Optimization of Chemical Properties of Cassava Varieties Harvested at Different Times using Response Surface Methodology

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Received 24 September 2015; Published online 12 December 2015

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Abstract

Three improved cassava varieties-TME 419, TMS 98/0505 and TMS 30572 were monitored from planting and harvested at three months interval-10, 13 and 16months respectively. Selected chemical properties of the cassava varieties- hydrogen cyanide, amylose, moisture and starch contents were determined at each harvesting regime. These chemical properties were optimized and a faced central composite design (k=2) was employed to study the effect of experimental variables on the chemical properties. Moisture content ranged from 49.96% (TME 419-16months) to 70.21% (TMS 98/0505-13months). Hydrogen cyanide ranged from 40.92mg/kg (TME 419-13months) to 47.85mg/kg (TMS 98/0505-16months). Amylose content of the cassava varieties varied from 17.64% (TMS 30572-10months) to 23.11% (TMS 98/0505-16Months). Starch content ranged from 13.30% (TMS 98/0505-16months) to 32.39% (TME 419-13months). However, optimization showed that the following minimum and maximum values were obtainable from the chemical properties studied: minimum moisture content 55.94% (TME 419-16months), maximum moisture content 70.89% (TMS 98/0505-13months). Minimum hydrogen cyanide 41.03mg/kg (TME 419-13months), maximum hydrogen cyanide obtainable was 46.48mg/kg (TMS 30572-16 month). Minimum amylose obtainable was 18.31% (TMS 30572-13months) and the maximum amylose obtainable was 21.70% (TMS 98/0505-10 months). Minimum percentage of starch obtainable was 17.99 from the cassava variety TMS 98/0505 harvested at the 16th month while the maximum obtainable was 32.32, from the cassava variety TME 419 harvested at the 13th month.

Keywords: Time of Harvest; Cassava Varieties; Chemical Properties; Response Surface Methodology; Optimization

1. Introduction

Among the root and tuber crops, cassava is perhaps the most important food and cash crop and the
most widely grown (Asiedu, 1992). Its importance is increasing in Africa because of its diverse uses, cheapness and its tolerance to environmental stresses such as drought, fire, low soil fertility and its high productivity where other crops fail (Asiedu, 1992). As a food crop, cassava has some inherent characteristics which make it attractive especially to the small holder farmers in Nigeria. Firstly, it is rich in carbohydrates especially starch and consequently has a multiplicity of end users (Albert et al, 2005). Besides starch, the cassava tuber contains some soluble carbohydrates- glucose and sugar (1-3%), these convey a pleasant sweet taste to the tubers of the non-poisonous strains (Ospina and Wheatley, 2007). As a cash crop, cassava generates cash income for the largest number of households and in comparison with other food crops (such as yam or maize), cassava demands less of farmers resources-it is propagated from stems (which is not edible), tolerates moisture stress, makes limited soil fertility demands and does not require elaborate storage facilities (Ihekoronye, 1999).

The chemical composition of the cassava roots- amylose, hydrogen cyanide, starch content, moisture content etc. differs considerably according to variety, age of the harvested crop, soil conditions, climate and other environmental factors during cultivation (Okogbenin et al., 2003). Cassava can be continuously harvested and marketed throughout the year and this provides a consistent supply of product available for immediate processing at a fairly predictable price throughout the year making it preferable to other more seasonal crops such as grains, peas, beans and other food security crops (Ihekoronye, 1999). By knowing the best stage to harvest cassava with optimum chemical properties, it would be possible to schedule harvesting, handling and marketing operations efficiently. Also, the starch and amylose composition of staple food materials such as cassava determines the processing and consumption characteristics of their food products (Almazan, 1992). Previous investigators have determined to a limited extent the effect of time of harvest and variety on the chemical properties of different cassava varieties and none has investigated the range of harvesting periods used in this work. Also, none has optimized the chemical properties using the variables- cassava varieties and time of harvest.

Response surface methodology is a powerful and efficient mathematical approach widely applied in the optimization of processes (Adinarayana and Ellaiah, 2002; Puri et al., 2002). The designs capable of generating a response surface include Central Composite and Box-Behnken designs (Lucas, 1994). The face centered central composite design is simpler to carry out because it requires operating a process at only three level settings of each variable thereby eliminating unexpectedly large experimental error (Lawson and Madrigal, 1994). The aim of this work was to optimize selected chemical properties of selected improved cassava varieties using response surface methodology and investigate the effect of variety and time of harvest on these chemical properties.

