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# Effects of Harvest Age and Pre-Treatment on the Nutritional Composition of Some Released Cassava Mosaic Resistant Varieties in Ghana

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***Abstract:***
*The proximate composition of three cassava varieties recently released by the Crop Research Institute of Ghana, were evaluated at different ages of harvest. The nutritive values of the flour produced from these cassava roots were studied to find out how they were affected by age, variety and pre-treatment. The pre-treatment methods used were chipping, toasting, chipping and steeping in citric acid, grating, and steeping in citric acid and toasting. Results obtained from the study showed that the nutritive values of the cassava flour were affected by age, variety and pre-treatment methods. The protein content from various factor combinations ranged from 1.30% to 3.06% while the moisture content ranged from 0.28% to 5.12% and ash content from 0.26% to1.79%. The carbohydrate content ranged from 87.57% to 93.56% while fat content ranged from 0.24% to3.17% and fiber content from 1.29% to 3.47%. The flour samples had satisfactory quality attributes in terms of protein, fat, fibre, ash, carbohydrate, and moisture content.*

***Keywords:*** *Cassava, pre-treatment, variety, harvest age, proximate composition*

## 1. Introduction

The quality of any particular food material is greatly influenced by its nutritional composition. Cassava which is one of the most important staple foods in most West African countries is basically a major source of carbohydrate and contains other food nutrients such as fats, proteins, ash, moisture fibre, as well as trace elements in smaller quantities. It is estimated that about 40% of all the calories consumed in Africa is provided by cassava which ranks second only to cereal grains as chief source of energy in the diet of most West African countries (IITA,2005; Ngoddy,1989).

In most countries of the West African sub-region, rapid urban growth and development place a dynamic challenge to cassava products, and market development for cassava foods will continue to increase. Although cassava roots are processed by several traditional methods, which vary widely from region to region into products such as *gari, lafun, landang, fufu, akara, okpokpo garri, ampesi, lulu,* syrups, dextrins, chips, starch and alcohol (Safo-Kantanka and Acquistucci, 1996; Etudaiye et al., 2009), high quality cassava flour that can replace wheat and other imported flours in tropical countries (Wheatley and Best, 1991) are highly encouraged for wide adoption. The production of high quality cassava flour involves a systematic pre-treatment and drying process which could affect the nutritional composition of the end product (Eje et al., 2015; Eriksson et al., 2014.)

Cassava has been reported to have a peculiar characteristic of possessing a wide harvesting window which ranges from 9 to 24 months and could act as a famine reserve crop. It however continues to go through a lot physiological changes which affect the nutritional composition during this underground storage period.

It is therefore important to investigate how pre-treatment methods and the age at which the roots are harvested affect the nutrient composition of flour from three of the newly released varieties in Ghana.

## 2. Materials and Methods

### *2.1. Materials*

*Ampong, Broni and Otuhia* cassava varieties recently released by the Crop Research Institute of Ghana were used for this research work. The tubers were harvested at 10 months, 12months and 14 months.

### *2.2. Experimental Design*

A 3x3x5 factorial design in CRD (Completely Randomised design) was used for the evaluation of the effect of harvest age, variety and pre-treatment on the nutrient composition of the processed cassava flour. The principal factors in the study were the variety, harvest age and pre-treatment. The data generated were statistically analysed using Genstat 12$^{th}$ edition. General Analysis of Variance (ANOVA) and mean separation were performed using Fischer's Least Significant Difference of means to determine significant differences at 5 % probability level.

### *2.3. Processing of Cassava Flour*

The cassava roots were processed at the Food and Post-Harvest Engineering Laboratory of Kwame Nkrumah University of Science and Technology Kumasi, Ghana.

Tubers from each of the three cassava varieties were divided into five portions, then washed and peeled. Each of the five portions was subjected to a distinct pre-treatment prior to drying. The lots were dried in a mechanically ventilating cross flow dryer at a temperature of 70$^{o}$C. The pre-treatment was carried out in the following ways.

