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Production and characterization of cassava (Manihot esculenta Crantz) flours using different thermal Treatments
Interciencia, vol. 32, núm. 9, septiembre, 2007, pp. 615-619
Asociación Interciencia
Caracas, Venezuela

Available in: http://www.redalyc.org/articulo.oa?id=33932907
PRODUCTION AND CHARACTERIZATION OF CASSAVA (Manihot esculenta CRANTZ) FLOURS USING DIFFERENT THERMAL TREATMENTS

Elequina Eduvigis Pérez Sira, Mary Lares Amaiz, Zurima González and Juscelino Tovar

SUMMARY

The aim of this study was to produce flours from the edible portion of cassava (Manihot esculenta Crantz) roots, treat them by heat in different forms (normal and pressure cooking, in limited and excess water conditions, and in the presence or absence of NaCl) and characterize them in their chemical composition, physical and functional properties. The flour preparation procedure affected both the chemical composition and gelatinization profile. The control (raw flour) and heat-treated samples displayed a set-back reduction. Pregelatinized flours showed decreased consistency and absorption indices, and augmented departure time, stability, tolerance index and time to breakdown values, as compared to control sample. These flours are suggested as potential ingredients in new or conventional product development.

PRODUCCIÓN Y CARACTERIZACIÓN DE HARINAS DE YUCA (Manihot esculenta CRANTZ) USANDO DIFERENTES TRATAMIENTOS TÉRMICOS

Elequina Eduvigis Pérez Sira, Mary Lares Amaiz, Zurima González and Juscelino Tovar

RESUMEN

El objetivo de este estudio fue producir harinas de la parte comestible de la raíz de yuca (Manihot esculenta Crantz) utilizando diferentes formas de procesamiento térmico (cocción convencional y a presión, en un sistema con límite y exceso de agua, así como en ausencia y presencia de NaCl) y posteriormente caracterizarlas en su composición química, propiedades físicas y funcionales. El procedimiento de preparación afectó la composición química y el perfil de gelatinización de las harinas. La muestra control (harina cruda) y aquellas tratadas con calor mostraron una reducción de la tendencia a retrogradar. Al compararlas con la harina cruda (control), las harinas pregelatinizadas mostraron disminución en la consistencia e índice de absorción, y aumento en el tiempo de salida, estabilidad, índice de tolerancia y tiempo de ruptura. Se sugieren estas harinas como potenciales ingredientes en productos convencionales y en el desarrollo de nuevos productos.

Introduction

Cassava is in transition from a starchy staple food to a raw material for food, feed and other industries. Major development work on this crop has taken place in the artificial drying of cassava root to produce flour for the food industry. However, quality concerns during the development of these products have been the chemical composition (nutritional value), microbial counts (hygiene standards for food products), mycotoxins, and cyanogenic potential of the final or intermediary products. (Gerard et al., 1994).

In Latin America, cassava roots are mainly consumed in pregelatinized or fried forms in a variety of dishes. In Venezuela, for instance, the root is eaten in a number of ways such as soups, casabe (cassava flat cake), naiboa (cassava with raw sugar and grated white cheese) and buñuelos (fried cassava dough balls with cane-juice syrup), among others. Colombian food industry produces cassava sour starch to elaborate pandebono and buñuelos.

In order to attain an integral utilization of this tropical crop, besides the concerns pointed out by Gerard et al. (1994), further studies are necessary to evaluate the feasibility of including cassava in different food formulations. This may lead to reduced production costs of the processed goods, due to the increased use of the local crop as a raw material.

According to Abraham et al. (1984), partial replacement of wheat flour by other cereal and non-grain staple food in baked goods and other products is not always possible, unless the starchy flour replacers receive previous treatments, like gelatinization by heat. Value adding processes, such as drying and wet milling, are useful for the production of flours and starches from roots and tubers which may, in turn, be offered to the new product development industry. Thermally treated flours exhibit specific functional properties, which are determined, principally, by the raw material nature and type of process applied. The gelatinization degree is a function

KEYWORDS / Cassava Flour / Cassava Root / Functional Properties / Rheological Properties /

Received: 01/19/2007. Modified: 07/24/2007. Accepted: 07/30/2007.

