Nutrient composition and effect of processing on antinutritional factors and mineral bioavailability of cultivated *amochi* in Ethiopia

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Abstract

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Amochi (*Arisaema schimperianum* Schott) is an important off-season tuber crop in Southern Ethiopia. Uncooked *amochi* is irritating in contact with the skin. Proximate contents, antinutritional factors (oxalate and phytate) and effects of processing (cooking and fermentation) on antinutritional factors and mineral availability were determined for *amochi* cultivars using established methods of the AOAC. The ranges of proximate contents from five cultivars were: moisture 65.25–85.37%, fat 0.10–0.15%, protein 0.56–1.13%, crude fibre 0.59–0.70%, ash 0.88–1.03%, carbohydrate 12.60–33.16% and caloric value 52.70–133.56 kcal/100 g dry matter per wet tuber mass. The differences between cultivars were significant ($p < 0.05$), although the overall levels of fat and protein were low. The carbohydrate and caloric values indicated that *amochi* could be a valuable food crop if supplemented with animal or plant protein. For antinutrient determination, four cultivars were analysed as raw, cooked and cooked after five days' fermentation. *Amochi* tubers had high oxalate levels and low phytate levels. Cooking resulted in reduction of oxalate and phytate levels. Further significant reduction occurred when the tubers were cooked after fermentation. These reductions were coupled with an increase in the levels of Fe, Zn and Ca. Cultivars differed significantly in their levels of phytate but not of oxalate. High levels of oxalate might have been the cause of skin irritation. *Amochi* meal preparation should follow extended fermentation and cooking. Effects of different heat and fermentation processes, and environmental factors such as season, soil and water conditions on *amochi* oxalate levels should be determined.

Keywords: *Arisaema schimperianum,* cooking; fermentation; oxalate; phytate; proximate analysis

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Introduction

Root and tuber crops are dominant staple foods in Southern Ethiopia. *Arisaema schimperianum* Schott, locally '*amochi'* or '*kolto'* in S. Ethiopia, is an herbaceous plant grown for its edible tubers. Because of the frequent occurrence of drought in the region, much attention has been paid to high yielding drought-tolerant crops such as enset (*Ensete ventricosum*), and recently also to new tuber crops such as *amochi*.

Amochi grows in various habitats, along roadsides, farm edges, in forests and on agricultural lands. It was long considered as a weed. Whenever there is a food shortage, *amochi* is harvested from all such habitats and consumed as food. While the larger tubers are harvested, small offsets remain in the soil and serve as propagules in subsequent seasons (Gedebo *et al.*, 2007). *Amochi* currently is one of the most important root crops in some of the villages of Dita and Chencha, administrative sub-zones of S. Ethiopia. The plant grows during the off-season, January–June, and is harvested between June and September. In these months, *amochi* is a common component of the villagers' diet (Gedebo *et al.*, 2006).

Preparation of *amochi* comprises washing and crushing of tubers between millstones. Following crushing, it can be cooked as various local dishes, immediately or after a period of fermentation under anaerobic conditions, usually buried underground. *Amochi* is irritating in contact with the skin, making food preparation very difficult (Gedebo *et al.*, 2006). The irritation may be due to the presence of antinutritional factors in the edible portion. The term 'antinutritional factors' usually refers to natural products, such as oxalate and phytate, which reduce nutrient utilization, food intake or both (Sefa-Dedeh & Agyir-Sackey, 2004). A high content of calcium oxalate crystals has been implicated in the irritation caused by coco-yam (Sefa-Dedeh & Agyir-Sackey, 2004). Oxalate usually tends to precipitate calcium as calcium oxalate crystals, and makes it unavailable for use by the body (Oke, 1967). Phytate is a storage form of phosphorus, found in some plant seeds and in many roots and tubers (Dipak & Mukherjee, 1986). There are reports that phytic acid has the potential to bind Ca, Zn, Fe and other minerals, thereby reducing their availability in the body (Sefa-Dedeh & Agyir-Sackey, 2004; Davis & Olpin, 1979). In many crops it has been found that cooking and fermentation reduce the level of such anti-nutritional factors (Sefa-Dedeh & Agyir-Sackey, 2004; Oke, 1967).