1. Chipping pre-treatment (T1): The tubers were chipped to a size of 10× 10 × 50mm as recommended by Floreze and Morini (2000).
2. Toasting pre-treatment (T2): The tubers were grated with a mechanical grater, and dewatered by placing under a load for about 15hours after which it was screened and then toasted in a toasting pan for 6min (Eje et al.2015).
3. Chipping and steeping in citric acid solution (T3): The third samples were chipped to size of 10 × 10 × 50mm and steeped in citric acid solution (20%m/v) for 12h Owuamanam (2007).
4. Grating Pre-treatment (T4): For the fourth samples, the cassava tubers were grated and dewatered by placing it under a load for about 15hours.
5. Steeping in citric acid and Toasting (T5): The fifth samples (T5) were sliced and steeped in citric acid solution (20%m/v) before grating, dewatering and toasting for 6min using a toasting pan.

The pre-treated samples were dried to a constant weight in a mechanically ventilating cross flow dryer.

The dried samples were ground into fine flour with a laboratory mill and the excess fibres were removed by passing the flour through a 250μm sieve in accordance with the recommendations of the African Organization for Standardization (ARSO,2012).

### *2.4. Proximate Analysis*

#### 2.4.1. Determination of Moisture Content

The moisture content of the cassava flour was determined using the AOAC (1990) method of moisture determination. 5g of each cassava flour sample was weighed in triplicate into previously dried and weighed moisture cans. The cans were placed in a thermostatically controlled oven which was pre-set to a temperature of 105 °C. The samples were left in the oven for 24 hours during which they attained constant weight. The moisture content was then determined using the following expression.

$$\%moisture = \frac{(weight\ of\ can+fresh\ sample)-(weigh\ of\ can+dry\ sample)}{weight\ of\ fresh\ samples} \text{ x } 100 \qquad (2.1)$$

#### 2.4.2. Crude Protein Determination

The crude protein content was determined using the Kjeldahl method. This method involves various stages of sample digestion, distillation and titration. 2.0g of the cassava flour sample was weighed and transferred into a 500ml Kjeldahl flask. One spatula full of catalyst Kjeldahl (potassium sulphate + copper sulphate + selenium powder mixture) together with 20ml of concentrated sulphuric acid ($H_2SO4$) were added to the flask and thoroughly shaken to ensure that the flour becomes wet.

The flask was then slowly heated in a digestion burner in a Kjeldahl room to digest the sample. The heating is continued until the boiling ceases and the solution becomes clear green. The flask and its content were cooled to room temperature after which the digested flour was transferred into a 50ml volumetric flask and distilled ammonia-free water was added to the 50ml mark. The Kjeldahl flask was thoroughly rinsed with successive small quantities of distilled water.

The steam generator of the distillation apparatus was flushed before use by boiling distilled water in it with the connections arranged to circulate through the condenser for about 10minutes. 25 ml of 2% boric acid was pipette into a 250ml conical flask with about two drops of mixed indicator added to the flask. The conical flask and its contents were placed under the condenser such that the condenser tip was totally immersed in the boric acid solution. Ten millimetre (10.0) ml of the digested sample solution was mixed with 20ml of 40% sodium hydroxide (NaOH) solution in a decomposition flask and the Kjeldahl distillation unit was set up. The distillation process was allowed to continue for about 3minutes as the liberated ammonia is collected over the boric acid.

The solution was titrated with 0.01N HCl unit until the first appearance of violet colour was noticed. The same process was used to run a reagent blank with equal volume of distilled water. The nitrogen content of the sample was then calculated for all the samples using the following formula.

$$N\ (gkg^{-1}) = \frac{(ml\ HCL - ml\ blank) x Normaility\ of\ Hcl\ x 14.01}{weight\ of\ sample\ (g) x 10} \quad (2.2)$$

The percentage protein was obtained by multiplying the nitrogen content (N) by the appropriate factor of 6.25.