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PRODUÇÃO E CARACTERIZAÇÃO DE FARINHAS DE MANDIOCA (Manihot esculenta CRantz) USANDO DIFERENTES TRATAMENTOS DE CALOR
Elevena Eduvigés Pérez Sira, Mary Lares Amaiz, Zurima González e Juscelino Tovar

RESUMO
O objetivo deste estudo foi produzir, usando-se tratamentos diferentes de calor (cozedura em um sistema da água limitada e adicional, na presença ou na ausência do NaCl e pressão), farinhas da porção comestível da raiz de mandioca (Manihot esculenta Crantz) e caracterizar-las quanto a sua composição química, física e funcional. O procedimento para preparar farinhas afetou a composição química e o perfil do gelatinização dos mesmos. O controle (farinha crua) e as amostras de farinha que foram tratadas com calor mostraram uma redução do “set back”. Ao serem comparadas com a farinha crua, as farinhas cozinhadas mostraram redução nos valores da consistência e do índice da absorção de água e um aumento nos valores do tempo de saída, do índice de tolerância à mistura e do tempo de ruptura. Estas farinhas são sugeridas como ingredientes potenciais em produtos convencionais e no desenvolvimento de novos produtos.

Materials and Methods
Roots of sweet variety of cassava (Manihot esculenta Crantz, cv. Tempanito) were obtained from the germplasm bank of the Faculty of Agronomy, Universidad Central de Venezuela. According to the producer, roots from this cultivar have a cyanogenic potential (CNp) of <20.0mg HCN per 100g dry weight.

Elaboration of raw cassava flour (Control)
Raw cassava flour was prepared following the scheme shown in Figure 1. The roots were selected, washed, peeled and cut in small chunks, which were dried in a tray drier (Mitchell Dryers, N° 655149, Manchester, UK) at 60°C for 24h, until constant moisture (<10%) was reached. The dried chunks were milled in a hammer mill (Fitz Mill Conminuting Machine, Model D, The Fitzpatrick Company; Inc., Chicago, USA) with a 00 sieve (0.5mm).

Elaboration of pregelatinized cassava flour
Raw cassava flour was used for preparing four different pregelatinized cassava flours (Figure 2), as follows:

**Batch 1. Flour pregelatinized in a limited water system.** This flour (flour A) was prepared by mixing one part of raw flour and one part of water (1:1 flour:water, w/w) in a homogenizer (Cowles Dissolver, Model 1 V-G, Serial LA 266, The Cowles Dissolver Co., Inc., Cayuga, New York, USA). The mixture was dried in a drum drier (Sterling Speedtrol, Model 20, serial 810, Sterling Power System, Inc., Indiana, USA) at 152°C (60psi) during 9sec, and milled in the above mentioned equipment.

**Batch 2. Flour pregelatinized in an excess water system.** This flour (B) was prepared by mixing one part of raw flour and ten parts of water (1:10 flour:water, w/w) in the homogenizer and pregelatinized (100°C) for 30min. The pregelatinized mixture was drum-dried and milled as described for flour A.

**Batch 3. Flour pregelatinized in a water system containing NaCl.** Flours (C) was prepared by mixing one part of raw flour, ten parts of water (1:10 flour:water, w/w) and 2% NaCl (flour weight basis) in the homogenizer. The mixture was pregelatinized at 100°C for 30min. The pregelatinized flour was drum-dried and milled as described for flour A.

**Batch 4. Flour pregelatinized in an intermediate water system and autoclaved.** This flour (D) was prepared by mixing one part of raw flour and three parts of water (1:3 flour:water) and pregelatinized under pressure in a sterilizer (Type QES-20-36-CSI, Serial 283674, American Sterilizer, Co., Erie, PA, USA) at 121°C (15lb) during 30min. The drying and milling steps on the pregelatinized mixture were performed as described for flour A. This preparation was designated “autoclaved flour”.

Three replicates (batches) of each type of flour were prepared. All flours were stored at 14 ±2°C in hermetic containers until further analysis.

Evaluation of cassava flours
The following analyses were performed to raw and processed cassava flours: moisture, ash and crude protein content, protein, amino acids, starch and amylose, fat, mineral content, fat and glucides.

