The resistant starch content of some cassava based Nigerian foods

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Abstract

The resistant starch (RS) content of some Nigerian cassava varieties and staples, “fufu”, “garri” and “abacha” processed from them were determined. Tubers of six varieties studied contained different concentrations of resistant starch, ranging from 5.70% in TMS 4(2)1425 to 7.07% in the TMS 30,572. Processing using traditional methods reduced the RS content in all cassava based foods compared with tubers from which they were processed. RS concentration was reduced by an average of 70.4% in “fufu”, 52.8% in “garri” and 35.85% in “abacha” for the four varieties of cassava tested. Cassava processing steps involving fermentation were responsible for the major reductions in concentration of RS. Steps involving cooking or frying, resulted in increase in concentrations of RS relative to other processing methods. Modifications of traditional methods of processing such as the addition of bitter leaf during retting or the addition of oil to mash during dewatering of “garri” affected RS concentrations in foods studied. Results of this work suggest that manipulation of processing methods and conditions employed during cassava processing can be used to improve RS concentration in cassava based foods, thus making them more functional.

1. Introduction

Resistant starch is defined as that fraction of starch, which escapes digestion in the small intestine and passes into the large intestine where it is more or less fermented by gut microflora. It is considered a functional component of food due to the health benefits it confers following its consumption.

Many studies suggest that resistant starch (RS) intake decreases postprandial glycaemic and insulimic responses (Bodinham et al., 2008; Brown, 1996; Li et al., 2010), lowers plasma cholesterol and triglyceride concentrations (Liu and Ogawa, 2009), increases satiety and decreases fat storage (Chiu and Stewart, 2013). Its beneficial effect on human type 2 diabetes has also been proposed (Bodinham et al., 2014). The prevalence of diabetes in Nigeria is expected to grow from 1,707,000 in the year 2000 to 4,835,000 in 2030 (WHO, 2015) RS as a prebiotic can promote the growth of beneficial microorganisms such as bifidobacteria, which exert a lot of beneficial effects on human body. Butyrate, a short chain fatty acid (SCFA) produced as a result of fermentation of RS has been hypothesized to reduce the risk of colon cancer and to benefit inflammatory bowel disease (Sajilata et al., 2006). These properties make RS an important functional fiber component of food, which can be exploited in the prevention and management of chronic non communicable diseases.

The nature of RS in foods is variable and is classified on the basis of its botanical source and processing. Resistant starch (RS) is naturally found in starchy foods such as potato, corn and rice and is classified into four subtypes based on its physicochemical properties. Type 1 (RS1) is physically unavailable starch. Amylolytic enzymes have no access to starch accumulated in undamaged plant cells as the gastrointestinal tract lacks enzymes capable of degrading the components of plant cell walls. Type 2 (RS2) is native granular starch, such as that found in potato and banana. Type 3 (RS3) is retrograded starch made by cooking/cooling processes on starchy materials occurring in the form of water-insoluble semi-crystalline structures. As a result of retrogradation, more thermostable structures are formed by amylose rather than by amylopectin. The amount of resistant starch produced this way
increases along with the increasing amylose content of starch. Type 4 (RS4) is chemically modified starch (Waclaw, 2004).

According to the FAO (2013), Nigeria is the world’s largest producer of cassava (about 54 million metric tons per annum), 95% of which is also consumed in the country. Major staple cassava based foods consumed in Nigeria are “garri”, “fufu” and “abacha”. “Garri” is granular flour with a sticky sour fermented flavor made from gelatinized fresh cassava tubers. “Fufu” is sticky dough made by pounding cooked fermented roots into a paste. “Abacha” is sun dried fermented cooked cassava chips.

Current methods of processing cassava into these foods remain essentially traditional and targeted at detoxifying cyanogenic glycosides and development of aroma. Several research studies have elucidated the biological and chemical mechanisms involved in these processes and considerable effort has been directed towards methods for the improvement of the nutritional value of these foods. However, as far as we know, very little attention has been paid to the processing of cassava for the purpose of improving its functional characteristics. Functional foods are foods that not only provide nutritional value but also provide health benefits when consumed in a regular diet.

This study is intended to draw attention to this area of need, provide some baseline data about the occurrence of RS in cassava and to highlight the existence of the possibility of exploiting processing methods to improve the functional characteristics of our cassava based foods.

