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Chemical composition and the effect of processing on oxalate content of cocoyam *Xanthosoma sagittifolium* and *Colocasia esculenta* cormels

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Abstract

The chemical composition as well as the effect of processing on the cormels of two *Xanthosoma sagittifolium* species and *Colocasia esculenta* cormels were evaluated. A 3×3 factorial experimental design with cocoyam varieties [*Xanthosoma* (white-flesh), *Xanthosoma* (red-flesh) and *Colocasia*] and cormel section (distal, middle and apical) was performed to determine the chemical composition of the cormels. Oxalate contents of the various cormels were also evaluated and the effect of processing assessed using standard analytical methods. The mean values of the proximate composition of the three cocoyam species evaluated were; crude protein 2.98–5.50 g/100 g, total fat 0.28–0.97 g/100 g, ash 1.56–2.98 g/100 g, starch 12.2–36.0 g/100 g and crude fibre 1.11–3.00 g/100 g. The results showed that the different sections of the cocoyam cormels studied were significantly different ($P \leqslant 0.05$) in chemical composition. The apical section of all the species had high protein content while the distal section had high levels of ash, fibre and minerals. Potassium was the most abundant mineral (763–1451 μg/100 g) with appreciable amounts noted for zinc (17–51.1 μg/100 g), magnesium (46.7–85.0 μg/100 g) and phosphorus (41.6–63.1 μg/100 g). Oxalate compositions of the fresh samples were in the range of 254–381 μg/100 g for the *X. sagittifolium* (red-flesh), 302–323 μg/100 g for the *X. sagittifolium* (white-flesh) and 328–460 μg/100 g for the *Colocasia esculenta*. No significant differences ($P \leqslant 0.05$) were found between the oven-dried and solar-dried samples. However, drum drying reduced the oxalate levels by approximately 50% to average levels ranging from 99.9 to 191 μg/100 g.

Keywords: *Xanthosoma sagittifolium*; *Colocasia esculenta*; Chemical composition; Oxalate composition; Processing effect

1. Introduction

Xanthosoma sagittifolium and *Colocasia esculenta* species are tropical root crops commonly referred to as cocoyams. They are used as subsistence staples in many parts of the tropics and sub-tropics in Africa. They produce starch storage corms and cormels and have several genera and species throughout the world. Investigations have shown that cocoyams contain digestible starch, protein of good quality, vitamin C, thiamin, riboflavin and niacin and have high scores of proteins and essential amino acids (Onayemi & Nwigwe, 1987). World production of the crop is estimated to be 5.5 million tonnes annually and provides about a third of the food intake of more than 400 million people in the tropics (FAO, 1991). More than three quarters of the world cocoyam production come from Africa with Ghana and Nigeria being the world's leading producers (Onwueme, 1982).

The dietary importance of root crops has led workers to devise various means to determine the composition of food commodities. Several authors have evaluated the chemical composition of whole corms and cormels of both the *X. sagittifolium* species and *C. esculenta* species (Bradbury & Holloway, 1988; Otshuka et al., 1984; Wills, Lim, Greenfield, & Bayliss, 1983). It has been observed that, in spite of the fact that cocoyams are neglected crops, their compositional value is high, with an average protein content of 6% and 390 calories per

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100 g dry matter. Agbor-Egbe and Richard (1990) have compared the composition of 32 cultivars of *X. sagittifolium* species and *C. esculenta* species. They reported differences among the species. This observation supports earlier work done by Coursey (1968) which indicated that the composition of food commodities are dependent on the variety, location, season, method of processing and storage. Onwueme (1982) reported that the cormels of cocoyams show distinctive variation within the tubers, that is, from the distal attachment to the growing apex (geotropic). Despite these observations, little attention has been given to cocoyams.

One major limiting factor in the utilization of cocoyam is the presence of oxalates which impart acrid taste or cause irritation when foods prepared from them are eaten. Ingestion of foods containing oxalates has also been reported to cause caustic effects, irritation to the intestinal tract and absorptive poisoning (Sakai, 1978). Oxalates are also known to interfere with the bio-availability of calcium (Fink, 1991).