### 2. Material and Methods

#### Chemicals and Reagents

All chemicals and reagents used in the experiments were of analytical grade and obtained from Sigma-Aldrich (St Louis MO, USA).
Cassava samples

Cassava roots of TME 419, TMS 98/0505 and TMS 30572 (Agadagba species) were obtained from the National Root Crops Research Institute (NRCRI), Umudike, Abia State, Nigeria. These roots were monitored from planting and harvested at 10, 13 and 16 months respectively. The harvesting periods coincided with the wet (June and September) and part of the dry season (December).

Isolation of starch

Starch was extracted from the cassava varieties according to the method described by Abera and Kumar (2003) with modifications. Peeled fresh cassava roots of each of the cassava varieties was shredded by a motorized cassava shredding machine at a speed of 650rpm, using 3mm shredding aperture of the machine. The cassava shreds were blended (Model Master Chef 65, Moulinex France) with water for 5 minutes and sifted through a 200 mesh screen. The residue was rinsed twice to remove remnants of starch. The slurry was left for 3 hours before decanting the liquor. The starch was suspended three times in water (the last suspension in distilled water) and non-starch materials removed by decanting the supernatant. The starch was then dried in a hot air oven at 45°C for 18h to attain 11-12% moisture content (wb), sifted with 200 mesh sieve, placed in a polythene bag and stored at room temperature until required.

Determination of hydrogen cyanide, moisture and starch content of the cassava varieties

Triplicate samples were analyzed for Hydrogen cyanide, moisture and starch content using standard official methods (AOAC, 1990).

Determination of amylose content of the cassava varieties

Amylose content of starch of the cassava varieties was determined according to Onwuka (2005). The absorbance was read at 625nm in a Spectro-photometer after standing for 5 minutes. A standard curve using different concentrations of pure amylose (2mg-10mg) was prepared. The amylose concentration of the test sample was extrapolated from the standard curve using the absorbance value.

Experimental design and statistical analysis

A faced central composite design (k=2) was employed to study the linear, interactive and quadratic effects of the independent experimental variables. The statistical design with the model fitted to each set of data is shown below:

\[ Y = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \beta_{11} x_1^2 + \beta_{22} x_2^2 + \beta_{12} x_1 x_2 + \epsilon \]  

(1)

Key:

Y= dependent response variables; moisture content, starch content, amylose and hydrogen cyanide of cassava varieties, \( \beta_0 \) = intercept, \( \beta_{1, \ldots, 2} \) = estimated regression coefficients, \( x_1, x_2 \) = independent variables in the model (cassava variety-cv, time of harvest-th), \( \epsilon \) = random error.
The experimental variables were of three levels as shown in Table 1 while the experimental design with coded terms is as shown in Table 2. The center points were \( \text{th} = 13 \text{months}, \text{cv} = \text{TMS 98/0505} \); corner points were \( \text{th} = 16 \text{months}, \text{cv} = \text{TMS 30572} \) while the star points were \( \text{th} = 10 \text{months}, \text{cv} = \text{TME 419} \). Runs 1-8 were performed once while run 9 was performed seven times (Box et al., 2005). A total of 16 experimental runs were generated.

**Table 1** Experimental variables used in the faced-central composite design \((k=2)\) for determination of chemical properties

<table>
<thead>
<tr>
<th>Independent variables</th>
<th>Variable levels</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cassava varieties (x_1)</td>
<td>A ( \text{B} ) C</td>
</tr>
<tr>
<td>Time of harvesting (x_2(\text{months}))</td>
<td>10 13 16</td>
</tr>
</tbody>
</table>

Where \(A=\) cassava shred from TME 419  
\(B=\) cassava shred from TMS 98/0505  
\(C=\) cassava shred from TMS 30572 \((\text{Agadagba})\).

