18 mg/day, and the RDA for potassium is 200 mg for adults (NRC, 1974). The iron content is within the RDA requirement for men (8 mg/day). Potassium is very important in maintaining the body's fluid volume and osmotic equilibrium (Paul *et al.*, 2018). The ratio of Na/K (1/4–5) (or about 0.2) in the eggplant powder makes it an important ingredient in ameliorating hypertensive disorder. Ndife *et al.* (2019) also found that potassium has the highest concentration of minerals in eggplant powder. With potassium being the highest mineral content (489.53 to 628.58 mg/100g), the use of eggplant powder to garnish foods will have a beneficial effect in lowering

Table 3. Effect of pretreatment and drying on the vitamin composition of eggplant flour (mg/100gdw)

Powder sample	Vitamin C	Vitamin B ₁	Vitamin B ₂	Vitamin B ₃	β-carotene	Vitamin E
CS	9.87 ± 0.03 ^a	0.35 ± 0.01 ^a	0.29 ± 0.01 ^a	1.93 ± 0.01 ^a	19.71 ± 0.13 ^a	3.17 ± 0.01 ^a
CO	8.51 ± 0.12 ^b	0.29 ± 0.01 ^b	0.26 ± 0.01 ^b	1.74 ± 0.00 ^{ab}	17.44 ± 0.02 ^b	2.87 ± 0.04 ^b
BS	7.76 ± 0.06 ^c	0.24 ± 0.00 ^c	0.23 ± 0.00 ^c	1.44 ± 0.06 ^b	15.62 ± 0.02 ^c	2.28 ± 0.03 ^c
BO	7.49 ± 0.01 ^d	0.23 ± 0.00 ^c	0.20 ± 0.00 ^d	1.64 ± 0.30 ^{ab}	12.39 ± 0.13 ^d	2.17 ± 0.01 ^d

Note: a-d means that different superscripts within the same column are significantly different ($p < 0.05$). CS: Citric acid and sundried eggplant flour; CO: Citric acid and oven-dried treated eggplant flour; BS: Blanched and sun-dried treated eggplant flour; and BO: Blanched and oven-dried treated eggplant Flour.

excessive sodium consumption, and thus will be able to prevent hypertensive disorder (Hasslam, 2008).

Effect of pretreatment and drying on vitamins composition of eggplant flour

Table 3 shows the effect of pretreatment and drying on the vitamin composition of the eggplant flour. Results revealed that the vitamin concentration of eggplant flour was reduced significantly ($p < 0.05$) by blanching such that, all the blanched flour had lower vitamin content than the citric acid-treated flour. Since citric acid pretreatment for eggplant may be scarce in the literature, our result is in line with Nyangena *et al.* (2019) who showed that citric acid pretreated and dried mango sliced samples increased vitamin C retention compared to blanching which induced greater vitamin C loss. Ndife *et al.* (2019) posited a similar view on lower vitamin content when the eggplant slices were only blanched but not citric acid treated. The reduction in vitamin levels could be related to heat sensitivity and the lixiviation of vitamins into the blanching water. The significant variations ($p < 0.05$) in CS pretreated vitamins content of eggplant flour were for vitamin C (9.87 mg/100ml), B₁ (0.35 mg/100g), B₂ (0.29 mg/100g), B₃ (1.93 mg/100g), β-carotene (19.71 mg/100g), and vitamin E (3.17 mg/100g). At the same time, CO pretreated eggplant flour followed closely for vitamin C (8.51 mg/100g), B₁ (0.29 mg/100g), B₂ (0.26

mg/100g), B₃ (1.74 mg/100g), β-carotene (17.44 mg/100g), and vitamin E (2.87 mg/100g), respectively. On the other hand, BS-pretreated eggplant flour was slightly higher than BO flour, but both treatment results were insignificant ($p > 0.05$). It was observed that blanching was more detrimental to all the vitamins, especially β-carotene retention than the citric acid treatment. Confirming our result, a higher carotenoid value was obtained from pretreated and oven-dried Apple mango slices at 50 °C and 1% citric acid (Nyangena *et al.*, 2019) than other pretreatment methods. β-carotene and vitamin E are strong dietary antioxidant compounds that are important in scavenging free radical actions *in vivo* to check oxidative damage.

Effect of pretreatment and drying on the functional properties of eggplant flour

The result of the functional properties of the eggplant flour are presented in Table 4. It is envisaged that the knowledge of the functional properties of eggplant flour would encourage and diversify its use to garnish, thicken, supplement, and increase the nutrient density of some foods commonly consumed by children and the elderly. By harnessing the nutrient and bioactive potentials, eggplant flour can even be exploited and exported to other countries of the world from tropical countries for the above purposes.