Several attempts have been made to reduce oxalate content in cocoyams. Although it has been reported that the traditional methods for drying cocoyams reduce oxalate (Purseglove, 1986), they do not completely eliminate it as itching is still reported by many consumers (Onayemi & Nwigwe, 1987). Osisiogu et al. (1974) observed that the irritant principle of cocoyams could be destroyed by volatilization and not by heating. Available reports about the effects of processing on oxalates appear conflicting and inconclusive.

This research was therefore aimed at evaluating the chemical composition of the *X. sagittifolium* and *C. esculenta* cormels as well as determining the effect of processing on their oxalate levels.

2. Materials and methods

2.1. Materials

2.1.1. Preparation of fresh cocoyam samples

Fresh samples of two varieties of *X. sagittifolium* (red and white varieties) cormels and one variety of *C. esculenta* var *esculenta* corms were, respectively, harvested from local farms at Akyem-Begoro and Anyinam in the Eastern Region of Ghana and transported to the laboratory for the study. Within 2 days of harvest, the samples were peeled and the edible portion cut into three sections, representing the distal, middle and apical parts of the cormels. A sample ratio, based on weight, was used to divide each cormel into three parts, i.e. a ratio of 2:3:1 for the distal, middle and apical sections. The above ratio was arrived at by examining the colour variation across the cormel. Portions of the raw sample of the sections were blended and used for the analysis. The other portions were dried at 50 °C for 24 h using the air oven method. The dried samples were subsequently milled into flour in a hammer mill (Christy and Norris Co., USA) to pass through a 4 mm sieve. The flour products were kept in sealed polyethylene containers for analysis.

2.1.2. Experimental design

A 3×3 factorial experimental design was used and the principal factors were:

1. Type of cultivar: *X. sagittifolium* (white-flesh), *X. sagittifolium* (red-flesh) and *C. esculenta*.
2. Cormel section: Distal, middle and apical.

Samples were then analyzed for chemical composition (moisture, protein, fat, ash, starch and fibre) and minerals (calcium, magnesium, zinc, iron, sodium, potassium and phosphorus).

2.1.3. Preparation of samples to study the effects of dehydration methods on the oxalate decomposition

Fresh samples of the varieties were peeled and the edible portions prepared for air-oven, solar- and drum-drying. For the air-oven and solar-dried samples, the edible portions were sliced into sizes (20, 40 and 60 g) with surface area of the sizes in the range of 1.96×10^3 m^2 to 9.50×10^3 m^2. The dried products were milled into flour and used for analysis. Preparations of samples for drum drying involved two forms, wet- and dry-milled processes. In the wet-milled process, the edible portion was blended in a Waring blender and the mash obtained adjusted with water to obtain a 75% (w/w) paste before drum-drying. In the dry-milled process, flours obtained from the air-oven-dried samples were mixed with water to form 75% (w/w) paste and the resulting pastes drum-dried. The flaky drum-dried products were further dried at 40 °C for 30 min and milled into flour. The pre-gelled flour was packaged in polyethylene containers and used for analysis.

2.1.4. Experimental design

X. sagittifolium and *C. esculenta* species were processed using three methods of dehydration, namely, air-oven, solar- and drum-drying. The tubers were washed, peeled and processed as follows:

2.1.4.1. Air-oven drying. A 2×3×3 factorial experimental design was developed for the samples and replicated using a cabinet dryer (Gallenkamp, UK). The factors and levels used are:

1. Drying time: 12 and 24 h
2. Size of cormel: 20, 40 and 60 g
3. Type of cultivar: *X. sagittifolium* (white-flesh), *X. sagittifolium* (red-flesh) and *C. esculenta*

2.1.4.2. Solar drying. A 2×3×3 factorial design was used and duplicated. The factors and their levels were as follows:

1. Dehydration time: 2 and 3 days
2. Size of cormel: 20, 40 and 60 g
3. Type of cultivar: *X. sagittifolium* (white-flesh), *X. sagittifolium* (red-flesh) and *C. esculenla*

2.1.4.3. Drum-drying. Double roller drum dryer using steam at 80 psi, clearance angle of 0.012 mm and rotating at the speed of 25–50 rpm was used on 2 kg samples. The products obtained were milled and used for the determination.

2.2. Chemical analysis

2.2.1. Chemical composition

The samples were analysed, in triplicate, for moisture, ash, crude fat, crude protein and fibre contents using Association of Official Analytical Chemists' Approved methods 925.10, 920.87, 920.85, 923.03 and 963.09 (AOAC, 1990). Carbohydrate was estimated by difference.

