Production and evaluation of Ighu from selected cassava varieties using a motorized shredder—a response surface analysis

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Abstract
Cassava varieties, TME419, TMS30572, and TMS98/0505, were planted and harvested at 3-month intervals of 10, 13, and 16 months, respectively. A central composite response surface design was used to study the effects of the variables cassava variety, harvesting time, and shredding aperture on selected physicochemical properties of Ighu samples. Regression models showed that the experimental variables had significant ($P \leq 0.05$) effects on the hydrogen cyanide, moisture content, thickness, and width of dry Ighu. Minimum values obtainable for the physicochemical properties were 8.1195 mg/kg (10-month, 3-mm shredding aperture from TMS98/0505), 7.58% (13-month, 3-mm shredding aperture from TME419), 0.19 mm (13-month, 3-mm shredding aperture and from TMS30572), and 0.99 mm (16-month, 3-mm shredding aperture from TME419) for hydrogen cyanide, moisture content, thickness, and width, respectively. In addition, Ighu produced from 3-mm shredding aperture (TMS30572) at 10-month harvest was the most preferred of all the samples.

Introduction
Cassava (Manihot esculenta), a short-lived perennial plant, stands between 1 and 5 m tall. The main food product is the tuberous roots, which can be retrieved from the soil (Lebot 2009), and it is for these roots that the crop is cultivated (Bradbury and Holloway 1988). The roots deteriorate quickly from the internal heat generated from high respiration rate of the tissue (Ikujenlola and Opawale 2007), high moisture content (Hahn 1989), and subsequent infection and rotting by microbes. This rapid postharvest deterioration means that processing is more important than for any other root crop (Andrew 2002).

Traditionally, cassava roots are processed by various methods into numerous products and utilized in various ways according to the peoples’ culture and food habits (Akoroda and Arene 1990; Uzuegbu and Eke 2000). The main products derived from processing cassava are garri, Ighu (abacha), cassava flour, fufu or akpu, and other cassava-based products (Oji 1994). Shredded cassava known variously within the eastern part of Nigeria as Ighu, Nsisa, eberahejiapu/jigbo, mpataka, asharasha, abacha, and jiapummiri in different lgbo dialects (Njoku and Banigo 2006) is a convenient food and a local delicacy. Dry Ighu is usually soaked in water and eaten as a dessert with coconut, groundnut, palm kernel, dry fish, and meat (Ihekoronye and Ngoddy 1985). It could also be presoaked or partially wetted with water, prepared into a meal with vegetable, palm oil or its emulsion, dry fish, ugba (fermented oil bean), onion, and beans as a local salad (Adepoju and
The cassava varieties were washed and steamed in water for 20 min on a standard 80-cm diameter gas ring and later cooled. When cool, they were peeled. The peeled, steamed cassava tubers were placed into the hopper of the shredding machine and shredded over the shredding plate which has protruding perforations designed to shred the peeled tubers as they slide on top of it because of its reciprocating motion. The shredded tuber strands were discharged beneath the shredding plate to the collection base. Three different shredding disk apertures (3, 6, and 10 mm) of the machine were used for the shredding process. The cassava shreds were soaked in potable water overnight during which time the water was changed twice. They were then thoroughly washed and the washed samples were spread in very thin layers on a flat basket constructed from palm frond material and sundried. The width and thickness of the dry Ighu were measured with Vernier calipers and recorded. Three replicates of each test were carried out and the average value was taken. The hydrogen cyanide and moisture content of the Ighu samples were determined according to Onwuka (2005).

Sensory evaluation was conducted on the cassava shreds using 20 panelists composed of staff and students of Michael Okpara University of Agriculture, Umudike, Nigeria. The coded samples of Ighu produced using the machine were evaluated for appearance, texture (ease of breakage), thickness, and general acceptability using a 9-point Hedonic scale which ranged from 1 (like extremely) to 9 (dislike extremely), with five as neither like nor dislike (Iwe 2010).