Figure 1. Elaboration of raw cassava flour
Figure 2. Elaboration of pregelatinized cassava flours
(AOAC, 2000), starch and amylose contents (Juliano, 1971; MAC, 1974) starch gelatinization index (Chiang and Johnson, 1977). Color parameters L, a, b were measured using a Hunter Lab Colorimeter Model D-25; total color change “ΔE”, was calculated as $ΔE = \sqrt{ΔL^2 + Δa^2 + Δb^2}$, and blue-yellow hue variation with relation to luminosity (L/b; Hunter Lab, 1996) REVISAR.

The particle size distribution (granulometry) was determined in the pregelatinized and gelatinized cassava flours; it was expressed as the material retained (%) in the following sieves: 20, 35, 42, 60, 80 and 155 mesh (Tyler series), after agitation during 5min in a shaking sieves equipment (Controls, MTR 83111809, Milano, Italy). The rheological properties of pregelatinized cassava flours were evaluated following the Brabender Amylograph and Farinograph recommended procedures (Merca and Juliano, 1981; AACC, 2000), modifying the sample weight: 40g (14% moisture basis) in 500ml total suspension) and 150g (14% moisture basis) were used for amylograms and farinograms, respectively.

Statistical evaluation of analytical data

Data collected for each flour were analyzed by one-way ANOVA followed by the Duncan test, using the Stagraphics® software (Mannugistics, 1992). The one-way analysis of variance test was utilized to assess significant differences (P≤0.01 and P≤0.05) among samples and the Duncan multiple range test was employed to detect which sample(s) was (were) statistically different at the same significance levels.

Results and Discussion

Physical and chemical properties of cassava flours

The chemical composition of raw cassava flour (Table I) was similar to the results reported by other authors (Wal-

<table>
<thead>
<tr>
<th>Parameter (%)</th>
<th>Raw</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moisture</td>
<td>9.11 a</td>
<td>4.09 c</td>
<td>3.62 c</td>
<td>3.43 c</td>
<td>5.26 b</td>
</tr>
<tr>
<td>Ash</td>
<td>1.98 c</td>
<td>1.94 c</td>
<td>2.17 b</td>
<td>4.40 a</td>
<td>1.56 c</td>
</tr>
<tr>
<td>Crude protein (N×6.25)</td>
<td>3.48 a</td>
<td>3.14 a</td>
<td>2.94 a</td>
<td>3.0 a</td>
<td>3.10 a</td>
</tr>
<tr>
<td>Starch</td>
<td>86.25 a</td>
<td>86.25 a</td>
<td>85.63 a</td>
<td>84.75 a</td>
<td>80.00 b</td>
</tr>
<tr>
<td>Amylose</td>
<td>28.75 a</td>
<td>25.50 b</td>
<td>25.52 b</td>
<td>24.75 b</td>
<td>24.51 b</td>
</tr>
</tbody>
</table>

Mean values in rows with the same letter are not statistically different using ANOVA and Duncan multiple rank (α≤0.01). n≥3.

A considerable portion of particles in the pregelatinized samples was retained between 60 and 115 mesh sieves (Figure 3), although there was also an important amount of particles from NaCl-pregelatinized and autoclaved flours (46.6 and 52.7%, respectively) with a size below 125µm. Thus, the pregelatinized flours tended to have a small particle size (Figure 3).

The gelatinization index of pregelatinized flour in an excess of water (Table II) was 84.78%, higher than that for the flour pregelatinized under limited water conditions (79.58%). This indicates that the low water availability did not allow full starch gelatinization. The autoclaved sample showed a somewhat lower degree of gelatinization (79.55%) than the conventionally pregelatinized flour, a fact that might be related to the possible formation of retrograded enzyme-resistant starch fractions upon drum-drying of the pregelatinized flours, including the sample pregelatinized with NaCl, while their b and ΔE values increased (Table II). The decrease in the a index was noticeable in sample D (autoclaved flour). The b index was higher than the a index in all of the flours, showing a prevalence of yel-

