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Biochemical Characteristics of Taro (*Colocasia esculenta*) Flour as Determinant Factors of the Extend of Browning During Achu Preparation

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Abstract: Achu is a thick porridge traditionally made in center Africa by boiling taro corms and cormels followed by peeling and pounding in a mortar. The present studies were performed with two key objectives in mind. Firstly to gain a better understanding of the basic processes of the browning reaction that can occur during preparation of Achu. Secondly to identify a variety that is much less susceptible to these browning reactions and especially during reconstitution of its flour into Achu. Traditional and reconstituted achu were prepared from six taro varieties and their organoleptic and biochemical characteristics were assessed. Mean values obtained in g/100 g dry weight were as follows: reducing sugars 1.3-2.3; total phenols 0.03-0.07; amino groups 0.05-0.1; phenolics and procyanidins 0.03-0.11. The browning reaction that occurred during the reconstitution was significantly correlated ($R^2 = 0.74$; $p<0.05$) to the concentration of total phenolic compounds in the flours used. There was a high correlation ($R^2 = 0.89$; $p<0.05$) between the reduction in phenolics and a reduction in browning reactions. Irrespective of variety, reconstituted Achu was less acceptable and browner than traditional Achu, but of all the flours tested, those derived from the taro varieties Ibo Ekona and Ibo Ngdere showed a lower susceptibility to browning reactions during reconstitution.

Key words: *Colocasia esculenta*, taro paste, flour, phenolics, browning reaction

Introduction

Taro is usually eaten in Cameroon in the form of a thick, smoothed-textured porridge called achu. Achu is prepared by sequential cooking, peeling and pounding taro corms and cormels and subsequent addition of water to generate the porridge. The preparation and consumption of Achu is limited because of its long processing time: cooking (2-4 h) and final pounding the corms (1-3 h). Taro is not currently grown on a commercial scale and defined cultivars of taro do not exist. However there are regional eco-types throughout Cameroon and Chad with different characteristics. Initial studies evaluating methods for improving the selection and development of taro flour prepared for use in the preparation of Achu have been performed (Njintang, 2003). Results from earlier studies (Njintang *et al*., 2001; Njintang and Mbofung, 2003) had suggested that the production and use of taro flour for the preparation of Achu might be limited by the occurrence of browning reactions and the subsequent reduction in acceptable flavour and texture. Browning in most foods has been reported to vary with cultivars or species (Ozo and Caygill, 1986; Parpinello *et al*., 2002). In the case of yams, such browning has been reported to affect the acceptability of food produced from it (Ihekoronye and Ngoddy, 1985).

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Differences in the browning reactions of foods may be related to certain biochemical characteristics e.g., the levels of oxidative enzymes (peroxidases and polyphenol-oxidases) and their substrates (simple phenolics, flavonoids, catechins, procyanidins etc.). Browning during processing of foods has been correlated with the level of reducing groups of sugars content (Carey and Cronin, 1990), total phenolic compounds (Parpinello *et al*., 2002; Varoquaux *et al*., 1991) and amino groups (Hodge and Osman, 1976; Tsao *et al*., 1978). Important differences have been reported in the total levels of the reducing sugars and phenolics in Cameroonian taro cultivars (Agbor-Egbe and Rickard, 1990; Agbor-Egbe, 1991). However detailed studies to identify and characterize these different cultivars with respect to browning behavior and other physicochemical properties have not been performed. Such studies would facilitate the identification of cultivars or varieties that present fewer drawbacks for use in the production of flours for Achu i.e., significantly reduced browning during processing.

The main objectives of the present studies were to evaluate the biochemical characteristics of flours produced from six different varieties of taro, relative to freshly prepared Achu from these varieties and to identify some of the components involved in the mechanism of browning during reconstitution of the taro flours into Achu.

Materials and Methods

Reagents

All chemicals used in the extractions were of analytical grade and those used in the HPLC analyses were HPLC grade. Standards were obtained from commercial sources; either Sigma/Aldrich or Extrasynthese (Genay, France). The exception was the procyanidins-enriched grape seed extract which was a gift from Dr. Dario Zanichelli (University of Bologna, Italy).

Taro Samples

Taro corms and cormels of 6 varieties were obtained from small-scale family farms in Cameroon and Chad. Three varieties (country Ngdere, Ibo Ngdere and Kwanfre Ngdere) were harvested in Ngaoundere, Cameroon. Two varieties (country Ekona and Ibo Ekona) were harvested in Ekona, Cameroon and one variety (Sosso Chad) was harvested in Mayo kebbi, Chad. In this study all the Cameroonian varieties were harvested at maturity 8-9 months after planting and the Chadian variety 7 months after planting.