Table 4. Effect of pretreatment and drying on the functional properties of eggplant flour

Powder sample	BD (g/g)	SI (%)	WAC (g/mg)	OAC (mg/ml)	Wettability (%)
CS	0.50 ± 0.00 ^a	1.55 ± 0.01 ^b	5.48 ± 0.00 ^b	4.85 ± 0.00 ^a	4.35 ± 0.00 ^a
CO	0.45 ± 0.00 ^c	1.61 ± 0.01 ^a	5.61 ± 0.01 ^a	4.74 ± 0.02 ^b	3.40 ± 0.00 ^b
BS	0.47 ± 0.00 ^b	1.37 ± 0.02 ^c	3.85 ± 0.01 ^d	4.57 ± 0.04 ^c	2.23 ± 0.11 ^c
BO	0.42 ± 0.00 ^d	1.25 ± 0.01 ^d	4.14 ± 0.02 ^c	0.64 ± 0.02 ^c	1.43 ± 0.04 ^d

Note: a-d means with different superscripts within the same column are significantly different ($p < 0.05$). CS: Citric acid and sun-dried treated eggplant flour; CO: Citric acid and oven-dried treated eggplant flour; BS: Blanched and sun-dried treated eggplant flour; and BO: Blanched and oven-dried treated eggplant flour; BD: Bulk density; SI: Swelling index; WAC: Water absorption capacity, and OAC: Oil absorption capacity.

Table 5. Effect of pretreatment and drying on antioxidant activities of eggplant flour

Powder sample	Polyphenol (mgGAE/g)	Flavonoid (mgQE/g)	ABTS (mgMol/TE/g)	DPPH (%)	FRAP (mg/TE/100g)
CS	28.29 ± 0.01 ^c	22.12 ± 0.01 ^a	61.34 ± 0.08 ^a	68.48 ± 0.03 ^a	65.36 ± 0.06 ^a
CO	29.78 ± 0.03 ^a	20.70 ± 0.01 ^b	60.63 ± 0.24 ^b	64.33 ± 4.07 ^a	64.29 ± 0.01 ^b
BS	28.80 ± 0.06 ^b	16.39 ± 0.01 ^c	53.79 ± 0.03 ^c	65.46 ± 0.08 ^a	60.77 ± 0.04 ^c
BO	26.49 ± 0.01 ^d	11.38 ± 0.01 ^d	52.38 ± 0.01 ^d	62.78 ± 0.04 ^a	58.67 ± 0.10 ^d

Note: a-d means that different superscripts within the same column are significantly different ($p < 0.05$). CS: Citric acid and sun-dried treated eggplant flour; CO: Citric acid and oven-dried treated eggplant flour; BS = Blanched and sundried treated eggplant flour; and BO: Blanched and oven-dried treated eggplant

Bulk density is the ratio of the mass per volume of a substance and it indicates the porosity, packaging size, mouth-feel, and flavor of a product. It is generally affected by the particle size (Egbonu *et al.*, 2014). Bulk density also relates to the heaviness of solid particles the heavier the flour particle, the bulkier it becomes. The bulk density of the dehydrated eggplant flour ranged from 0.42 to 0.50%. The bulk density of CS eggplant flour (0.50 g/g) was significantly ($p < 0.05$) higher than other flour samples, while BO (0.42 g/g) had the lowest value. The swelling index ranged from 1.25% to 1.61%. CO had the highest value, while BO had the lowest value. The swelling index shows the degree of exposure of the internal structure of starch present in a food plant to the action of water (Egbonu *et al.*, 2014). The swelling index of flour particles was reported to increase as time and temperature increased (Egbonu *et al.*, 2014). Both the bulk density and swelling index compared with the results of Ndife *et al.* (2019) on steam-blanched *Solanum aethiopicum* flour. The water absorption capacity (WAC) of the eggplant flour ranged from 3.85 to 5.61%. CO treatment had a significantly ($p < 0.05$) higher value, and BS had the lowest value. On the other hand, oil absorption capacity ranged from 0.64 to 4.85%, with CS pretreated flour as the highest value, while BO had the lowest value. The ability of powdered plant products to absorb water and oil enhances their sensory properties such as flavor retention and mouth-feel (Egbonu *et al.*, 2014).

The wettability content of the eggplant flour ranged from 1.43 to 4.35%. CS also had the highest value (4.35%), while BO had the lowest value (1.43%). Wettability is believed to reduce the surface tension between the solid and liquid interface thus causing the wetting of the solid surface (Egbonu *et al.*, 2014). Irrespective of the pretreatment method, sun-drying showed greater bulk density, oil absorption capacity, and wettability, while the oven-drying method showed greater water absorption capacity. The observation was that sun-drying under the shade posited greater functional values than the oven-drying method, possibly as a result of the indirect

temperature effect from hot weather and the windy environment.

Effect of pretreatment and drying on antioxidant properties and activities of the eggplant flour

Table 5 shows the effect of pretreatment and drying on the antioxidant properties of eggplant flour. The antioxidant capacity of dried eggplant flour showed varied trends for both citric acid (sun and oven-dried) as well as the blanched (sun and oven-dried) flour. Generally, phenolics, flavonoids, and antioxidant activity were higher in citric acid-dried flour than in blanched-dried flour. Other researchers also revealed that blanching at higher temperatures and/or time obtained greater losses in the total phenolic, flavonoid, and antioxidant capacity of some vegetables (Goncalves *et al.*, 2009; Volden *et al.*, 2009; Jaiswal *et al.*, 2012).

