Study on the effects of harvesting time and storage conditions of *Tacca leontopetaloides* (L.) Kuntze Tuber in an Giang Province, Vietnam

H T Binh$^1$ and V T T Dao$^1$

$^1$ An Giang University, National University of Ho Chi Minh city

**Abstract.** The study was conducted to determine the harvest time and weight of Tacca tubers (*Tacca leontopetaloides* (L.) Kuntze) for flour production. It also assessed changes in quality according to pretreatment methods as well as storage conditions over an 8 week period. Results showed that Tacca tubers harvested after 6 months of planting will have a high dry matter content and flour recovery efficiency, especially at month 7th but remains unchanged afterwards. In addition, tubers weighing over 150g will give better flour recovery efficiency. Washing before storage also affects the quality of tubers more than preservation mode. During storage, tuber weight decreases with amount of dry matter increases. Particularly, the amount of sugar, total Saponins and total Polyphenols decreases but Starch content tends to increase slightly after 6 weeks of reduction. Despite the change in color, surface condition and structure, the Tacca tuber retains good sensory properties during storage.

**Keywords:** Harvesting Time, Storage Conditions, Tacca leontopetaloides (L.), An Giang Province

1. **Introduction**

An Giang is a province with a large area of hilly land, concentrating varieties plants bringing a high value in medicine and great economic to the local. Huyen Tinh tuber which also called Bach Tinh, Cu Nua with the scientific name *Taccaleontopetaloides* (L.) Kuntze belongs to family Taccaceae, close to Dioscoreaceae. This root plant is suitable for cultivate along the foot of mountain, under the shade, easy to grow and take care of, particularly it can be intercropped with fruit trees under the canopyofhills. Therefore, with an average yield of 1 to 1.5 tons of tubers/worker, growers can earn at least 3-4 million VND/Acre. Tuber, which grows underground, farmers use the mother tubers as propagules and collected daughter tubers only. Furthermore, raw tubers are used to treat stomach ailments, diarrhea and dysentery [1]. However, fresh tuber cannot directly consume because it contains the number of toxic substanaces such as taccalin, saponin and acid phenolic, it can be treated with heat to eliminate these toxins before consumption [2].

*Tacca leontopetaloides* (L.) Kuntze is also a staple food source as flour. After harvesting, the tubers are processed into make flour with yield recovery estimating from 18%-20%. The nutrients propotional distribution (dry weight-based) are 0.66 % total of nitrogen, 0.91% lipid, 0.05% ash and 85.7% starch [2]. Tacca flour is now widely used as a drink with lukewarm water, it is highly likely improved healthand treat stomach pain and some intestinal diseases such as dysentery, constipation according to the local’s experience.
In fact, the Tacca are concentratedly grown in Tinh Bien district, An Giang province. However, most people grow scattered and small, because there is no specific research on this cultivating methods as well as the effectiveness of planting this herbal plant under canopy of forest or bare land that is the reason why it has not planted in the large areas.

Since Tacca in An Giang has ever never been researched and only been used as additive material for making traditional cakes. Yet the study on Tacca starch has not been totally conducted; particular, the research on factors effecting to the qualities and flour yield recovery has not paid much attention. There some factors such as tuber’s maturity, the weight, harvesting time, treatment and storage methods before processing. Therefore, the study is aiming to research the effect of the listed factors to Tacca tubers qualities after harvest to ensure maintained the good quality and limit the matters loss in during preservation process.

2. Methods
The experiments were designed with randomised variances and triplicate analysis. The evaluation data were implemented by running Microsoft Excel and statistical analysis were programming by Statgraphics Centurion XV.

2.1 Investigating the effects of harvesttime and tuber weight on harvest
Samples collected based on harvest time starting from the initial planting period to the 5, 6, 7 and 8-months-old. These groups were then classified by weight; for example groups of lower than 150g/tuber; 150 – 250g and group of over 250g. The main analysis attributes are chemical compositions such as dry matter content, starch, amylose, reducing sugar, saponin and polyphenol and yield recovery of Tacca flour. The average weight for experiment is 5kg.