Traditional and Reconstituted Achu Preparation

The traditional Achu was prepared by washing taro corms/cormels, boiling for 2 h, then peeled and pounded in a mortar for 1 h to obtain achu. Reconstituted Achu was prepared by cleaning the corms/cormels, peeling them and cutting 0.5 cm-thick slices, which were spread on perforated aluminium trays placed within a convection oven and dried for 48 h at 45±2°C. The dried slices (chips) were then fine milled (to pass through a 500 μm sieve) using a desktop electrical grinder (Cullati, Polymix, Kinematica AG, Luzernerstrasse, Germany). The resulting taro flour (50 g) was mixed with distilled water (150 mL) and cooked with gentle stirring for 45 min to obtain Achu designated as reconstituted Achu. During cooking, additional water (150 mL) was added and the mixture gently stirred.

Achu Sampling

Each *achu* preparation (both traditional and reconstituted) was divided into two parts. One part was used for the organoleptic characteristic analyses. A second part was dried at 45±2°C and ground in a Culatti mill to a fine powder (500 μm). Flour samples and the two type of Achu were analysed for selected biochemical characteristics.

Determination of Total Reducing Sugars, Phenols and Amino Groups

Exactly 1 g of sample (flour or oven-dried Achu) was weighed into a 50 mL polyethylene centrifuge tube and 10 mL of 80% v/v ethanol:water was added. The sample was mixed using a vortex mixer and then shaken by hand in a water bath at 20°C for 30 min. The mixture was centrifuged (15 min, 20°C, 5000 rpm, TUV, Sigma, Bioblock Scientific, Germany) and the supernatant transferred to fresh 50 mL tube. The residue was reextracted twice more with 10 mL ethanol 80% v/v ethanol:water. The supernatants were pooled and the volume adjusted to 50 mL with 80% v/v ethanol:water. Total reducing sugars were determined using the DNS assay using D-glucose as standard curves (Bernfeld, 1955). Total phenols, expressed as gallic acid equivalents, were determined using the Folin-Ciocalteu reagent method (Swain and Hillis, 1959). Total amino groups were determined according to a previously described method (Devani *et al*., 1989); essentially a yellow N derivative of 3, 5-diacetyl-1,4-dihydrolutidine is formed and measured at 410 nm (λmax of the derivative). Calibrations curves were done using ammonium sulphate and the free amino groups in samples were expressed as N equivalents/100 g of flour.

LC-Diode Array and LC-Fluorescence Analyses of Phenolics and Proacyanidins

Simple phenolics, catechins and proyanidins were analysed in all samples by HPLC. For the low MW components such as phenolic acids, a Phenomenex Luna C_{18} (2) reverse-phase column (250×4.6 mm, 5 μm) with a Phenomenex Security guard pre-column with a C_{18} cartridge was used. For the procyanidin analyses, a Phenomenex Luna Silica (2) normal-phase column (250×4.6 mm, 5 μm) with `Securityguard` pre-column with a silica cartridge was used. Analysis were performed using an Agilent HP1100 HPLC system, equipped with a photo-diode array detector (capable of collecting data simultaneously at 6 wavelengths between 200-800 nm for each peak) and a fluorescence detector (with programmable excitation and emission wavelengths).

For LC-diode array analyses of free phenolic compounds, triplicate samples (40 mg) were extracted in 2 mL screw-top tubes with 1 mL 70% v/v MeOH at 70°C (Techne Dri-Block) for 30 min with vortex mixing (Vortex Genie 2, model G-560E, Scientific Industries, USA) every 5 min to improve extraction efficiency. Samples were left to cool for 20 min and centrifuged (17,000 g, 4°C, 20 min) using a Sigma 4k10 centrifuge and a 12167 fixed-angle rotor. The supernatants were removed with syringes and filtered through 0.2 μm Target PVDF (Chromos Express, Macclesfield, UK) prior to analysis. A general-purpose binary-solvent method, which separates a wide range of secondary metabolites, was used (Bennett *et al*., 2003). Solvent A = Millex Q water (distilled, de-ionised 18.2 MΩ) with 0.1% v/v trifluoriacetic acid; solvent B = HPLC grade MeOH containing 0.1% v/v trifluoracetic acid. Flow Rate = 1.0 mL min^{-1}. Linear gradient: 0 min (100% A), 10 min (80% A, 20% B), 25 min (50% A, 50% B), 30 min (100% B), 35 min (100% B), 40 min (100% A), 55 min (100% A). UV/Visible data was collected at 227 nm (most UV-absorbing compounds), 270 nm (aromatic compounds including all phenolics and polyphenolics), 325 nm (cinnamates and their derivatives, flavanones and flavones), 370 nm (flavonols) and 520 nm (anthocyanins). Overall data was collected between 200-600 nm.

