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Effects of Sun-Drying and Oven-Drying on the Nutrients, Anti-Nutrients, and Bioavailability of some Minerals in Commonly Consumed *Capsicum* Varieties in Nigeria

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ABSTRACT

The levels of nutrients and anti-nutrient in common *Capsicum* varieties after drying, have not been widely reported. Thus, this study was designed to determine the effects of sun-drying and oven-drying on the nutrients, anti-nutrients and bioavailability of minerals in six commonly consumed *Capsicum* varieties in Nigeria. Two varieties of *Capsicum chinense* – yellow and red *ata rodo*; three varieties of *Capsicum annuum* – *tatase*, *bawa*, and *ata shombo*; and *Capsicum frutescens* – *ata wewe* were purchased fresh from *Oja Oba* market in Ibadan, Oyo State, Nigeria. They were washed, sliced, and processed by sun-drying and oven drying methods, before determining their proximate, minerals, ascorbic acid, anti-nutrients and bioavailability of Ca, Fe and Zn, using standard methods. The proximate results revealed that sun-drying method retained these parameters much better in most of the *Capsicum* varieties. The levels of eight minerals were modulated by the processing methods, with sun-drying yielding better results for most minerals in the *Capsicum* varieties. Furthermore, the ascorbic acid content was significantly ($p<0.05$) depleted by both drying protocols, with oven drying-method retaining it much better in most varieties. On another hand, the effect of drying methods was not significantly different ($p>0.05$) for the anti-nutrients in most varieties. The phytate/minerals and oxalate/calcium molar ratios revealed high bioavailability of Ca, Fe and Zn from all *Capsicum* varieties processed via sun-drying or oven-drying. Both drying methods have modulatory effects on the nutrient and anti-nutrient contents of the *Capsicum* varieties and can be safely applied for optimum bioavailability of Ca, Fe and Zn.

Keywords: Anti-nutrients, Ascorbic acid, Bioavailability, *Capsicum* varieties, Minerals, Proximate composition.

Introduction

Capsicum is known to be the genus in Solanaceae family with greatest economic value, having up to 35 species.[1] Only five of these species have been well domesticated globally, which are *Capsicum pubescens*, *C. frutescens*, *C. chinense*, *C. baccatum* and *C. annuum*.[2] Most of them are either categorized as 'chili pepper' being of small fruit and spicy or 'sweet pepper', being of larger fruit with very minimal spicy flavour.[3] Their fruits are of various colours including orange, yellow, red, and green; and have been included in Mexican Indians' meals as far as 9000 years ago.[4,5] They are currently being cultivated and used globally for their nutritional, culinary and medicinal benefits. These benefits emanate from the nutrients and vast amount of capsaicinoids, flavonoids and carotenoids present in the peppers.[6-12] The common and local names of varieties studied are as follows: two varieties of *Capsicum chinense*, that is, yellow (yellow, black or Cameroon pepper – common (C), bàrkồnō – Hausa (H), *ose Nsukka* – Igbo (I), *ata rodo* – Yoruba (Y), and red (scotch bonnet pepper (C), atarugu (H), *ose Oyibo* (I), *ata rodo* (Y)); three varieties of*Capsicum annuum*, that is, 1 – red bell pepper (C), *tattasai* (H), *tatashi*/*uhie mbirigba* (I), *tatase* (Y), 2 – cayenne pepper (C), *sambo* (H), *ose talugwu* (I), *bawa* (Y), and 3 – cayenne chili pepper (C), *sombo* (H), *shọmbe* (I), *ata shombo* (Y); and *Capsicum frutescens* - bird pepper (C), *ose Igbo*/*ose Nnụnụ* (I), *ata wewe* (Y).