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Raw</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
</tr>
</thead>
<tbody>
<tr>
<td>Color</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>L</td>
<td>89.10 a</td>
<td>87.46 b</td>
<td>88.42 a</td>
<td>89.22 a</td>
<td>86.16 b</td>
</tr>
<tr>
<td>a</td>
<td>1.87 c</td>
<td>1.52 a</td>
<td>1.79 a</td>
<td>1.44 a</td>
<td>0.39 b</td>
</tr>
<tr>
<td>b</td>
<td>9.90 c</td>
<td>12.52 b</td>
<td>11.19 b</td>
<td>9.92 b</td>
<td>14.66 a</td>
</tr>
<tr>
<td>ΔE</td>
<td>8.53 a</td>
<td>3.11 b</td>
<td>1.46 c</td>
<td>0.45 c</td>
<td>5.79 a</td>
</tr>
<tr>
<td>L/b</td>
<td>9.00 a</td>
<td>6.99 a</td>
<td>7.90 a</td>
<td>8.90 a</td>
<td>5.88 b</td>
</tr>
</tbody>
</table>

ΔE = $\sqrt{ΔL^2 + Δa^2 + Δb^2}$. The reported values for chemical parameters represent the mean of three measurements. Dissimilar letters in the same row indicate statistical difference (1%).
starch, also in agreement with the temperature found in the present study.

All samples showed measurable initial viscosity at 30°C, although compared to the processed flours the value for the raw sample (40BU) was not significant (Table III). This is a reasonable result, since the processed flours were submitted to an additional cooking-drying step, which increased the gelatinization degree, and it is in agreement with the gelatinization index values found in the flours. The development of initial viscosity is one of the most important characteristics of pregelatinized and gelatinized starches.

All cassava flours showed peak viscosity values ≥1000BU, which reflects the starch granule ability to swell freely until its physical rupture (Table III). Similar results were obtained by Matos and Pérez (2003) for isolated cassava starch. After peak viscosity, the values decreased significantly along the rest of the test, reaching minimal values after 30min at 90°C. This decrease, termed breakdown, provides an index of starch granule fragility under heating and shear stress environment. The breakdown values were lower in the C (processed in excess water with addition of NaCl) and D (autoclaved) flours, while it increased in the sample pregelatinized in an excess of water (A), as compared to raw flour. All viscosity values at 90°C were higher than corresponding viscosities measured after 30min at 90°C (Table III). The setback values, which provide an idea about the retrogradation tendency of a particular starch, were negative for all the flours, including the raw one. Judged on this basis, the regular cooking process and/or the drying step reduced the apparent retrogradation tendency, while autoclaving and cooking with previous addition of salt seemed to increase it. The viscosity values after 30min at 50°C were relatively similar to those recorded at 50°C, with the exception of the raw flour, where there was a moderate increase of this parameter (Table III). Except for the autoclaved sample, the consistency of pregelatinized flours was higher than in the raw flour.

**Rheological Properties**

**Amylograms.** The initial gelatinization temperature of raw cassava flour was 67.5°C (Table III), similar to that reported by Lorenz and Kulp (1982), Éggleston et al. (1993) and, Aryee et al., (2006), who recorded gelatinization temperatures in the range of 66.8 to 70.4°C for 31 varieties of cassava root. Moreover, Pérez et al., (1998) reported 68°C as initial gelatinization temperature for isolated cassava starch, also in agreement with the temperature found in the present study.

All samples showed measurable initial viscosity at 30°C, although compared to the processed flours the value for the raw sample (40BU) was not significant (Table III). This is a reasonable result, since the processed flours were submitted to an additional cooking-drying step, which increased the gelatinization degree, and it is in agreement with the gelatinization index values found in the flours. The development of initial viscosity is one of the most important characteristics of pregelatinized and gelatinized starches.

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**Farinograms.** The raw flours failed to develop dough in the farinograph, which prevented its evaluation. Regarding the pregelatinized flours, there was an increase in departure time, stability, tolerance index and time to breakdown, as well as a reduction in absorption percentage of pregelatinized samples as compared to the control (flour A; Table IV). Arrival time and dough development time, on the other hand, remained unchanged. Apparently, the thermal treatments applied caused modifications in cassava flours, probably altering interactions between some of their constituents, which favored better dough tolerance to mixing.