2.2.2. Mineral analysis

Standard AOAC (1990) method was used to digest 2.0 g flour samples. One hundred millilitre (100 ml) standard solutions were prepared from the digest and used for the mineral analysis. Minerals (calcium, magnesium, zinc, iron, sodium, potassium and phosphorus) were determined using standard analytical methods.

2.2.2.1. Estimation of Ca, Mg, Zn and Fe. Part of the standard solution of the digest was used to determine Ca, Mg, Zn and Fe using a Perkin Elmer Atomic Absorption Spectrophotometer (Carl Zeiss, German Democratic Republic) Model AAS-3, with air acetylene flame at 422, 286, 720 and 722 nm, respectively.

2.2.2.2. Estimation of Na and K. Two (2) millilitres of the digest were used to estimate sodium and potassium using the flame photometric method. Five (5) millilitres of the standard solution were placed in a beaker and the inlet tube of the photometer placed in the solution. The solution was absorbed, atomised by the flame photometer (Model PEP7, Jenway, UK) with butane gas and their quantities estimated by a detector.

2.2.2.3. Phosphorus determination. The method described by Murphy and Riley (1962), as modified by Watanabe and Olsen (1985), was used in determining phosphorus. Aliquots of digest were added to 1.25% p-nitrophenol in a 50 ml volumetric flask and the solution neutralised with 5N HC1. The samples were diluted and reduced with ascorbic acid. Absorbance was measured on the UV/VIS/NIR Spectrophotometer (Model PU8620 Phillips, Netherlands) with a 1 cm cuvette at 712 nm.

2.3. Oxalate determination of cocoyam samples

The AOAC (1990) analytical method was used to determine the oxalate content of the processed samples. The oxalate content was determined by titrating an aliquot of extracts from the homogenized samples with 0.01 M $KMnO_4$ solution. Prior to determination, the heavy metals in the acidified extracts were precipitated with 5 ml tungstophosphonc acid reagent and centrifuged at 1700 rpm for 15 min.

2.4. Statistical analyses

The data obtained from the studies were statistically analyzed using Statgraphics (Graphics Software System, STCC, Inc. USA). Comparisons between sample treatments and the indices were done using analysis of variance (ANOVA) with a probability $P \leqslant 0.05$.

3. Results and discussion

3.1. Chemical analysis

3.1.1. Proximate composition

The proximate compositions of the cormels of *X. sagittifolium* and *C. esculenta* species investigated are presented in Table 1. Mean values obtained for *Xanthosoma* and *Colocasia* species in g/100 g dry weight basis were: crude protein 1.56–2.98, starch 12.2–36.6 and crude fibre 1.11–3.00. The moisture content of the fresh weight ranged from 57.63 to 77.4% in *X. sagittifolium* (red-flesh), 54.46 to 7 1.97% in *X. sagittifolium* (white-flesh) and 59.30 to 72.06% in the *C. esculenta* var *esculenta*. For the sections (distal, middle and apical) of the varieties, high moisture was found at the apical section of the two *Xanthosoma* species and distal sections of the *Colocasia* species. Wide variations in moisture content were found at the different sections of all the varieties. A similar trend was found in the results obtained for fat, ash and crude fibre. The variations in the mean values of protein content of the sections of each variety were also distinct, being largest for the distal section, followed by the middle section and the apical section. All the sections had protein contents of less than 5% with the exception of the distal section of *X. sagittifolium* (red-flesh) variety which had a value of *5.5%*. However, the protein content of *C. esculenta* var *esculenta* was slightly higher than that of *Xanthosoma* species and showed a greater range of values. Similar observations had been reported for the chemical

Table 1
ximate composition of sections of three cocoyam varieties (g/100 g, dry sample)

Variety	Section	Moisture	Protein	Starch	Fat	Ash	Fibre
Xanthosoma sagittifolium (red-flesh)	Distal	68.5	4.09	22.7	0.60	2.98	1.16
	Middle	57.6	3.96	33.6	0.43	2.68	1.70
	Apical	77.4*	3.94	12.2	0.74	3.93*	1.77
Xanthosoma sagittifolium (white-flesh)	Distal	63.5	5.50	27.0	0.58	2.38	1.11
	Middle	54.5	4.92	36.6	0.28	1.98	1.72
	Apical	72.0*	4.94	18.0	0.43	3.29*	1.35
Colocasia esculenta	Distal	72.1*	4.69	17.8	0.97	1.88	2.80
	Middle	59.6	4.30	31.0	0.75	1.66	2.74
	Apical	59.3	2.98	32.5	0.64	1.56	3.00

