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Effect of Harvest Period on Starch Yield and Dry Matter Content from the Tuberous Roots of Improved Cassava (*Manihot esculenta* Crantz) Varieties

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Abstract: The aim of this study was to evaluate the variation of starch yields and dry contents from the tuberous roots of five improved cassava varieties ("Bonoua2", "Ay15", "971A", I88/00158 and "90/00039") at different harvest periods (11, 13, 15 and 17 months after planting). Indeed, the harvest period had significant effect at 0.05 level on dry matter contents and starch yields. All improved cassava varieties had their peak of dry matter contents (40.57%±2.41) and starch yields (20.17%±2.82%) at 13 months after planting. The tuberous roots of "Bonoua2" improved cassava variety had the highest starch yields at 11, 13 and 15 months after planting, with the respective values of 18.26%±1.52%, 20.78%±2.57% and 18.08%±3.18% respectively. Concerning the highest starch yield at 17 months after planting, it was obtained with "971A" improved cassava variety (19.38%±2.55%). The tuberous roots of "Bonoua2" improved cassava variety detained also the highest dry matter contents at 11 and 15 months after planting. The values were of 39.83%±1.19% and 38.70±2.61% respectively. As for the highest dry contents at 13 and 17 month after planting, they were given by the tuberous roots of "971A" improved cassava variety, with the respective values of 42.99%±1.48% and 39.04%±2.57%.

Key words: Cassava, improved varieties, Harvest period, dry matter content, starch yield, tuberous roots

INTRODUCTION

Cassava (*Manihot esculenta* Crantz) is one of the most important staple foods in the human diet in the tropics and ranked as the sixth most important source of calories in the human diet worldwide (Alfredo *et al.*, 2000) for an estimated 800 million people (Akparobi *et al.*, 1998). It's grown in the area between the latitudes 30° N and 30° S (Zira, 2007). Cassava tolerates hot climate, but a critical point exist between a daily average temperature of 18 and 20°C, below which the plants don't grow normally and the yields decrease rapidly (Zira, 2007). Cassava is a competitive crop, especially for the production of starch, animal feed and alcohol production (Oguntunde, 2005). Their storage roots have the high starch content and can form the major source of various intermediate products including flour, starch and dextrins for food, feed, confectionery, wood, pharmaceutical, adhesives, explosives and other industrial uses. In addition, the storage roots' starches from cassava have some special properties not found in cereal starches (Moorthy, 1994). The performance of these products in food, feed and other industries vary according to the crop or variety from which the product was obtained (Benesi *et al.*, 2003; Singh *et al.*, 2005). Otherwise, dry matter production is an important determinant of storage root yield in cassava and could be an important selection criterion in breeding programmes for enhanced yield (Mohamed *et al.*, 2009). Seeing the importance of both parameters, the studies are needed to establish the most suitable crop stage for harvest time that would provide storage roots with high dry matter and starch contents (Wholey and Booth, 1979). Therefore, this study was carried out to determine the effect of different harvest periods on the dry matter and the starch from the tuberous root of five improved cassava varieties in the south of Côte d'Ivoire. The results of survey came to give the best harvest period of cassava tuberous roots.

MATERIALS AND METHODS

Raw materials: The tuberous roots of improved cassava varieties came from the collection of the National Agronomic Research Centre (CNRA, Côte d'Ivoire). These cassava varieties were "Bonoua2", "Ay15", "971A",

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"I88/00158" and "90/00039". Their tuberous roots were harvested at four different periods (11, 13, 15 and 17 months). They were immediately transported in a heap aired store for analyses in which the temperature and the relative humidity rate are 28°C±1°C and 80%±3% respectively.

Starch isolation: Cassava starches were extracted according to the procedure described by Amani *et al.* (2002). Two (2) kilogram of fresh tuberous roots of cassava varieties were weighed at different harvest periods (11, 13, 15 and 17 months). These tubers were washed and peeled. After peeling, they were cut up into small slices (4 x 4 cm) with stainless steel knife. The slices were ground in a grinder (Model 38BL 40 New Hartfort, connecticut, USA) and the paste recovered in 4% (w/v) sodium chloride solution to separate proteins from the starch during 24 h at 28°C±1°C. The slurry was sieved successively through 750 µm, 150 µm and 100 µm sieves. Then, the starches were alternatively decanted and washed at least four times with distilled water. The starch suspensions were oven-dried at 45°C for 48 h (MEMMERT, 854 Scwachbach, West Germany]. The dry products were ground in a grinder (IKA LABORTECHNIK, K M20, 79219 Staufen, West Germany), followed by determination of starch yield.