2. Materials and methods

2.1. Cassava varieties

Six improved cassava varieties of the Tropical Manihot Species (TMS); TMS 30,555, TMS 117, TMS 693, TMS 30,572, TMS98/0505 and TMS 4(2) 1425, as identified by the International Institute for Tropical Agriculture (IITA) Ubiaja field, Edo State, were used for this study. Cassava roots were harvested from nine-month old plants.

2.2. Processing of cassava roots into cassava based food products

Traditional methods, which have been extensively studied and widely reported in literature, were used to process the various cassava based foods. "Garri" was processed using the method reported by Oluwole et al. (2004). Cassava roots were peeled, washed and grated into a mash. The mash was stuffed into a clean sack. The cassava mash filled sack was left to stand under the weight of a solid slab at room temperature for 72 h to achieve both dewatering and fermentation. The dewatered mash was sieved using a sieve to break the mash cake into smooth granules and then fried to obtain "garri" granules. Oil "garri" was prepared by a modification of this process, which comprised the addition of palm oil (10 g/kg) to grated cassava mash before dewatering and garrification.

The method described by Ogbo (2006) was adopted for the processing of "fufu". Cassava roots were peeled, washed, cut into pieces of approximately 10 cm length \( \times \) 5 cm diameter and soaked in plastic containers. The container was left under room temperature to ferment until tubers retted. The retted roots were hand pulverized, wet sieved and dewatered in a clean sack. Modifications of this method used by some processors were performed by the addition of 10 g mild steel nails and 5 g of bitter leaves/L of steep water.

The method of Ogbo et al. (2004) was employed to process "abacha". The cassava roots were washed, boiled for 10 mins, peeled and sliced as thinly as possible using a hand held shredder. The slices were soaked in water for 48 h, washed, drained and spread in mats to sun dry. Modification of the process comprised boiling the cassava root for 20 instead of 10 min.

The schematic diagram of the methods for processing of the cassava based foods is presented in Fig. 1.

2.2.1. Determination of resistant (RS) and digestible (DS) starch

Samples used for the determination of resistant and digestible (non-resistant) starches were prepared as follows. Cassava tubers were diced, and the various processed samples of foods broken up as appropriate and then dried in the oven (Gallenkamp) at 50 °C until they attained less than 15% moisture. Moisture content of the samples was determined by method 967.03, AOAC (2005). The dried samples were subsequently ground into fine powder using a hand operated grinder.

Resistant starch was determined using a kit assay (K- RSTAR, Megazyme Bray, Co. Wicklow, Ireland). This kit follows the protocols of the AOAC method 2002.02 (2003) procedures explicated by Niba and Hoffman (2003). Samples (100 ± 0.5 mg) prepared as already described were incubated with pancreatic \( \alpha \)-amylose (10 mg/ml) solution containing amylglucosidase (AMG) for 16 h at 37 °C with constant shaking. After hydrolysis, samples were washed thrice with ethanol (99% v/v and 50% ethanol) followed by centrifugation. The separated pellet from supernatant was further digested with 2 M KOH. Digested pellet and supernatant were separately incubated with AMG. Glucose released was measured using a glucose oxidase-peroxidase (GOPOD) reagent kit (K- GLOX, Megazyme Bray, Co. Wicklow, Ireland) by absorbance at 510 nm against the reagent blank. The glucose content of the supernatant and digested pellet were used in calculation of digestible starch (DS) and Resistant Starch (RS) respectively by applying the factor of 0.9.

2.2.2. Determination of cyanide content of the cassava based foods

Total cyanides in dried food samples were analyzed spectrophotometrically using the picroc paper method of Bradbury et al. (1999). The method involved the immobilization of linamarase in a round filter paper disc containing phosphate buffer at pH 6.0. The disc was placed in a flat bottomed plastic bottle. A 100 mg portion of the powdered food sample was added to the filter paper and 0.5 ml of distilled water was added. This was followed immediately by the addition of a
yellow picrate paper attached to a plastic strip to the bottle. The bottle was closed immediately with a screw lid and allowed to stand for 24 h at room temperature. The picrate paper was removed and immersed in 5 ml distilled water in a test tube with occasional gentle stirring for 30 min. An unreacted picrate paper was taken as blank. The absorbance of the solution was measured against the blank at 510 nm. The total cyanide content in ppm was calculated by multiplying the absorbance by 396.