LC-fluorescence detection analyses of catechin, epicatechin and procyanidins were performed using a Luna Silica (2) normal-phase column and the HP1100 system using a previously described method (Bennett *et al*., 2003). Procyanidins were extracted from triplicate samples (40 mg) with 100% v/v MeOH and processed as for phenolic samples. Peaks were identified by comparison of retention times of single standards (catechin, epicatechin, procyanindin B1 and procyanidin B2) and with those of a procyanidin-enriched grape seed extract. Solvent A = Millex Q water (distilled, de-ionised 18.2 MΩ) with 50% v/v glacial acetic acid; B = HPLC grade MeOH; C = HPLC grade dichloromethane. Flow Rate = 1.0 mL min^{-1}. Linear gradient: 0 min (4% A, 14% B, 82% C), 30 min (4% A, 28.4% B, 67.6% C), 45 min (4% A, 39.2% B, 56.8% C), 50 min (4% A, 86% B, 10% C), 55 min (4% A, 14%

B, 82% C), 65 min (4% A, 14% B, 82% C). UV/Visible detection at 220 nm (general UV-absorbing compounds), 280 nm (phenolics) and overall PDA data collected between 200-600 nm. Fluorescence detection was done with an excitation wavelength of 276 nm and emission wavelength of 316 nm.

Organoleptic Analysis

Traditional and reconstituted *achu* were analysed by an organolepic evaluation panel. About 20 g of fresh-cooked achu of each variety was presented to 12 trained panelists drawn from the University of Ngaoundere sub-population familiar with Achu. Selected panelists underwent two training programs each of 60 min on how to evaluate colour, flavour and texture. Organoleptic evaluations were performed using a multiple comparison test as previously used (Ihekoronye and Ngoddy, 1985). Achu prepared by the traditional method from corms and cormels was selected as the control and labelled R. Each of the panelists received a tray containing the reference sample R and three coded Achu samples prepared from taro corms and cormels, taro flour and taro chips. Each panelist was asked to taste and rate each sample on the basis of colour, consistency, flavour and overall acceptability. A numerical scale varying from 1 to 9 was used where extremely brown, extremely soft or no flavour were assigned a value of 1 and extremely white, extremely hard or extremely flavoured were assigned a value of 9.

Browning Behaviour

During the preparation of reconstituted *achu*, samples were taken at different time-points (10, 20, 30, 40 50 and 60 min) and the colour assessed by the sensory panel using suitable standards ranging from 0 to 100% of completed browning reaction. In order to quantify the degree of browning, suitable standards representing 0 and 100% browning were prepared as follows: 0% browning was made of traditional Achu variety Country Ekona (which was shown to present no significant browning) while completely brown (100%) reference standard was made of reconstituted-flour Achu variety Kwanfre Ngaoundere. The two standards were mixed in specific graded proportion in order to obtain a series of standard paste of varying degree of browning, ranging from 0 to 100 %.

Statistical Analysis

Differences were evaluated statistically using the analysis of variance followed by the Duncan multiple range test as installed in the statistical package for social science (SPSS, 1993). Relationships between browning behaviour and such independent variables as reducing sugars, phenolic compounds or free amino groups, were evaluated using linear and polynomial models with the help of the statistical Packages Statistica (Statsoft, 1995) and Sigma plot.

Results and Discussion

Total Reducing Sugars, Amino Groups and Phenols

Table 1 shows the variation in some biochemical characteristics of the different varieties of raw taro flour. Reducing sugar levels in the different samples analysed showed no significant differences, although reducing sugars from Sosso Chad variety (2.3 g/100 g) was nearly twice that of flour from Ibo Ekona (1.3 g/100 g). Generally, all the taro varieties studied had high reducing sugar contents in comparison with previous studies. It has been suggested that high levels in reducing sugars could be the result of amylolytic activity of endogenous amylases (Onigbinde and Akinyele, 1988).

Large variations were observed in the total amino content of the different varieties (Table 1). The co-occurrence of high concentrations of amino groups and reducing sugars is a characteristic known to favor browning reactions during processing. The free amino compounds contents of flour of the varieties used in this study were considerably higher than the free amino acid content (5.6 mg/100 g)

Table 1: Biochemical characteristics of taro flours used for producing reconstituted Achu

Parameters	Varieties: Country Ekona	Ibo Ekona	Country Ngdere	Ibo Ngdere	Kwanfre Ngdere	Sosso Chad
Free amino nitrogen (mg N/100 g)	78.09±2.76^{ab}	69.10±12.78^{b}	102.28±2.07^{a}	59.32±5.93^{b}	80.08±10.86^{ab}	89.66±9.55^{a}
Total phenols (mg gallic acid eq/100 g)	43.23±3.30^{cd}	35.61±5.31^{d}	53.65±5.18^{bc}	36.62±0.75^{d}	70.23±7.04^{a}	63.26±1.16^{ab}
Reducing sugars (%)	2.02±0.12^{ab}	1.30±0.11^{b}	1.99±0.40^{ab}	1.61±0.11^{ab}	1.69±0.27^{ab}	2.33±0.63^{a}

Means±SD; Figures in rows followed by different superscripts indicate significantly ($p<0.05$) different values determined by Duncan's Multiple Range Test

Table 2: Variation in free phenolic compounds contents in Non-hydrolyzed (NH) and Acid-hydrolyzed (AH) taro samples (μg g^{-1} on dry weight basis)