* Significant at $P \leqslant 0.05$.

composition of other cocoyam varieties (Agbor-Egbe & Richard, 1990). The crude protein contents obtained in this study were comparable with the mean values of 5.60 g/100 g reported for sweet potato (Bradbury, 1988), considerably higher than mean values of 1.07 g/100 g reported for cassava (Gomez & Valdivieso, 1983) and lower than 9.02–9.96 g/100 g reported for yams (Afoakwa & Sefa-Dedeh, 2001; Agbor-Egbe & Treche, 1983). The yield of starch at the sections of the varieties varied from 12.23 to 36.64%, the highest being obtained at the middle section of the *Xanthosoma* species and the apical section of the *Colocasia* species. Considerable variations in the distribution of starch within the corms and cormels were observed.

In general, wide variations were observed in the proximate composition values obtained between sections as well as between varieties. Such variations have been ascribed to differences in the genetic background as well as climate, season, and the agronomic factors (Onwueme, 1982). The high levels of starch and fibre in cocoyams have been utilized in the preparation of various food products. Preparations of speciality foods for the prevention of allergic diseases (based on carbohydrates in cocoyams) have been reported (Kay, 1973; Rehm & Espig, 1991). It has also been reported that fibre from *Colocasia* species, incorporated into ice-cream sherbet, effectively activated the action of intestinal bifidobacteria for good digestion and vitamin synthesis (Sotozono, 1989). However, the low levels of protein in cocoyams means that food products from such commodities should be improved by combining them with other high-protein sources for good nutritive value.

Analysis of variance on the data showed that, levels of moisture, protein, fat, ash, starch and crude fibre were significantly different ($P \leqslant 0.05$) between sections of each variety and between varieties. Multiple range analysis ($P \leqslant 0.05$) showed that most notable sources of variation were between the *Xanthosoma* species and the *Colocasia* species.

3.1.2. Mineral analysis

Levels of minerals in the varieties studied are given in Table 2. For the *Xanthosoma* species, higher levels of minerals were obtained at the apical sections than at the distal and middle sections. With respect to the distal and middle sections, the concentrations of minerals did not show any significant variation. The *X. sagittifolium* (red-flesh) variety had comparatively higher concentrations of minerals at the three sections than the *X. sagittifolium*

Table 2
Mineral composition of two *Xanthosoma* species and *Colocasia esculenta* var *esculenta* species (mg/100 g, dmb)

Variety	Section	Ca	Fe	Mg	Zn	K	Na	P
X. sagittifolium (red-flesh)	Distal	7.70	3.73	69.8	51.1*	1451*	21.6	48.9
	Middle	8.53	2.62	64.5	25.8	769	21.1	47.7
	Apical	24.3*	2.81	85.0	20.9	1525*	23.7	63.1
X. sagittifolium (white-flesh)	Distal	7.91	3.34	64.2	46.3	985	28.9	52.5
	Middle	9.55	3.36	58.9	28.3	963	30.3	43.0
	Apical	19.0*	3.89	67.6	51.1	1388*	49.1	41.6
C. esculenta	Distal	7.09	3.75	64.8	28.4	1004	34.6	60.2
	Middle	4.68	2.68	48.7	17.0	763	29.8	54.7
	Apical	5.21	3.10	57.2	17.7	835	28.5	61.5

* Significant at $P \leqslant 0.05$.