2.2. Comparison Tacca quality cultivated under canopy and outside forest at 6th-month-old
Harvesting in two locations as intercropping under forest canopy and planting in open fields (bare land) at 6th months. The main analysis attributes are chemical compositions such as dry matter content, starch, amylose, reducing sugar, saponin and polyphenol and yield recovery of Tacca flour. The average weight for experiment is 5kg.

2.3 Investigation of the effect of Tacca tubers on pre-processing and storage.
Tubers were collected by their age-months and their weight according to above experiment results. The next step is rinsing them under running water to washed soil and dust, keeping dry for about 2 days. Then, tubers were stored under different conditions including piling in an open space, in the dark and perforated PE packaging (10mm hole diameter, density 8-9 holes/10cm²). Parallel storage of samples without preliminary processing (control) with the storage conditions as above. The average weight for experiment is 25kg. The main analysis attributes are physical, chemical and sensory evaluation over time of storage.

| Chemical composition         | Method                                      |
|------------------------------|---------------------------------------------|
| Total dry matter content     | Drying at 105°C to constant weight          |
| Starch and Reducing sugar content | Bertrand method                              |
| Amylose/Amylopectin content  | Determined by AACC International method 61-03.01 |
| Total Saponins content       | Namba method                                 |
| Total Polyphenol content     | Colorimetric method, using reagent Folin-ciocalteu |

3. Results and Discussion

3.1 The effect of the time harvesting and tuber weight
The tubers appearance after harvesting has a pale yellow color, the surface is plump, not rough, but it is very easy to scratch due to the soft outer shell (skin). The structure depends on the weight of the bulb.
The longer the growth period increases the weight and the accumulation of nutrients inside the tubers, thus the tubers become firmer than the smaller tubers. However, sensory properties do not vary greatly between harvesting times.

![Figure 1. The weight ratio of Tacca tubers is harvested at different times](image)

The tubers’ weight increase over a growing period of 5 to 8 months. After 5 months growth, tubers weighing less than 150 g/tuber accounted for a high proportion. However, after 6 months, the proportion of small tubers (less than 100g/tuber) decreased significantly and the percentage of tubers with larger weight increased, especially the group of tubers larger than 250g/tuber increased significantly as the figure from 2.57% (5 months) to 22.73% (6 months). After 6 months of growth, the differences in the weight of the tubers are not significantly, except for small tubers under 50g/tuber do not appear after 7 months.

Regarding to the harvesting period affecting to concentration of Tacca’s nutrient, it is virtually significant affected but amylose ratio and saponin content (Table 2).

Table 2. The changing composition of Tacca tubers during the harvest time

| Harvest time (month) | Total dry matter (%) | Reducing sugar (%) | Amylose (%) | Starch (%) | Saponin (%) | Polyphenol (mg/g) |
|----------------------|----------------------|--------------------|-------------|------------|-------------|------------------|
| 5th                  | 24.48<sup>a</sup>   | 0.29<sup>b</sup>  | 19.19<sup>ab</sup> | 26.26<sup>a</sup> | 5.07<sup>a</sup> | 0.55<sup>a</sup> |
| 6th                  | 32.14<sup>b</sup>   | 0.34<sup>b</sup>  | 17.73<sup>a</sup> | 32.4<sup>b</sup> | 4.16<sup>a</sup> | 0.59<sup>a</sup> |
| 7th                  | 37.15<sup>c</sup>   | 0.17<sup>a</sup>  | 19.12<sup>ab</sup> | 35.35<sup>c</sup> | 3.77<sup>a</sup> | 3.51<sup>b</sup> |
| 8th                  | 40.32<sup>c</sup>   | 0.19<sup>a</sup>  | 19.46<sup>b</sup> | 35.82<sup>c</sup> | 6.76<sup>a</sup> | 3.18<sup>b</sup> |

| Tuber weight (g)     | Total dry matter (%) | Reducing sugar (%) | Amylose (%) | Starch (%) | Saponin (%) | Polyphenol (mg/g) |
|----------------------|----------------------|--------------------|-------------|------------|-------------|------------------|
| <150                 | 29.48<sup>a</sup>   | 0.22<sup>a</sup>  | 16.75<sup>a</sup> | 29.56<sup>b</sup> | 6.39<sup>b</sup> | 2.27<sup>c</sup> |
| 150-200              | 33.66<sup>b</sup>   | 0.25<sup>a</sup>  | 19.84<sup>b</sup> | 33.39<sup>b</sup> | 2.96<sup>a</sup> | 1.78<sup>a</sup> |
| 250-300              | 37.41<sup>b</sup>   | 0.28<sup>a</sup>  | 20.04<sup>b</sup> | 34.42<sup>b</sup> | 5.48<sup>ab</sup> | 1.81<sup>a</sup> |

P = 0.0013 0.0013 0.0927 0.0000 0.2598 0.0000

Note: (*) The numbers with same letter a, b, c... in each column for each attribute indicating no significant difference of 5% through the LSD test.

