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Starch and sugar conversion in *Dioscorea esculenta* tubers and *Curcuma longa* rhizomes during storage

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ABSTRACT
An investigation was carried out to reveal the changes in the concentration of soluble carbohydrates under tuber dormancy in food yam (*Dioscorea esculenta*) tubers and in an economically important spice cum medicinal plant turmeric (*Curcuma longa*) rhizomes under storage. Harvested, fully matured tubers of yam and rhizomes of turmeric were stored in wooden boxes under the conditions of 28 ± 2°C temperature and 65 to 75% relative humidity in dark. The moisture content, dry weight, starch, sugars, organic acids and respiration were studied in the tubers during 1 to 7 weeks after storage individually. This investigation revealed that the moisture content, dry weight and starch levels decreased gradually with a concomitant increase in sugar content under different stages of dormancy.

Keywords: Carbohydrate. Dormancy. Storage tubers rhizomes starch.

INTRODUCTION
Dormancy is an arrest in development of buds, seeds, embryos or spores under unfavourable conditions of growth. The term dormancy may be applied in a general sense to any phase in the life cycle of whole plant, or of particular organs, in which active growth is temporarily suspended (Panneerselvam, 1998, 2007; Jaleel *et al.*, 2007a). Ile *et al.*, (2006) divided the dormant period as "pre-dormancy" or early rest, "mid dormancy" and "post dormancy" or after rest. Dormancy is a subject of interest to agronomists, horticulturists and physiologists.

Seed dormancy is a genetically inherited trait whose intensity is modified by the environment during seed development and maturation. The ability of seeds to delay their germination until the favorable time reaches in the right place is an important survival mechanism. Seed dormancy is an important physiological stage in the life cycle of many seed bearing plants. In an ever-changing environment, dormancy increases survival of species by distributing its germination over time and also by avoiding pre-harvest sprouting, which affects seed quality adversely in many cereals (Arumugam *et al.*, 2008).

Food yam (*Dioscorea esculenta* (Lour.) Burk.) is one of the important edible tuber crops cultivated in India and many other tropical countries including Africa. It is an important cultivated species of yam (Amusa *et al.*, 2003). Yams are valuable source of carbohydrate, fibres and low level fats, which makes them good dietary source (Grindley *et al.*, 2002; Jaleel *et al.*, 2007b) and also processed in to various staple, intermediate and end product forms (Coursey, 1967). Yams also have medicinal properties (Kelmanson *et al.*, 2000; Jaleel *et al.*, 2008a, b). Diosgenin, a steroid sapogenin of yam, has been utilized to manufacture steroid hormones, such as cortisone, estrogen and progesterone (Araghinkinam *et al.*, 1996). Several species of *Dioscorea* are amongst the principle sources of diosgenin, which can be converted to medicinally important steroids (Jaleel *et al.*, 2007c). Originated from India and found in South American countries, turmeric (*Curcuma longa* L.) is largely used in

medicinal and food preparations (Braga *et al.*, 2006). Due to its easy digestibility, turmeric has been used in industry to prepare special food and children's foods (Jyothi *et al.*, 2003). Turmeric has long been known in India and many other countries as important dietary sources in addition to their use in traditional medicine for wound healing, inflammation and stomach acidity (Kumar *et al.*, 2006).

Phenotype and agronomic properties of tropical tubers and roots (Whistler & Bemiller, 1999) and the dormancy-breaking and germination requirements (Albrecht & McCarthy, 2006) have been well documented. Little is known concerning the changes in carbohydrate accumulation during dormancy and sprouting in yam tubers and turmeric rhizomes. Therefore, the objectives of this study were to explore the changes occurring in the yam tubers and turmeric rhizomes during different phases of dormancy in terms of moisture content, dry weight, starch, total reducing and non reducing sugars, sugar phosphates, organic acid, sucrose, glucose, fructose, and respiration rate.

MATERIALS AND METHODS

Plant Materials, Cultivation and Storage Methods

Tubers of *D. esculenta* and rhizomes of *C. longa* were obtained from Tamil Nadu Agricultural University, Coimbatore, India. One hundred each planting material for both *D. esculenta* and *C. longa* were planted in the Botanic Garden of Annamalai University. The crops come to bearing after 9 to 10 months. The tubers and rhizomes were dugout after the aerial parts fully decayed. This period was considered as the initial period of dormancy.