**Materials and Methods**

**Source of cassava samples**

Cassava roots of TME419, TMS98/0505, and TMS30572 (Agadagba species) were obtained from the National Root Crops Research Institute (NRCRI), Umudike, Umuahia Abia State, Nigeria. These roots were monitored from planting and harvested at 10, 13, and 16 months, respectively.

**Preparation of Ighu**

The Statistical Package for Social Sciences (SPSS—version 20, IBM SPSS Statistics 20, IBM Corporation, Armonk, NY) was used to obtain mean, standard deviation and analysis of variance (ANOVA) was done and judged for significance at $P \leq 0.05$. Means were separated using Duncan’s multiple range test. Optimization was done using the Optimization toolbox of Matlab R2012a software.

**Results and Discussions**

The results of the physicochemical properties of dry Ighu samples are shown in Table 1.
Hydrogen cyanide (mg/kg)

There was a significant difference in the HCN content of the dry Ighu samples and they varied from 8.20 to 9.83 mg/kg. Ighu produced from the cassava varieties TMS30572 10-month, 3-mm shredding aperture and TMS98/0505 13-month, 3-mm shredding aperture had the lowest HCN content while Ighu produced from the cassava variety TMS30572 16-month, 10-mm shredding aperture had the highest HCN content. The low value of HCN in the dry Ighu samples is brought about by the soaking and the drying processes and the cassava varieties used are improved varieties which have been reported to have low cyanide content (Nweke et al. 1999). Rosling (1987) observed that the cyanide content of food products decreased by drying and processing operations like soaking and cooking. Washing could reduce the HCN content of cassava (Kay et al. 1977). HCN values are lower than the safe level of 10 mg/kg recommended by FAO/WHO (Adindu et al. 2003) and the higher HCN content (9.83 mg/kg) of TMS30572 (10-mm shredding aperture) could be attributed to the short drought experienced at the 16th month of harvest (December). Ernesto et al. (2002) found that flour produced from cassava grown in years with average rainfall in northern Mozambique contained, on average, 40 ppm total cyanide, compared with about 120 ppm in a drought year. Both of these values are well above the World Health Organization safe level of 10 ppm, but the threefold increase in dry years is alarming (Ernesto et al. 2002; Cardoso et al. 2005).

Regression analysis showed that the quadratic effect of shredding aperture and cassava varieties significantly \((P \leq 0.05)\) affected the HCN content of dry Ighu samples. And they accounted for 95.3% of the variation in the HCN content of dry Ighu samples. ANOVA showed that shredding aperture and interaction between harvesting time and shredding aperture significantly affected the HCN content of the Ighu samples.

With reference to optimization, the minimum possible HCN value is 8.1195 mg/kg and to obtain this, the time of harvesting should be 10 months, shredding aperture should be 3 mm, and the choice cassava variety should be TMS98/0505. The response surface curves showing the effects of the experimental variables on the HCN content of dry Ighu samples are shown in Figures 1–3.

Moisture content

Moisture content of the dry Ighu samples varied from 7.60% (TMS30572 16-month, 3-mm shredding aperture) to 9.21% (TMS98/0505 10-month, 3-mm shredding aperture).
There was a significant difference in the moisture content of the dry Ighu samples. Mohammed (2011) reported moisture content of 11.2–12% for dry cassava chips. Processing the cassava tuber into a dry form reduces the moisture content and converts it into a more durable and stable product with less volume which makes it more transportable (IITA 1990; Ugwu 1996). The moisture content of the dry Ighu samples was low—less than 10%, making them very stable for storage up to 12 months (FAO 1995).

