# Carbohydrate Metabolism during Dormancy and Sprouting in Yam *(Dioscorea)* Tubers: Changes in Carbohydrate Constituents in Yam *(Dioscorea)* Tubers during Dormancy and Sprouting

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Changes in carbohydrate constituents were stuided in tubers of *Dioscorea rotundata*, *Dioscorea alata*, and *Dioscorea esculenta* during dormancy and sprouting for a period of 90 days. Decrease in starch content (35%) was the most significant change observed in all yam species. This decrease was reflected in proximal, middle, and distal regions of tubers. More than 50% of the starch reduction took place during the dormancy period. The mobilization of starch to sugars and its utilization was reflected in fluctuating levels of reducing and nonreducing sugars during presprouting/sprouting periods. Changes were also observed in the amylose fraction in starch. Chromatographic sugar analysis in tubers indicated the presence of glucose and sucrose in fresh tubers. Fructose and maltose were detected during dormancy/sprouting periods.

**Keywords:** *Dioscorea tubers; carbohydrates; dormancy; sprouting*

## INTRODUCTION

Edible yams (*Dioscorea rotundata*, *Dioscorea alata*, and *Dioscorea esculenta*) are tropical tuber crops that serve as an important staple food in many parts of the world. The crop is propagated vegetatively from pieces of mother tuber. Yam tubers have a natural dormancy period, after which they sprout and produce new shoots or vines. The dormancy period is of importance in connection with the food use of yams because it determines the time for which the tubers may be stored. Once the dormancy is broken, sprouting occurs and prolonged storage is no longer possible. To increase the storage life of yam tubers, it is necessary to delay sprouting. On the other hand, breaking dormancy by inducing early sprouting would facilitate rapid propagation of the crop. Very little is known about the mechanism of dormancy in yam tubers and the metabolic changes that take place during dormancy and sprouting. There is limited information available on the changes in carbohydrates in yam tubers during sprouting.

Investigations on the biochemical changes in stored yam tubers have shown that changes in starch, sugars, and protein take place during long-term storage (Ikediobi and Oti, 1983; Onayeme and Idowu, 1988; Sundaresan et al., 1991; Ravindran and Wanasundera, 1993). The relationship between sugars and the pattern of breakage of dormancy in *D. alata* was studied by Mozie (1987). The present paper deals with the changes in carbohydrate constituents in three yam species (*D. rotundata*, *D. alata*, and *D. esculenta*) and comparative changes in different regions of tubers (viz., proximal, middle, and distal) during storage. This information is important because sprouting occurs mainly in the apical (proximal) region in yam tubers (Passam, 1977).

## MATERIALS AND METHODS

**Materials.** Mature tubers of *D. rotundata* (cv. Sree Priya), *D. alata* (cv. Sree Rupa), and *D. esculenta* (cultivar SreeLatha) were obtained from the Institute farm for this study. Uniform sized tubers were selected for each species. Tubers were stored in open racks in a thatched storage shed at 29 ± 1 °C and a relative humidity of 70 ± 2%. The dormancy period was measured as the time taken from the first day of storage until the appearance of the first sprout on the tuber. The sprouting pattern was monitored, and the tubers were taken for biochemical analysis at 10-day intervals up to a period of 90 days.

**Methods.** Three yam tubers (in each species) were taken for each sampling. Slices of yam tissue were cut from proximal, middle, and distal regions of *D. rotundata* and *D. esculenta* and from proximal and distal regions in *D. alata*, and pooled separately. Three samples were analyzed from each portion, in duplicate. The average values of six estimations are reported.

Dry matter was estimated by drying tuber pieces at 70 °C to constant weight in a hot air oven. Amylose was estimated according to the method of Williams et al. (1970). A 100-mg dry powdered tuber sample was extracted with 10 mL of 0.5 M potassium hydroxide and centrifuged at 5000 *g* for 15 min, and amylose was estimated in the supernatant by addition of iodine reagent.

