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Full Length Research Paper

Effects of processing methods on nutrient retention and contribution of white yam (*Dioscorea rotundata*) products to nutritional intake of Nigerians

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Consumption of indigenous foods is being encouraged globally as a means of meeting dietary needs of people. Yam products constitute staple source of energy to many Nigerians but little is documented on their nutrient composition. This study was carried out to determine the effects of processing methods on nutrient retention and possible contribution of some diets prepared from yam to nutrient intake of consumers. Fresh yam tubers were purchased from Sango market in Ibadan, peeled and cut into small pieces, then divided to eight portions. One portion was treated as raw sample while others were processed into roasted, fried, boiled, pounded yam (two samples), *amala* and porridge. All samples were analysed for proximate, energy and mineral composition using standard methods of AOAC and atomic absorption spectrophotometric methods. Raw yam was very low in crude protein (2.3 g), lipid (0.8 g), and fibre (1.4 g) moderate in ash (3.4 g), iron (4.1 mg) and zinc (5.6 mg), high in carbohydrates (33.3 g), energy (369.6 kcal), sodium (580 mg) and potassium (470 mg) /100 g edible portion. Roasting and frying brought significant improvement on crude protein, lipid and energy content of the products ($p<0.05$). Boiling yam caused significant reduction in all nutrient content except fibre, while boiling and pounding yam significantly improved its crude lipid, ash and energy content ($p<0.05$). Frying and using water for boiling yam in pounded yam preparation brought significant retention of nutrients in yam. Processing yam to *amala* and porridge resulted in significant improvement in nutrient content of the diets. Diets from yam can serve as good source of energy and minerals, and their 100 g portion can contribute between 12.4 to 20.9% gross energy, 11.0 to 46.0% iron and 17.3 to 48.7% zinc to recommended dietary allowances (RDAs) of consumers.

Key words: White yam, processing methods, nutrient retention, nutrient intake, diets.

INTRODUCTION

Yams are plants belonging to the Dioscorea genus that produce edible starchy storage tubers which are staple foods with cultural, economic and nutritional importance in the tropics (Akissoe et al., 2003), and are the third most important tropical root crop after cassava and sweet potato (Fu et al., 2005). Many different forms and cultivars of the edible yam species are available in different areas and it is likely that these differ in composition and nutritional values (Bhandari et al., 2003). *Dioscorea* spp. also has medicinal properties as their tubers contain diosgenin, a biochemical precursor in the synthetic production of progesterone and other corticosteroids (Albrecht and McCarthy, 2006).

Dioscorea rotundata Poir (white yam) is a species of yam native to Africa which produces edible tubers and has economic importance (Omonigho and Ikenebomeh, 2000). It is one of the most important cultivated yams popular and most consumed in Cameroon (Lape and Treche, 1994). It has a long shelf-life which does not affect its cooking and organoleptic qualities and can be available all year round.

The most common cooking methods of white yam in the Western and Central Africa are boiling, frying and roasting. Boiled yam is usually consumed with palm oil,

Figure 1. White yam (*Dioscorea rotundata*) tuber.

pepper sauce, or any preferred sauce. Boiled yam can be mashed with palm oil into *eto* (Among the Akan of Ghana), porridge (in Nigeria) served with stew; or pounded with a traditional mortar and pestle to create a thick starchy paste known as pounded yam, eaten with traditional sauces such as egusi and palmnut soup. Another method of consumption is to sun-dry perboiled yam pieces which is then milled into a light-brownish powder when dry (*elubo*) in Nigeria. The light-brown powder can be prepared with boiling water to create a thick brown starchy paste known as *amala* which is consumed with local soups and sauces.

Okaka and Anayekwu (1990) evaluated the production and quality of dry yam snack and found that frying temperature affect the colour of the yam chips, while Bonire et al. (1990) reported only the sodium and potassium content of two cultivars of white yam. The Food Basket Foundation International (FBFI) in one of its publication series compiled the nutrient composition of commonly eaten foods in Nigeria in their raw, processed and prepared forms, and provided information on nutrient and energy content of water yam (*Dioscorea alata*) (FBF Publication Series, 1995), but no information was available on white yam, which is most commonly eaten in Nigeria.