2.4.3. Fat determination (Ether extract)

The fatty acid ester of glycerol (fat) content of the sample was obtained by extracting the fat with ether using the AOAC (1990) official method of fat determination. Two grams of the dried cassava sample was folded in a piece of filter paper which was placed in the thimble of a Soxhlet apparatus.

A piece of cotton wool was placed at the top of the condenser to avoid the escape of solvent during extraction. The fat was extracted from the sample with petroleum ether for 2 hours by gentle heating without interruption.

The extraction flask was dismantled after cooling and the ether was then evaporated on a water bath until no odour of the ether was noticed. The flask was cooled overnight at room temperature after which the flask and its content were weighed to obtain the weight of the extracted fat. The fat content of the sample was then calculated as follows:

$$\%\ crude\ fat = \frac{weight\ of\ extracted\ fat}{initial\ sample\ weight}\ x\ 100. \quad (2.3)$$

2.4.4. Determination of Crude Fibre

The weighed residue from the ether extract (fat determination) was transferred into a 500ml digestion flask. 200ml of boiling 1.25% sulphuric acid ($H_2SO_4$) was added together with 0.5g of asbestos and the flask was immediately set on a hot plate and a condenser connected to the digestion flask. The flask was heated for 30 minutes after which the content was immediately filtered through a linen cloth in a funnel and washed with large volume of boiling water until the washings were no longer acidic. The acidity was monitored using a pH meter. The residue was washed back together with the asbestos into a flask with 200ml boiling 1.25% sodium hydroxide (NaOH) solution. The flask was then connected to a reflux condenser and boiled for 30 minutes after which the content was filtered through linen cloth in a funnel and washed with large volumes of boiling water. The residue was transferred into a Gooch crucible and washed with hot water from a wash bottle and was then washed with 15ml of 95% alcohol. The crucible and its content was dried at 110$^o$C to constant weight, cooled in a desiccator and then weighed. The crucible with its content was then incinerated in a muffle furnace at 600 $^0$C for 30 minutes, cooled in a desiccator and reweighed. The crude fibre content was then calculated as follows.

$$\%\ \text{crude fibre} = \frac{A-B}{C} x 100 \quad (2.4)$$

where A = weight of dry crucible and sample

B = weight of incinerated crucible and ash

C = initial sample weight (weight of residue)

2.4.5. Ash Determination

An ash crucible was washed and dried at 105$^0$C for one hour, cooled in desiccators and weighed. 2.0g of cassava sample was weighed into the porcelain crucible in triplicate and put into a furnace at 600$^o$C for 4 hours. The furnace was allowed to cool below 200 $^0$C and maintained for 20 minutes. The crucible was then placed in a desiccator with stopper top, cooled and reweighed (AOAC, 1990). The ash content was calculated as follows

$$\%\ ash = \frac{(A+C) - A}{(A+B) - A} x 100 \quad (2.5)$$

A = crucible weight

B = sample weight

C = ash weight

2.4.6. Determination of Total Carbohydrate

Total carbohydrate content was determined by summing up the percentage values of moisture, protein, fat, fibre, ash and subtracting them from 100%.

## 3. Results and Discussion

*3.1. Main Effect of Age on Proximate Composition of Cassava Flour*

Result of the main effect of harvest age on the proximate composition of the samples indicates that the protein, fat, fiber, ash moisture and carbohydrate contents of the flour samples are significantly ($p \leq 0.05$) affected by the harvest age of the tubers (Table 1).

| Age | Protein (%) | Fat (%) | Fibre (%) | Ash (%) | Moistue (%) | CHO (%) |
|---|---|---|---|---|---|---|
| 10 months | 2.10 | 0.46 | 2.50 | 0.85 | 2.74 | 91.35 |
| 12months | 1.71 | 1.79 | 2.10 | 0.83 | 3.38 | 90.14 |
| 14months | 2.53 | 0.64 | 2.35 | 1.00 | 2.18 | 91.30 |
| cv% | 14.30 | 23.00 | 18.00 | 11.40 | 12.40 | 0.70 |
| L.s.d. | 0.13 | 0.09 | 0.17 | 0.04 | 0.14 | 0.27 |
| L.s.d =Least significant difference,CV= Coefficient of variation,CHO=Carbohydrate | | | | | | |