Soluble carbohydrates (sugars) were twice extracted from dried powdered samples with boiling ethanol (80% v/v). Pooled alcohol extracts were used for determination of total and reducing sugar. Total sugars were estimated by the phenol-sulfuric acid method (Dubois et al., 1956) and reducing sugars by the Nelson−Somogyi method (Nelson, 1944). Nonreducing sugars were obtained by subtracting reducing sugars from total sugars. Starch was estimated in the residue left after sugar extraction. The residue was hydrolyzed with 2 N HCl, and glucose formed was estimated by the phenol−sulfuric acid method. Glucose values were multiplied by 0.9 to compute starch content. Individual sugars were detected by paper chromatography as described by Mozie (1987). Tuber samples were extracted with boiling ethanol (80% v/v). Extracts were clarified by passing through ion-exchange resins, concentrated, and separated by paper chromatography on Whatman No. 1 paper using *n*-butanol:acetic acid water (12:3:5 v/v) as solvent. After drying, the individual sugars were located by spraying with diphenylamine−aniline reagent. Standards of glucose, fructose, sucrose, and maltose were run simultaneously for identification of individual sugars.

## RESULTS

**Sprouting of Yam Tubers.** Tubers of *D. rotundata*, *D. alata*, and *D. esculenta* sprouted between 60 and 70 days of storage. The sprout length was monitored in

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the case of all three species. A very rapid increase in sprout length was observed in *D. rotundata* and *D. alata* (sprouts measured ~100 cm at 90 days), whereas sprouts reached a height of only 40 cm in *D. esculenta*.

**Weight Loss and Dry Matter.** Tubers of all three yams species experienced significant weight and moisture loss during the storage period. Percentage weight loss was highest in tubers of *D. esculenta* (31.7%), followed by *D. alata* (26.7%) and *D. rotundata* (18.48%). About 50% of the total weight loss was accounted for during dormancy. Rate of weight loss was higher during the sprouting period than during dormancy.

Moisture loss was higher in tubers of *D. esculenta* (25%) than in *D. alata* and *D. rotundata* (12%). In *D. rotundata*, distal regions showed 16% moisture loss compared with proximal (9%) and middle regions (11%). In the other two yam species, moisture loss was uniform throughout the tuber. In tubers of *D. rotundata* and *D. alata*, the rate of moisture loss was very low during dormancy, whereas in *D. esculenta*, significant moisture loss was observed during pre-sprouting period (data not shown).

**Starch Content in Storage.** Starch content decreased by 32% in tubers of *D. rotundata* after 90 days of storage (Figure 1a). The extents of decrease in proximal, middle, and distal regions were 33, 29 and 41%, respectively. In proximal and middle regions, a significant reduction in starch content was observed at 60 days, when sprouting commenced. In distal regions however, a decrease in starch (28%) was observed during the dormancy period, followed by a 13% decrease after sprouting commenced.

Starch decreased in *D. alata* from an initial level of 78% to 45 % after 90 days of storage. A decrease of 26% was observed during dormancy. The pattern of decrease was similar in proximal and distal regions of tubers (Figure 1b).

In *D. esculenta* starch content decreased by 40% during 90 days of storage. The extent and pattern of decrease was similar in all three regions of the tubers. As in the case of *D. alata*, there was considerable reduction (28%) in starch content during dormancy.

**Reducing and Nonreducing Sugars.** Changes in the level of reducing and nonreducing sugars in tubers of *D. rotundata*, *D. alata*, and *D. esculenta* during tuber dormancy and sprouting are shown in Figures 2 (a, b, c) and 3 (a, b, c), respectively. An increase in reducing and nonreducing sugars of *D. rotundata* was observed in proximal, middle, and distal regions during the sprouting period. An increase in sugars was also seen in the proximal region during dormancy. Reducing sugars of *D. alata* increased two- to three-fold prior to sprouting and decreased during the sprouting process. Nonreducing sugars also increased during dormancy in both proximal and distal regions and showed a peak during sprouting. Reducing sugars of *D. esculenta* increased significantly in all regions of tuber during dormancy (peaks observed at 10 and 30 days) and continued to increased during sprouting. Nonreducing sugars, on the other hand, decreased during dormancy and showed no increase during sprouting.

**Amylose.** The amylose content was monitored at different stages to determine whether there were alterations in starch fractions during sprouting. In tubers of *D. rotundata*, amylose fraction increased after 1 month and then gradually decreased; the lowest levels were seen during sprouting. In *D. alata* and *D. esculenta* a decrease in amylose was observed during the first month, after which the values were almost constant. These results indicate that changes occur in starch fractions prior to sprouting.