Regression analysis showed that the linear and quadratic effects of harvesting time and shredding aperture and quadratic effect of cassava variety had a significant effect ($P \leq 0.05$) on the moisture content of dry Ighu samples and these variables accounted for 93.2% variation in the moisture content of dried Ighu samples. ANOVA showed that the variables had a significant effect ($P \leq 0.05$) on the moisture content of the dry Ighu samples. Response surface plots of the effects of the variables are shown in Figures 4–6. The plots show that moisture content reduced with a reduction in shredding aperture. The lowest moisture content of 7.58% was obtained when the shredding aperture was 3 mm from cassava variety TME419. However, from optimization, the lowest moisture content obtainable was 7.58%, from the cassava variety TME419 (13-month) shredded with 3-mm shredding aperture.

**Thickness**

Cassava variety TME419 16-month, 3-mm shredding aperture had the lowest thickness of 0.20 mm while cassava variety TMS98/0505 10-month, 6-mm shredding aperture had the highest thickness of 0.59 mm. Thickness of the dry Ighu samples differed significantly.
Results of the regression of data on thickness of dry Ighu samples showed that the linear effects of harvesting time and interaction between harvesting time and cassava variety were significant \((P \leq 0.05)\) and these accounted for 97.9% variation in the thickness of dry Ighu samples. ANOVA showed that all the variables except shredding aperture were significant. Response surface curves of the effects of the variables are shown in Figures 7–9. From optimization, the minimum thickness of dry Ighu obtainable was 0.19 mm and it was obtained from 3-mm shredding aperture, cassava variety TMS 30572 and at 13 months of harvest.

**Width**

The width of the dry Ighu samples ranged from 1.01 mm (TME419 16-month, 3-mm shredding aperture) to 5.65 mm (TME419 10-month, 10-mm shredding aperture). There was a significant difference in the width of the dry Ighu samples. It was observed that shredding aperture increased with width of the Ighu samples. This is attributable to the larger shredding surfaces which produced larger cassava shreds. The same observation was made by Etoamaihe (2010).

Regression results showed that the linear and quadratic effects of shredding aperture significantly affected the width of dry Ighu samples. From ANOVA, harvesting time and shredding aperture were significant. The response surface curves (Figs. 10–12), confirmed that with the increase in shredding aperture the width of cassava shreds produced by the machine also increased. From optimization, the minimum width of dried cassava shreds obtainable was 0.99 mm and it was obtained at the 16th month from the cassava variety TME419 and 3-mm shredding aperture.
Sensory evaluation of dry Igbaru samples

Table 2 shows the sensory evaluation results of dry Igbaru samples. Cassava variety TMS 30572, harvested at 10 months and shredded with 3-mm aperture, was preferred to all the other samples in all the sensory attributes evaluated. Ekwu et al. (2009) reported that consumers of abacha—also known as igbaru, mpataka, eberejiapu, nsisa, asharasha, and jiapummiri—do not like thick ones. They observed that it does not enhance effective mixing of the ingredients and condiments used in the preparation of abacha meal.

Appearance

The regression results of data on appearance of dry Igbaru samples show that cassava varieties and interaction between harvesting time and cassava varieties significantly affected ($P \leq 0.05$) the appearance of dry Igbaru samples. Fermentation alters the sensory characteristics of the cassava roots in a way that is often appreciated by local consumers (Ukwuru and Egbonu 2013). Oluwole (2009) reported that physical appearance is an important feature of food products. He added that consumers “eat with their eyes” and use the appearance of foods to predict quality.

ANOVA showed the effects of the other independent variables to be significant ($P \leq 0.05$). The studied independent variables accounted for 73.0% of the variation in appearance of the dry Igbaru samples. Response surface plots of the effects of the variables are shown in Figures 13–15.