(white-flesh) variety. The results obtained for the *Xanthosoma* species in this investigation agree with the observations of Lauzon and Kawabata (1988). With respect to the *C. esculenta* var *esculenta*, high mineral values were obtained at the distal section, indicating some differences in mineral distribution between the *Colocasia* and the *Xanthosoma* species. In general, considerable variation in mineral distribution was noted between sections of the varieties. Analysis of variance showed that levels of minerals in the samples analysed were significantly ($P \leqslant 0.05$) different between sections of each variety with the exception of values obtained for iron. The variation of mineral distribution among the three varieties was also significant ($P \leqslant 0.05$). Potassium was the most abundant mineral (763–1451.30 μg/100 g) found with appreciable amounts noted for zinc (17.0–51.1 μg/100 g), magnesium (48.7–85.0 μg/100 g) and phosphorus (41.6–63.1 μg/100 g). Iron concentration was the lowest of minerals observed in the varieties studied. The mineral levels and trends obtained for *Colocasia* and *Xanthosorna* species are similar to those recorded for mineral-rich seeds such as *Tetracarpidium conophorum* (Edem, Ekwere, & Eka, 1994) but higher than those reported for other root crops (Ankrah, 1974). Although little is known regarding the environmental and physiological processes that regulate the uptake of minerals in plants, considerable variations in mineral concentration have generally been observed. The influence of species, concentration of minerals in the soil and age of the plant have been reported (Fennema, 1988).

3.2. Calcium oxalate content

3.2.1. Evaluation of fresh samples

The presence of oxalates in foods, especially cocoyams, has been associated with acridity and toxicity when such commodities are consumed. The levels of oxalates in the locally grown cocoyams are important in the assessment of their nutritional status. The data comparing oxalate contents of sections of fresh cocoyam samples investigated are presented in Table 3. Mean values obtained for the sections in each variety were in the range of 254–381 μg/100 g for *X. sagittifolium* (red-flesh), 302–323 μg/100 g for *X. sagittifoiium* (white-flesh) and 328–460 μg/100 g for *C. esculenta* var *esculenta*. For the *X. sagittifolium* (red-flesh) variety, highest oxalate content was found at the apical section, followed by the distal and middle sections. In comparing the values of oxalates obtained from the intra-sections to the whole section of the edible portions, as is normally reported in the literature, a variation was observed, implying that oxalate values quoted may not represent the optimal levels in the cormels. Similar observations were made for the *X. sagittifolium* (white-flesh) though values obtained in this case were lower.

Table 3
Oxalate content of fresh cocoyam samples (μg/100 g)

Variety	Section	Oxalate content
Xanthosoma sagittifolium (red-flesh)	Whole	309
	Distal	295
	Middle	253
	Apical	380*
Xanthosoma sagittifolium (white-flesh)	Whole	302
	Distal	322
	Middle	305
	Apical	269
Colocasia esculenta	Whole	459*
	Distal	488*
	Middle	328
	Apical	402*

* Significant at $P \leqslant 0.05$.

For the sections of *X. sagittifolium* (white-flesh) variety, the highest oxalate level was obtained at the distal sections. Considerably high levels of oxalate were detected at the distal section of the *C. esculenta* var esculenta. Oxalate values for the Colocasia species were found to be much lower than the values in the ranges of 430–1560 μg/100 g obtained by Huang and Tanadjadja (1992) using anion exchange high performance liquid chromatography. In general, the oxalate values obtained for the samples in this study were lower than values of 443–842 μg/100 g reported by Onayemi and Nwigwe (1987). Levels of oxalate obtained in the fresh samples of the three samples investigated were also found to be considerably higher than the reported threshold levels of 71 mg/100 g. ANOVA conducted on the oxalate content of fresh cocoyam varieties, showed that the values obtained were significantly different ($P \leqslant 0.05$) from each other at the sections as well as among the varieties. The presence of oxalates in cocoyams is known as to cause acridity and absorptive poisoning, and it binds calcium, thereby inhibiting its absorption.

The studies conducted by Onayemi and Nwigwe (1987) and Huang and Tanadjadja (1992) both indicated low consumption of *Colocasia* species in the areas of study. However, in Ghana, *C. esculenla* species are consumed as much as *Xanthosoma* species. The appreciably low oxalate levels found in *Colocasia* species grown in Ghana may account for its wide consumption, especially in the coastal and forest regions.