The total dry matter content of the tubers has increased due to the accumulating of nutrients over the time. The same phenomenon occurs to starch, however; this number virtually unchanged with seven months ages tubers. The reason for that might be at the age of 8 months, the plant has discontinued the photosynthesis process in order to provide nutrients for the root so the starch has not accumulated. This result is bringing the similar result to the research on sweet potato and cassava of [3]. The reducing sugar content considerably decreased at 7-8 months-old and was significant difference with the tuber groups harvested at 5-6 months. This is because the process conversion of starch to create reducing sugar
providing energy for plant’s respiration. In contrast, there was the increase in polyphenol content and was statistically significant difference between 5-6 and 7-8 months of tubers. However, during the growth period from 5 to 8 months-old, saponin content and the ratio of amylose/amyllopectin were slight modification. In addition to the age of harvesting, the weight also affects the compositions of the bulb (Table 2). The nutrient accumulation process is helping tubers to gain weight, so the groups with the weight over 150g/tuber were containing the higher dry matter content such as starch and amylose in comparison to lower weight tubers groups. On the other hand, the polyphenol percentage decreases as the tuber weight increases. However, there is no significant difference in reducing sugar and saponin content among these groups of weight.

### Table 3. The yield recovery of Tacca flour according to harvest time and the tubers' weight

| The harvest time | Tubers' weight (g) |  
|------------------|--------------------|
| (month)          | <150   | 150-200 | 250-300 |
| 5th              | 22.67 ± 0.67 | 22.18 ± 1.95 | 25.07 ± 1.2 |
| 6th              | 26.25 ± 5.52 | 28.49 ± 5.14 | 27.77 ± 4.18 |
| 7th              | 25.55 ± 0.42 | 30.63 ± 0.83 | 34.4 ± 0.64 |
| 8th              | 27.05 ± 0.95 | 31.05 ± 0.46 | 36.89 ± 1.48 |

*Note: (*) The numbers with same letter a, b, c... in each column for each attribute indicating no significant difference of 5% through the LSD test.*

Both factors have significant effects on the yield recovery of Tacca flour (Table 3). The longer the period of the growth the more efficiency in recovery of the flour. The figure showed that over six-month-growth-tubers are increasing in dry matter content particularly starch content. Moreover, the bigger the tuber, the greater the flour recovery due to the containing the higher dry matter. This is also consistent with the survey results of the local people who are processing flour from tuber root. It is showing that flour produced from big tubers will bring a greater flour productivity.

#### 3.2 Comparison the quality of 6 months-old Tacca tubers cultivating under the forest canopy and planting in the field

![Figure 2. Tacca tubers composition in the field and under the forest canopy](image)

According to the statistical analysis showing that there was no significant difference in each indicator (Figure 3), although there was a difference in tubers’ ingredients between the crops and under the forest canopy at 6th months. Thus, it can be said that the quality of Tacca tuber is not affected by the location
of planting. In terms of economic aspect, growing under a forest canopy or intercrop with fruit trees can take advantage of bare land to increase income rather than cultivating in the field.

3.3 Effect of preliminary processing and storage on the quality of Tacca tubers

3.3.1. Effects of the preparation and storage on sensory characteristics of Tacca tubers

Raw tubers after harvesting have a pale yellow color and the plump surface but is easy to be scratched due to the soft outer shell and the structure is firm. Treated samples (washed and dried) is giving a lighter color and the structure is slightly softer than untreated samples due to the removal of all soil deposits.

- The color: After 2 weeks of storage, tubers’ color was darker than the original over time. This phenomenon is more noticeable with the piled up sample than the group store in dark and in packaging storage. However, at the week 6th, the color of untreated samples were turning to dark yellow while the treated samples were slightly red.