Peppers have been reported to be rich in beta carotene, ascorbic acid and folate [11,13], dietary fiber, essential amino acids, essential fatty acids, macro- and micro-minerals.[12,14-17] However, they equally have some anti-nutrients that tend to limit the bioavailability of the nutrients, especially minerals.[15,17] As one of the fruity vegetables, it is not too surprising that the moisture content of fresh peppers ranges from 80 to 89 percent,[14,17,18] which raises their perishability shortly after harvesting. This is a major reason why most producers of Capcicum prefer to dry their products for better management of both local and international trades. At the household level, several consumers prefer the fresh form of peppers for unique taste, while some others rely much more on the dry form due to their longer shelf life. Thus, both the dry and fresh forms are widely produced and supplied globally for various purposes.[19]

In Nigeria, most *Capsicum* farmers often market the fresh form immediately after harvest and some remnants are usually sundried for further storage and sales; while a portion still rot away. Drying as a method of preservation has been shown to modulate the levels of nutrients, anti-nutrients and phytochemical components of peppers.[20-22] However there is paucity of data on the effects of drying on most of the *Capsicum* sp being commonly consumed in Nigeria. Therefore, this study was designed to determine the effects of sun-drying

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(traditional) and oven-drying (non-conventional) processing methods on the levels of some nutrients (proximate parameters, ascorbic acid, and minerals), anti-nutrients, and bioavailability (of calcium, iron and zinc) in six commonly consumed *Capsicum* varieties in Nigeria.

Materials and Methods

Sample collection and preparation

Two varieties of *Capsicum chinense* – yellow *ata rodo* (yellow pepper) and red *ata rodo* (scotch bonnet pepper); three varieties of *Capsicum annuum* – *tatase* (red bell pepper), *bawa* (cayenne pepper), and *ata shombo* (cayenne chili pepper); and *Capsicum frutescens* – *ata wewe* (bird pepper) were obtained from *Oja Oba* market at Ibadan, Oyo State, Nigeria in December 2015. The samples were identified and authenticated by Mr Esimekhuai, D.P.O. at the University of Ibadan Herbarium and voucher specimens (with numbers: UIH-22963, UIH-22962, and UIH-22964) were deposited at the same place. The samples were washed with distilled deionized water and thinly sliced. Only edible portions of the samples were processed for analyses. Each variety was divided into two portions. The two portions were separately processed (oven-dried and sun-dried). About 1 kg of each variety was separately subjected to the following processing techniques: i) sun drying – spreading of samples under the sun with intermittent turning of samples for about 5 days, ii) oven drying-samples were dried at 65ºC in Gallenkamp hot air oven (Weiss Technik, Loughborough, England), till a constant weight was obtained. Each of the dried samples was separately milled with Eurolex blender model GM 1153 (Eurolex, New Delhi, India) and stored in separate air-tight containers at -20^{o}C until when needed for analysis.

Chemical analyses

Sun-dried and oven-dried samples were analyzed for their proximate, ascorbic acid, minerals and anti-nutrient contents. Only edible parts of the samples were used for analyses. The proximate and ascorbic acid contents were determined using the standard method of the Association of Official Analytical Chemists (AOAC) published in 2005. Moisture content was determined on the fresh samples with hot air oven set at 105 ^{o}C till a constant weight was obtained. The crude fiber was determined using defatted samples that were taken through acid and alkali digestion, before being ashed in the muffle furnace. The fat content was determined using petroleum ether for soxhlet extraction at 60 ^{o}C. The percentage composition of ash was determined by the muffle furnace set at 500 °C for 6 h. Ascorbic acid was estimated using 2,6 dichlorophenol indophenol dye. The mineral contents were also evaluated after dry ashing, according to the method of AOAC[23] as modified by Akinyele and Shokunbi.[24] Saponin level was determined by spectrophotometric method of Bruner.[25] Phytate was analyzed titrimetrically with $FeCl_3$ solution according to Maga.[26] Oxalate content of the samples was also determined by titration with $KMnO_4$ solution using AOAC method.[23] The absorption and bioavailability of calcium, iron, and zinc in humans are known to be predictable via calculated molar ratios of phytate to mineral and oxalate to calcium.[27-30] The molar ratios were calculated using 660 g/mol and 128 g/mol as the molecular weights of phytate and oxalate, respectively. The adopted critical values used to predict bioavailability were phytate/calcium: 0.17,[31,32] phytate/iron: 1,[33,34] phytate/zinc: 15,[34-36] phytate x calcium/zinc: 200,[37,38] oxalate/calcium: 2.5.[27] Analyses were carried out in duplicate and the relative standard deviation (% RSD) was below 5% for each measurement. Results are presented on wet weight basis.

