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 central 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 procyandins 0.03-0.11. The browning reaction that occurred during the reconstitution was significantly correlated (R² = 0.74, p<0.05) to the concentration of total phenolic compounds in the flours used. There was a high correlation (R² = 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 Ngdore showed a lower susceptibility to browning reactions during reconstitution.

Keywords: Colocasia esculenta, taro paste, flour, phenolics, browning reaction

Introduction

Taro is usually eaten in Cameroon in the form of a thick, smooth-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 flavor 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 (Thekoronye and Ngoddy, 1985).
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 (Gemay, 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 ahu. 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 Cullati 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 Achi) 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, HUV, Sigma, Bielblock 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 assay (Swain and Hillis, 1959). Total amino groups were determined according to a previously described method (Devän 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 Procyanidins

Simple phenolics, catechins and procyanidins were analysed in all samples by HPLC. For the low MW components such as phenolic acids, a Phenomenex Luna C18 (2) reverse-phase column (250x4.6 mm, 5 μm) with a Phenomenex Security guard pre-column with a C18 cartridge was used. For the procyanidin analyses, a Phenomenex Luna Silica (2) normal-phase column (250x4.6 mm, 5 μm) with Securityguard pre-column with a silica cartridge was used. Analyses 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 Dn-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 121 7 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 = MilliQ water (distilled, de-ionised 18.2 MΩ) with 0.1% v/v trifluoroacetic acid; solvent B = HPLC grade MeOH containing 0.1% v/v trifluoroacetic 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% A), 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, flavonones 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, procyanidin B1 and procyanidin B2) and with those of a procyanidin-enzyme-free grape seed extract. Solvent A = MilliQ 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 organoleptic 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 cornels 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 cornels, 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 Ekona (which was shown to present no significant browning) while completely brown (100%) reference standard was made of reconstituted-flour Achu variety Kwanfere 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 amyloytic activity of endogenous amylases (Onigbindi 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 Achi

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</thead>
<tbody>
<tr>
<td>Free amino nitrogen (mg N/100 g)</td>
<td>78.09±2.76a</td>
<td>69.10±12.78a</td>
<td>102.28±2.07a</td>
<td>59.32±5.93a</td>
<td>80.08±10.86a</td>
<td>85.66±9.55a</td>
<td></td>
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</tr>
<tr>
<td>Total phenols (mg gallic acid eq/100 g)</td>
<td>43.23±3.30a</td>
<td>35.61±5.31a</td>
<td>53.65±5.19a</td>
<td>36.62±0.75a</td>
<td>70.23±7.04a</td>
<td>63.26±1.16a</td>
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<tr>
<td>Reducing sugars (%)</td>
<td>2.02±0.12a</td>
<td>1.30±0.11a</td>
<td>1.09±0.10a</td>
<td>1.61±0.11a</td>
<td>1.69±0.27a</td>
<td>2.33±0.63a</td>
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</table>

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)

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Raw flour</th>
<th>Traditional Achi</th>
<th>Reconstituted-flour Achi</th>
</tr>
</thead>
<tbody>
<tr>
<td>Varieties</td>
<td>NH</td>
<td>AH</td>
<td>NH</td>
</tr>
<tr>
<td>Soso Chad</td>
<td>9.4±0.19a</td>
<td>12.22±0.12a</td>
<td>7.51±0.09a</td>
</tr>
<tr>
<td>Country Ibo</td>
<td>9.4±0.17a</td>
<td>7.6±0.16a</td>
<td>9.3±0.17a</td>
</tr>
<tr>
<td>Ibo Ekona</td>
<td>8.5±0.10a</td>
<td>6.9±0.16a</td>
<td>7.6±0.09a</td>
</tr>
<tr>
<td>Country Ngdere</td>
<td>8.4±0.17a</td>
<td>9.08±0.17a</td>
<td>8.04±0.16a</td>
</tr>
<tr>
<td>Ibo Ngdere</td>
<td>8.3±0.10a</td>
<td>7±0.16a</td>
<td>nd</td>
</tr>
<tr>
<td>Kwanfere Ngdere</td>
<td>10.5±0.19a</td>
<td>12.75±0.12a</td>
<td>5.5±0.16a</td>
</tr>
</tbody>
</table>

n = 2; Means±SD; Figures in columns 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 (Hassain 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, 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 Kwanfere 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 (Armou 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 Achi and reconstituted-flour Achi had lower levels of phenolic compounds than taro flour, but this was not the case with reconstituted-flour Achi from varieties Ibo Ngdere and Kwanfere 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 flavonoid glycosides (Agbor-Egbe and Rickard, 1990).