Varieties	Treatments: Raw flour NH	Raw flour AH	Traditional Achu NH	Traditional Achu AH	Reconstituted-flour Achu NH	Reconstituted-flour Achu AH
Sosso chad	9.05±0.19^{b}	9.41±0.10^{c}	6.41±0.17^{b}	12.22±0.12^{a}	7.51±0.09^{e}	11.00±0.12^{b}
Country Ekona	9.48±0.17^{b}	11.37±0.19^{b}	7.60±0.16^{a}	12.38±0.19^{a}	9.32±0.17^{c}	11.61±0.19^{b}
Ibo Ekona	9.42±0.10^{b}	8.58±0.10^{d}	6.96±0.16^{b}	9.29±0.12^{c}	7.68±0.06^{e}	12.17±0.23^{a}
Country Ngdere	8.64±0.17^{c}	11.98±0.19^{b}	6.89±0.17^{b}	9.08±0.17^{c}	8.04±0.16^{d}	9.33±0.17^{c}
Ibo Ngdere	8.30±0.10^{c}	7.11±0.16^{e}	nd	nd	12.31±0.19^{b}	11.02±0.16^{b}
Kwanfre Ngdere	10.56±0.19^{a}	12.73±0.12^{a}	5.58±0.16^{c}	10.58±0.09^{b}	13.21±0.12^{a}	11.72±0.20^{b}

n = 2; Means±SD; Figures in column followed by different superscripts indicate significantly ($p<0.05$) different values determined by Duncan's Multiple Range Test. nd=non determined

previously reported for taro (Hussain *et al*., 1984). This discrepancy may be caused by the different analytical procedures employed. The method used in the present study determined all the NH_2 groups of molecules including amino acids, proteins and other amino-compounds i.e., the total amino content.

The total phenol content of the varieties, expressed as gallic acid equivalents, ranged from 35.6 mg/100 g in Ibo Ekona to 70.2 mg/100 g in Kwanfre Ngdere. Previously reported total phenols content of *Colocasia* sp., expressed as chlorogenic acid equivalent, was 203-838 mg/100g (Agbor-Egbe, 1991). The presence of high levels of phenols in food generally favours the occurrence of browning during processing (Amiot *et al*., 1992, 1993).

LC-UV Detection Phenolic Analysis

The total phenolic compounds analysed using the HPLC method did not vary significantly between varieties (Table 2). Traditional Achu and reconstituted-flour Achu had lower levels of phenolic compounds than taro flour, but this was not the case with reconstituted-flour Achu from varieties Ibo Ngdere and Kwanfre Ngdere. In addition, acid hydrolysis of flour generally increased the phenolic compounds content, suggesting the interaction of some phenolic compounds with other flour compounds to form insoluble polymers. This may also be due to, as previously suggested, the liberation of aglycones from the flavonol glycosides (Agbor-Egbe and Rickard, 1990).

LC-Fluorescence Procyanidin Analysis

Procyanidins, also called condensed tannins, are polyflavonoids in nature, consisting of chains of flavan-3-ol units (either catechin and/or epicatechin). The variation in proanthocyanidin content of taro flour, reconstituted-flour Achu and traditional achu (expressed as (+)- catechin equivalents) for the six varieties is presented in Fig. 1. Procyanidin ranges were 7.0-11.3, 1.4-4.2 and 0.7-1.7 μg g^{-1} for the taro flour, traditional achu and reconstituted achu, respectively. The procyanidin contents were found to be lower than previously reported values, expressed as cyanidin chloride equivalent, of 2.4-10.2 g kg^{-1} (Agbor-Egbe, 1991). In addition, a major reduction in free

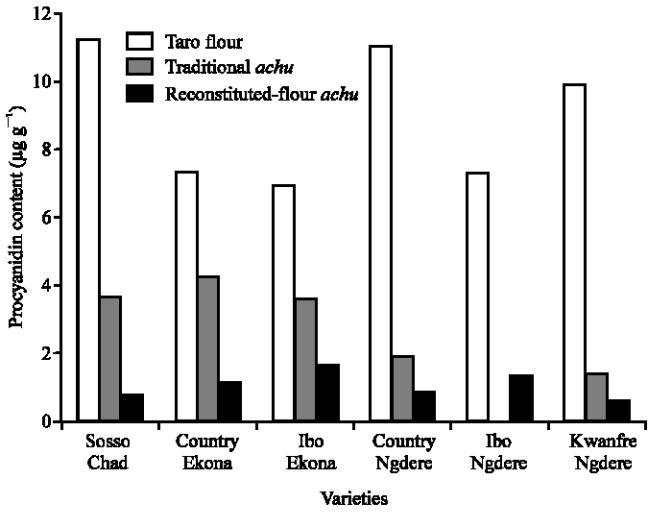

Fig. 1: Procyanidin contents of taro flour, traditional Achu and reconstituted Achu prepared from six taro varieties. Content expressed as (+)-catechin equivalents. The procyanidin value for traditional achu variety Ibo Ngdere was not determined

Table 3: Organoleptic attributes of taro achu obtained by the traditional preparation method and by reconstitution of the different flours