The mature healthy tubers and rhizomes of uniform size and weight were kept in special storage room at 28 ± 2°C and RH 65-75%. The sprouting period for *D. esculenta* is 56 ± 5 days and 70 ± 5 days for *C. longa* (Panneerselvam, 1998). Sprouts only occur at the head portion around the point of detachment from the mother plant. The biochemical changes during dormancy (to inhibit the bud growth) and during sprouting (to initiate the bud growth) may take place at the region of bud (head portion). The study was made from one week after storage (WAS) till the day of sprouting at the interval of 7 days using the bud and the portion up to 1 cm below the bud. Sufficient number of tubers and rhizomes were selected for the study. For each study, new tubers were used; the replicates were made from the different tubers of a lot, which were selected at random.

Moisture Content (MC) And Dry Weight (DW)

In both *D. esculenta* and *C. longa* MC and DW were determined using the following method. 10 g of fresh material was placed in a petridish and transferred to an oven, maintained at 60 °C for 48 hrs. The oven-dried material was transferred to a desiccator and weighed. The procedure was repeated until a constant weight was obtained. MC and DW were calculated and expressed as percentage of fresh weight (FW).

Starch, Sugars and Organic Acids (OA)

Starch was extracted and estimated following the standard method of Clegg (1956). Soluble sugars (reducing and non-reducing) were estimated (Nelson, 1944) and qualitative determination of sugars was done by the method of Bell (1955) with the help of prepared ion exchange resins. Paper and co-chromatography (Stahl, 1969) were conducted for the separation of individual sugars by following Nelson's arsenomolybdate method (Nelson, 1944). Sugar phosphates (Benson, 1955) and OA (Harborne, 1973) were separated chromatographically.

Respiration

Respiration rate was determined by the Wasburg manometric technique (Umbreit *et al.*, 1964). The study was performed with Brown Wasburg Apparatus, Model-V. The experiments were conducted at 28 °C.

Statistical Analysis

Statistical analysis was performed using one way analysis of variance (ANOVA) followed by Duncan's Multiple Range Test (DMRT). The values are mean ± SD for six samples in each group. P values ≤ 0.05 were considered as significant.

RESULTS

Moisture Content (MC) and Dry Weight (DW)

The rate of loss of MC in the yam tubers was at an average of 0.4 percentage per week

(PPW) up to 6 WAS. At the time of sprouting there was a rapid loss of MC and at accounted for 1.1 PPW for the 7 and 8 WAS. The total loss in MC for entire storage period up to sprouting was 6.33%. In the case of tu rmeric the rate of loss of MC was 0.7 PPW up to 7 WAS. From 8 to 10 WAS, the rate of loss of MC was 1.64 PPW. The total loss in MC for the 10 WAS period was 9.61% (Table 1).

The rate of increase in DW in the tubers of yam was 0.3 PPW up to 6 WAS period. The increase in DW was 1.5% for the 7 and 8 WAS and the total increase in DW up to sprouting was 3.52%. The pattern of increase in DW of yam was similar to that of rhizomes of turmeric. The DW was higher in rhizomes of turmeric than that of tubers of yam at the time of sprouting.

Starch, Sugars and Organic Acid (OA)

There was a gradual decrease in starch content (2.16%) up to 5 WAS in tubers of yam. The rate of decrease was 0.43 PPW. Then there was a sharp decrease up to 8 WAS *i.e.* the time of sprouting. From 5 to 8 WAS, the starch content decreased by 8.72% at the rate of 2.96 PPW. There is a total loss of 10.88% of starch content from the period of harvest to sprouting (Table 2).