*Table 1: Main effect of harvest age on proximate composition of cassava flour*

The mean protein content of the samples harvested at 14 months of age was 2.53% and is significantly higher ($p \leq 0.05$) than those harvested at 10 months with mean values of 2.10% which is in turn significantly higher than the ones harvested at 12 months (1.71%). This is in agreement with the findings of Apea – Bah *et al*. (2011) which indicates that the value of the protein content of flour from four local varieties decreased progressively from 1.10% at 9 months' harvest age to 0.37% at 13 months after which it increased to peak value of 1.42% at 15months. Sunee *et at.* (2006) also reported a progressive reduction in the protein content of flour from 2.81% at 6months harvest age to 1.41% at 12 months' harvest age. The significant effect of age on protein content is possibly as a result of the differing rate of nitrogen metabolism in the growing plant.

The fiber content of the flour at 10months harvest age (3.50%) was higher ($p \leq 0.05$) than the value obtained at 12months harvest age (2.10%) but not statistically different ($p \leq 0.05$) from that of 14months.

The higher fibre content at 10months could be attributed to the fact that at this stage the plant is within the end of bulking of their fibrous roots and the associated translocation and conversion of sugar into starch in the roots as it advances to the dormancy stage which ends at 12 months for the start of another circle (Nassar, 2005).

The fat, ash and moisture content of the samples were significantly ($p \leq 0.05$) affected by harvest age. The fat content was higher ($p \leq 0.05$) at12 months (1.79%) than the value at 14 months (0.64%) which was in turn higher ($p \leq 0.05$) than the value obtained at 10 months (0.46%). The ash content (1.00%) was higher ($p \leq 0.05$) at 14months harvest age while the values obtained at 10 months (0.85%) and 12 months (0.83%) did not differ ($p \leq 0.05$) from each other. The values of carbohydrate content at 10months and 14 months' harvest age (91.35 and 91.3% respectively) were not significantly different ($P \leq 0.05$) from each other but higher ($p \leq 0.05$) than 90.14% obtained at 12months.

*3.2. Main Effect of Variety on the Proximate Composition of Cassava Flour*

The main effect of variety on the proximate composition of cassava flour is presented in Table 2.

| Variety | Protein(%) | Fat(%) | Fibre (%) | Ash (%) | Moisture (%) | CHO (%) |
|---|---|---|---|---|---|---|
| Ampong | 2.17 | 0.95 | 2.49 | 0.81 | 2.27 | 91.32 |
| Broni | 2.09 | 1.08 | 2.40 | 0.87 | 3.25 | 90.32 |
| Otuhia | 2.09 | 0.87 | 2.05 | 1.01 | 2.79 | 91.10 |
| cv% | 14.30 | 23.00 | 18.00 | 11.40 | 12.40 | 0.70 |
| L.s.d. | 0.13 | 0.09 | 0.17 | 0.04 | 0.14 | 0.27 |
| L.s.d =Least significant difference,CV= Coefficient of variation,CHO=Carbohydrate | | | | | | |

*Table 2: Main effect of Variety on proximate composition of cassava flour*

The result of the analysis indicates that the protein content of cassava flour from *Ampong, Broni* and *Otuhia* cassava varieties were 2.17%, 2.09% and 2.09% respectively which were not significantly different ($p \leq 0.05$) from each other. They are however within the range of values reported by some researchers on the protein content of some local and cassava mosaic disease (CMD) resistant varieties. Ooye *et al*. (2014) reported a protein content range of 0.35% to 1.43% for some cassava varieties from Nigeria while Afoakwa *et al.* (2012) reported protein content range of 1.17% to 3.48% for six varieties of both local and improved CMD resistant varieties in Accra Ghana.