		Varieties					
Sensory		Country Ekona	Ibo Ekona	Country Ngdere	Ibo Ngdere	Sosso Chad	Kwanfre Ngdere
Colour	Reconstituted Achu	3.40±0.25^{a1}	6.17±0.45^{a}	4.25±0.30^{bc}	5.4±0.40^{ab}	2.75±0.20^{bc}	1.83±0.15^{c}
	Traditional Achu	8.00±0.60^{a}	7.33±0.50^{a}	8.00±0.60^{a}	7.5±0.50^{a}	4.00±0.30^{b}	2.20±0.20^{c}
	p*	0.00	ns	0.01	ns	ns	ns
Overall acceptability	Reconstituted Achu	4.83±0.25	6.17±0.35	4.83±0.25	3.50±0.20	4.00±0.20	3.00±0.15
	Traditional Achu	7.10±0.40	7.17±0.50	7.60±1.01	6.00±0.20	5.17±0.40	4.50±0.50
	p*	0.00	ns	0.00	0.00	ns	ns
Texture	Reconstituted Achu	5.80±0.35	5.00±0.30	4.40±0.20	3.80±0.30	4.00±0.25	3.20±0.30
	Traditional Achu	4.83±0.30	7.67±1.50	7.17±1.75	7.00±0.85	7.00±0.70	7.83±0.50
	p*	ns	ns	0.00	0.00	0.00	0.00

Means±SD; n = 24; Figures in a row followed by different superscripts indicate significantly ($p<0.05$) different values determined by Duncan's Multiple Range Test. p* is the level of significance for the effect of processing method within attributes

procyanidin content was observed during preparation of reconstituted Achu and this varies from 76% (variety Ibo Ekona) to 93% (variety Kwanfre Ngdere). The reduction in free procyanidins during preparation of traditional Achu ranged from 42% (variety Country Ekona) to 86% (variety Kwanfre Ngdere). The reduction in methanol-soluble free procyanidins during cooking may result from oxidative reaction that occurs at high temperature. It has been suggested earlier that, based on the absorbance measurements, insoluble polymerized pigments bound to cell walls for example are generally not extracted (Goupy *et al*., 1995). The procyanidin content of traditional achu was higher than those of reconstituted-flour achu. This may be due to the fact that cooking of corms reduces the enzymatic browning, probably by inactivation of oxidative enzymes and consequently reducing the amount of procyanidins-derived polymers and adducts with proteins and other flour components. The variation in procyanidin profiles of taro flours during reconstitution into Achu suggests that non-enzymatic oxidation of phenols may contribute to the browning of taro flour.

Organoleptic Characteristics

Achu as a food prepared from taro possesses specific organoleptic properties. Table 3 shows the sensory attributes of reconstituted and traditional Achu for the six taro varieties studied. It is evident from these results that traditional *achu* had higher scores for colour, consistency and general taste

acceptability. Following the traditional way of cooking, two of the six varieties studied, Kwanfre Ngdere and Sosso Chad were observed to undergo a browning reaction during pounding in a mortar. Kwanfre Ngdere showed the highest degree of browning of all the varieties evaluated. In contrast, irrespective of variety, browning was observed to occur during reconstitution of all the flours into Achu. Such browning has been reported in the case of yam and *Xanthosoma* flour (Ngoddy and Onuoha, 1985; Njinguet, 2000). Generally, browning reactions in Kwanfre Ngdere was observed to start during peeling, slicing and drying, similar to the rapid browning reaction that occurs in some varieties of apples (Parpinello *et al*., 2002). This is indicative of high levels of oxidative enzymes and/or phenolics in Kwanfre Ngdere. Only minor `damage` to the corm of Kwanfre Ngdere was required to cause the browning reaction, which is essentially a natural plant defense response to herbivore feeding. Previous studies concluded that the appearance of darkening during the preparation of *fufu* (*amala*) from yam flour is predominantly an enzymatic reaction (Anosike and Ikediobi, 1985). It is difficult to say the same in the case of the browning observed during processing of variety Sosso corms into achu. At best, the browning observed here might be likened to that reported by some authors after the cooking of Irish potatoes (Silva *et al*., 1991; Griffiths and Bain, 1997). According to these authors such browning is due to a reaction between phenols, in particular chlorogenic acid and iron. It can also be postulated that the development of the non-enzymatic browning during reconstitution may be related to general phenolic oxidation and polymerization. For the taste panel, reconstituted Achu was less appreciated than that prepared by the traditional method. Irrespective of the method of preparation, Achu obtained from Kwanfre Ngdere or Sosso Chad was generally least appreciated. The low acceptability rating of Achu prepared from these varieties was most likely due to the development of a brown colour during preparation and the bitterness associated with the formation of tannin-like polymers for example. In fact a significant correlation ($R = 0.86$, $p<0.05$) was observed between the colour and general acceptability of Achu.