One of the bases for food quality is the balance between the nutrient and antinutrient composition. Since *amochi* is not yet widely known as a food crop, except in S. Ethiopia during the past two decades (Gedebo *et al.*, 2007), information on its nutritional properties has not yet been included in the food composition table for use in Ethiopia (Gobezie *et al.*, 1997). To our knowledge, there are no reports on the nutrient composition of cultivated *amochi*. The purpose of the present study was therefore to determine: (1) proximate composition, (2) antinutritional factors, (3) the effect of processing on antinutritional factors and mineral bioavailability of *amochi* cultivars, and (4) the causes of irritation by *amochi*.

Materials and Methods

General sample preparation

Fresh tuberous roots of five *amochi* cultivars considered important by the farming community of Mesho (6°15.231'N lat., 37°34.401'E long.) and Dalbansa (6°11.348' N lat., 37°29.484' E long.) villages, owing to their yield ability and general adaptability (Gedebo et al., 2007) were harvested from the agricultural research station of Chencha. From each cultivar, 20 plants were randomly harvested. The cultivars were referred to by their local name; '*Maze*', '*Dashare*', '*Oge*', '*Kalazo*' and '*Bondare*'. After harvesting, the tubers were washed in tap-water to remove all soil, dried in air to remove external moisture, and weighed. The tubers were then placed in polyethylene bags and transported in an ice-box to the laboratory in Addis Ababa (Ethiopian Health and Nutrition Research Laboratory, EHNRL) within 24 h of harvesting. In the EHNRL laboratory, the samples were kept at –20 °C until analysed.

Proximate analysis

Before analysis, the samples were thawed for 5 h at room temperature and shredded in a food processor. The proximate composition of protein, crude fibre, crude fat, ash and moisture content of the edible portions of the five duplicate *amochi* samples was determined according to the methods of the Association of Official Analytical Chemists (AOAC, 1990). The moisture content was determined from 10-g samples of shredded material by drying to constant mass at 92 °C; the crude protein content was determined by the micro-Kjeldahl method (%protein = %N×6.25). The crude fat content was determined using diethyl ether in a Soxhlet extraction apparatus, and the crude fibre content by dilute acid and alkali hydrolysis. The carbohydrate content was estimated by difference. The energy value was calculated using Atwater factors (values for crude protein, fat and carbohydrates were multiplied by 4, 9 and 4, respectively, and the results summed).

Processing for antinutritional factor determination

For the determination of antinutritional factors, tubers of four cultivars *Maze*, *Dashare*, *Oge* and *Kalazo* were considered (material of *Bonde* was insufficient). The tubers were thawed at room temperature for 5 h. After diseased and non-edible parts had been removed, all samples were shredded in a food processor. The blend was then divided into three portions in preparation for three processing levels: 'unfermented and uncooked', 'unfermented and cooked', and 'fermented and cooked'.

Unfermented and uncooked: After storage at –20 °C for five days, the blends were thawed for 5 h at room temperature and analysed.

Unfermented and cooked: After storage at –20 °C for five days, the blends were thawed for 5 h at room temperature, cooked, then analysed.

Fermented and cooked: The blend was set to ferment for five days, cooked, then analysed.

Fermentation

Fermentation was carried out by imitating the traditional process used for *amochi* by the farming community of Mesho village, in the Chencha administrative sub-zone of S. Ethiopia. Freshly blended samples were kept in a sieve for 5 h, to allow leaching of free liquid from the blend. Traditionally, this is done in a porous bamboo container. The liquid was discarded and the semi-solid residue was placed in a bowl, wrapped in enset leaves. The bowl was covered with a cotton towel and closed with a lid. The traditional method is to make a hole in the ground, into which the blended *amochi* is placed, wrapped in enset leaves and made air-tight with layers of stone on top. The bowl containing the sample was kept at room temperature for five days. In traditional practice, the duration varies from two days to several months, depending on food availability (Gedebo *et al*., 2007).