In spite of the importance of white yam and its products as a staple food in Nigeria there is relatively little information on the nutrient composition of its various prepared products. This study was therefore carried out to determine the nutrient composition, effects of processing methods on nutrient retention and possible contribution of white yam (*D. rotundata*) (Figure 1) products to nutrient intake of consumers.

MATERIALS AND METHODS

Sample procurement and preparation

D. rotundata tubers were purchases from Sango market in Ibadan in the month of march, during the dry season. Some of the tubers were peeled and cut into small round pieces, thoroughly mixed as together and divided into seven portions. One portion was analysed raw yam sample (Sample 1). Unpeeled whole yam tubers were roasted with coal fire on iron wire mesh, and the burnt skin scraped with knife to remove the black burnt portion with the skin, and labeled as Sample 2. The other six portions were washed with distilled water and treated as follows:

One portion of the peeled, washed yam slices was further sliced into smaller pieces of about 10 cm diameter, washed with distilled water and drained. Salt (sodium chloride) was added to taste with thorough mixing of the slices, and then fried with vegetable oil, adding little water at intervals to allow the yam to be done and to reduce drying of frying oil (Okaka and Anayekwu, 1990). The fried yam was labeled as Sample 3. Three portions of washed yam slices were pooled together and boiled with distilled water at 100℃ for 30 min and labeled as follows: the first portion served as boiled yam and labeled Sample 4. Another portion was pounded with mortar and pestle with the boiling water and labeled as Sample 5. The last portion was pounded with distilled water and labeled as Sample 6. The seventh portion was perboiled at 60℃ for 10 min, left in the warm water for 18 h, drained and sundried for 4 days. The dried perboiled yam was then grinded to flour, prepared into a thick paste (*amala*) (Ihekoronye and Ngoddy, 1985) and then labeled as Sample 7. The last portion was boiled with palm oil and salt to taste, mashed when soft to yield porridge, and labeled as Sample 8. All prepared samples were analysed for proximate and mineral composition.

Proximate nutrient composition

The proximate nutrient composition of the eight samples was determined using the standard methods of analysis of Association of Official Analytical Chemists (AOAC, 1995). Moisture content of the samples was determined by air oven (Gallenkamp) method at 105℃. The crude protein of the samples was determined using micro-Kjeldahl method. Crude lipid was determined by Soxhlet extraction method using petroleum ether as extracting solvent, while the ash content was determined using a muffle furnace set at 550℃ for 4 h. Crude fibre was determined using the method of Saura-Calixto et al. (1983). The carbohydrate content was obtained by difference. Gross energy content of the samples was determined using Gallenkamp ballistic bomb calorimeter. All determinations were carried out in triplicates.

Potassium and sodium content were determined by digesting the ash of the samples with perchloric acid and nitric acid, and then taking the readings on Jenway digital flame photometer/spectronic 20 (Bonire et al., 1990). Phosphorus was determined by vanado-molybdate colorimetric method (Ologhobo and Fetuga, 1983). Calcium, magnesium, iron and zinc content were determined spectrophotometrically by using Buck 200 atomic absorption

Table 1. Proximate composition of raw and processed yam products (g/100 g).

Sample	1	2	3	4	5	6	7	8
Moisture	58.8	52.0	33.9	62.3	72.0	71.1	23.6	33.4
Crude protein	2.3	3.4	3.0	1.8	1.5	1.2	6.7	9.7
Crude lipid	0.8	2.0	5.3	0.9	1.3	1.0	3.2	12.7
Crude fibre	1.4	1.2	1.2	1.3	1.6	1.6	2.5	3.7
Ash	3.4	3.0	2.8	2.8	3.9	2.7	3.4	6.6
Carbohydrates	33.3	38.4	53.8	30.6	20.0	22.4	60.6	33.9
Gross energy	369.6	370.4	397.6	360.2	398.3	376.2	284.6	479.8

Raw yam = Sample 1; Roasted yam = Sample 2; Fried yam = Sample 3; Boiled yam = Sample 4; Pounded yam with hot water = Sample 5; Pounded yam with cold water = Sample 6; *Amala* = Sample 7; Porridge = Sample 8.

Table 2. Mineral composition of raw and processed yam products (mg/100 g) sample.