Browning Behaviour Related to Biochemical Characteristics

Figure 2 shows the browning of taro flour during reconstitution into achu. Generally the different varieties behaved differently with respect to browning. Kwanfre Ngdere showed the highest level of browning while Ibo Ngdere showed the least tendency. In order to understand the browning mechanism involved during reconstitution into flour, the chemical characteristics analysed in the present study were correlated to browning (Table 4). A significant correlation ($r = 0.86$; $p<0.05$) was observed between browning and total phenols. The same observation has been made in previous studies on phenolic composition and browning susceptibility of various apple and pear varieties at maturity (Amiot *et al*., 1992; 1993). It was concluded that the browning observed was not only linked to the quantity of phenolics but also to their form (relatively tasteless low MW monomer phenolics versus high MW bitter-tasting polymers), but maturity had no effect on the degree of browning. Conversely, studies on *Cichorium endivia* (endive) and peaches had shown that browning decreased with maturity (Varoquaux *et al*., 1991; Lee *et al*., 1990). Other studies have shown that the concentration of phenolics is generally one of the major contributing factors to browning that occurs in food (Anosike and Ikediobi, 1985). This assertion seemed to have been confirmed by the results of the present studies because taro varieties with high levels of phenolics (Kwanfre Ngdere and Sosso Chad varieties) were consistently observed to present a higher level of browning as opposed to those (Ibo Ekona and Ibo Ngdere varieties) with lesser levels of phenolics.

In the present study no significant correlation was observed between browning and reducing sugars. Whereas a significant correlation was observed between free amino groups and browning ($r = 0.58$; $p<0.05$). This observation suggests the role of amino groups (in addition to that of total phenols) in the browning reaction that takes place in taro. There is also possibility of aromatic amino

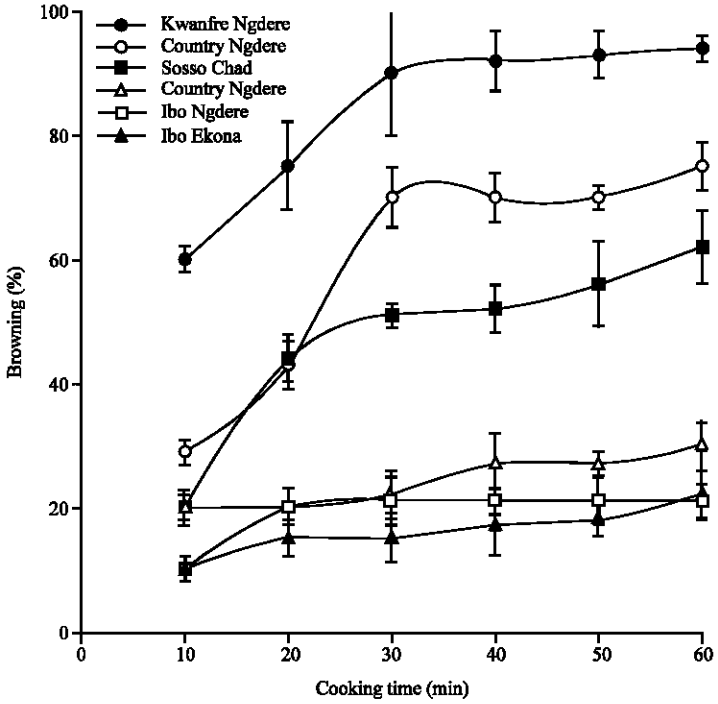

Fig. 2: Browning behavior of raw taro flours during reconstitution into Achu

Table 4: Correlations between browning and some chemical characteristics

Chemical characteristic	Correlation coefficient with browning index (R)
Reducing sugars	0.31
Total phenolics	0.86*
Free amino groups	0.58*
Procyanidins	0.91*
Decrease in free procyanidins	0.94*

*Correlation coefficient is significant at $p<0.05$

acids (L-phenylalanine, L-tyrosine and L-tryptophan) in proteins contributing to the browning reaction. A contour plot (Fig. 3A) re-emphasizes the variation in browning as a function of total phenols and free amino groups while Fig. 3B further shows the link between browning, total phenols and sugars. While the level of browning tended to increase with increases in phenolic content, this effect was further accentuated by an increase in the content of amino groups. Polyphenols and procyanidin content was significantly correlated to the browning index. In addition, the reduction in free procyanidins during reconstitution was significantly correlated to the browning index. This suggests that procyanidins may be the potential browning initiator in taro flour. It has been suggested that flavan-3-ols are good substrates for oxidative reactions leading to brown pigments; the most effective substrates were found to be epicatechin, procyanidin A2, oligomers and polymers containing A-type inter-flavanoid bonds (Lee and Whitaker, 1995; LeRoux *et al*., 1998). The results obtained in the current study on taro suggest that, for processing of taro corms or cormels into flour as raw material in the preparation of Achu, the cormels of Ibo Ngdere and Ibo Ekona should be selected so as to reduce the browning reaction.