Cooking

The cooking process also imitated the *amochi* cooking procedures of the farming community of Mesho village. Well-known traditional dishes of *amochi* are bread and porridge (Gedebo *et al*., 2007). In the present experiment, bread only was considered; therefore, 'cooking' refers to baking bread. The dough was laid flat between enset leaves on an *injera*-making (*injera*: Ethiopian flat bread made from *teff — Eragrostis tef*) electric hotplate, preheated for 15 min to bring it to working temperature. The dough was baked for 36 min; it was turned every 12 min during the first 24 min, and every 6 min during the last 12 min. After 36 min the bread was removed from the baking plate and cooled for 1 h on a flat plate made of straw, and kept in a refrigerator at 4 °C until analysed.

Determination of phytate and oxalate

For phytate determination, the method described by Haug and Lantzsch (Haug & Lantzsch, 1983) was applied to 0.5 g of dried, ground sample. The analysis was performed in duplicate. The oxalate in *amochi* tubers was separated into two fractions: 2 g of finely ground sample was extracted with 100 ml of boiling, deionised water for 30 min., filtered and adjusted to 200 ml. The residue of the hot water extract was further extracted with 150 ml boiling 1*N* HCl for 30 min., adjusted to 200 ml, and filtered. The oxalate concentration in the two fractions was determined as outlined in AOAC (1990) by $KMnO_4$ titration. The analysis was done in duplicate, and the results calculated and expressed on a dry-mass basis.

Determination of minerals

Duplicate aliquots (500 mg) from each of the dried, powdered samples were weighed, then wet-ashed by refluxing overnight at 150 °C with 15 ml of concentrated HNO_3 and 2.0 ml of 70% $HClO_4$. The samples were dried at 120 °C and the residue was dissolved in 10 ml of 4.0*N* HNO3 – 1% $HClO_4$. The mineral content of each sample was determined by means of an automated atomic absorption spectrophotometer (Pye Unicam Model SP 191, Cambridge), as outlined in AOAC (1990), for the specific minerals Fe, Zn and Ca. The mineral contents of the samples were quantified against standard solutions of known concentration, which were analysed simultaneously.

Statistical analysis

The sample analyses for all components were carried out in duplicate and the means and the standard deviations were calculated. One-way Analysis of Variance (ANOVA) was carried out by Tukey's method, to compare the mean values from proximate components of cultivars. For two-way ANOVA (cultivar *vs.* process), the General Linear Model (GLM) procedure with Tukey's method of multiple comparison was used. The analysis was done using MINITAB release 14.

Results and discussion

The proximate content ranges obtained for the five *amochi* cultivars were: moisture 65.25–85.37%, fat 0.10–0.15%, protein 0.56–1.13%, crude fibre 0.59–0.70%, ash 0.88–1.03%, carbohydrate 12.60–33.16% and caloric value 52.70–133.56 kcal/100g dry matter (Table 1).

In the light of the high moisture content found, *amochi* cultivars have substantial levels of carbohydrates, and caloric value showed significant differences ($P<0.05$) between them (Table 1). A daily energy requirement of 2500–3000 kcal has been reported for adults (Bingham, 1978). To obtain from any of these cultivars an energy value of 2750 kcal per day, which is within the range reported by Bingham (Bingham, 1978), an adult would need to consume 2059 g of cultivar *Maze*, 2217 g of cultivar *Dashare*, 3032 g of cultivar *Oge*, 2261 g of cultivar *Kalazo* and 5218 g of cultivar *Bondare*. An intake of up to 1000 g day^{-1} would provide 1335, 1240, 906, 1216 and 520 kcal from cultivars *Maze*, *Dashare*, *Oge*, *Kalazo* and *Bondare*, respectively. From these values, it is evident that, with the exception of *Bondare*, the cultivars would meet the FAO (1973) recommended range of 800–1200 kcal, if they were consumed at 1000 g day^{-1}.