2.3. Statistical analysis

Data were expressed as mean values ± standard deviation of three replicate measurements. Variation in levels of resistant starch among cassava varieties were determined by a one way analysis of variance (ANOVA) followed by Duncan’s multiple range test (P < 0.05).

3. Results and discussion

All the processed cassava based foods showed characteristics typical of their types. The result of the HCN content of the food samples showed 8 mg/kg, 5 mg/kg and 1.03 mg/kg for “garri”, “fufu” and “abacha” respectively, which were below the maximum level of tolerance (10 mg/kg) recommended by the FAO/WHO (1991).
3.1. Resistant starch content of different varieties of cassava

Table 1 shows that all the cassava varieties tested contained resistant starch (RS) and digestible starch (DS). Moongngarm (2013) in a study in Thailand had reported similar values of RS for cassava (RS, 9.69 ± 1.28 and DS, 55.99 ± 4.92). Statistical analysis of the data showed no significant differences in RS or DS contents at (P < 0.05) among the different varieties. However, TMS 30,572 showed nominally, the highest RS and lowest DS concentrations, when compared with the other varieties.

3.2. Resistant starch content of cassava based foods

RS content in foods is influenced by intrinsic and extrinsic factors as well as processing techniques (Alsaffar, 2011). Processing of cassava into the various Nigerian staples, "fufu", "garri" and "abacha" resulted in decreases in concentrations of RS relative to the tubers they were processed from (Tables 2–4). No significant differences (P < 0.05) were observed in the rate of RS loss among the four varieties of cassava tested following processing into all three types of foods. However, processing of cassava into the different foods resulted in losses of RS to significant degrees (Tables 2–4). The average loss in RS for the four varieties of cassava processed into “fufu” was 70.4%, while average losses for “garri” and “abacha” were 52.8% and 35.85%, respectively.

The major unit operations employed in the processing of cassava can be subdivided into two groups for the purpose of this report. Operations such as size reduction, soaking or steeping and dewatering may enhance conditions for chemical and physical reactions, which occur during processing. However, it is the second group of operations involving fermentation, cooking/frying, and drying that are most likely to define the influence of processing on the RS content of foods.

The fermentation of cassava is generally considered a lactic acid fermentation, but which also involves the activity of sundry Gram positive bacteria as well as yeasts and molds. Several microorganisms including the lactic acid bacteria are known to possess the ability to ferment RS. Fermentation would therefore represent a major process of loss of RS during the processing of cassava. Loss of RS was highest in "fufu", which was fermented 4–6 days when compared with "garri" (3 days) and "abacha" (2 days). The role of microbial activity in the loss of RS during the processing of cassava is further demonstrated in the modifications of retting by the addition of nails, used by processors to shorten retting time and bitter leaf (Vernonia amygdalina) to reduce odor. The enhancement of microbial activity by the addition of nails (Ogbo, 2006), resulted in greater loss of RS when compared with normally processed fufu while bitter leaf on the other hand, known to possess anti-microbial potentials (Oboh and Masodje, 2009) inhibited some microbial activities thus permitting retention of higher levels of RS in this sample compared with normally processed “fufu”. Decreases in RS concentration following fermentation have also been observed in other foods such as sorghum flour (AbdElmoneim et al., 2004) and legume based fermented foods (Yadav et al., 2007).

Modification of the traditional processing method by the addition of oil to mash was observed to result in an increase in the RS content of "garri". Generally, the presence of other ingredients in the food matrix such as protein, fat, dietary fiber and minerals are known to affect the formation of RS in food. Presence of lipids specifically results in the formation of starch–lipid complexes, which resist enzymatic digestion of starch (Sharma et al., 2008). Furthermore, the presence of oil in the fermenting mash may have affected microbial activity adversely.

Cooking and frying are processes well known to play significant roles in the formation or depletion of RS in foods depending on how they are applied. Boiling is believed to induce gelatinization, thereby permanently disrupting the amylase–amylopectin structure of the starch complex and thus making it more readily accessible by digestive enzymes. However, as these foods cool, the possibility of forming R3-resistant starches (retrograded starches) increases. This occurs as the starches undergo re-crystallization due to the formation of intermolecular hydrogen bonds. Furthermore, boiling also results in the leaching of free sugars, thus resulting in relative increases of overall RS concentration in such foods (Englyst and Cummings, 1982; Englyst and Cummings, 1987). Fried potato products, especially French fries, have been shown to contain more resistant starch than cooked potatoes (Garcia-Alonso and Goni, 2000). However, Nigudkar (2014) working with various rice and wheat flour menus has noted that dry heat treatment decreased RS content of a food preparation.