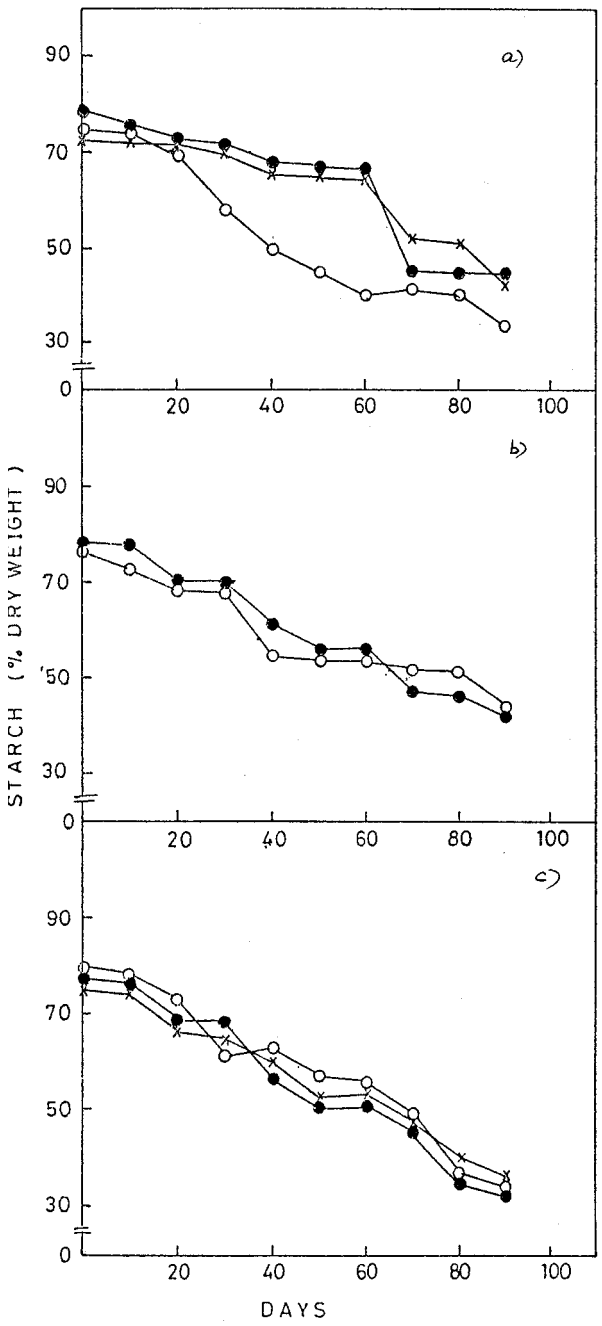


**Figure 1.** Starch content in yam tubers during dormancy and sprouting. Starch content was determined in proximal, middle, and distal regions of tubers at 10-day intervals. Three tubers were sampled at each stage in each yam species. The average of six estimations is represented in each case: (a) *D. rotundata*; (b) *D. alata*; (c) *D. esculenta*. Key: proximal (●); middle (×); distal (○) regions.

**Sugar Profile.** The qualitative sugar profile in tubers was studied during various stages of dormancy and sprouting, and the results are given in Table 1. Freshly harvested tubers of all three *Dioscorea* species showed the presence of glucose and sucrose. In *D. rotundata*, fructose was detected in distal regions after 10 days, and in proximal and middle regions after 20 days. Maltose was detected in all three regions in sprouted tubers at 80 days. In *D. alata*, fructose was detected in both proximal and distal regions at 20 days and maltose after 80 days in sprouted tubers. In *D.*