There were significant differences ($p<0.05$) in protein and fat contents among the five *amochi* cultivars. However, the difference may not be of practical importance, as the general level of protein and fat in the cultivars is very low (Table 1). The low level of plant proteins found in all of the analysed cultivars does not justify the use of *amochi* as a sole protein source in diets. The low protein levels in *amochi* would require dietary supplementation with animal protein, or complementary proteins from cereals and legumes, especially in diets intended for children and pregnant women.

The level of phytate under the three cooking processes of the *amochi* cultivars is shown in Table 2 (overleaf).

Unfermented and uncooked (raw) samples had the highest levels of phytate (24.76 mg/100g). Cooking brought about a significant ($P<0.05$) decrease in phytic acid content, compared to the uncooked control (Table 2). Similarly, cooking has been reported to decrease phytic acid content in peas (Bishnoi *et al.*, 1994) and pearl millet (Sharma & Kapoor, 1996). Since phytic acid is known to be heat-resistant, the reduction of the phytic acid level

Table 1. *Proximate nutrient composition of cultivated amochi cultivars from Chencha administrative sub-zone of S. Ethiopia*

Vernacular name	Moisture (%)	Fat (%)	Protein (%)	Crude fibre (%)	Ash (%)	Carbohydrate (%)	Caloric value (Kcal/100 g)
Maze	65.25±0.03^{e}	0.12±0.00^{ab}	0.56±0.00^{e}	0.6±0.01^{b}	0.91±0.02^{c}	33.16±0.02^{a}	133.56±0.02^{a}
Dashare	67.59±0.06^{d}	0.14±0.00^{ab}	0.88±0.00^{c}	0.7±0.02^{a}	0.88±0.01^{c}	30.51±0.01^{b}	124.02±0.02^{b}
Oge	75.82±0.07^{b}	0.13±0.00^{ab}	1.13±0.01^{a}	0.64±0.00^{b}	1.03±0.01^{a}	21.89±0.01^{d}	90.69±0.00^{d}
Kalazo	68.11±0.02^{c}	0.15±0.01^{a}	0.81±0.02^{d}	0.65±0.00^{b}	1.02±0.00^{a}	29.91±0.02^{c}	121.63±0.02^{c}
Bondare	85.37±0.14^{a}	0.1±0.01^{bc}	0.94±0.01^{b}	0.59±0.00^{b}	0.99±0.01^{b}	12.6±0.01^{e}	52.7±0.07^{e}

Note: Each value in the table is the mean of two determinations ± SD. Caloric values were determined on a dry-mass basis. Means not followed by the same letters in the same column were significantly different ($P <0.05$).

Table 2. *The phytate content (mg/100 g dry basis) of cultivated amochi cultivars from Chencha administrative sub-zone of S. Ethiopia, under different cooking processes*

Cooking process	Amochi cultivar				Cooking process mean
	Maze	**Dashare**	**Oge**	**Kalazo**	
Unfermented, uncooked	17.81±0.01	19.70±0.01	29.51±0.02	32.01±0.01	**24.76[a]**
Unfermented, cooked	15.50±0.00	19.01±0.01	28.21±0.01	30.00±0.01	**23.18[b]**
Fermented , cooked	8.81±0.02	10.00±0.01	22.71±0.02	24.61±0.01	**16.53[c]**
Cultivar mean	**14.04[d]**	**16.24[c]**	**26.81[b]**	**28.87[a]**	

Note: Values in the body of the table are means of two determinations ± SD. Process means with the same letters were not significantly different (p >0.05). Cultivar means with the same letters were not significantly different (p >0.05).