LC-Fluorescence Procyaniadin Analysis

Procyaniadins, also called condensed tannins, are polyflavonoids in nature, consisting of chains of flavan-3-ol units (either catechin and/or epicatechin). The variation in proanthocyanadin content of taro flour, reconstituted-flour Achi and traditional achi (expressed as (+) - catechin equivalents) for the six varieties is presented in Fig. 1. Procyaniadin ranges were 7.0-11.3, 1.4-4.2 and 0.7-1.7 μg g⁻¹ for the taro flour, traditional achi and reconstituted achi, respectively. The procyaniadin 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 N’dere was not determined

<table>
<thead>
<tr>
<th>Varieties</th>
<th>Country</th>
<th>Ibo</th>
<th>Country</th>
<th>Ibo</th>
<th>Soro</th>
<th>Kwanfere</th>
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<tbody>
<tr>
<td>Sensory</td>
<td></td>
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<tr>
<td>Colour</td>
<td></td>
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<tr>
<td>Recomposed Achu</td>
<td>3.48±0.28</td>
<td>6.13±0.45</td>
<td>4.24±0.35</td>
<td>5.49±0.49</td>
<td>2.75±0.28</td>
<td>1.83±0.13</td>
</tr>
<tr>
<td>Traditional Achu</td>
<td>8.04±0.67</td>
<td>7.13±0.57</td>
<td>8.03±0.60</td>
<td>7.50±0.50</td>
<td>4.04±0.35</td>
<td>2.04±0.27</td>
</tr>
<tr>
<td>Overall acceptability</td>
<td></td>
<td></td>
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<tr>
<td>Recomposed Achu</td>
<td>4.54±0.15</td>
<td>6.74±0.40</td>
<td>4.94±0.30</td>
<td>3.94±0.29</td>
<td>4.04±0.25</td>
<td>3.04±0.15</td>
</tr>
<tr>
<td>Traditional Achu</td>
<td>7.58±0.15</td>
<td>7.13±0.50</td>
<td>7.23±0.25</td>
<td>6.04±0.24</td>
<td>5.74±0.20</td>
<td>4.54±0.15</td>
</tr>
</tbody>
</table>

Mean±SD, n = 24. Figures in a row followed by different superscript indicate significantly (p<0.05) different values determined by Dunnett's Multiple-Range Test. *p for 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 Kwanfere N’dere). The reduction in free procyanidins during preparation of traditional Achu ranged from 42% (variety Country Ekona) to 86% (variety Kwanfere N’dere). 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 corns 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 (Njogu and Omwoha, 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 (Parrinello et al., 2002). This is indicative of high levels of oxidative enzymes and/or phenolics in Kwanfre Ngdere. Only minor 'damage' to the corn 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 corns 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 Achiu.

Table 4: Correlations between browning and some chemical characteristics

<table>
<thead>
<tr>
<th>Chemical characteristic</th>
<th>Correlation coefficient with browning index (R)</th>
</tr>
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<tbody>
<tr>
<td>Reducing sugars</td>
<td>0.31</td>
</tr>
<tr>
<td>Total phenolics</td>
<td>0.86*</td>
</tr>
<tr>
<td>Free amino groups</td>
<td>0.88*</td>
</tr>
<tr>
<td>Procyanidins</td>
<td>0.91*</td>
</tr>
<tr>
<td>Decrease in free procyanidins</td>
<td>0.94*</td>
</tr>
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*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-flavonoid bonds (Lee and Whittaker, 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 Achiu, 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 Achi prepared from these flours differ with respect to such attributes such as texture, colour and physicochemical properties. Traditionally prepared Achi was in general significantly more appreciated than Achi 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 Achi. Browning was dependent on the variety used to produce the flour with variety Kwanfere 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 achi lead to the conclusion that traditional Achi characteristics cannot be attained by reconstitution of raw taro flour. However, varieties Country
Ekona, Ibo Ekona and Ibo Ngere have a high potential for directed plant breeding and subsequent processing of taro corms into achu.

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