The fat content of the flour ranged from 0.85% for *otuhia* variety to 1.08% for *Broni* Variety. The fat content of *Ampong* variety (0.95%) did not differ ($p < 0.05$) from that of *otuhia* (0.87%) but lower ($p \leq 0.05$) than that of *Broni* Variety. The Crude fibre content of *Ampong* (2.49%) did not differ ($P \leq 0.05$) from the value obtained for *Broni* (2.40%) but significant difference ($p \leq 0.05$) existed between the two varieties and *otuhia* (2.05%) as can be observed in Table 4.2. The carbohydrate content of *Ampong* (91.32%) and *otuhia* (91.10%) did not differ ($p \leq 0.05\%$) from each other but they are significantly higher ($p \leq 0.05$) than the value obtained for *Broni* (90.32%) variety. The high carbohydrate content and desirable nutritional contents like protein obtained in this study suggests that the three cassava varieties could be effectively used as a reliable food security crop as proposed by FAO (2008).

*3.3. Main Effect of Pretreatment on Proximate Composition of Cassava Flour*

The main effect of pre-treatment on the proximate composition of cassava flour is as presented in Table 3. The protein content of cassava flour produced from chipping pre-treatment ($T_1$) and chipping with steeping in citric acid pretreatment ($T_3$) were significantly higher($p \leq 0.05$) than those from toasting pretreatment ($T_2$), grating pretreatment ($T_4$) and steeping in citric acid with toasting pre–treatment ($T_5$). The protein content of $T_2$ (1.87%), $T_4$ (1.81%) and $T_5$ (1.85%) did not significantly differ ($p \leq 0.05$) from each other even though they were lower ($p \leq 0.05$) than 2.59% and 2.45% obtained from the two chipping pre-treatment methods ($T_1$ and $T_3$).

| P T | Protein (%) | Fat (%) | Fibre (%) | Ash (%) | Moisture (%) | CHO (%) |
|---|---|---|---|---|---|---|
| T1 | 2.59 | 1.11 | 2.32 | 1.36 | 2.71 | 89.83 |
| T2 | 1.87 | 0.71 | 2.50 | 0.74 | 2.84 | 91.34 |
| T3 | 2.45 | 1.01 | 2.01 | 0.94 | 3.04 | 90.56 |
| T4 | 1.81 | 1.07 | 2.39 | 0.77 | 2.43 | 91.53 |
| T5 | 1.85 | 0.92 | 2.35 | 0.66 | 2.82 | 91.30 |
| cv% | 14.30 | 23.00 | 18.00 | 11.40 | 12.40 | 0.70 |
| L.s.d. | 0.16 | 0.12 | 0.22 | 0.06 | 0.18 | 0.35 |

L.s.d =Least significant difference,CV= Coefficient of variation,CHO=Carbohydrate,
PT=Pre-treatment,T1 to T5 represents pre-treatment methos as described in section 3.3

*Table 3: Main effect of pre-treatment on proximate composition of cassava flour*

It is interesting to note that the lower values of protein content of $T_2$, $T_4$ and $T_5$ pre – treatment could have arisen from loss of protein alongside the discharged waste water during the pre–drying dewatering processes of the mash associated with the three pre-treatment methods. The fat contents of $T_1$ (1.11%), $T_3$ (1.01), and $T_4$ pretreatment are significantly higher ($p \leq 0.05$) than that of $T_2$ (0.71%) and $T_5$ (0.92) pretreatment. The fiber content of $T_3$ (2.01%) was significantly lower ($p \leq 0.05$) than that of $T_1$ (2.32%), $T_2$, (2.50%) $T_4$ (2.39%) and $T_5$ (2.35) while the ash content of $T_1$ (1.36%) was higher ($p \leq 0.05$) than that of $T_3$ (0. 94) which was in turn higher than those of $T_2$ (0.74%) $T_4$ (0.77%) and $T_5$ (0.66%). The carbohydrate content of $T_1$ (89.83) and $T_3$ (90.5%) are lower than that of $T_2$ (91.34), $T_4$ (91.53) and $T_5$ (91.30).