in the cooked samples may not be due to destruction of the compound, but may rather be due to its ability to complex with protein and minerals (Bishnoi *et al*., 1994). The phytate reduction may, therefore, only be apparent. The further reduction of the phytic acid content after cooking was significant (P<0.05) in samples given five days' natural fermentation. Fermented and cooked samples had a 33% reduction of the phytic acid content. Such an effect of fermentation has been reported for food mixtures (Sharma & Kapoor, 1996). The reduction in phytic acid content may have partly been due to phytase activity, which is known to be affected by a wide range of microflora (Sharma & Kapoor, 1996) in the fermentation process.

The complexing of phytic acid with nutritionally essential minerals such as Ca, Fe and Zn, has been suggested to be responsible for its antinutritional activity (Davis & Olpin, 1979; Sindhu & Khetarpaul, 2003). In the present study, the reduction in the levels of phytic acid with cooking, and more evidently with cooking after fermentation, appeared to be coupled with the increase in the levels of Fe, Zn and Ca (Table 3, opposite). The increase in the levels of the minerals could be due to their release from complexes with phytic acid. However, the levels of phytate found in the edible portions of *amochi* are much lower than the phytate content of many nutritionally important food crops (Phillippy *et al*., 2004; Dintzis *et al*., 1992). The nutritional significance of phytate levels in *amochi* is, therefore, negligible.

The level of oxalate found in the *amochi* cultivars (23.42 g/100 g dry mass, Table 4) is much higher than that reported for most crop species. For example, Jiru and Urga (Jiru & Urga, 1995) reported the total oxalate content of some vegetables in Ethiopia: beetroot, cabbage, carrot, kale, lettuce, potato, sweet potato, spinach, and Swiss chard, where spinach had the highest value (9793.7 mg/100 g dry mass). Kansal and Pahwa (Kelsay & Pratter, 1983) also reported that spinach contained a very high amount of oxalate (11 g/ 100 g). *Amochi* appears to be the crop with the highest content of oxalate so far known.

The observed high levels of oxalate in *amochi* cultivars might have both nutritional and health significance. This is because oxalic acid usually forms a strong bond with various minerals, such as Na, K, Mg and Ca, resulting in oxalate salts (Jiru & Urga, 1995). Because of this, some vegetables, even if they are rich in Ca, are not so nutritionally, owing to high levels of oxalates. For example, the high levels of Ca in spinach were shown to be unavailable for absorption, owing to the

Table 3. *Mineral composition of cultivated amochi cultivars from Chencha administrative sub-zone of S. Ethiopia, under different cooking processes*

Mineral mg/100g	Cooking process	Amochi cultivar				Process mean
		Maze	Dashare	Oge	Kalazo	
Fe	Unfermented, uncooked	2.88±0.00	4.48±0.01	2.40±0.01	4.14±0.01	**3.48[b]**
	Unfermented, cooked	3.98±0.01	9.78±0.00	3.87±0.01	5.42±0.01	**5.76[a]**
	Fermented, cooked	4.97±1.41	9.96±0.26	5.40±2.14	5.68±0.35	**6.57[a]**
	Cultivar mean	**3.94[b]**	**8.07[a]**	**3.89[b]**	**5.08[b]**	
Zn	Unfermented, uncooked	2.13±0.01	2.55±0.01	3.04±0.01	1.47±0.01	**2.30[b]**
	Unfermented, cooked	2.53±0.01	3.13±0.01	3.13±0.00	3.87±0.01	**2.89[ab]**
	Fermented, cooked	2.88±0.01	2.87±0.01	5.67±0.01	2.08±0.00	**3.37[a]**
	Cultivar mean	**2.51[b]**	**2.83[b]**	**4.19[a]**	**1.86[b]**	
Ca	Unfermented, uncooked	43.04±0.01	72.32±0.01	46.38±0.02	42.77±0.01	**51.12[b]**
	Unfermented, cooked	59.75±0.03	81.27±0.02	61.95±0.01	59.07±0.01	**65.51[a]**
	Fermented, cooked	57.72±0.01	90.46±0.01	74.11±0.02	58.63±0.01	**70.23[a]**
	Cultivar mean	**53.50[c]**	**81.35[a]**	**60.81[b]**	**53.49[c]**	

Note: Values in the body of the table are means of two determinations ± SD. For each mineral, process means with the same letters were not significantly different (p >0.05). For each mineral, cultivar means with the same letters were not significantly different (p >0.05).