-1 = low factor setting  
1 = high factor setting  
0 = mid-point

**Table 2** Experimental design for determination of chemical properties

<table>
<thead>
<tr>
<th>Run</th>
<th>(X_1(\text{cassava variety}))</th>
<th>(X_2(\text{time of harvesting}))</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>-1</td>
<td>-1</td>
</tr>
<tr>
<td>2</td>
<td>-1</td>
<td>1</td>
</tr>
<tr>
<td>3</td>
<td>1</td>
<td>-1</td>
</tr>
<tr>
<td>4</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>5</td>
<td>-1</td>
<td>0</td>
</tr>
<tr>
<td>6</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>7</td>
<td>0</td>
<td>-1</td>
</tr>
<tr>
<td>8</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>9</td>
<td>0</td>
<td>0</td>
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<tr>
<td>10</td>
<td>0</td>
<td>0</td>
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<tr>
<td>11</td>
<td>0</td>
<td>0</td>
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<tr>
<td>12</td>
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<td>13</td>
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<tr>
<td>14</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>15</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>16</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

**Statistical and data analysis**

Data on each run was statistically regressed and analyzed for variance using Minitab software. Statistical significance was accepted at 5% probability levels \((p \leq 0.05)\). Plots of the fitted significant responses were made using Matlab software \((\text{version r}2012a)\) to visualize these effects more clearly.
Statistical Package for Social Sciences (SPSS – version 20) was used to obtain mean and standard deviation. Means were separated using Duncan’s Multiple Range Test (DMRT). Optimization was done using the Optimization toolbox of Matlab r2012a software (Garcia-Guzman et al., 2013).

3. Results and Discussion

The results of the chemical properties of the cassava varieties and varietal effect on the chemical properties of cassava harvested at different times are shown in Table 3 and Table 4 below. Time of harvesting had significant effect on all the chemical properties studied except hydrogen cyanide (HCN) and amylose (Table 3). Varietal differences significantly affected the chemical properties of the cassava varieties studied (Table 4).

Table 3 Effect of time of harvesting on the chemical properties of cassava varieties

<table>
<thead>
<tr>
<th>Variety/Age</th>
<th>Moisture content (%)</th>
<th>HCN(mg/kg)</th>
<th>Amylose (%)</th>
<th>Starch content (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>TMS 98/0505</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10 Months</td>
<td>66.95±3.82&lt;sup&gt;b&lt;/sup&gt;</td>
<td>43.68±3.33</td>
<td>22.04±0.44</td>
<td>23.20±3.5&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>13 Months</td>
<td>70.21±0.14&lt;sup&gt;a&lt;/sup&gt;</td>
<td>44.34±4.92</td>
<td>20.51±2.91</td>
<td>29.16±13&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>16 Months</td>
<td>62.02±0.3&lt;sup&gt;b&lt;/sup&gt;</td>
<td>47.85±1.34</td>
<td>23.11±0.18</td>
<td>13.30±3.8&lt;sup&gt;c&lt;/sup&gt;</td>
</tr>
<tr>
<td>TMS 30572</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10 Months</td>
<td>61.08±11&lt;sup&gt;b&lt;/sup&gt;</td>
<td>42.50±0.00</td>
<td>17.64±1.09</td>
<td>27.10±25&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>13 Months</td>
<td>68.59±8.5&lt;sup&gt;a&lt;/sup&gt;</td>
<td>42.68±4.5</td>
<td>19.58±3.14</td>
<td>30.23±33&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>16 Months</td>
<td>58.04±1.65&lt;sup&gt;b&lt;/sup&gt;</td>
<td>46.44±3.25</td>
<td>18.73±1.43</td>
<td>13.56±1.51&lt;sup&gt;c&lt;/sup&gt;</td>
</tr>
<tr>
<td>TME 419</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10 Months</td>
<td>61.05±1.41&lt;sup&gt;a&lt;/sup&gt;</td>
<td>41.75±0.28</td>
<td>21.30±0.49</td>
<td>30.30±1.84&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>13 Months</td>
<td>62.85±1.98&lt;sup&gt;a&lt;/sup&gt;</td>
<td>40.92±1.91</td>
<td>20.58±2.18</td>
<td>32.39±42&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>16 Months</td>
<td>49.96±1.67&lt;sup&gt;b&lt;/sup&gt;</td>
<td>44.85±6.15</td>
<td>19.84±0.74</td>
<td>13.49±0.06&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

a, b, c - means in the same column bearing different superscripts are significantly different (p≤0.05)