In this study blanched and oven-dried (BO) flour represented the lowest radical scavenging activity for ABTS (52.38 mg/TE/g), DPPH (62.78%), FRAP (58.67 mg/TE/100g), polyphenols (26.49 mg/GAE/g) and flavonoids (11.38 mg/QE/g) when compared to the significantly ($p < 0.05$) higher scavenging power of citric acid sun-dried (CS) flour for ABTS (61.34 mg/TE/g), DPPH (68.48%), FRAP (65.36 mg/TE/g), and flavonoids (22.12 mg QE/g).

These differences could be attributed to the hydrophilic nature and the lixiviation phenomenon of antioxidant compounds during blanching. The oven temperature at 55 °C also had a reduction effect on antioxidant compounds and the antioxidant capacity of eggplant flour during drying. A previous study has shown that dehydration at elevated temperatures resulted in products of lower quality due to pigment isomerization, polyphenols degradation, and vitamin C oxidation

(Arslan and Özcan, 2010). Blanching triggered instability of antioxidant compounds through solubility in blanching water, antioxidant linkage with proteins, or the alterations in their chemical structure which may hinder extraction

Table 6. Correlation coefficient of total polyphenol, flavonoids, vitamin C, and antioxidant activity.

	DPPH	FRAP	ABTS	TFC	TPC	VIT C
DPPH	1.000					
FRAP	0.996**	1.000				
ABTS	0.989**	0.998**	1.000			
TFC	-0.300	-0.366	-0.412	1.000		
TPC	0.991**	0.995**	0.977**	-0.478	1.000	1.000
VIT C	0.835*	0.825*	0.805*	0.133	0.785	

Note: ABTS: antioxidant capacity measured in ABTS assays, DPPH: antioxidant capacity measured in DPPH assays, FRAP: antioxidant capacity measured in FRAP, TPC: total phenol content, TFC: total flavonoids content, Vit C: Vitamin C, ** and *are significant at ($p < 0.05$) or ($p < 0.01$)

and determination by the antioxidant activity assays (Di Scala *et al.*, 2011).

The antioxidant activity of natural compounds has been proven to be involved in the termination of free radical reactions (Drammeh *et al.*, 2018). The DPPH and ABTS radical scavenging activity is especially used to evaluate the hydroxyl chain-breaking activity of lipid (and protein) peroxidation (Drammeh *et al.*, 2018). In the FRAP activity, the ferrous-tripyridyltriazine (Fe^{3+} -TPTZ) complex was reduced to its ferrous form as caused by the combined action of electron-donating antioxidants in the eggplant flour. All the dehydrated eggplant flour exhibited good FRAP values. The overall results revealed that citric acid-treated flour scavenging power in ABTS, DPPH, and FRAP had mean values of 12.95%, 3.4%, and 7.7% higher than that of the blanched-treated samples. It shows that eggplant flour can help in the positive management of oxidative stress-related ailments such as cancer, cardiovascular diseases, and lipid peroxidation *in vivo*.

Pearson correlation coefficient of total polyphenol, flavonoids, vitamin C, and antioxidant activity of eggplant flour

Table 6 shows the correlation coefficient of antioxidant compounds and antioxidant activity of eggplant flour. Total polyphenol (TP) showed a linear correlation with DPPH, ABTS, and FRAP at $R^2 = 0.991, 0.977, \text{ and } 0.995$, while vitamin C showed a linear correlation with DPPH, FRAP, ABTS at $R^2 = 0.835, 0.825, 0.805$, respectively. These results witnessed that TPC and vitamin C contributed significantly to the antioxidant activity of eggplant flour.

CONCLUSION

This study demonstrated that pretreatments (blanching and citric acid dip) and drying methods (oven and sun

drying) significantly affected the physicochemical and antioxidant properties of eggplant flour. Vitamins (C, E, and β -carotene) and minerals (Fe, Na, K, and Mg) showed increased concentrations of about 10–20% as a result of citric acid pretreatment than hot water blanching. The same applied to antioxidant activity, where it showed further that polyphenols and vitamin C contributed to the strong scavenging power of FRAP, DPPH, and ABTS assays. In terms of drying, sun drying under the shade posited higher vitamins and antioxidant values and, in most of the proximate, minerals and functional parameters than the oven drying method. We opine that the results of eggplant flour obtained in this study will encourage and diversify its use to garnish, supplement, and increase the nutrient density of foods like pap, porridge, soups, and sauces for both children and the elderly.

AUTHORSHIP CONTRIBUTION STATEMENT

Anthony Ukum: Design of experiment, Supervision, Writing – Original Draft, Writing – Review & Editing; Dennis Egbujor: Methodology, Formal analysis; Lilian Nwanagba: Project Administration, Supervision; Immaculeta Okparauka: Data curation.

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CONFLICT OF INTEREST

Authors declare no conflicting interest.

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