Parameter	1	2	3	4	5	6	7	8
Sodium	350.0	360.0	510.0	340.0	450.0	420.0	270.0	510.0
Potassium	470.0	290.0	420.0	390.0	370.0	130.0	210.0	480.0
Calcium	68.0	82.0	61.0	27.0	29.0	31.0	97.0	92.0
Magnesium	32.0	34.0	25.0	17.0	23.0	14.0	17.0	31.0
Iron	4.1	3.3	4.6	1.1	2.1	1.2	2.5	3.8
Phosphorus	163.0	145.0	155.0	119.0	169.0	131.0	122.0	221.0
Zinc	5.6	2.7	7.3	4.2	5.1	2.6	2.3	6.3

spectrophotometer (Buck Scientific, Norwalk) (Essien et al., 1992) and their absorption compared with absorption of standards of these minerals. Chi square test and analysis of variance (ANOVA) were employed to interprete the results and level of significance was set at $p<0.05$.

RESULTS

The result of proximate nutrient composition of raw yam and its processed products are as shown in Table 1. There were significant differences in moisture content of processed yam products as consumed compared with the raw sample (Sample 1) ($p<0.05$). Boiled (Sample 4) and pounded yam (Samples 5 and 6) were significantly higher in moisture content than the raw yam, while roasted yam (Sample 2), *amala* (Sample 7) and porridge (Sample 8) were significantly lower ($p<0.05$). There was significant reduction in crude protein content of boiled and pounded yam, while there was significant increase in its value for roasted, fried, *amala* and porridge samples (Samples 2, 3, 7 and 8 respectively) compared with the raw sample ($p<0.05$). Except for boiled yam (Sample 4), all other yam products were significantly higher in crude lipid compared with the raw sample ($p<0.05$).

Amala and porridge were significantly higher in crude fibre content than the rest of the samples ($p<0.05$). Roasting, frying and boiling resulted in significant reduction in ash content of the samples, while porridge had the highest ash value ($p<0.05$). Raw and processed yam products were high in gross energy. Fried yam, pounded yam with boiling water and porridge were significantly higher in gross energy than other products ($p<0.05$).

Table 2 shows the mineral composition of raw and processed yam products. Processing yam into various products resulted in highly significant reduction in mineral content of the products compared with the raw sample ($p<0.05$). However, preparing yam into porridge (Sample 8) resulted in significant increase in calcium, phosphorus and zinc content of the product compared with raw sample.

DISCUSSION

The results of proximate analyses of raw and processed yam samples are as shown in Table 1. Values obtained for crude protein, crude lipid, ash and crude fibre of raw yam sample was in close agreement with that in the literature (Oyenuga, 1968; Osagie, 1992). Raw yam was very low in crude lipid, crude fibre and protein, moderate in ash content, and high in moisture, carbohydrate and gross energy content. The high gross energy content of yam explains why it serves as a staple source of energy in Nigeria.

Roasting did not significantly reduce the moisture content of the yam ($p>0.05$), but significantly increased its crude protein and lipid value. Processing enhances nutrient availability in processed foods compared to the raw. There was slight increase in carbohydrate and gross energy content of roasted yam compared to the raw, though the increment was not significant.

Frying significantly reduced the moisture and ash content of fried yam compared to raw and roasted samples, and significantly improved the crude protein, lipid and gross energy content compared to the raw sample ($p<0.05$). The observed increase in lipid and energy content of fried yam was a direct result of contribution from vegetable oil used in frying. Fat and oil contribute higher percentage of energy compared with carbohydrates and proteins. The crude protein content of fried yam was lower compared with the roasted yam. This might imply destruction of some peptide chain by heat of frying (Ihekoronye and Ngoddy, 1985). The carbohydrate content of fried yam was significantly higher than that of raw, roasted and boiled yam. This might be due to reduction in moisture content level of fried yam as well as the effect of heat in softening the glycosidic bonds of the complex carbohydrates, thereby making them more readily available.