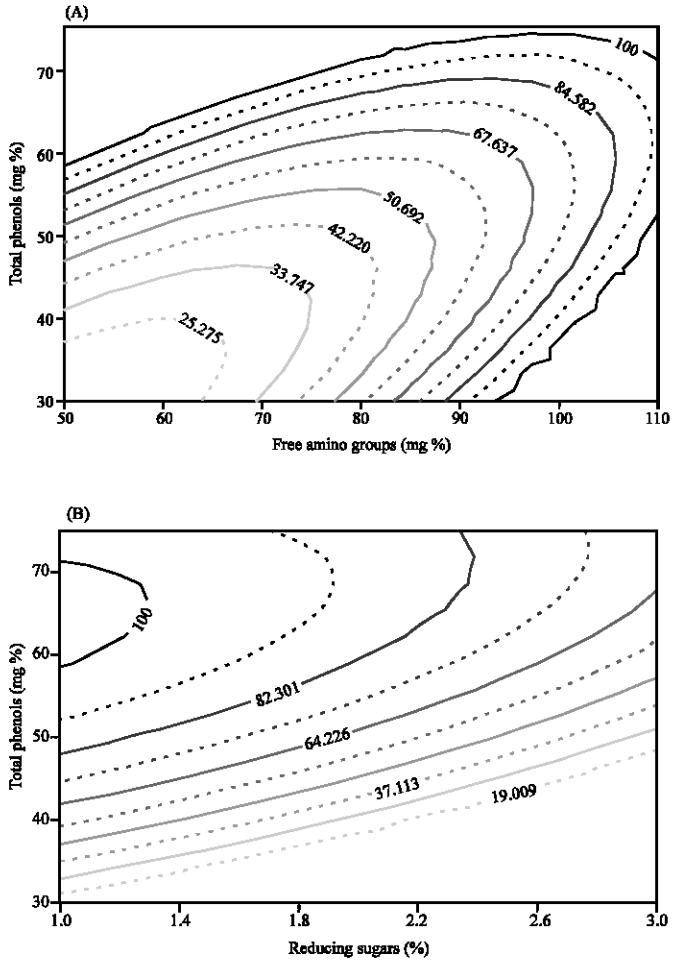

Fig. 3: Contour plots showing browning as a function of total phenols relative to free amino compounds (a) and reducing sugar (b)

Conclusions

This study has shown that flours produced from the different taro varieties differ in their biochemical characteristics. The organoleptic properties of Achu prepared from these flours differ with respect to such attributes such as texture, colour and physicochemical properties. Traditionally prepared Achu was in general significantly more appreciated than Achu prepared by reconstitution of the flours. Browning occurred during the processing of taro corms and cormels into flour and during the reconstitution of the flour into Achu. Browning was dependent on the variety used to produce the flour with variety Kwanfre Ngdere showing the highest tendency and variety Ibo Ekona the least. Correlation studies showed that browning of taro flour during reconstitution may occur through the oxidation of phenolics, with particular reference to procyanidins. The differences observed in browning during the production of flour and reconstituted achu lead to the conclusion that traditional Achu characteristics cannot be attained by reconstitution of raw taro flour. However, varieties Country

Ekona, Ibo Ekona and Ibo Ngdere have a high potential for directed plant breeding and subsequent processing of taro corms into achu.

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References

Agbor-Egbe, T. and J.E. Rickard, 1990. Identification of phenolic compounds in edible aroids. J. Sci. Food Agric., 51: 215-221.

Agbor-Egbe, T., 1991. Biochemical changes occurring during storage of *Colocasia* sp. and *Xanthosoma* sp. cormels under tropical ambient conditions. In Traditional African Foods, Quality and Nutrition. Proc. regional Workshop held by the International Foundation for Science (IFS), Dares Salaam, Tanzania, pp: 171-177.

Amiot, M.J., M. Tacchini, S. Aubert and J. Nicolas, 1992. Phenolic composition and browning susceptibility of various apple and pear varieties at maturity. J. Food Sci., 57: 958-962.

Amiot, M.J., S. Aubert and J. Nicolas, 1993. Phenolic composition and browning susceptibility of various apple and pear varieties at maturity. Acta Hortic., 343: 67-68.

Anosike, E.O. and C.O. Ikediobi, 1985. The Biochemistry of the browning of yam tuber. In Advances in Yam Res. Biochem. Soc. Nigeria, pp: 143-162.

Bennett, R.N., F.A. Mellon, N. Foidl, J.H. Pratt, M.S. DuPont, L. Perkibns and P.A. Kroon, 2003. Profiling glucosinolates and phenolics in vegetative and reproductive tissues of the multi-purpose trees *Moringa oleifera* L. (Horseradish Tree) and *Moringa stenopetala* L. J. Agric. Food Chem., 51: 3546-3553.

Bernfeld, P., 1955. Amylases alpha and beta. In: Methods in Enzymology. Colowick, S.B. and N.O. Kaplan Eds. New York: Academic Press, 1: 149-153.

Carey, A.T. and D.A. Cronin, 1990. A comparative study of cold -sweetening in two potato varieties. Irish J. Food Sci. Technol., 14: 95-107.