- The surface: After several weeks of storage, the surface of the tubers is gradually drier and the skin becomes rough due to the appearance of wrinkles, the bruising spots become darker and clearly visible. This happen is more apparently obvious in the treated samples than the untreated samples.

- The structure: Tubers’ structure becomes firmer over time of storage. This occurs in all preservative samples, but the untreated samples tend to be firmer than the treated samples after storaging in the same period.

The above phenomena occur almost samples but there is no significant difference between storage methods. In the same storage samples, there are significant differences in sensory attributes after 8 weeks of storage comparing to the first week and is no difference between 2 consecutive weeks. This happen is might be the moisture exchange between the tuber and the storage environment leading to moisture loss from the tubers.

Samples have been treated and stored in the packaging, the spoilage occurs to some tubers from weeks 7 and 8 (the number of damaged bags account for 1/4 of the total number of bags put into storage). Raw Tubers which are washed resulting in the higher moisture content and softer structure. Therefore when tubers are placed but the packaging but was not lined with perforations leading to water condensation, moisture drainage and mucus secretion. As a result, tubers become softer, more watery and contain the unpleasant odors.

3.3.2. Effect of preliminary processing and storage on the weight loss of Tacca tubers

Both factors of preliminary processing and storage have a significant effect on the loss of tuber weight during storage. The treated samples have higher mass loss than the untreated samples (Figure 3). The reason is that the treated samples (washed and dried) have a higher initial moisture content (71.13% compared to 68.15%), so during storage they will lose moisture and lose more weight. In addition, samples stored in perforated PE packaging have the lowest mass loss due to the properties that prevent the evaporation of water from the packaging. Samples stored in the piling method in space had higher weight loss than those stored in the dark, but this difference was not statistically significant.
Figure 3. The weight loss of Tacca tubers (%) by storage time

All samples experienced loss of mass during storage. After 8 weeks of preservation, the weight of tubers decrease when compared to the original weight of about 9.98-12.80%. In general, the loss of weight increase rapidly during the 4 weeks of storage, after that it tended to increase slowly and there is no statistically significant difference between the previous week and the 6th, 7th week. The cause are due to a decrease in the weight of the raw tuber, the evaporation and inspiratory activities of the tubers during storage. The similar happens to sweet potatoes preserved as the study result of [3].

3.3.3. The effect of preliminary processing and storage on the chemical compositions of Tacca tubers

The total dry matter content increases during storage and it is statistically significant difference between storage weeks (Figure 4). According to Zoran B [4] the increase in potatoes dry matter during storage showing that the amount of water lost due to moisture evaporation is much greater than the amount of dry matter loss due to respiration. Thus, the decrease in raw tubers’ moisture content is proportional to the increase in dry matter content which grows up rapidly in the first weeks.

However, changes in dry matter content in storage samples are influenced by the preparation activities but are not affected by the storage methods. It is explained that there is a difference in initial moisture content between samples, for example; treated samples containing higher moisture content so the total dry matter is lower than the untreated samples. In addition, during week 4th of storage, there is occurrence of the moisture exchanges between the samples and the storing environment, therefore; it leads to the difference in the total dry matter content between samples.
The decrease of reducing sugar content during 8 weeks of storage (Table 4) is a result of the internal respiration of the tubers in which monosaccharides (simple sugars) as glucose is converting into water, CO₂ and energy. This is also linked with Uzi A and Stanley J [5] researching on sweet potatoes. In addition, statistical analysis results showing that preliminary processing factor also has an impact on the changing of reducing sugar content of Tacca tubers during storage.

| The stored time (weeks) | 0      | 2nd    | 4th    | 6th    | 8th    |
|------------------------|--------|--------|--------|--------|--------|
| No treatment, in dark  | 2.29±0.03 | 1.10±0.04 | 0.91±0.03 | 0.82±0.07 | 0.64±0.09 |
| No treatment, piling   | 2.29±0.03 | 1.31±0.03 | 0.97±0.04 | 0.81±0.10 | 0.73±0.06 |
| No treatment, PE       | 2.29±0.03 | 1.31±0.10 | 0.78±0.04 | 0.85±0.08 | 0.53±0.01 |
| Pre-processing, in dark| 2.29±0.03 | 1.41±0.06 | 1.10±0.05 | 0.67±0.04 | 0.58±0.13 |
| Pre-processing, piling | 2.29±0.03 | 1.42±0.08 | 0.82±0.06 | 0.84±0.03 | 0.66±0.10 |
| Pre-processing, PE     | 2.29±0.03 | 1.49±0.06 | 1.16±0.07 | 1.04±0.05 | 0.67±0.03 |

Note: (*) The numbers with same letter a, b, c... in each row indicating no significant difference of 5% through the LSD test.