**TABLE III**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Raw</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
</tr>
</thead>
<tbody>
<tr>
<td>IGT (°C)</td>
<td>67.5</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Initial viscosity (UB)</td>
<td>40</td>
<td>760</td>
<td>&gt;1000</td>
<td>&gt;1000</td>
<td>&gt;1000</td>
</tr>
<tr>
<td>Peak viscosity (UB) (P)**</td>
<td>&gt;1000</td>
<td>&gt;1000</td>
<td>&gt;1000</td>
<td>&gt;1000</td>
<td>&gt;1000</td>
</tr>
<tr>
<td>Viscosity 90°C (UB)**</td>
<td>800</td>
<td>360</td>
<td>240</td>
<td>760</td>
<td>750</td>
</tr>
<tr>
<td>Viscosity 30min at 90°C (UB)**(H)</td>
<td>340</td>
<td>200</td>
<td>140</td>
<td>610</td>
<td>650</td>
</tr>
<tr>
<td>Viscosity 50°C (UB) (C)</td>
<td>440</td>
<td>360</td>
<td>250</td>
<td>750</td>
<td>750</td>
</tr>
<tr>
<td>Viscosity 30min at 50°C (UB)</td>
<td>205</td>
<td>330</td>
<td>250</td>
<td>740</td>
<td>750</td>
</tr>
<tr>
<td>Breakdown (UB) (P-H)**</td>
<td>660</td>
<td>800</td>
<td>860</td>
<td>390</td>
<td>350</td>
</tr>
<tr>
<td>Setback (UB) (C-P)**</td>
<td>-560</td>
<td>-640</td>
<td>-750</td>
<td>-250</td>
<td>-250</td>
</tr>
<tr>
<td>Consistency (UB) (C-H)**</td>
<td>100</td>
<td>160</td>
<td>110</td>
<td>140</td>
<td>100</td>
</tr>
</tbody>
</table>

*IGT: Initial gelatinization temperature (°C), UB: Brabender units. **: Brabender amylograph. ★★: Merca and Juliano (1981).*

**TABLE IV**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
</tr>
</thead>
<tbody>
<tr>
<td>Absorption (%)</td>
<td>126.3 a</td>
<td>101.5 b</td>
<td>109.9 b</td>
<td>104.6 b</td>
</tr>
<tr>
<td>Arrival time (min)</td>
<td>3.0 a</td>
<td>2.5 b</td>
<td>2.5 b</td>
<td>3.0 a</td>
</tr>
<tr>
<td>Dough development time (min)</td>
<td>5.0 a</td>
<td>4.5 b</td>
<td>5.0 a</td>
<td>5.0 a</td>
</tr>
<tr>
<td>Departure time (min)</td>
<td>10.0 c</td>
<td>16.5 a</td>
<td>16.0 a</td>
<td>13.5 b</td>
</tr>
<tr>
<td>Tolerance index (BU)</td>
<td>30.0 a</td>
<td>20.0 b</td>
<td>20.0 b</td>
<td>20.0 b</td>
</tr>
<tr>
<td>Stability (min)</td>
<td>7.0 c</td>
<td>14.0 a</td>
<td>13.5 a</td>
<td>10.5 b</td>
</tr>
<tr>
<td>Time to breakdown (min)</td>
<td>11.0 d</td>
<td>19.0 a</td>
<td>15.0 b</td>
<td>13.5 c</td>
</tr>
</tbody>
</table>

*: Brabender Farinograph. BU: Brabender units. Mean values with same letter are not statistically different using ANOVA and Duncan multiple rank (α ≤0.01). n ≥3.


Conclusions

Thermal pregelatinization methods applied in this study to cassava flour seemed to cause certain modifications in their physical, chemical and rheological properties. Major changes occurred in granularity, color and, specially, rheological properties.

The specific functional properties of heat-processed cassava flours could simplify their incorporation into certain products formulation such as, for instance, baked goods. This may lead to better utilization of local starch sources and a potential cost reduction via substitution of imported ingredients.

ACKNOWLEDGEMENTS

The present study was conducted under grants 03.32.3873.2004 from the Consejo de Desarrollo Científico y Humanístico (CDCH), Universidad Central de Venezuela, and 200200495 from the Fondo Nacional de Ciencia y Tecnología (FONACIT), Venezuela.

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