*3.4. Effects of Interaction of Harvest Age, Variety and Pretreatment on Proximate Composited of Cassava Flour*

Results of the effects of interaction of harvest age, variety and pre–treatment on proximate composition of cassava flour are presented in Table 4.

The protein content of $A_{14}T_3$ (3.06%) and $O_{14}T_3$ (3.01%) which are respectively flour samples from chips of *Ampong* and *Otuhia* varieties harvested at 14months and pre-treated with citric acid were significantly higher ($P \leq 0.05$) than the rest of the flour samples with exception **of** $A_{10}T_1$ (20.68%), $A_{14}T_4$ (2.70%), $B_{10}T_1$ (2.63%), B14T1 (2.90%), A14T3(2.82%), O10T1(2.79%), and $O_{14}T_1$ (2.91%), which did not significantly differ ($P \leq 0.05$) from the two samples.

The fat content of $B_{12}$ $T_1$ (3.17) was higher than the rest of the flour samples while the fiber content of $B_{14}T_5$ (3.53%) was also higher ($p \leq 0.05$) than the other samples with the exception of $A_{10}T_1$ (2.92%), $A_{10}T_2$ (2.94%), $A_{10}T_3$ (3.16) $A_{14}T_5$ (2.89%), $B_{14}T_1$ (3.47%) and $B_{14}T_2$ (3.42%) which did not differ ($p \leq 0.05$) from each other. Generally, the fibre content of all the samples were observed to range from 1.29% to 3.53% which falls within the range of 1.38% to 3.20% reported by Afoakwa et al, (2012) but much higher Than the range (0.01 to 0.8%) reported by Etudaiye *et al.* (2009). The Ash content of $A_{12}$ $T_1$ (1.79%) was also observed to be higher ($p \leq 0.05$) than the rest of the samples which ranged from 0.26% to 1.53%. The moisture content of the all the samples were observed to be generally low ranging from 0.28% for $A_{10}T_4$ to 5.12% for $B_{10}T_3$.

The generally low moisture content recorded by the samples emanates from the fact than the samples were dried to constant weight using mechanically ventilating oven dryer. This moisture content range was far below the 13% codex standard of FAO (1995) for maximum moisture content of cassava flour for effective storage.

The carbohydrate content was observed to range from 87.57% for $A_{12}T_1$ sample to 93. 56% for $A_{10}T_4$ sample. The $A_{10}T_4$ sample with 93.56% of carbohydrate which was at the upper limit of the range was significantly higher ($p \leq 0.05$) than the rest of the samples with the exception of $A_{10}T_5$ (93.41) $B_{14}T_4$ (92.68%) and $O_{12}T_5$ (92.99%) which were not significantly ($p \leq 0.05$) different.