In the rhizomes of *C. longa* starch content decreased slightly up to 6 WAS. The decrease in starch content was 2.41% up to 6 WAS at the rate of 0.40 PPW. There was a rapid loss of starch content from 6 WAS to 10 WAS *i.e.* the sprouting period. There is a decrease of 11.66% from 6 to 10 WAS at the rate of 2.99 PPW. The loss of starch content was found to be 14.07% from the time of storage till sprouting in the rhizomes of *C. longa.*

There was a slight increase in non-reducing sugars (Table 2) in the tubers of *D. esculenta* up to 5 WAS of storage whereas in the rhizomes of *C. longa*, they increased continuously up to 7 WAS. There was a sharp increase of non-reducing sugars from 5 to 8 WAS and from 7 to 10 WAS week in the tubers of *D. esculenta* and in the rhizomes of *C. longa* respectively.

The pattern of increase of non-reducing sugars is similar for the tubers of *D. esculenta* and the rhizome of *C. longa.* There was an increase of 23.2% of non-reducing sugars in the tubers of *D. esculenta* from the beginning of storage period to sprouting. There was an increase of 12.72% of non-reducing sugars in the rhizomes of *C. longa* from the beginning of the storage period to sprouting.

There was a slight increase of reducing sugars in the tubers of *D. esculenta* up to 5 WAS whereas in *C. longa* the slight increase continues up to 7 WAS. There was a sharp increase of reducing sugars from 5 to 8 WAS and from 7 to 10 WAS in the tubers of *D. esculenta* and the rhizomes of *C. longa,* respectively.

Qualitative Determination of Sugars

The extract of soluble sugars of the tubers of *D. esculenta* and the rhizomes of *C. longa* were analysed at weekly intervals using paper chromatographic technique with four solvent systems and specific spray reagents. Glucose, fructose and sucrose have been observed till 5 WAS in *D. esculenta* and up to 7 WAS of *C. longa.* Maltose was present from the 6 WAS in *D. esculenta* and from 7 WAS in *C. longa* with other soluble sugars. All the four sugars were observed at the time of sprouting. Maltose does not appear in the earlier stages. It appeared at 6 WAS in *D. esculenta* and from 7 WAS in *C. longa.* It appeared in traces in the qualitative separation but quantitatively it was not statistically significant (Table 4).

Quantitative Estimation of Individual Sugars

Individual sugars were eluted from the unsprayed chromatogram paper strips and the eluate were used for quantitative estimation of individual sugars. In the tubers of *D. esculenta* there was an increase of sucrose from the beginning of storage till the 4 WAS. From 4 to 8 WAS *i.e.* there was a rapid increase of sucrose to the extent of 32.66%. The total increase of sucrose content was 33.75% from the beginning of storage till sprouting. In the rhizomes of *C. longa*, there was an increase of sucrose content from the initial period to 6 WAS. From 6 to 10 WAS, there was a rapid increase of sucrose content. The total increase of sucrose from the beginning of storage till sprouting was 13.9%.

In the tubers of *D. esculenta* there was a slight increase of glucose content up to 5 WAS. The glucose content increased sharply from 5 to 8 WAS. The total increase of glucose from the beginning of storage till sprouting was 92.2%. In the rhizomes of *C.*

longa glucose increased gradually up to 6 WAS, while there was a sharp increase from 6 to 10 WAS *i.e.* the time of sprouting. The total increase of glucose from the beginning of storage till sprouting was 69.43%.

Fructose increased slightly up to 5 WAS period in the tubers of *D. esculenta*. There was a rapid increase of fructose from 5 to 8 WAS. The total increase of fructose content from the beginning of storage till sprouting was 69.2%.

In the rhizomes of *C. longa* there was a small increase of fructose from the beginning of storage to 6 WAS. There was a sharp increase of fructose content from 6 to 10 WAS. There was an increase of 75.7% from the initial storage period till sprouting.

Qualitative Determination of Sugar Phosphate

The extract for phosphorylated sugars of the tubers of *D. esculenta* and of the rhizomes of *C. longa* were analysed with two solvent systems and specific reagents. Glucose-1-phosphate and glucose-6-phosphate have been observed till the 3 WAS in *D. esculenta* and till 5 WAS in *C. longa*. Fructose-6-phosphate was present from the 4 WAS in *D. esculenta* and from 6 WAS in *C. longa*, along with the other two sugar phosphates till sprouting. These three sugar phosphates have been observed at the time of sprouting.