Statistical analysis

Data were evaluated using statistical package for social sciences (SPSS) version 22.0. The student's T-test or the one-way analysis of variance (ANOVA) was used to compare means and the significance level was set at $p < 0.05$.

Results and Discussion

The levels of some proximate parameters from the analysed *Capsicum* varieties are presented in Table 1. The parameters (g/100 g) – moisture content, crude fat, crude fiber and ash were 62.0-82.6, 1.19-2.09, 1.01-1.78, and 2.57-2.89, respectively. The moisture contents of the *Capsicum* varieties obtained were not significantly different ($p > 0.05$) over the processing methods. The moisture content is a similar range with the report on ten varieties of Capsicum from India.[14] The crude fats were significantly higher ($p < 0.05$) for oven-dried red *ata rodo* and *ata wewe* compared with the sun-dried form, while most other varieties do not have significant difference between the processing methods. The percentage fat reported in this study is slightly less than the values reported from 12 varieties from South Korea,[12] but higher than the values reported from *Capsicum* variety from Sokoto, Nigeria,[22] and in the same range with those reported from three varieties grown in Ethiopia.[15] The crude fiber and ash on the other hand were significantly higher ($p < 0.05$) in most of the sun-dried *Capsicum* portions, compared with the oven-dried portions. The minerals settling on the samples, from the environment, during sun-drying may account for this difference, especially in ash content. The fiber content obtained from this study is lower than those reported by Tambuwal *et al*.[22] for varieties from Sokoto, Kim *et al*.[12] for varieties from South Korea and Esayas *et al*.[15] for varieties from Ethiopia; though in the same range with those reported by Litoriya *et al*.[14] for varieties from India. The ash content is in the same range as most of the previous studies. These variations are likely due to differences in the varieties of Capsicum analysed, time of collection during the year and/or in the geographical locations, where the samples were collected. As Capsicum varieties are usually less patronized for their macronutrients contents, there may not be so much concern on the compositions of especially fat and fiber.

The concentration of ascorbic acid as affected by the two drying methods is presented in Table 2. The ascorbic acid levels in the fresh forms of the *Capsicum* varieties ranged from 49.3 mg/100 g in *ata shombo* to 68.9 mg/100 g in *tatase*. These were reduced to concentrations ranging from 31.4 mg/100 g in sun-dried *ata shombo* to 52.7 mg/100g in oven-dried *tatase*. The two drying methods significantly reduced ($p < 0.05$) the levels of ascorbic acid in all the *Capsicum* varieties studied. Both drying methods had similar negative impact on the level of ascorbic acid in most of the *Capsicum* varieties. Oven-drying method was found to be better in retaining ascorbic acid for *tatase*, whereas sun-drying was better for *ata wewe*. The ascorbic acid composition of the *Capsicum* varieties reported in this study is within the range (11.9 to 195.8 mg/ 100 g) reported for 90 *Capsicum* varieties from across North America,[11] though lower than values from *Capsicum* varieties reported by Moraes *et al*.[18] – 144.8 mg/ 100 g, Castro *et al*.[39] – 75 to 277 mg/100 g, and Litoriya *et al*.[14] – 76.3 to 161.3 mg/100 g; but higher than values from *Capsicum* varieties reported by Emmanuel-Ikpeme *et al*.[16] – 22.2 to 47.6 mg/100 g. These variations reflect the fact that ascorbic acid varies widely among *Capsicum* varieties and make it necessary to select specific variety with high ascorbic acid content, if this nutrient is of utmost priority. Drying was similarly shown to significantly reduce the level of ascorbic acid in *Capsicum* varieties.[18,20] Thus, it becomes necessary to strike a balance between nutrient content and shelf life in the selection of the *Capsicum* varieties. Fresh form is the better option, if ascorbic acid is to be optimally derived from *Capsicum* varieties.

Table 3 shows the mineral concentrations of the *Capsicum* varieties processed with two drying methods. The minerals vary in this order: K > Na > Mg > Ca > Fe > Zn > Cu > Mn. *Ata wewe* had the highest levels of Ca, Mg, Na and Fe, whereas *tatase* had the highest levels of K, Mn and Zn, with *bawa* having the highest level of Cu.