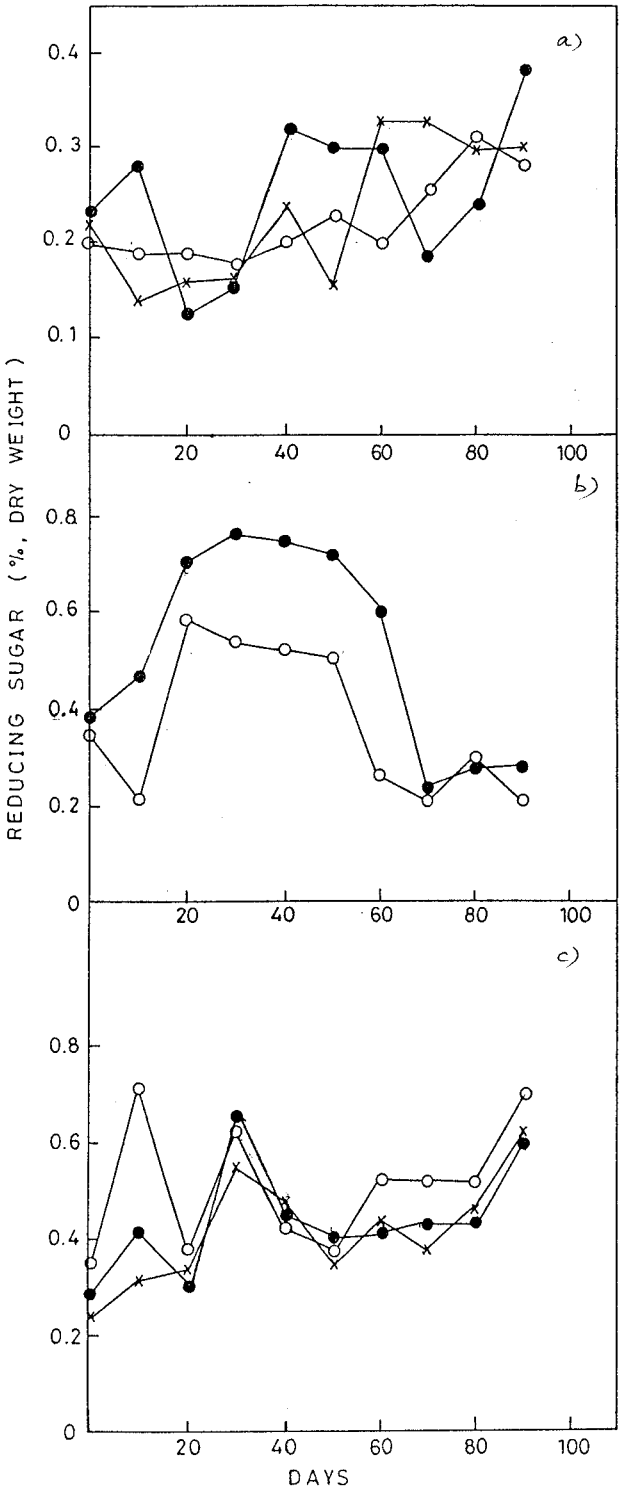


**Figure 2.** Reducing sugar levels in yam tubers during dormancy and sprouting. Reducing sugar (expressed as glucose) was determined in proximal, middle, and distal regions of tubers at different stages of storage. Sampling was done as in the case of starch. Values represent the average of six estimations: (a) *D. rotundata*; (b) *D. alata*; (c) *D. esculenta*. Key: proximal (●); middle (×); distal (○) regions.