3.2.2. Effect of processing method on calcium oxalate content

3.2.2.1. Effect of air-oven and solar drying. Fig. 1 shows the effect of variety and size of cocoyam slices on oxalate levels after using the air-oven method for dehydration at different drying times (12 and 24 h). For the 12-h dried samples, the *X. sagittifolium* (white-flesh) and the

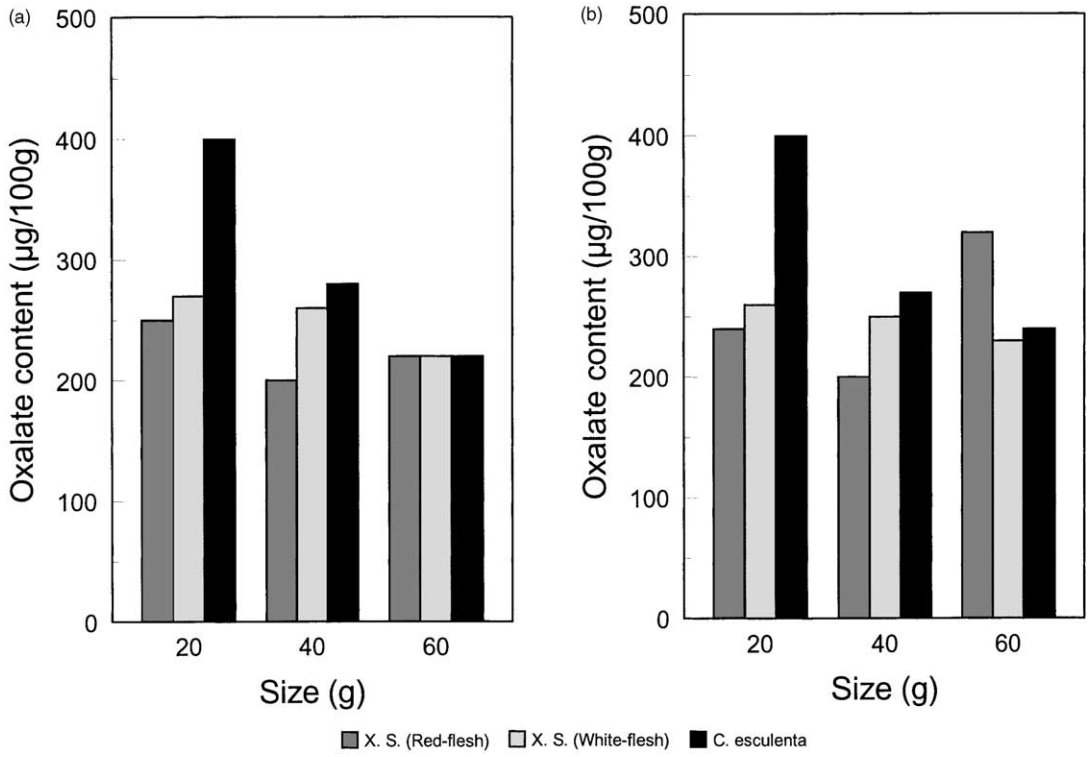

Fig. 1. Effect of variety and size on oxalate levels derived from 12-h (A) and 24-h (B) oven-dried chips.

C. esculenta var *esculenta* species showed a decreasing effect on oxalate content as sample size was increased. The effect was more pronounced in the *Colocasia* species than in the *Xanthosoma* species. Ultra violet rays from the sun's radiation, reported to influence oxalate decomposition, may account for the observed trends, since there was a gradual increase in surface area from the 20 g sample to the 60 g sample. For the *X. sagittifolium* (red-flesh) variety, the trend differed. Oxalate content decreased in the 40 g sample and then increased slightly in the 60 g samples. The trend of oxalate levels, observed for the 24 h dried samples, was not different from that obtained in the 12 h dried samples, except that there was a steady increase in the oxalate values in the *X. sagittifolium* (red-flesh) variety. The variation may be due to inherent genetic factors. Furthermore, since the drying conditions of temperature, relative humidity and air velocity were not constant during the drying periods, the variations observed could be due to such influences.