Table 4 Effect of varietal differences on the chemical properties of selected cassava varieties

<table>
<thead>
<tr>
<th>Variety/Age</th>
<th>Moisture content (%)</th>
<th>HCN(mg/kg)</th>
<th>Amylose (%)</th>
<th>Starch content (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>10 Months</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TMS 98/0505</td>
<td>66.95±3.82&lt;sup&gt;a&lt;/sup&gt;</td>
<td>43.68±0.33</td>
<td>22.04±0.44</td>
<td>23.20±0.35&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>13 Months</td>
<td>61.08±0.14&lt;sup&gt;a&lt;/sup&gt;</td>
<td>42.50±0.00</td>
<td>17.64±1.09</td>
<td>27.10±0.25&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>16 Months</td>
<td>62.05±1.41&lt;sup&gt;a&lt;/sup&gt;</td>
<td>41.75±0.28</td>
<td>21.30±0.49</td>
<td>30.30±1.84&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>13 Months</td>
<td>70.21±0.01&lt;sup&gt;a&lt;/sup&gt;</td>
<td>44.32±4.92</td>
<td>20.51±2.91</td>
<td>29.16±0.13&lt;sup&gt;c&lt;/sup&gt;</td>
</tr>
<tr>
<td>16 Months</td>
<td>68.59±0.85&lt;sup&gt;a&lt;/sup&gt;</td>
<td>42.68±0.45</td>
<td>19.58±3.14</td>
<td>30.23±0.33&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>10 Months</td>
<td>62.85±1.98&lt;sup&gt;b&lt;/sup&gt;</td>
<td>40.92±1.91</td>
<td>20.58±2.18</td>
<td>32.39±0.42&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>16 Months</td>
<td>62.02±0.03&lt;sup&gt;a&lt;/sup&gt;</td>
<td>47.85±1.34</td>
<td>23.11±0.18</td>
<td>13.30±0.38&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
</tbody>
</table>
Moisture content

Moisture content ranged from 49.96% (TME 419) to 70.21% (TMS 98/0505). Ukwuru and Egbonu (2013) reported that like other roots and tuber crops, cassava has a high water content (65%) which is probably the major limitation in improving the utilization potential. The differences in moisture could be attributed to differences in variety and also to differences in the extent of drying (Chen et al., 2003a). However, differences in the extent of drying could not apply in the present study because all varieties were subjected to the same treatments, and were hence equally affected by any variation in environmental conditions. The moisture content of the different varieties rose after 10 months, peaked at the 13th month after which they fell at the 16th month. All the varieties had low moisture content at the 16th month. Harvesting period coincided with the wet (June and September) and part of the dry season (December). High moisture content at the 13th month is as a result of rainfall while low moisture content at the 16th month can be attributed to the dry season. This is in agreement with the work of Kawano et al. (1987) who observed that cassava root dry matter (RDMC) tended to be higher at the dry season (i.e. low moisture content) than at the wet season (i.e. high moisture content). Pathama et al. (2003) reported that at 14-16 months there is a decrease in the moisture content of the cassava varieties studied.

Regression models developed showed that linear and quadratic effect of cassava varieties and time of harvesting and interaction between cassava varieties and time of harvesting significantly affected (p≤0.05) moisture content and they accounted for 98.7% of the variation in moisture content. The resulting polynomial after removing non-significant terms for the analysis becomes:

\[
\text{Moisture content} = -44.3 - 6.41cv + 18.7th + 0.671cv.th - 5.61cv^2 - 0.760th^2
\]  