Tuberous root starch yield: Starch yield was determined according to the method of Krochmal and Kilbride (1966) previously described by Sofa-Kantanka and Osei-Minta (1996). The amount of dried starch obtained from two (2) kg of fresh cassava tuberous roots was weighted and expressed as a percentage of the fresh tuberous roots. The starch yield was calculated as follows:

$$\text{Starch yield} = 100 * (WDS/WFTR)$$

Where:
WDS = The weight of dried starch
WFTR = The weight of fresh tuberous roots

Tuberous root dry matter content: The dry matter content was determined by drying in an oven at 105°C during 24 hrs to constant weight (AOAC, 1990). The amount of dried pulp of cassava tuberous roots from five (5) gram of fresh pulp of cassava tuberous roots was weighed. The dry matter content was expressed as follows:

$$\text{Dry matter content} = 100 * (W_2/W_1)$$

Where:
W_2 = The weight of dried pulp of tuberous root
W_1 = The weight of fresh pulp of tuberous root

Statistical analysis: All analyses were performed in triplicates. Results were expressed by means of ± SD. Statistical significance was established using Analysis of Variance (ANOVA) models to estimate the main effects and their interaction effects. Means were separated according to Duncan's multiple range analysis ($p\leq0.05$), with the help of the software STATISTICA 7 (Statsoft Inc, Tulsa-USA Headquarters) and XLSTAT-Pro 7.5.2 (Addinsoft Sarl, Paris-France).

RESULTS

Starch yields: The starch yields from tuberous roots of five cassava varieties harvesting at 11, 13, 15 and 17 months after planting are summarized in the Table 1. They were ranged from 13.24-18.45%, 17.77-23.08%, 14.10-18.08% and 16.71-19.38% for tuberous roots of improved cassava varieties harvesting at 11, 13, 15 and 17 months after planting respectively. The highest yields of starch at 11, 13 and 15 months after planting were obtained with the tuberous roots of "Bonoua2" improved cassava variety. Concerning the highest starch yield at 17 months after planting, it was given by the tuberous roots of "971A" improved cassava variety. As for the lowest yields of starch from cassava variety tuberous roots at 11, 13 and 15 months after planting, it was obtained with the tuberous roots of "90/00039" improved cassava variety. Besides, the tuberous roots of "I88/00158" improved cassava variety produced the smallest starch yield at 17 months after planting. The starch yields from tuberous roots at 13 months after planting were slightly high, whatever the variety is. The Analysis of Variance (ANOVA) table summarized the information related to the sources of variation in the data (Table 2). It revealed that the Variety main effect and the Harvest period main effect appeared significant at 0.05 level. While both effects are significant, the main effect of

Table 1: Starch content (%) from tuberous roots of five cassava varieties at different harvest period

	Harvest period after planting (months)			
Cassava varieties	11	13	15	17
Bonoua2	18.26±1.52^{ab}	20.78±2.57^{ab}	18.08±3.18^{ab}	18.22±2.20^{ab}
Ay15	16.86±3.01^{ab}	23.08±1.93^{b}	17.05±2.47^{ab}	17.88±3.38^{ab}
971A	17.46±1.20^{ab}	20.72±2.74^{ab}	17.44±3.04^{ab}	19.38±2.55^{ab}
I88/00158	18.45±1.84^{ab}	18.51±2.36^{ab}	15.89±0.67^{ab}	16.71±2.71^{ab}
90/00039	13.24±1.90^{a}	17.77±1.40^{ab}	14.10±1.52^{a}	16.88±0.37^{ab}

Each value is an average of three replicate. Values are mean±standard deviation.
Means not sharing a similar letter in a line and column are significantly different ($p\leq0.05$) as assessed by the test of Duncan

Table 2: ANOVA table for two-way analysis of main effects of variety and harvest period on starch

Effect	Degrees of freedom	Sum of squares	Mean square	F-ratio	p-value
Variety	4	99.31	24.83	1.727	0.163*
Harvest period	3	122.61	40.87	2.843	0.050*
Variety*Harvest period	12	51.20	4.27	0.297	0.986ns
Error	40	574.96	14.37		
Total	59	848.09	24.83		

The symbol of * state shows significant difference at 5% level. The ns sign shows not significant difference at 5% level

Table 3: Dry matter content (%) from tuberous roots of five cassava varieties at different harvest period

	Harvest period after planting (months)			
Cassava varieties	11	13	15	17
Bonoua2	39.83±1.19^{defg}	42.33±2.16^{fg}	38.70±2.61^{cde}	38.94±2.74^{bcde}
Ay15	34.49±2.13^{ab}	40.51±1.94^{efg}	31.87±2.29^{a}	35.34±1.02^{bc}
971A	37.14±1.29^{bcde}	42.99±1.48^{g}	34.43±1.28^{ab}	39.04±2.57^{def}
I88/00158	37.08±2.79^{bcde}	39.40±0.05^{def}	36.37±2.51^{bcd}	37.56±2.09^{bcde}
90/00039	31.17±0.71^{a}	37.60±1.24^{bcde}	31.54±1.41^{a}	31.24±1.44^{a}