Texture

Regression analysis showed that the experimental variables had no significant effect ($P \geq 0.05$) on the texture of dry...
**Table 2. Effects of processing conditions on the sensory properties of dry Ighu.**

| Samples | X₁ | X₂ | X₃ | Appearance | Texture (ease of breakage) | Thickness | General acceptability |
|---------|----|----|----|------------|-----------------------------|-----------|-----------------------|
| 1       | 10 | 3  | TME419 | 5.45<sup>bcd</sup> | 4.25<sup>abc</sup> | 4.45<sup>def</sup> | 4.85<sup>abcd</sup> |
| 2       | 10 | 3  | TMS30572 | 2.15<sup>a</sup> | 2.60<sup>b</sup> | 2.55<sup>c</sup> | 1.95<sup>d</sup> |
| 3       | 10 | 10 | TME419 | 7.55<sup>b</sup> | 6.55<sup>ab</sup> | 6.00<sup>b</sup> | 7.25<sup>c</sup> |
| 4       | 10 | 10 | TMS30572 | 5.25<sup>bcd</sup> | 5.10<sup>cde</sup> | 5.60<sup>bc</sup> | 5.35<sup>cd</sup> |
| 5       | 16 | 3  | TME419 | 3.80<sup>gh</sup> | 4.15<sup>gh</sup> | 3.85<sup>abcd</sup> | 4.15<sup>def</sup> |
| 6       | 16 | 3  | TMS30572 | 2.85<sup>gh</sup> | 3.50<sup>gh</sup> | 3.70<sup>gh</sup> | 3.65<sup>gh</sup> |
| 7       | 16 | 10 | TME419 | 5.25<sup>bcd</sup> | 4.90<sup>def</sup> | 5.60<sup>bc</sup> | 5.75<sup>b</sup> |
| 8       | 16 | 10 | TMS30572 | 5.55<sup>bc</sup> | 4.80<sup>defg</sup> | 5.55<sup>bc</sup> | 5.55<sup>bc</sup> |
| 9       | 10 | 6  | TMS98/0505 | 5.55<sup>bc</sup> | 5.45<sup>cde</sup> | 5.65<sup>bc</sup> | 5.90<sup>c</sup> |
| 10      | 16 | 6  | TMS98/0505 | 5.15<sup>bcde</sup> | 5.20<sup>bcde</sup> | 5.45<sup>bc</sup> | 5.80<sup>c</sup> |
| 11      | 13 | 3  | TMS98/0505 | 3.05<sup>gh</sup> | 3.50<sup>gh</sup> | 3.40<sup>gh</sup> | 3.10<sup>g</sup> |
| 12      | 13 | 10 | TMS98/0505 | 7.30<sup>bc</sup> | 6.70<sup)c</sup> | 7.05<sup>bc</sup> | 7.30<sup>bc</sup> |
| 13      | 13 | 6  | TME419 | 4.45<sup>bcd</sup> | 4.10<sup>dfg</sup> | 3.60<sup>gh</sup> | 4.05<sup>gh</sup> |
| 14      | 13 | 6  | TMS30572 | 5.75<sup>b</sup> | 5.70<sup>bcd</sup> | 5.85<sup>bc</sup> | 5.50<sup>c</sup> |
| 15      | 13 | 6  | TMS98/0505 | 4.85<sup>bcd</sup> | 4.95<sup>cd</sup> | 5.10<sup>cde</sup> | 4.75<sup>bcde</sup> |
| 16      | 13 | 6  | TMS98/0505 | 4.35<sup>bcd</sup> | 5.25<sup>b</sup> | 5.05<sup>bcd</sup> | 4.80<sup>bcde</sup> |
| 17      | 13 | 6  | TMS98/0505 | 4.05<sup>b</sup> | 4.30<sup>gh</sup> | 4.55<sup>bcd</sup> | 4.25<sup>def</sup> |
| 18      | 13 | 6  | TMS98/0505 | 4.15<sup>defg</sup> | 3.40<sup>gh</sup> | 3.45<sup>gh</sup> | 4.00<sup>gh</sup> |
| 19      | 13 | 6  | TMS98/0505 | 5.15<sup>bcd</sup> | 5.30<sup>bcd</sup> | 5.65<sup>c</sup> | 4.90<sup>cde</sup> |
| 20      | 13 | 6  | TMS98/0505 | 5.45<sup>b</sup> | 5.90<sup>b</sup> | 5.50<sup>c</sup> | 5.75<sup>c</sup> |
| 21      | 13 | 6  | TMS98/0505 | 4.70<sup>bcd</sup> | 5.40<sup>bcd</sup> | 5.70<sup>c</sup> | 5.75<sup>c</sup> |
| 22      | 13 | 6  | TMS98/0505 | 5.80<sup>b</sup> | 6.00<sup>b</sup> | 5.25<sup>bc</sup> | 5.85<sup>c</sup> |
| 23      | 13 | 6  | TMS98/0505 | 5.20<sup>bcd</sup> | 5.10<sup>bcde</sup> | 4.65<sup>bcde</sup> | 5.55<sup>bc</sup> |