Qualitative Determination of OA

OA were extracted from the tubers of *D. esculenta* and the rhizomes of *C. longa* during the storage period. OA have been identified using paper chromatographic technique with two solvent systems and specific spray reagents (Table 3). Succinic, malic and citric acids were observed. All the acids are present at the time of sprouting in both the tubers of *D. esculenta* and the rhizomes of *C. longa*.

Table 1. Moisture content and dry weight of *D. esculenta* tubers and *C. longa* rhizomes during storage period.

Weeks after storage (WAS)	Moisture content (MC)		Dry weight (DW)	
	D. esculenta	*C. longa*	*D. esculenta*	*C. longa*
0	71.40 ± 0.19^{a}	73.15 ± 0.25^{a}	28.60 ± 0.19^{a}	26.85 ± 0.25^{a}
1	71.29 ± 0.18^{a}	72.93 ± 0.23^{b}	28.71 ± 0.18^{a}	27.07 ± 0.23^{b}
2	70.95 ± 0.15^{b}	72.34 ± 0.27^{b}	29.05 ± 0.15^{b}	27.60 ± 0.27^{b}
3	70.61 ± 0.16^{b}	71.86 ± 0.22^{c}	29.39 ± 0.16^{b}	28.14 ± 0.22^{c}
4	70.31 ± 0.18^{b}	71.55 ± 0.26^{c}	29.69 ± 0.18^{b}	28.45 ± 0.21^{c}
5	69.82 ± 0.15^{c}	70.87 ± 0.20^{d}	30.18 ± 0.16^{c}	29.13 ± 0.24^{d}
6	69.36 ± 0.17^{c}	70.23 ± 0.23^{d}	30.64 ± 0.16^{c}	29.77 ± 0.26^{d}
7	68.75 ± 0.15^{d}	69.58 ± 0.24^{e}	31.25 ± 0.15^{d}	30.42 ± 0.22^{e}
8	67.88 ± 0.17^{e}	68.57 ± 0.21^{f}	32.12 ± 0.17^{e}	31.43 ± 0.24^{f}
9	-	67.56 ± 0.26^{f}	-	32.44 ± 0.25^{g}
10	-	66.12 ± 0.26^{g}	-	33.88 ± 0.22^{h}

Values are expressed in % of total weight. Values are given as mean ± SD of six samples in each group. Values that are not sharing a common superscript (a-h) differ significantly at $P \leq 0.05$ (DMRT).

Table 2. Starch, non-reducing and reducing sugar contents of *D. esculenta* tubers and *C. longa* rhizomes during storage period.

Weeks after storage (WAS)	Starch		Non-reducing sugar		Reducing sugar	
	D. esculenta	*C. longa*	*D. esculenta*	*C. longa*	*D. esculenta*	*C. longa*
0	758.65 ± 8.83^{a}	681.58 ± 6.80^{a}	68.28 ± 0.85^{a}	56.37 ± 0.57^{a}	8.67 ± 0.41^{a}	3.87 ± 0.37^{a}
1	758.35 ± 7.17^{a}	680.35 ± 7.47^{b}	66.37 ± 0.69^{b}	55.88 ± 0.65^{b}	7.79 ± 0.43^{b}	3.93 ± 0.38^{a}
2	757.33 ± 6.75^{b}	678.98 ± 7.69^{c}	66.53 ± 0.62^{b}	55.73 ± 0.64^{b}	8.19 ± 0.42^{a}	4.16 ± 0.32^{b}
3	756.58 ± 7.02^{c}	677.39 ± 6.14^{d}	67.07 ± 0.69^{c}	55.28 ± 0.71^{b}	8.27 ± 0.49^{a}	4.29 ± 0.35^{b}
4	749.75 ± 6.15^{d}	672.75 ± 6.85^{e}	68.39 ± 0.62^{a}	55.33 ± 0.77^{b}	8.36 ± 0.35^{a}	4.36 ± 0.39^{b}
5	742.19 ± 8.95^{e}	667.88 ± 8.45^{f}	69.47 ± 0.68^{d}	55.49 ± 0.63^{b}	8.65 ± 0.33^{a}	4.48 ± 0.37^{b}
6	730.13 ± 6.15^{f}	665.17 ± 7.16^{g}	72.73 ± 0.72^{e}	56.09 ± 0.53^{a}	9.44 ± 0.38^{c}	4.53 ± 0.38^{b}
7	710.69 ± 6.31^{g}	650.35 ± 6.85^{h}	76.85 ± 0.85^{f}	56.47 ± 0.63^{a}	11.48 ± 0.45^{d}	4.88 ± 0.34^{b}
8	676.13 ± 7.99^{h}	630.64 ± 7.97^{i}	84.13 ± 0.65^{g}	58.45 ± 0.73^{c}	14.75 ± 0.37^{e}	5.12 ± 0.38^{c}
9	-	608.47 ± 8.05^{j}	-	61.28 ± 0.77^{d}	-	5.87 ± 0.37^{c}
10	-	585.63 ± 6.15^{k}	-	63.99 ± 0.64^{e}	-	6.63 ± 0.34^{d}