Table 1: Some proximate parameters (g/100 g wet weight) of six commonly consumed *Capsicum* varieties processed with two drying methods

Varieties	**Processing method**	**Proximate Parameters (g/100 g)**			
		Moisture	Crude fat	Crude fiber	Ash
Yellow *ata rodo*	Sun-dried	82.1 ± 2.11^a	1.19 ± 0.01^a	1.01 ± 0.02^a	2.78 ± 0.02^a
	Oven-dried	82.6 ± 3.08^a	1.20 ± 0.01^a	1.06 ± 0.01^b	2.67 ± 0.01^b
Red *ata rodo*	Sun-dried	78.5 ± 1.89^a	1.48 ± 0.01^b	1.42 ± 0.02^a	2.75 ± 0.01^a
	Oven-dried	79.0 ± 2.10^a	1.54 ± 0.02^a	1.27 ± 0.01^b	2.70 ± 0.01^b
Tatase	Sun-dried	76.5 ± 1.96^a	1.95 ± 0.02^a	1.74 ± 0.01^a	2.88 ± 0.02^a
	Oven-dried	77.6 ± 2.26^a	1.92 ± 0.03^a	1.57 ± 0.01^b	2.82 ± 0.01^a
Bawa	Sun-dried	77.5 ± 2.40^a	1.79 ± 0.02^a	1.57 ± 0.01^a	2.64 ± 0.02^a
	Oven-dried	78.3 ± 2.29^a	1.84 ± 0.04^a	1.47 ± 0.02^b	2.67 ± 0.02^a
Ata shombo	Sun-dried	76.0 ± 1.83^a	1.80 ± 0.02^a	1.78 ± 0.02^a	2.62 ± 0.02^a
	Oven-dried	77.0 ± 2.68^a	1.71 ± 0.03^b	1.49 ± 0.01^b	2.57 ± 0.01^b
Ata wewe	Sun-dried	61.4 ± 1.65^a	1.94 ± 0.01^b	1.39 ± 0.01^b	2.71 ± 0.03^b
	Oven-dried	62.0 ± 1.79^a	2.09 ± 0.03^a	1.49 ± 0.02^a	2.89 ± 0.02^a

Values of the same variety and different processing methods are significantly different at $p < 0.05$, if having different superscript.

Table 2: Level of ascorbic acid (mg/100 g fresh weight) in six commonly consumed *Capsicum* varieties processed with two drying methods

***Capsicum* Variety/Processing method**	**Fresh**	**Sundried**	**Oven dried**
Yellow *ata rodo*	60.5 ± 3.84^a	46.1 ± 1.94^b	44.6 ± 1.67^b
Red *ata rodo*	62.7 ± 3.55^a	48.4 ± 2.49^b	47.7 ± 2.04^b
Tatashe	68.9 ± 4.10^a	42.7 ± 2.62^c	52.7 ± 2.13^b
Bawa	66.1 ± 2.36^a	45.7 ± 1.50^b	49.4 ± 3.93^b
Ata shombo	49.3 ± 3.02^a	31.4 ± 1.86^b	33.6 ± 3.47^b
Ata wewe	50.1 ± 2.30^a	40.2 ± 3.72^b	34.7 ± 2.07^c

Values in rows with different superscripts are significantly different at $p < 0.05$.

Table 3: Concentrations (mg/100 g wet weight) of minerals in six commonly consumed *Capsicum* varieties processed with two drying methods