| Variety | Harvest Age (months) | Pre-treatment | Sample code | Protein (%) | Fat (%) | Fibre (%) | Ash (%) | Moisture (%) | CHO (%) |
|---|---|---|---|---|---|---|---|---|---|
| Ampong | 10 | T1 | $A_{10}T1$ | 2.68 | 0.38 | 2.92 | 1.44 | 1.44 | 91.14 |
| Ampong | 10 | T2 | $A_{10}T2$ | 1.93 | 0.43 | 2.94 | 0.96 | 1.19 | 92.55 |
| Ampong | 10 | T3 | $A_{10}T3$ | 2.11 | 0.75 | 3.16 | 0.26 | 1.04 | 92.68 |
| Ampong | 10 | T4 | $A_{10}T4$ | 2.00 | 0.55 | 2.85 | 0.76 | 0.28 | 93.56 |
| Ampong | 10 | T5 | $A_{10}T5$ | 1.79 | 0.27 | 2.50 | 1.06 | 0.97 | 93.41 |
| Ampong | 12 | T1 | $A_{12}T1$ | 2.34 | 2.67 | 2.34 | 1.01 | 4.07 | 87.57 |
| Ampong | 12 | T2 | $A_{12}T2$ | 1.40 | 0.67 | 3.04 | 0.57 | 2.40 | 91.93 |
| Ampong | 12 | T3 | $A_{12}T3$ | 2.08 | 1.50 | 2.31 | 0.77 | 3.93 | 89.41 |
| Ampong | 12 | T4 | $A_{12}T4$ | 1.30 | 2.17 | 2.47 | 0.50 | 3.00 | 90.57 |
| Ampong | 12 | T5 | $A_{12}T5$ | 1.38 | 1.17 | 2.60 | 0.30 | 3.80 | 90.76 |
| Ampong | 14 | T1 | $A_{14}T1$ | 2.82 | 0.83 | 1.49 | 1.53 | 2.14 | 91.19 |
| Ampong | 14 | T2 | $A_{14}T2$ | 2.44 | 0.83 | 1.91 | 0.76 | 2.48 | 91.58 |
| Ampong | 14 | T3 | $A_{14}T3$ | 3.06 | 1.00 | 1.90 | 0.83 | 2.43 | 90.78 |
| Ampong | 14 | T4 | $A_{14}T4$ | 2.70 | 0.50 | 2.05 | 0.72 | 2.22 | 91.81 |
| Ampong | 14 | T5 | $A_{14}T5$ | 2.44 | 0.50 | 2.89 | 0.65 | 2.66 | 90.86 |
| Broni | 10 | T1 | $B_{10}T1$ | 2.63 | 0.21 | 2.73 | 1.34 | 0.72 | 92.36 |
| Broni | 10 | T2 | $B_{10}T2$ | 1.71 | 0.36 | 2.36 | 0.47 | 4.86 | 90.24 |
| Broni | 10 | T3 | $B_{10}T3$ | 2.34 | 0.56 | 0.68 | 1.02 | 5.12 | 90.28 |
| Broni | 10 | T4 | $B_{10}T4$ | 1.74 | 0.48 | 2.43 | 0.84 | 4.23 | 90.28 |
| Broni | 10 | T5 | $B_{10}T5$ | 1.77 | 0.44 | 1.99 | 0.33 | 4.26 | 91.21 |
| Broni | 12 | T1 | $B_{12}T1$ | 2.20 | 3.17 | 1.82 | 0.72 | 3.87 | 88.23 |
| Broni | 12 | T2 | $B_{12}T2$ | 1.46 | 2.17 | 2.39 | 0.61 | 3.00 | 90.38 |
| Broni | 12 | T3 | $B_{12}T3$ | 2.24 | 1.33 | 1.86 | 1.14 | 4.20 | 89.24 |
| Broni | 12 | T4 | $B_{12}T4$ | 1.62 | 2.50 | 2.24 | 0.73 | 3.40 | 89.52 |
| Broni | 12 | T5 | $B_{12}T5$ | 1.38 | 2.33 | 2.07 | 0.80 | 4.60 | 88.81 |
| Broni | 14 | T1 | $B_{14}T1$ | 2.90 | 0.50 | 3.47 | 1.27 | 2.66 | 89.19 |
| Broni | 14 | T2 | $B_{14}T2$ | 2.44 | 0.50 | 3.42 | 1.01 | 3.01 | 89.62 |
| Broni | 14 | T3 | $B_{14}T3$ | 2.60 | 0.67 | 2.41 | 1.08 | 1.16 | 92.09 |
| Broni | 14 | T4 | $B_{14}T4$ | 1.98 | 0.50 | 2.60 | 0.85 | 1.38 | 92.68 |
| Broni | 14 | T5 | $B_{14}T5$ | 2.29 | 0.50 | 3.53 | 0.78 | 2.24 | 90.66 |
| Otuhia | 10 | T1 | $O_{10}T1$ | 2.79 | 0.44 | 2.68 | 1.55 | 4.01 | 88.53 |
| Otuhia | 10 | T2 | $O_{10}T2$ | 1.82 | 0.24 | 2.48 | 0.53 | 2.86 | 92.07 |
| Otuhia | 10 | T3 | $O_{10}T3$ | 2.54 | 0.29 | 2.38 | 0.89 | 3.98 | 89.93 |
| Otuhia | 10 | T4 | $O_{10}T4$ | 1.76 | 0.93 | 2.59 | 0.76 | 2.91 | 91.05 |
| Otuhia | 10 | T5 | $O_{10}T5$ | 1.93 | 0.57 | 2.74 | 0.60 | 3.25 | 90.91 |
| Otuhia | 12 | T1 | $O_{12}T1$ | 2.02 | 1.33 | 1.67 | 1.79 | 3.80 | 89.38 |
| Otuhia | 12 | T2 | $O_{12}T2$ | 1.35 | 0.67 | 1.60 | 0.92 | 3.07 | 92.40 |
| Otuhia | 12 | T3 | $O_{12}T3$ | 1.99 | 2.50 | 1.72 | 1.22 | 3.53 | 89.03 |
| Otuhia | 12 | T4 | $O_{12}T4$ | 1.37 | 1.33 | 2.08 | 0.85 | 2.53 | 91.84 |
| Otuhia | 12 | T5 | $O_{12}T5$ | 1.50 | 1.33 | 1.29 | 0.48 | 1.50 | 92.99 |
| Otuhia | 14 | T1 | $O_{14}T1$ | 2.90 | 0.50 | 1.76 | 1.61 | 1.69 | 91.54 |
| Otuhia | 14 | T2 | $O_{14}T2$ | 2.29 | 0.50 | 2.33 | 0.83 | 2.73 | 91.32 |
| Otuhia | 14 | T3 | $O_{14}T3$ | 3.06 | 0.50 | 1.64 | 1.28 | 1.93 | 91.59 |
| Otuhia | 14 | T4 | $O_{14}T4$ | 1.83 | 0.67 | 2.22 | 0.90 | 1.95 | 92.42 |
| Otuhia | 14 | T5 | $O_{14}T5$ | 2.14 | 1.17 | 1.57 | 0.94 | 2.08 | 92.09 |
| cv (%) | | | | 14.30 | 23.00 | 18.00 | 11.40 | 12.40 | 0.70 |
| L.s.d. | | | | 0.49 | 0.36 | 0.67 | 0.17 | 0.55 | 1.06 |