Table 4. *The oxalate content (g/100 g dry basis) of cultivated amochi cultivars from Chencha administrative sub-zone of S. Ethiopia, under different cooking processes*

Cooking process	Amochi cultivar				Cooking process mean
	Maze	Dashare	Oge	Kalazo	
Unfermented, uncooked	24.27±0.00	23.09±0.00	23.98±0.00	22.35±0.00	**23.42[a]**
Unfermented, cooked	15.12.±0.70	13.17±0.71	11.49±0.71	13.02±0.71	**13.20[b]**
Fermented, cooked	4.56.±0.00	7.20±0.00	5.96±0.00	10.07±0.00	**6.95[c]**
Cultivar mean	**14.65[a]**	**14.48[a]**	**13.81[a]**	**15.15[a]**	

Note: Each value in the table is the mean of two determinations ± SD. Process means with the same letters were not significantly different (p >0.05). Similarly, cultivar means with the same letters were not significantly different (p >0.05).

formation of calcium oxalate (Jiru & Urga, 1995; Weaver *et al*., 1987). The presence of spinach in a meal could reduce the availability of Ca even from other foodstuffs consumed during the same meal (Kelsay & Pratter, 1983).

Calcium oxalate is particularly water-insoluble and has a tendency to precipitate (or solidify) in the kidneys or in the urinary tract, to form calcium oxalate crystals. Coe et al. (1992) reported that 80% of all kidney stones were composed of calcium oxalate, alone or surrounding a calcium phosphate core. Thus, attempts to prevent calcium stones have focused on reducing calcium and oxalate urinary concentrations, by reducing the rate of urinary excretion of both calcium and oxalate, as well as by increasing urine volume (Coe et al., 1992).

Cooking resulted in a significant reduction (P<0.05) in oxalate content (Table 4). Such reduction of oxalate through cooking has also been reported for African yam bean (Onyeike & Omubo-Dede, 2002) and cocoyam (Akban & Umoh, 2004; Fasset, 1973; Vilyakon & Standal, 1989). Cooking following five days' natural fermentation resulted in a more pronounced reduction of oxalate in *amochi*. If such a significant reduction is obtained after five days' fermentation, we hope that extended fermentation would do more.

The *amochi* cultivars did not differ significantly in their oxalate content. However, the amount of oxalate in crop plants depends not only on the plant cultivars, but also on the season, soil nutrients and local soil-water conditions where they grow (Singh & Saxena, 1973). Since *amochi*-growing farmers usually have an extended harvesting time, from June to September, future studies should consider the influence of these environmental factors.

Amochi is irritating in contact with the skin, which makes food preparation very troublesome (Gedebo *et al*., 2006). Since it has been shown that the presence of oxalate in crop plants produces irritation (Safa-Dedeh & Agyir-Sackey, 2004; Osisiogu *et al*., 1974), we suggest that the observed high levels of oxalate in *amochi* (Table 4) could be the likely cause of the irritation. In tropical root crops, calcium oxalate is present as fine needle-like crystals. The presence of these crystals has been considered as either a source of or a contributor to the acridity, which initiates irritation and swelling of mouth and throat (Holloway *et al*., 1989). As cooking following natural fermentation for only five days resulted in such a significant reduction in the levels of oxalate, we suggest that *amochi* meal preparation should follow extended fermentation. Future studies in this regard should consider determining the optimum duration of fermentation.

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