From the response surface curve (Fig. 1), 66.7% moisture was obtained from cassava variety TMS 98/0505 at the 10th month of harvest. However, optimization showed that the minimum moisture content obtainable was 55.94% and from the cassava variety TME 419, at the 16th month of harvest while the maximum moisture content obtainable was 70.89%, from the cassava variety TMS 98/0505 harvested at the 13th month.
The hydrogen cyanide content of the cassava varieties ranged from 40.92mg/kg (TME 419-13months) to 47.85mg/kg (TMS 98/0505-16months). All the varieties had low hydrogen cyanide - less than 50mg/kg because they are improved varieties (Albert et al., 2005). The precise plant age at harvest had no effect on the hydrogen cyanide content of the cassava varieties but varietal differences did (Tables 3 and 4). Reports have shown that age, variety and environmental conditions influence the occurrence and concentration of hydrogen cyanide in various parts of the cassava plant and at different stages of development respectively (Albert et al., 2005). This means that some varieties generally considered sweet (low cyanide content) can have a high cyanogenic potential under certain conditions (Westby, 2002). Bokanga et al. (1994) reported that total cyanide levels in roots increase in a year of low rainfall or drought due to water stress on the plant. Santisopasri et al. (2001) reported that the cyanogen concentration of stressed plants harvested in a high rainfall period was lower than those from non-stressed plants harvested during a low rainfall period. The increase in cyanogens in cassava products during periods of drought is thought to be the result of high endogenous levels in the source plants, but much of the evidence to support this is anecdotal (Mlingi et al., 1992).

Regression models developed showed that linear and quadratic effect of time of harvesting and quadratic effect of cassava varieties significantly affected (p≤0.05) hydrogen cyanide content and they accounted for 98.6% of the variation in the HCN content. The resulting polynomial after removing non-significant terms for the analysis becomes:

Fig. 1. Response surface curve of the effects of time of harvesting and cassava varieties on the moisture content of cassava.

Hydrogen cyanide

The hydrogen cyanide content of the cassava varieties ranged from 40.92mg/kg (TME 419-13months) to 47.85mg/kg (TMS 98/0505-16months). All the varieties had low hydrogen cyanide - less than 50mg/kg because they are improved varieties (Albert et al., 2005). The precise plant age at harvest had no effect on the hydrogen cyanide content of the cassava varieties but varietal differences did (Tables 3 and 4). Reports have shown that age, variety and environmental conditions influence the occurrence and concentration of hydrogen cyanide in various parts of the cassava plant and at different stages of development respectively (Albert et al., 2005). This means that some varieties generally considered sweet (low cyanide content) can have a high cyanogenic potential under certain conditions (Westby, 2002). Bokanga et al. (1994) reported that total cyanide levels in roots increase in a year of low rainfall or drought due to water stress on the plant. Santisopasri et al. (2001) reported that the cyanogen concentration of stressed plants harvested in a high rainfall period was lower than those from non-stressed plants harvested during a low rainfall period. The increase in cyanogens in cassava products during periods of drought is thought to be the result of high endogenous levels in the source plants, but much of the evidence to support this is anecdotal (Mlingi et al., 1992).

Regression models developed showed that linear and quadratic effect of time of harvesting and quadratic effect of cassava varieties significantly affected (p≤0.05) hydrogen cyanide content and they accounted for 98.6% of the variation in the HCN content. The resulting polynomial after removing non-significant terms for the analysis becomes:
HCN = 68.6 - 0.227cv - 4.36th + 0.0700cv.th - 2.24cv^2 + 0.192th^2 (3)

From the response surface curve (Fig. 2), 47.99mg/kg HCN was obtained from cassava variety TMS 30572 at the 16th month of harvest. However, optimization shows that the minimum hydrogen cyanide obtainable was 41.03mg/kg from the cassava variety TME 419, at the 13th month while the maximum hydrogen cyanide obtainable was 46.48mg/kg, from the cassava variety TMS 30572 harvested at the 16th month.

Fig. 2. Response surface curve of the effects of time of harvesting and cassava varieties on the hydrogen cyanide content of cassava.

**Amylose**

Amylose contents of the cassava varieties varied from 17.64 % (TMS 30572-10months) to 23.11% (TMS98/0505-16Months). Richard et al. (1991) reported amylose content of 13.6 to 23.8% in some cassava varieties studied and amylose content of fresh cassava starch was reported to range between 22.6 to 26.2% for five Indian cassava varieties (Moorthy et al., 1992). Amylose content did not show any significant variations (p≥0.05) with age of the crop, however varietal differences were noticed (Tables 3 and 4). However, Apea-Bah et al. (2011) observed that neither age at harvest nor varietal difference significantly affected the amylose content (16.48 to 36%) of four cassava varieties studied. Tsakama et al. (2010) noticed a significant difference in amylose content among eleven cassava varieties with values ranging from 10.5% to 18.6%. Amylose content of cassava is believed to be influenced genetically and neither age of the plant nor environmental factors played a major role in determining it (Ihekoronye & Ngoddy, 1985). The difference in amylose content among starches may be due to different factors such as genotype, environmental conditions, cultural practice etc. (Cottrell et al., 1995).
Regression models developed shows that quadratic effect of cassava varieties significantly affected (p≤0.05) amylose content and accounted for 69.9% of the variation in amylose content of cassava. The resulting polynomial after removing non-significant terms for the analysis becomes:

\[
\text{Amylose} = 35.4 - 3.72cv - 2.29\text{th} + 0.213cv\cdot\text{th} - 1.69cv^2 + 0.0897\text{th}^2
\]  

(4)

From the response surface curve (Fig. 3), amylose content of 21.72% was obtained from the cassava variety TMS 98/0505 harvested at the 16\textsuperscript{th} month. However, optimization showed that the minimum percentage of amylose obtainable was 18.31 from the cassava variety TMS 30572, at the 13\textsuperscript{th} month of harvest while the maximum obtainable was 21.70, from the cassava variety TMS 98/0505 harvested at the 10\textsuperscript{th} month.

![Fig. 3. Response surface curve of the effects of time of harvesting and cassava varieties on the amylose content of cassava.](image)

**Starch content**

Starch content of the cassava varieties ranged from 13.30% (TMS 98/0505-16months) to 32.39% (TME 419-13months). Ikegwu et al. (2009) reported that the percentage starch of 13 improved cassava cultivars studied ranged from 48.25 to 52.05%. There was a significant difference (p≤0.05) in starch content among the varieties and the harvesting periods studied. Safo-Kantanka and Oseiminta (1996) observed that statistically significant differences were established between the varieties and age at harvest in the amount of starch that could be recovered from equal quantities of fresh root. Higher starch content was recorded during the harvesting periods of 10 and 13months respectively than the last (16\textsuperscript{th} month). The low starch content at the 16\textsuperscript{th} month (December) could be attributed to water stress (short drought). Vilai et al. (2001) reported that
starch content is markedly influenced by environmental conditions especially water stress. They observed that cassava plants deprived of water were characterized of lower starch compared to cassava plants without water stress. On the other hand, Safo-Kantanka and Osei-minta (1996) observed that the cassava variety (91934) which produced the lowest RMRDC (highest moisture content) also had the lowest starch content. However, Tsakama et al. (2010) reported that starch extraction is not 100% efficient in any case and that starch extraction is said to depend on the softness of the roots on harvest.

Regression models developed showed that linear and quadratic effect of time of harvesting and quadratic effect of cassava varieties significantly affected (p≤0.05) starch content and they accounted for 98.5% of the variation in starch content. The resulting polynomial after removing non-significant terms for the analysis becomes:

\[ \text{Starch content} = -141 - 4.42cv + 28.3th + 0.272cv.th + 2.47cv^2 - 1.18th^2 \]  

(5)

From the response surface curve (Fig. 4), starch content of 30.83% was obtained from the cassava variety TME 419 harvested at the 13th month. However, optimization showed that the minimum percentage of starch obtainable was 17.99 from the cassava variety TMS 98/0505, at the 16th month of harvest while the maximum obtainable was 32.32, from the cassava variety TME 419 harvested at the 13th month.

![Response surface curve of the effects of time of harvesting and cassava varieties on the starch content of cassava.](image)

**Fig. 4.** Response surface curve of the effects of time of harvesting and cassava varieties on the starch content of cassava.

### 4. Conclusions

The result of this study shows the effect of time of harvesting and variety on selected chemical properties of selected cassava varieties. Moisture content of the cassava varieties peaked at the 13th
month (September) as a result of rainfall and dropped at the 16th month (December) due to the short dry season. Both variety and time of harvesting significantly affected (p≤0.05) the moisture content of the cassava varieties. All the cassava varieties had low HCN content and harvesting times did not significantly affect (p≥0.05) their HCN content but varietal effects were noticed. Analysis of variance showed significant differences in starch content among the cassava varieties and the harvesting periods studied and greater starch content was recorded at the 10th and 13th month of harvest. Amylose content did not show any significant variations with age of the cassava varieties but varietal differences affected it.

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