Boiled yam was higher in moisture content compared with the raw sample. This was believed to be a direct result of added water from boiling. Boiling of yam resulted in significant reduction in crude protein and ash value compared to the raw sample. However, boiled yam was high in carbohydrate and gross energy content with no significant difference from that of raw yam ($p>0.05$). Pounding yam brought an improvement in the crude lipid, crude fibre, and ash content of the processed foods (Samples 5 and 6) compared with raw yam (1), though the difference was not significant. However, there was significant increase ($p<0.05$) in moisture content of the pounded yam compared with raw yam and all other processed food samples.

Pounding yam with its boiling water (Sample 5) brought significant improvement on the crude protein, lipid, ash and gross energy compared with all other processed foods, and retained more of the nutrients than the one pounded with cold water (Sample 6). This was an indication that some of these nutrients leached into the cooking water, which is usually discarded. This observation was in line with the findings of Bradbury et al. (1998) and Adepoju et al. (2010) who reported nutrient loss by cooking and soaking food items for a period of time through leaching.

Cooking yam flour to *amala* resulted in significant increase in its crude protein, lipid, fibre, and ash; with a reduction in its energy content ($p<0.05$). The significant increase in nutrient content was believed to be due to the action of heat on the peptide and glycosidic bonds, rupturing them and releasing the nutrients, thereby making them more available. Processing has been reported to enhance nutrient availability (Kataria and Chauhan, 1988; Oste, 1991). Preparing yam to porridge brought a highly significant improvement in its nutrient and energy content. This might be due to the contribution of the added ingredients (palm oil and salt).

The result of mineral composition of raw and processed yam is shown in Table 2. Raw white yam was very high in sodium and potassium, high in phosphorus and zinc, moderate in iron but low in calcium and magnesium. Processing yam into various products resulted in significant reduction in all mineral content to varying degrees ($p<0.05$). Roasting of yam resulted in significant reduction in potassium, phosphorus, iron and zinc content with a slight increase in calcium value. Frying also resulted in significant reduction in the mineral content, though to a lesser extent compared with roasting.

There was a highly significant reduction in mineral content of boiled and pounded yam samples (Samples 4, 5 and 6). This was believed to be due to the leaching of the minerals into the boiling water (Bradbury et al., 1998). Adepoju et al. (2010) reported that soaking of food items in water result in loss of minerals due to leaching into the soaking water. Yam pounded with its boiling water (Sample 5) retained more minerals compared with both boiled yam and yam pounded with ordinary distilled water (Samples 4 and 6), thereby confirming leaching of these minerals into the boiling water.

The lower values of mineral content in *amala* was believed to be due to leaching of these minerals into the soaking water, as preparation of yam flour for *amala* requires parboiling and soaking overnight. Reconstituting yam flour to *amala* did not bring any significant improvement in the mineral content of the prepared *amala*. Preparing the yam to porridge significantly retained more of the minerals than any other processed products. It also brought significant increase in potassium, calcium, phosphorus and zinc content of the prepared menu compared with the raw sample values of these minerals. From Table 3, 100 g portion of prepared yam products can contribute between 12.4 to 20.9% gross energy, 11.0 to 46.0% iron and 17.3 to 48.7% zinc to recommended dietary allowances (RDAs) of consumers.

Conclusion

Processing yam to various products resulted in significant improvement in its nutrient composition. Roasting, frying and preparing yam to *amala* improved the macronutrient content of yam significantly. Boiling yam resulted in significant reduction of all nutrients studied, while pounding yam with boiling water retained greater part of the nutrients. The energy content of yam products qualifies them as source of energy to consumers. It is recommended that yam should be cooked with calculated amount of water to prevent decantation which results in nutrient loss.

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Table 3. Nutrient contribution of 100 g portion of yam products to % RDAs of consumers*.

Sample	Energy		Iron		Zinc	
	2300	**% RDA**	**10 mg**	**% RDA**	**15 mg**	**% RDA**
2	370.4	16.1	3.3	33.0	2.7	18.0
3	397.6	17.3	4.6	46.0	7.3	48.7
4	360.2	15.7	1.1	11.0	4.2	28.0
5	398.3	17.3	2.1	21.0	5.1	34.0
6	376.2	16.4	1.2	12.0	2.6	17.3
7	284.6	12.4	2.5	25.0	2.3	15.3
8	479.8	20.9	3.5	35.0	6.3	42.0

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