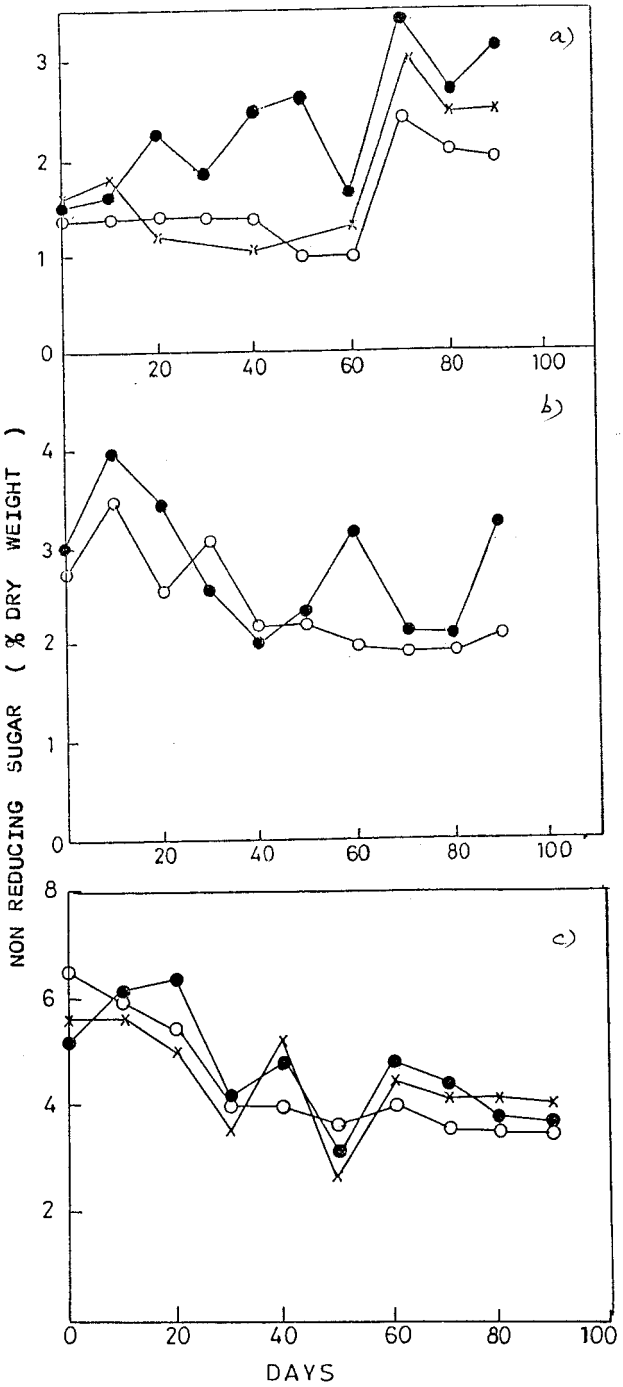


**Figure 3.** Nonreducing sugar levels in yam tubers during dormancy and sprouting. Nonreducing sugars were obtained as the difference between total and reducing sugar. The values represent the average of six estimations: (a) *D. rotundata*; (b) *D. alata*; (c) *D. esculenta*. Key: proximal (●); middle (×); distal (○) regions.

*esculenta* tubers, maltose was present along with fructose after 20 days of storage.

## DISCUSSION

The dormancy period is generally associated with minimum endogenous metabolic activity, resulting in very little loss of essential constituents. The breaking of dormancy results in increased metabolic activity and respiration rate (Onwueme, 1973; Passam et al., 1978, Wickham et al., 1981). Differences also exist in the pattern of respiratory activity between proximal and distal apices of tubers (Coursey and Russul, 1969; Passam, 1977).

The results of the present study indicate that changes in starch and sugars were initiated even during the dormancy period. Decrease in starch content was the most significant change that occurred during sprouting. An average decrease of 35% was observed during 90 days storage. Although visible emergence of sprouts was seen only from the apical region of tubers, changes

**Table 1. Chromatographic Detection of Sugars in Yam Tubers during Dormancy and Sprouting[a]**

| | | region | | |
|---|---|---|---|---|
| yam species | days | proximal | middle | distal |
| *D. rotundata* | 0 | GS | GS | GS |
| | 10 | GS | GS | GSF |
| | 20−70 | GSF | GSF | GSF |
| | 80−90 | GSFM | GSFM | GSFM |
| *D. alata* | 0 | GS | | GS |
| | 20−70 | GSF | | GSF |
| | 80−90 | GSFM | | GSFM |
| *D. esculenta* | 0−10 | GS | GS | GS |
| | 20−90 | GSFM | GSFM | GSFM |

[a] G, glucose; S, sucrose; F, fructose; M, maltose.

in reserve material were reflected in all regions of the tubers. The difference observed in the pattern of starch mobilization and moisture loss between proximal, middle, and distal regions of *D. rotundata* tubers is possibly due to the large size of the tubers. In *D. alata* and *D. esculenta*, tubers are smaller in size and there is very little variation in the pattern of starch mobilization between different regions of tubers. Alterations in amylose content during storage indicated that reversible/irreversible changes in starch constituents (amylose, amylopectin) were also taking place during presprouting and sprouting periods.

The mobilization of starch into sugars was reflected in the increased levels of reducing and nonreducing sugar observed during certain stages of dormancy and sprouting. The appearance of fructose at the 20th day suggested breakdown of sucrose at this stage, possibly by action of invertase (Hariprakash and Nambisan, unpublished results). These results differ from those of Mozie (1987) who showed that fructose appeared only on breakage of dormancy and was absent in dormant tubers. Maltose appeared only after sprout formation in tubers of *D. rotundata* and *D. alata*, indicating that amylase was involved actively in starch breakdown only at a later stage (Hariprakash and Nambisan, unpublished results). The presence of of high levels of $\beta$-amylase in tubers of *D. esculenta* (Lila Babu et al., 1990) explained the presence of maltose in these tubers at all stages.

To have a clearer understanding of the mechanism of carbohydrate breakdown during dormancy and sprouting, it would be necessary to monitor the activity of the enzymes of carbohydrate metabolism during this period. The role of endogenous mechanisms that trigger these metabolic changes in the tuber during dormancy and sprouting should be investigated.

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