Devani, M.B., Shishoo, S.A. Shah and B.N. Suhagia, 1989. Spectrophotometric for the micro determination of nitrogen in Kjedahl digest. J. Assoc. Offic. Anal. Chem., 72: 953-956.

Goupy, P., M.J. Amiot, F. Richard-Forget, F. Duprat, F. Aubert and J. Nicolas, 1995. Enzymatic browning of model solutions and apple phenolic extracts by apple polyphenoloxidase. J. Food. Sci., 60: 497-501, 505.

Griffiths, D.W. and H. Bain, 1997. Photo-induced changes in the concentrations of individuals chlorogenic acid isomers in potato (*Solanum tuberosum*) tubers and their complexation with ferric ions. Potato Res., 40: 307-315.

Hodge, J.E. and E.M. Osman, 1976. Principle of Food Science, Part 1, in Food Chemistry (Ed. Fennema, O.) Marcel Dekker Inc., New York, pp: 41-138.

Hussain, M., G. Norton and R.J. Neale, 1984. Composition and nutritive value of cormels of *Colocasia esculenta* (L.) Schott. J. Sci. Food Agric., 35: 1112-1119.

Ihekoronye, A.I. and P.O. Ngoddy, 1985. In Integrated food science and technology for the tropics. Macmillan Publishers Ltd., London, pp: 266-292.

Le Roux, E., T. Doco, P. Sarni-Manchado, Y. Lozano and V. Cheynier, 1998. A-type proanthocyanidins from pericarp of Litchi chinensis, Phytochemistry, Vol. 48.

Lee, C.Y., V. Kagan, A.W. Jaworski and S.K. Brown, 1990. Enzymatic browning in relation to phenolic compounds and polypheoloxidase activity among various peach cultivars. J. Agric. Food Chem., 38: 99-191.

Lee, H.S. and J.R. Whitaker, 1995. Enzymatic browning and its prevention in foods. Am. Chem. Soc. Symp. Series 600. Am. Chem. Soc., Washington, DC., pp: 338.

Ngoddy, P.O. and C.C. Onuoha, 1985. Selected problems in yam processing. In Advances in Yam Research. Sym. Yam Biochem.; Anambra State Univ. Technol., Enugu: Biochemical Soc. Nigeria, pp: 293-318.

Njinguet, B., 2000. Utilisation de la farine de macabo (*Xanthosoma sagitifolium*) pour la préparation du kwakoukou.. M.Sc Thesis, ENSAI, University of Ngaoundere, Cameroon.

Njintang, Y.N., 2003. In: Studies on the production of taro (*Colocasia esculenta*) flour for use in the preparation of Achu-a taro based food. Ph.D Thesis, ENSAI, University of Ngaoundere, Cameroon.

Njintang, Y.N. and C.M.F. Mbofung, 2003. Development of taro (*Colocasia esculenta* (L) Schott) flour as an ingredient in food processing. Effect of gelatinisation and drying temperature on the dehydration kinetics and colour of flour. J. Food Eng., 58: 259-265.

Njintang, Y.N., Aboubakar, A. Abdou Bouba and C.M.F. Mbofung, 2001. Performance of taro (*Colocasia esculenta*) flour as ingredient in the processing of achu (a taro based paste): Studies on the browning development during cooking. Biosci. Proc., 8: 282-292.

Onigbinde, A.O. and I.O. Akinyele, 1988. Biochemical and nutritional Changes in corn (*Zea mays*) during storage at three temperatures. J. Food Sci., 53: 117-119.

Ozo, O.N. and J.C. Caygill, 1986. *O*-Dihydroxyphenoloxidase action on natural polydric phenolics and enzymic browning of Edible yams. J. Sci. Food Agric., 37: 283-288.

Parpinello, G.P., F. Chinnici, A. Versari and C. Riponi, 2002. Preliminary study on glucose oxidase-catalase enzyme system to control the browning of apple and Pear purées. Lebensm.-Wiss.U.-Technol., 35: 239-243.

Silva, G.H., R.W. Chase, R. Hammerschmidt and J.N. Cash, 1991. After cooking darkening of Spartan Pearl potatoes as influenced by location, phenolic acids and citric acid. J. Agric. Food Chem., 39: 871-873.

SPSS., 1993. SPSS for Windows, SPSS Inc.Chicago, IL.

Statsoft, 1995. Statistica for Windows, release 5, Statsoft Inc. Tulsa, OK.

Swain, T. and W.E. Hillis, 1959. The quantitative analysis of phenolic constituent. J. Sci. Food Agric., 1: 63-68.

Tsao, T.F., A.L. Fray and J.M. Harper, 1978. Available lysine in heated fortified rice meal. J. Food Sci., 43: 1106.

Varoquaux, P., F. Varoquaux and G. Breuils, 1991. Browning potential of various *Cichorium endivia* L. cultivars as a function of harvest time. Lebensmittel Wissenschaft Technol., 24: 270-273.