Values are expressed in mg g^{-1} dry weight. Values are given as mean ± SD of six samples in each group. Values that are not sharing a common superscript (a-k) differ significantly at $P \leq 0.05$ (DMRT).

Table 3. Changes in sugars, sugar phosphates and organic acids in *D. esculenta* tubers and *C. longa* rhizomes during storage period..

Weeks after storage (WAS)	Sugars								Sugar phosphates						Organic acids					
	Glucose		Fructose		Sucrose		Maltose		Glucose-1 phosphate		Glucose-6 phosphate		Fructose-6 phosphate		Succinic acid		Malic acid		Citric acid	
	Y	T	Y	T	Y	T	Y	T	Y	T	Y	T	Y	T	Y	T	Y	T	Y	T
0	+	+	+	+	+	+	-	-	+	+	+	+	-	-	+	+	+	+	+	+
1	+	+	+	+	+	+	-	-	+	+	+	+	-	-	+	+	+	+	+	+
2	+	+	+	+	+	+	-	-	+	+	+	+	-	-	+	+	+	+	+	+
3	+	+	+	+	+	+	-	-	+	+	+	+	-	-	+	+	+	+	+	+
4	+	+	+	+	+	+	-	-	+	+	+	+	+	-	+	+	+	+	+	+
5	+	+	+	+	+	+	-	-	+	+	+	+	+	-	+	+	+	+	+	+
6	+	+	+	+	+	+	+	-	+	+	+	+	+	+	+	+	+	+	+	+
7	+	+	+	+	+	+	+	-	+	+	+	+	+	+	+	+	+	+	+	+
8	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
9	N	+	N	+	N	+	N	+	N	+	N	+	N	+	N	+	N	+	N	+
10	N	+	N	+	N	+	N	+	N	+	N	+	N	+	N	+	N	+	N	+

Y: yam, T: turmeric, '+': present, '–': absent, N: not observed.

Table 4. Sucrose, glucose and fructose contents and rate of respiration in *D. esculenta* tubers and *C. longa* rhizomes during storage period.