The percentage retentions of oxalate contents for the samples are shown in Table 4. The retention values obtained for the 1 and 24 h oven-dried samples ranged from 63.5 to 99.5% for *Xanthosoma* spp. (red-flesh) and 49.5 to 86.0% for the *Colocasia* species. This may be due to the effect provided by the large cross-sectional area of the corms of the *Colocasia* species which had greater exposure to heat penetration. The analyses of

Table 4
Percentage retention of oxalate composition in the processed cocoyam samples

Variety	Size (g)	Oven-dried		Solar-dried	
		12-h	24-h	2-day	3-day
Xanthosoma sagittifolium (red-flesh)	20	78.0	77.5	83.5	53.5
	40	63.5	66.5	60.0	48.5
	60	71.5	99.5	34.5	40.0
Xanthosoma sagittifolium (white-flesh)	20	89.0	86.5	68.5	88.5
	40	83.5	82.0	36.5	63.5
	60	74.5	73.0	31.5	54.5
Colocasia esculenta	20	86.0	86.0	62.5	58.0
	40	63.0	58.0	35.5	41.5
	60	49.5	49.5	37.0	38.5

Table 5
ANOVA Summary showing significant *F*-values of oxalate content of dehydrated products

Source of variation	Air oven-dried	Solar-dried
Variety	96.45	42.91
Drying time	1.93.00	10.16
Size	95.17	216.61
Variety×Drying time	9.98	55.79
Variety×Size	70.33	6.52
Drying time×Size	6.93	13.63

Significant at $P \leqslant 0.05$

variance conducted on the results of the oven-dried samples in Table 5 indicate that variety and size had significant effects ($P \leqslant 0.05$) on oxalate levels. However, drying time did not show any significant effect ($P \leqslant 0.05$).

Fig. 2 shows the oxalate values obtained when sizes of varieties were solar-dried for 2 days and 3 days. An average of 8 h exposure to solar radiation per day was used. Moisture content of the solar-dried products ranged from 6 to 22%. This is due to the wide variation of relative humidity and solar radiation observed during drying. For the two *Xanthosoma* species, the drying times showed decreasing effect on oxalate levels as cormel size was increased. The decreasing effect was more pronounced in the 2 day solar-dried samples than in the 3 day solar-dried samples. Oxalate retention was higher in the *X. sagittifolium* (red-flesh) variety than in the *X. sagittifolium* (white-flesh) variety (Table 4). This may be due to higher oxalate levels in fresh samples as compared to the *X. sagittifolium* (white-flesh) species. The pattern of oxalate levels obtained for the *C. esculenta* var *esculenta* was slightly different from that of the *Xanthosoma* species. Oxalate values for the 2-day solar-dried samples showed slight increases from the 40 g sample to the 60 g sample, whereas in the 3-day solar-dried sample, a decrease was observed. Lower oxalate retention values were recorded for the *Colocasia* species than for the *Xanthosoma* species. In general, the pattern of oxalate levels obtained for the solar-dried samples was similar to that of the oven-dried samples except that lower oxalate values were obtained in the solar-dried samples than in the oven-dried samples. This observation can be seen from the percentage retention values (Table 4). ANOVA revealed that variety, time and size all had significant ($P \leqslant 0.05$) effects on the oxalate levels of the solar-dried samples (Table 5).

3.2.2.2. Effect of drum drying. Cocoyam samples were given two forms of treatments (dry and wet milling) and were subsequently drum-dried. The oxalate levels measured and percentage retention values are presented in Table 6. Significant variations, but few consistent trends, were observed in the data. For the two treatments, lower oxalate values were observed for the dry-milled samples. This might be attributed to the effects of the drying and milling processes which could have contributed to oxalate degradation. The oxalate contents of the products did not show any wide variations. However,