Means in the same column bearing different superscripts are significantly different (P ≤ 0.05). X₁, time of harvesting (months); X₂, shredding aperture (mm); X₃, cassava variety.

The production of Ighu using a motorized shredder showed that the variables had no significant effect (P ≥ 0.05) on the texture of dry Ighu samples. ANOVA showed that the variables had no significant effect on the texture of dry Ighu samples. Texture is measured by the sense of feeling by the skin to determine such textural attributes as crispness, hardness or softness, chewiness, fibrousness, sliminess, etc. (Oluwole 2009). The independent variables accounted for 50% of the variation in the texture of dry Ighu samples.

**Thickness**

Regression analysis showed that the variables had no significant effect on the thickness of dry Ighu samples. ANOVA indicated that the variables had a significant effect on the thickness of dry Ighu samples. The variables accounted for 57% of the variation in the thickness of the dry Ighu samples.

**General acceptability**

From regression analysis, the variables had no significant effect on the general acceptability of dry Ighu samples. ANOVA showed that the effects of the independent variables on the general acceptability of dry Ighu samples were significant and they accounted for 66% of the variation in the general acceptability of the dry Ighu samples. Oluwole (2009) reported that the general/overall acceptability is the combination of all other sensory parameters and that if a product records acceptable quality levels with regard to most of the other parameters, it is expected that such a product will have good overall acceptability.

**Conclusion**

Ighu was produced from selected cassava varieties harvested at various maturity regimes. There was a significant difference (P < 0.05) in the physicochemical and sensory properties of dry Ighu. All Ighu samples had low HCN content, making them safe for human consumption, and low moisture content, making them suitable for long-term storage. The HCN content of the dry Ighu varied from 8.20 to 9.83 mg/kg and regression analysis showed that the quadratic effects of shredding aperture and cassava varieties had significant effects on the HCN content of dry Ighu. Optimization showed that minimum HCN obtainable was 8.1195 mg/kg. Moisture content varied from 7.60% to 9.21%. Linear and quadratic effects of harvesting time and shredding aperture and quadratic effect of cassava variety had significant effects on the moisture content of dry Ighu. Thickness of dry Ighu ranged from 0.20 to 0.59 mm. Regression analysis showed that linear effects of harvesting time and interaction...
between harvesting time and cassava variety had significant effects on the thickness of dry Ighu. Width of dry Ighu ranged from 1.01 to 5.65 mm. Width of Ighu samples increased with an increase in shredding aperture. Linear and quadratic effects of shredding aperture significantly affected width. Cassava varieties and interaction
between harvesting time and cassava varieties significantly affected the appearance of dry Ighu. Regression analysis showed that experimental variables had no significant effect on texture, thickness, and general acceptability of dry Ighu. In addition to the above data, Ighu produced from the cassava variety TMS30572 (10-month) using the 3-mm shredding aperture was the most preferred of all the samples in terms of the sensory attributes evaluated.

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Conflict of Interest
None declared.

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