Varieties	**Processing method**	**Ca**	**Mg**	**K**	**Na**	**Mn**	**Fe**	**Cu**	**Zn**
Yellow *ata rodo*	Sun-dried	3.58 ± 0.311^a	30.0 ± 0.267^a	359 ± 3.15^a	35.7 ± 3.83^a	0.281 ± 0.009^a	1.45 ± 0.038^a	0.283 ± 0.019^b	0.291 ± 0.025^a
	Oven-dried	3.32 ± 0.420^a	21.0 ± 2.39^b	339 ± 6.26^b	25.9 ± 1.65^b	0.212 ± 0.004^b	1.54 ± 0.061^a	0.471 ± 0.074^a	0.236 ± 0.012^b
Red *ata rodo*	Sun-dried	3.69 ± 0.319^a	16.1 ± 0.600^a	316 ± 1.13^b	33.4 ± 2.04^b	0.244 ± 0.017^a	1.64 ± 0.015^a	0.304 ± 0.030^a	0.254 ± 0.030^b
	Oven-dried	3.72 ± 0.134^a	15.0 ± 1.04^a	333 ± 3.59^a	48.7 ± 1.08^a	0.250 ± 0.022^a	0.85 ± 0.297^b	0.326 ± 0.054^a	0.373 ± 0.022^a
Tatase	Sun-dried	4.08 ± 0.231^a	17.6 ± 0.216^a	570 ± 4.55^a	45.1 ± 2.81^a	0.391 ± 0.025^a	1.61 ± 0.083^a	0.151 ± 0.008^a	0.891 ± 0.058^a
	Oven-dried	4.15 ± 0.047^a	17.8 ± 0.514^a	530 ± 7.64^b	37.2 ± 3.27^b	0.326 ± 0.029^b	0.97 ± 0.087^b	0.173 ± 0.047^a	0.634 ± 0.016^b
Bawa	Sun-dried	5.50 ± 0.200^a	29.6 ± 2.74^a	237 ± 1.28^a	31.3 ± 2.29^a	0.114 ± 0.031^a	1.15 ± 0.127^a	0.510 ± 0.080^a	0.382 ± 0.039^a
	Oven-dried	4.68 ± 0.322^b	21.0 ± 1.94^b	196 ± 1.44^b	28.3 ± 1.89^a	0.109 ± 0.018^a	0.86 ± 0.027^b	0.434 ± 0.035^a	0.361 ± 0.015^a
Ata shombo	Sun-dried	8.59 ± 0.991^a	36.2 ± 4.11^a	240 ± 2.87^a	38.0 ± 2.62^a	0.261 ± 0.011^a	1.39 ± 0.076^a	0.472 ± 0.093^a	0.415 ± 0.017^a
	Oven-dried	6.79 ± 0.065^b	32.3 ± 0.773^a	221 ± 3.62^b	30.8 ± 2.07^b	0.196 ± 0.008^b	1.01 ± 0.089^b	0.271 ± 0.033^b	0.363 ± 0.026^b
Ata wewe	Sun-dried	13.9 ± 0.496^a	61.1 ± 0.717^a	404 ± 4.85^a	61.9 ± 3.78^a	0.175 ± 0.016^a	3.94 ± 0.248^a	0.274 ± 0.055^a	0.592 ± 0.011^a
	Oven-dried	13.4 ± 0.883^a	53.0 ± 3.45^b	332 ± 5.14^b	50.4 ± 2.59^b	0.132 ± 0.013^a	2.69 ± 0.301^b	0.376 ± 0.078^a	0.551 ± 0.015^b

Values of the same variety and different processing methods are significantly different at $p < 0.05$, if having different superscript.

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The levels of Ca were significantly higher ($p < 0.05$) in the sun-dried portion of *bawa* and *ata shombo* compared with the oven-dried form, with no significant difference ($p > 0.05$) across other varieties. Relative to the other minerals, there were no uniform modulations in the mineral contents of the *Capsicum* varieties. Sun-dried samples had significantly higher ($p < 0.05$) concentrations of minerals in most of the varieties, across the minerals analyzed. The levels of minerals in the *Capsicum* varieties analyzed are similar to those previously reported in *Capsicum* varieties from India,[14] South Korea,[12] and Cote d'Ivoire,[17] for most of the minerals. This suggests that the mineral contents of *Capsicum* varieties in Nigeria are similar to those in the international community and as such can favorably compete as export products. Therefore, the mineral of interest and perhaps organoleptic properties would likely determine the choice of the *Capsicum* variety for consumption. Furthermore, the sun-drying (conventional) method is of greater benefit, as far as the mineral contents of the *Capsicum* varieties are concerned. This could be partly due to the exposure of these set of samples to the atmosphere, where some metals can possibly settle on them as the wind blows. The samples were sun-dried in a similar way as conventionally practiced in Nigeria.