Preparation activities have contributed to the modification of starch content of during storage whereas there was no significant difference between the preservation methods. In general, starch content tended to gradually decrease after 4 weeks-storaged and increased again from week 6th (Table 5). The reason for this changing is that after harvesting, the conversion process of starch in the tuber cells happened and turned the complex sugar into simple molecules, for example; glucose. These molecules then participated to the respiration process leading to the decrease in starch content rapidly. The respiratory process usually strongly takes place in the first weeks of storage and it slightly decreases afterward [6]. In addition, there was a reducing the amount of nutrients during storage such as protein, non-protein nitrogen, lipids, vitamins, phosphorus and calcium [7] [5]. It is indicating that the value of starch content (% on dried weight-based) of raw materials has increased. It is matching with Benjamin M P [8] demonstrating that the unreacted starch content of preserved corn decreased during the first 10 weeks and increased steadily thereafter.
The total saponins and polyphenols content of Tacca tubers is likely to a decrease during 8 weeks of storage; however, this is a slight modification and is statistically insignificant between weeks of storage due to the short shelf life. According to Madan V K [9] indicating that there was the decrease in saponin Asparagus racemosus root powder during 12 months of storage.

Table 7. Content of total Saponins (%) in tubers by storage time (week)

| The stored time (weeks) | 0               | 4th              | 8th              |
|------------------------|-----------------|------------------|------------------|
| No treatment, in dark  | 2.02± 1.24      | 0.93± 0.99       | 0.97± 0.43       |
| No treatment, piling   | 2.02± 1.24      | 0.86± 0.96       | 0.69± 0.78       |
| No treatment, PE       | 2.02± 1.24      | 1.44± 1.74       | 0.8± 0.63        |
| Pre-processing, in dark| 2.02± 1.24      | 0.99± 0.65       | 0.74± 0.53       |
| Pre-processing, piling | 2.02± 1.24      | 0.72± 0.76       | 0.89± 1.18       |
| Pre-processing, PE     | 2.02± 1.24      | 1.08± 1.31       | 0.78± 0.87       |

Note: (*) The numbers with same letter a, b, c... in each row indicating no significant difference of 5% through the LSD test.

The modification of Tacca tubers qualities during storage are greatly affected by preliminary processing due to the effect of the initial moisture content of the raw material. There is not significant difference of preservation methods although the result showed that using perforated packaging for preservation has lead to a significant decrease in weight loss. The probabilities are the short time of storage’s study (8 weeks only), the unstable qualities of tuber root resources between crops, the sampling techniques, pre-processing samples and delivery manners. In brief, Tacca tubers has changed in sensory...
characteristics after 8 weeks of storage but could be continuing the preservation for longer periods of time (excluding the treated samples storing in the packaging).

4. Conclusion
The basic ingredients of Tacca tubers and the flour yield recovery are considerably affected by harvesting time and weight bulbs but are not depending on cultivating location. At 7th months-old, tubers’ dry matter content (mainly starch) increases the efficiency of flour recovery and this process is not likely to happen to tubers growing over these time. It is also showing that tubers weight over 150g/tuber is giving the better qualities and higher recovery efficiency. The pre-processed tubers before storage have an effect on Tubers qualities than storage methods. The harvested Tacca tubers are reduced in weight and increased in total dry matter content during each week of storage. Starch content decreased during first 4 weeks and increased again from the week 6th, whereas the amylose ratio of starch has changed significantly. Besides, the content of dry substances such as reducing sugars, total saponins or total polyphenols are weekly tending to decrease. In conclusions, after 8 weeks of preservation, the tubers have modified in color, surface appearances, structure characteristics but remained the good qualities regarding sensory characteristics (exception for samples treated in the packaging) that is likely to continue longer preservation.

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