Table 2
Starch content of "fufu" processed from different cassava varieties.

<table>
<thead>
<tr>
<th>Cassava variety</th>
<th>TMS 30,555</th>
<th>TMS 30,572</th>
<th>TMS 693</th>
<th>TMS 98/0505</th>
</tr>
</thead>
<tbody>
<tr>
<td>&quot;Fufu&quot;, processed normally</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Resistant starch (g/100 g)</td>
<td>2.21 ± 0.07</td>
<td>2.39 ± 0.09</td>
<td>1.59 ± 0.06</td>
<td>1.91 ± 0.08</td>
</tr>
<tr>
<td>Average% loss in RS due to processing relative to tuber</td>
<td>68.2</td>
<td>66.2</td>
<td>76.5</td>
<td>72.5</td>
</tr>
<tr>
<td>Digestible starch (g/100 g)</td>
<td>56.1 ± 2.0</td>
<td>53.6 ± 1.8</td>
<td>61.7 ± 2.1</td>
<td>58.4 ± 1.7</td>
</tr>
<tr>
<td>Average% loss in DS due to processing relative to tuber</td>
<td>11.5</td>
<td>5.8</td>
<td>16.1</td>
<td>14.7</td>
</tr>
<tr>
<td>&quot;Fufu&quot;, processed with nail added during retting</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Resistant starch (g/100 g)</td>
<td>1.64 ± 0.09</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&quot;Fufu&quot;, processed with bitter leaf added during retting</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Resistant starch (g/100 g)</td>
<td>2.40 ± 0.14</td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

Means in rows are not significantly different at (P < 0.05).
The two cassava based food products, "garri" and "abacha", which received these treatments showed higher RS values than "fufu", which did not (Tables 3 and 4). The higher values of RS observed in "abacha" compared with "garri" may have been on account of the shorter duration of fermentation received by this product. Modification of "abacha" processing by boiling for a longer (20 min) did not result in a significant change of RS concentration. Observations similar to these have been reported with potatoes (Kingman and Englyst, 1994; Gormley and Walshe, 1999) and various rice and wheat menus (Nigudkar, 2014).

Drying, particularly under the sun as in the processing of "abacha" is akin to storage, which is associated with increases in RS concentration in foods. The transformation of RS during storage appears to be affected by temperature. Cooked potato storage at a temperature approximating 0°C led to the formation of more resistant starch than at room temperature (Gormley and Walshe, 1999). Drying may have contributed to the higher levels of RS in "abacha" compared with "garri".

### 3.3. Digestible starch content of cassava based foods

The levels of DS in the various foods were also affected by processing as shown by its losses to significantly different extents (Tables 2–4). Average loss of DS in "fufu", "garri" and "abacha" were 12%, 40.6% and 53.2% respectively. The implication of this is that "fufu" contained 57.4%, while "garri" and "abacha" contained respectively, 38.7% and 30.6% of digestible starch. The lower levels of DS in "garri" and "abacha" are attributable to enhanced losses of DS due to heat treatments received by these foods. Heat gelatinizes starch, thus improving its water solubility. "Abacha", which received a fermentation and then a washing step after cooking expectedly showed the lowest content of DS. The lower the DS level of food, the lower is the risk that its consumption will elicit diseases associated with diabetes.

### 4. Conclusion

This study has shown that cassava varieties cultivated in Nigeria contain some quantities of RS like cassava and other tubers in other parts of the world. Generally, processing of cassava into "fufu", "garri" and "abacha" using traditional methods result in losses of some quantities of both RS and DS originally present in the tuber. These losses occur to different extents because of the differences in processing treatments employed to make these foods. Additionally, modifications of the traditional process used by local processors may reduce or exacerbate losses of RS and DS during processing. These observations suggest that manipulation of processing methods and conditions can be used to increase RS and reduce DS, thus making cassava based foods more functional. Availability of more functional cassava based foods to Nigerians will contribute to efforts by authorities to reduce the prevalence of diabetes.

### References


Niba, L.L., Hoffman, J., 2003. Resistant starch and β-glucan levels in grain sorghum (Sorghum bicolor) and influenced of soaking and autoclaving. Food Chem. 81, 113–118.