Table 4 presents the concentrations of three anti-nutrients in the six varieties of *Capsicum* studied, as modulated by two drying methods. Saponin contents in the varieties were relatively higher than the oxalate contents, which were also higher than the phytate contents. The saponin, phytate, and oxalate levels (mg/100 g) were 30.5-66.4, 3.53-9.27, and 9.04-14.3, respectively. *Ata wewe* had the highest saponin and phytate levels, whereas *tatase* had the highest level of oxalate, across the varieties. Conversely, *tatase* had the least levels of saponin and phytate, while yellow *ata rodo* had the least oxalate content, among all varieties studied. The phytate content is within similar range reported by Joung *et al*.[40] – 4 to 36 mg/100 g) and Don *et al*.[17] – 6 to 8 mg/100 g. There are limited data on the saponin and oxalate content of Capsicum varieties for further comparison. Both drying methods had similar effect on saponin contents for most of the *Capsicum* varieties, as they were not significantly different ($p > 0.05$) from each other. Oven-dried form of most of the *Capsicum* varieties had significantly higher ($p < 0.05$) level of phytate, when compared with the sun-dried form. Similar trend exist for oxalate contents of *bawa*, *ata shombo* and *ata wewe*. High content of oxalate in food can pose greater risk of developing kidney stones in consumers. Thus reduced dietary intake of oxalate has been advised by experts.[41,42] In view of this fact, the relatively low oxalate content of *Capsicum* varieties, when compared with other vegetables, can be an advantage when included in food preparations.

The presence of phytate in the diet usually limit the bioavailability of divalent cations like iron, zinc, and calcium in the gastrointestinal tract, and pH of the small intestine (6–7) tend to increase the dissociation and formation of phytate-divalent cation complexes that precipitate, making them less available for absorption and consequent utilization by the human body.[43] The calculated molar ratios of phytate/minerals and oxalate/calcium are as presented in Table 5. These ratios are useful in predicting the bioavailability of the minerals from the six *Capsicum* varieties studied. The phytate/calcium and oxalate/calcium ratios of the varieties are lower than the 0.17 and 2.5 critical values, respectively; hence, suggesting the bioavailability of calcium from all of them, irrespective of the drying method. This also affirms the relatively low level of oxalate in the Capsicum varieties studied. Furthermore, the phytate/iron molar ranged from 0.185 in sun-dried *ata wewe* to 0.633 in oven-dried *bawa*. All values obtained for this molar ratio are below 1.0; implying high iron bioavailability from all the varieties. The phytate/zinc molar ratio of the sun-dried and oven-dried Capsicum varieties ranged from 0.390 to 1.95, making them all lower than the critical value of 15.0. The phytate/zinc molar ratio has been disaggregated to ≥15, 5–15, and <5 as equivalent to low (10–15%), moderate (30–35%), and high (50–55%) zinc bioavailability, respectively.[34,35,44] These cut-offs suggest that zinc bioavailability from all these peppers is predictably high. This finding is further substantiated with the phytate x calcium/zinc molar ratio, which is conventionally acceptable to be a better predictor of zinc bioavailability, in the presence of phytate and calcium. All values obtained for this molar ratio are far below the critical value of 200, predicted to have negative effect on zinc absorption;[37,38] implying high zinc bioavailability.

Table 4: Levels of anti-nutrients in six commonly consumed *Capsicum* varieties processed with two drying methods