Each value is an average of three replicate. Values are mean±standard deviation.
Means not sharing a similar letter in a line and column are significantly different ($p \leq 0.05$) as assessed by the test of Duncan

Table 4: ANOVA table for two-way Analysis of Main effects of variety and harvest period on dry matter

Effect	Degrees of freedom	Sum of squares	Mean square	F-ratio	p-value
Variety	4	341.69	85.42	23.847	0.0001*
Harvest period	3	302.50	100.83	28.149	0.0001*
Variety*Harvest period	12	69.14	5.76	1.608	0.128*
Error	40	143.28	3.58		
Total	59	856.62			

The symbol of * state shows significant difference at 5% level

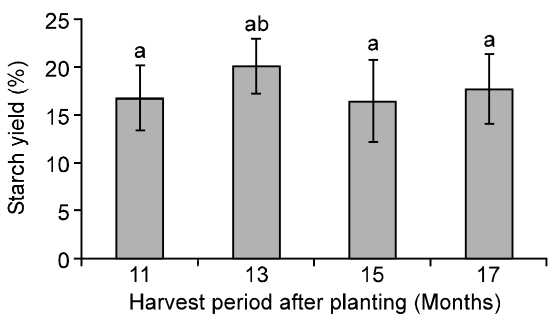

Fig. 1: Starch yield from tuberous roots of cassava varieties harvesting at four harvest periods after planting

Harvest period appeared to be stronger. The interaction effect between the factor Variety and the factor Harvest period didn't appear significant at 0.05 level. Otherwise, there was not significant variation at 0.05 level between the starch yields of five improved cassava varieties at the same and different harvest period. However, slight differences were observed between them. All starches of improved cassava varieties didn't increased significantly ($p \leq 0.05$) from 11 months after planting to 13 months after planting and then didn't decreased meaningfully ($p \leq 0.05$) until 17 months after planting. Nevertheless, the starch yield obtained at 13 months after planting was slightly higher than those given at 11, 15 and 17 months after planting (Fig. 1). The starch average yield from tuberous roots of improved cassava varieties ranged from 16.51%±3.42% at 15 months after planting to 20.17%±2.82% at 13 months after planting.

Dry matter content: The dry matter contents from tuberous roots of "Bonoua2", "Ay15", "971A", "I88/00158" and "90/00039" improved cassava varieties harvesting at different periods after planting are shown in Table 3. They were varied from 31.17-39.83%, 37.60-42.99%, 31.54-38.70% and 31.24-39.04% for 11, 13, 15 and 17 months after planting respectively. The lowest dry matter contents at 11, 13, 15 and 17 months after planting were obtained with the "90/00039" improved cassava variety. The tuberous roots of "Bonoua2" gave the highest dry matter contents at 11 and 15 months after planting. Concerning the 13 and 17 months after planting, the highest dry matter contents were given by "971A" improved cassava variety. Otherwise, the result of ANOVA showed the significant differences of Variety main effect and Harvest period main effect at 0.05 level (Table 4). The both main effects appeared to be stronger. Besides, the interaction effect between the factor Variety and the factor Harvest period appeared meaningfully ($p \leq 0.05$). The statistical analysis revealed that the dry matter contents of improved cassava varieties were not significantly different ($p \leq 0.05$) for each harvest period after planting. However, they differed meaningfully ($p \leq 0.05$) at different harvest period after planting. The dry matter contents of all improved

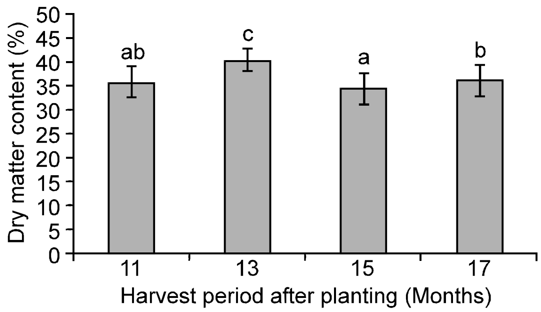

Fig. 2: Dry matter content from tuberous roots of cassava varieties harvesting at four harvest periods after planting

cassava varieties increased significantly ($p \leq 0.05$) from 11 months after planting to 13 months after planting and then they decreased significantly ($p \leq 0.05$) until from 17 months after planting. The dry matter average content obtained at 13 months after planting differed meaningfully ($p \leq 0.05$) of those obtained at 11, 15 and 17 months after planting (Fig. 2). Furthermore, the dry matter average contents from tuberous roots of improved cassava varieties varied from 34.58%±3.32% at 15 months after planting to 40.57%±2.41% at 13 months after planting.