CHO=carbohydrate,CV=Coefficience of variation,L.s.d.=Least significant difference.A,B ,O=Ampog, Broni and Otuhia varieties respectively while subscript 10,12 and 14 = harvest ages in months, and T1 to T5 represents pre-treatment methods as presented in section2.3

*Table 4: Effects of interaction of harvest age, variety and pretreatment on proximate composition of cassava flour*

**4. Conclusion**

The proximate composition of cassava flour was significantly (P≤0.05) affected by harvest age, variety and pre-drying treatments. The highest protein content was obtained from $A_{14}T_3$ and $O_{14}T_3$ which are respectively flour samples from chips of *Ampong* and *Otuhia* varieties harvested at 14months and pre-treated with citric acid. The protein content generally ranged from1.30% to 3.06% while the moisture content range of 0.28% to 5.12% was far below the 13% codex standard of FAO (1995) for maximum moisture content of cassava flour for effective storage.

The results generally showed that processing of *Ampong*, *Broni* and *Otuhia* cassava varieties into flour using chipping, toasting, grating and citric acid pre-treatment resulted in acceptable flour yield. The flours obtained had satisfactory quality attributes in terms of protein, fat, fibre ash, carbohydrate, and moisture content. Results obtained from this work will go a long way in assisting the industrialists and potential end users of the new cassava varieties with nutritional information of the processed flour.

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