Varieties	**Processing method**	**Anti-nutrients (mg/100 g wet weight)**		
		Saponin	**Phytate**	**Oxalate**
Yellow *ata rodo*	Sun-dried	32.2 ± 1.21^b	5.64 ± 0.077^a	10.1 ± 0.175^a
	Oven-dried	36.9 ± 1.68^a	4.52 ± 0.095^b	9.04 ± 0.254^b
Red *ata rodo*	Sun-dried	34.4 ± 2.14^a	5.04 ± 0.103^b	12.0 ± 0.188^a
	Oven-dried	36.3 ± 2.03^a	5.75 ± 0.212^a	12.2 ± 0.167^a
Tatase	Sun-dried	30.5 ± 1.97^a	3.53 ± 0.066^b	14.3 ± 0.382^a
	Oven-dried	32.4 ± 2.65^a	3.84 ± 0.053^a	14.1 ± 0.441^a
Bawa	Sun-dried	43.2 ± 2.31^a	5.81 ± 0.088^b	13.2 ± 0.104^b
	Oven-dried	41.3 ± 1.83^a	6.42 ± 0.095^a	14.1 ± 0.371^a
Ata shombo	Sun-dried	46.5 ± 2.16^a	6.30 ± 0.108^b	11.3 ± 0.226^b
	Oven-dried	43.4 ± 3.01^a	6.64 ± 0.111^a	13.2 ± 0.215^a
Ata wewe	Sun-dried	66.4 ± 3.44^a	8.57 ± 0.141^b	10.1 ± 0.146^b
	Oven-dried	63.1 ± 2.89^a	9.27 ± 0.189^a	12.4 ± 0.203^a

Values in the same variety on a column are significantly different ($p < 0.05$), if the superscripts are different

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Table 5: Molar ratios of phytate to calcium, iron and zinc, phytate x calcium/zinc, and oxalate to calcium of six commonly consumed *Capsicum* varieties processed with two drying methods

Varieties	Processing method	[Phy]/[Ca][a]	[Phy]/[Fe][b]	[Phy]/[Zn][c]	[Phy] X [Ca]/[Zn][d]	[Ox]/[Ca][e]
Yellow *ata rodo*	Sun-dried	0.096	0.330	1.91	0.171	0.882
	Oven-dried	0.083	0.249	1.89	0.157	0.851
Red *ata rodo*	Sun-dried	0.083	0.261	1.95	0.180	1.02
	Oven-dried	0.094	0.574	1.52	0.141	1.02
Tatase	Sun-dried	0.052	0.186	0.390	0.040	1.10
	Oven-dried	0.056	0.336	0.597	0.062	1.06
Bawa	Sun-dried	0.064	0.429	1.50	0.206	0.750
	Oven-dried	0.083	0.633	1.75	0.205	0.942
Ata shombo	Sun-dried	0.044	0.385	1.50	0.321	0.411
	Oven-dried	0.059	0.558	1.80	0.306	0.608
Ata wewe	Sun-dried	0.037	0.185	1.43	0.495	0.227
	Oven-dried	0.042	0.292	1.66	0.555	0.289
Critical values		0.17	1.0	15.0	200	2.5

[a] – (mg phytate/MW of phytate: mg Ca/MW of Ca), [b] – (mg phytate/MW of phytate : mg Fe/MW of Fe), [c] – (mg phytate/MW of phytate : mg Zn/MW of Zn), [d] – (mg phytate/MW of phytate X mg Ca/MW of Ca : mg Zn/MW of Zn), and [e] – (mg oxalate/MW of oxalate : mg Ca/MW of Ca).

Conclusion

The findings suggest that there is a need to encourage the general population on the consumption of *Capsicum* varieties, due to their high availability and rich contents of minerals and ascorbic acid. These nutrients are differently modulated by the conventional sun-drying method and the oven-drying method, with both methods mainly reducing the level of ascorbic acid. Though the varieties contain some anti-nutrients, these would minimally limit the bioavailability of minerals (when consumed), especially calcium, iron, and zinc. Our findings show that both drying methods can be safely adopted for processing the six varieties, and perhaps many other *Capsicum* varieties, on a large scale. Furthermore, moderately incorporating these *Capsicum* varieties into various menus of consumers in Nigeria, can help to minimize the deficiencies of calcium, iron, zinc, and ascorbic acid as well as other macro- and micro-minerals reported from this study.
The study thereby simultaneously provided the scarce data on the composition of these peppers in their commonly consumed forms. Thus, the data obtained can be useful for the nutrition education of the public as a means to improve the nutritional status of the pepper consumers in Nigeria. It can also be a useful guide to small- or large-scale industries, hoping to embark on processing of *Capsicum* varieties, using oven-drying (non-conventional) method, thereby minimizing the post-harvest loss of *Capsicum* fruits.

Conflict of interest

The authors declare no conflict of interest.

Authors' Declaration

The authors hereby declare that the work presented in this article is original and that any liability for claims relating to the content of this article will be borne by them.

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