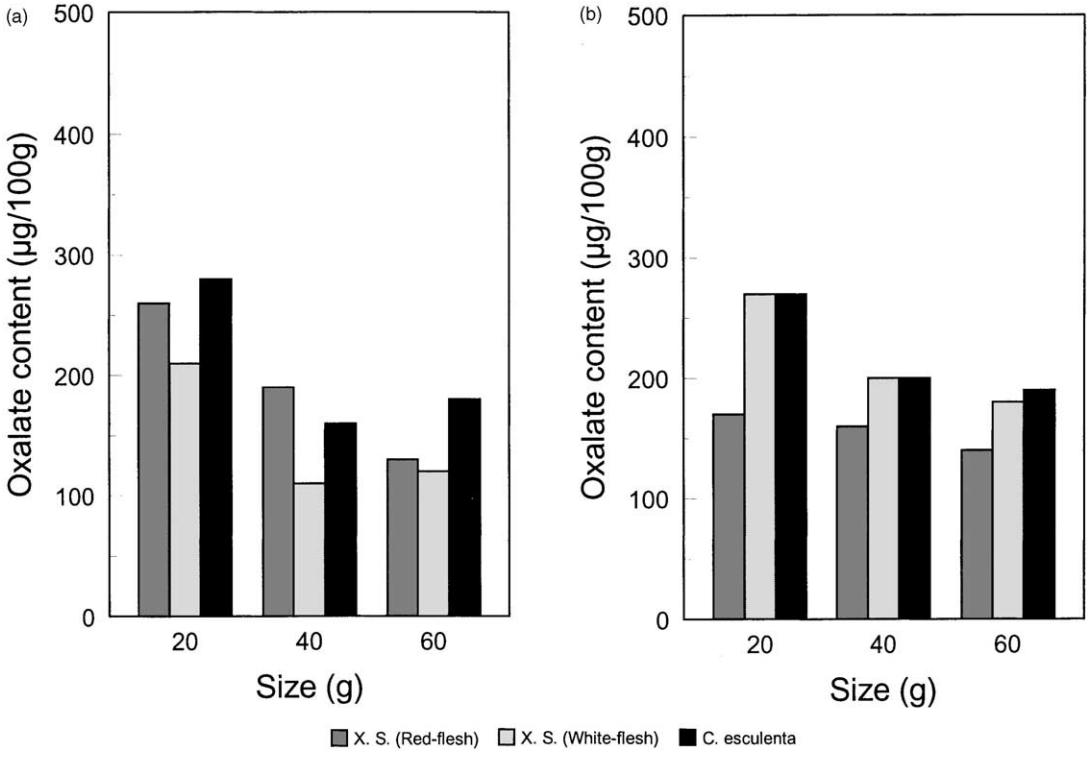

Fig. 2. Effect of variety and size on oxalate levels derived from 2-day (A) and 3-day (B) solar-dried chips.

Table 6
Composition (μg/100 g) and percentage retention of oxalates in drum-dried cocoyam products

Variety	Condition	Oxalate composition	Percentage retention
Xanthosoma sagittifolium (red-flesh)	Dry milled	144	46.5
	Wet milled	157	50.5
Xanthosoma sagittifolium (white-flesh)	Dry milled	99.9	32.5
	Wet milled	159	53.5
Colocasia esculenta	Dry milled	164	35.5
	Wetmilled	192	41.5

comparing the results of the drum-dried products to values obtained in the fresh samples showed significant changes in the rates of oxalate reduction. Drum-drying reduced oxalate levels by approximately 50% to average levels ranging from 99.9 to 192 μm/100 g. However, these values were higher in comparison to the results obtained by Onayeni and Nwigwe (1987) when samples of *Xanthosoma* and *Colocasia* species were sliced, soaked and boiled. Oxalate levels ranging from 9 to 26% were reported. High temperatures are known to cause the calcium oxalate-containing cells (raphides) to collapse, leading to the breakdown of oxalate structure. The mechanism of oxalate reduction by heat has not been fully elucidated. Generally, the rate of oxalate decomposition was higher in the *Colocasia* species than in the *Xanthosoma* species.

4. Conclusion

The chemical composition ofthe three varieties of cocoyam, *X. sagittifolium* (red-flesh and white-flesh) and *C. esculenta* var *esculenta* shows wide variations among the varieties and across their respective cormels. The *Xanthosoma* spp. (white-flesh variety) had the highest nutritive value. Similarly, the distal sections of the cocoyams species studied had comparatively more components than the middle and apical sections. The low levels of protein in cocoyams mean that food products from such commodities should be improved by consuming them with other high-protein sources for good nutritive value. Higher levels of minerals are located at the apical sections than at the distal and middle sections. With respect to the distal and middle sections, the concentrations of minerals did not show any significant variation. The oxalate levels of the varieties studied were higher than the threshold value of 71 μg/100 g for humans. Wide variation in oxalate contents exist between the *X. sagittifolium* and *C. esculenta* species with the *C. esculenta* having relatively higher oxalate levels. However, the oxalate levels reported for Nigerian cocoyams are much higher than those of the cocoyams from Ghana. This may account for the relatively higher consumption of cocoyams in Ghana than in Nigeria. The various processing methods used reduced the oxalate levels by approximately 50%. The greatest reduction was observed for the drum-dried products, which reduced the oxalate contents to safer levels. Processes that eliminate oxalates in cocoyams are critical for the development of cocoyam food products.

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