DISCUSSION

The starch yields from tuberous roots of improved cassava varieties didn't differ meaningfully ($p \leq 0.05$) for each harvest period. This result would be due to the similarity of the physiological characteristics of improved cassava varieties (Segnou, 2002). During the harvest periods, the starch yields didn't vary also significantly ($p \leq 0.05$) according the statistical analysis. Besides, the ANOVA showed the slight influence of two main effects of Variety and Harvest period on starch yields by obtained data. It showed also that the interaction effect was not statistically significant at 0.05 level. Indeed, the interaction effect between the factor Variety and the factor Harvest period didn't influence the starch yields. In addition, it would suggest that the main effect of each factor was the same whatever the other level is. Our results were similar to the reports of Apea-Bah *et al.* (2011), who found that the interaction between age at harvest and variety on starch yield of the flour was not significant ($p \leq 0.05$). Otherwise, the starch yields from tuberous roots of improved cassava varieties at 13 months after planting differed slightly to those obtained at other harvest periods. The difference of the starch yields would result from the volume of leaf canopy (number of leaves, leaf area) that the improved cassava variety is able to develop, their interception of solar radiation by this leaf canopy, the canopy photosynthetic activity and the speed of translocation of nutrients from the leaves to the tuberous roots during the vegetative cycle (Cock, 1976; Veltkamp, 1985). Besides, this difference could be assimilated to the tissues age. Because of that, the decrease of starch yields after 13 month after planting would suggest a lignification of the tuberous roots of improved cassava varieties.

The dry matter contents from tuberous roots of improved cassava varieties didn't vary statistically ($p \leq 0.05$) from a variety to another for each harvest period. The observed differences not significant at different harvest periods would suggest that there were not sensitive modifications of dry matters contents of one variety to another. Our results were higher than those reported on nine (9) improved cassava varieties (V63, V23, V66, V64, V60, V61, V4, V62, V65) by Megnanou *et al.* (2009), who recorded 33.70±5.85 as dry matter average content. Otherwise, the Analysis of Variance ANOVA showed the significant difference at 0.05 level of main effects of Variety and Harvest period and of their interaction effect. These results indicated that the both parameters would affect the dry matter contents from tuberous roots of cassava. Besides, the statistical analysis of mean comparison showed the significant differences ($p \leq 0.05$) between the dry matter contents at different harvest periods. These differences at different vegetative stages would be the consequence of the moisture content difference in their tissues (Treche, 1989). They would result from the volume of leaf canopy, their interception of solar radiation, the canopy photosynthetic activity and the speed of translocation of nutrients from the leaves to the tuberous roots during the vegetative cycle. Otherwise, the decreases of dry matter contents to harvest, 13 months after planting, would be due to the return of the rainy season. So in more humid soil, the tuberous roots stuffed themselves more water easily (Segnou, 2002). The best harvest period revealed by the study was closed to that reported on four improved cassava clones (8017, 8034, 8061 and 820 516) and a local clone) by Segnou (2002), who noticed 12 months after planting as best harvest time. Our harvest period was similar to that obtained on "Afisiafi" and "Tekbankye" cassava varieties to Ghana by Apea-Bah *et al.* (2011), who reported 13 months after planting as ideal harvest time. Indeed, the best harvest period corresponds to the vegetative stage at which the tuberous roots have the highest fresh weight and dry matter contents (Osiru and Hahn, 1995). These tuberous roots constitute thus an ideal raw material for processing into food by-products derived from cassava (gari, flour, starch) (Kogbe *et al.*, 1989). When the tuberous roots are left up beyond this period, the water obstruction and the starch concentration cause burstings in the soil. The Cracks resulting from these burstings are ways to the microorganisms responsible for rots, with significant loss of raw material as well qualitatively than quantitatively (Segnou, 2002).

Conclusion: This study showed the effects of harvest period of two biochemical parameters (dry matter and starch) from tuberous roots of improved cassava varieties. The harvest period had significant effect on dry matter contents and starch yields. It affected more the dry matter contents than the starch yields during the vegetative cycle. The starch yields of improved cassava varieties didn't increased significantly ($p \leq 0.05$) from 11 months after planting to 13 months after planting and then decreased also not meaningfully ($p \leq 0.05$) until 17 months after planting. Otherwise, The dry matter contents of all improved cassava varieties increased significantly ($p \leq 0.05$) from 11 months after planting to 13 months after planting and then they decreased significantly ($p \leq 0.05$) until from 17 months after planting. So, the tuberous roots of improved cassava varieties should be harvested at 13 months after planting to obtain optimum starch yields and dry matter contents.

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