Weeks after storage (WAS	Sucrose (mg g^{-1} DW)		Glucose (mg g^{-1} DW)		Fructose (mg g^{-1} DW)		Rate of respiration (U)	
	D. esculenta	*C. longa*	*D. esculenta*	*C. longa*	*D. esculenta*	*C. longa*	*D. esculenta*	*C. longa*
0	58.28 ± 1.65 [a]	48.35 ± 1.27 [a]	4.82 ± 0.45 [a]	2.15 ± 0.46 [a]	2.64 ± 0.18 [a]	1.05 ± 0.21 [a]	17.33 ± 1.03 [a]	10.37 ± 1.45 [a]
1	57.57 ± 1.86 [b]	47.07 ± 1.27 [b]	4.86 ± 0.48 [a]	2.10 ± 0.47 [a]	2.48 ± 0.19 [a]	0.92 ± 0.09 [b]	16.25 ± 1.05 [b]	9.50 ± 1.32 [b]
2	57.43 ± 1.45 [b]	46.36 ± 1.40 [c]	4.84 ± 0.36 [a]	2.15 ± 0.48 [a]	2.66 ± 0.10 [a]	0.96 ± 0.26 [b]	16.00 ± 1.63 [b]	9.67 ± 1.68 [b]
3	58.26 ± 1.75 [a]	47.85 ± 1.52 [b]	4.97 ± 0.46 [a]	2.19 ± 0.49 [a]	2.74 ± 0.14 [a]	1.03 ± 0.24 [a]	15.80 ± 1.45 [c]	10.33 ± 1.56 [a]
4	58.91 ± 1.62 [a]	47.45 ± 1.45 [b]	4.99 ± 0.48 [a]	2.15 ± 0.45 [a]	2.87 ± 0.21 [a]	1.10 ± 0.16 [a]	16.75 ± 1.48 [b]	11.20 ± 1.48 [c]
5	63.78 ± 1.75 [c]	48.65 ± 1.65 [a]	5.19 ± 0.47 [b]	2.27 ± 0.47 [a]	3.10 ± 0.22 [b]	1.08 ± 0.22 [a]	17.67 ± 1.85 [a]	11.33 ± 1.36 [c]
6	67.12 ± 1.67 [d]	49.36 ± 1.72 [d]	6.22 ± 0.49 [c]	2.27 ± 0.47 [a]	3.52 ± 0.14 [b]	1.15 ± 0.23 [a]	23.00 ± 1.96 [d]	12.33 ± 1.45 [d]
7	71.39 ± 1.60 [e]	50.15 ± 1.00 [e]	7.64 ± 0.46 [d]	2.47 ± 0.48 [a]	3.72 ± 0.16 [b]	1.29 ± 0.14 [a]	30.67 ± 1.55 [e]	13.75 ± 1.68 [e]
8	78.16 ± 1.78 [f]	51.17 ± 1.10 [f]	9.27 ± 0.47 [e]	2.69 ± 0.49 [a]	4.47 ± 0.15 [c]	1.41 ± 0.16 [a]	35.37 ± 1.76 [f]	17.50 ± 1.75 [f]
9	-	52.69 ± 1.90 [g]	-	3.09 ± 0.40 [b]	-	1.56 ± 0.17 [a]	-	21.67 ± 1.78 [g]
10	-	55.08 ± 1.03 [h]	-	3.55 ± 0.49 [b]	-	1.85 ± 0.15 [a]	-	27.80 ± 1.86 [h]

U = □l of O_2 consumed $hour^{-1}$ g^{-1} FW. Values are given as mean ± SD of six samples in each group. Values that are not sharing a common superscript (a-h) differ significantly at $P \leq 0.05$ (DMRT).

Respiration

The rate of respiration decreased in the tubers of *D. esculenta* up to 3 WAS. Then there was a slight increase of respiration up to 5 WAS. Later the rate of respiration increased sharply till sprouting period. In *D. esculenta* the increase of respiration from first week to 5 WAS was only 1.96% whereas it increased about 100% from 5 to 8 WAS (Table 4).

In the rhizomes of *C. longa* respiration decreased up to 2 WAS, followed by a slight increase up to 6 WAS. Later there was a sharp increase up to the time of sprouting. The increase in the rate of respiration from the initial of storage period till 6 WAS was about 18%. The rate increased by 125% from 6 to 10 WAS *i.e.* the time of sprouting (Table 4).

DISCUSSION

This study examined a variety of metabolites and enzymes associated with the major carbohydrate metabolic pathways within yam tubers and turmeric rhizomes in order to determine the changes in carbohydrate metabolism during dormancy period. The pattern of loss of MC was similar in both the materials and this loss of weight also includes the loss of substrate through respiration. A 20% loss of MC was reported for potato tubers (Blenkinsop *et al.,* 2002). MC was high in the tubers of *D. esculenta* compared to rhizomes of *C. longa*. Wide variations were reported in the moisture content of yams, both between species and also within the species (Coursey, 1967).

The results on DW exhibited a gradual increase till 6 and 7 WAS in *D. esculenta* and *C. longa* respectively. Later there is a rapid increase in dry matter. The pattern of increase of DW was similar for both the materials. DW was higher in rhizomes of *C. longa* than in tubers of *D. esculenta* at the time of sprouting. The rate of increase in DW corresponds to the rate of decrease in MC in dormant period. A gradual increase in DW of the two materials during the period of storage may be primarily attributed to the loss of MC and may be due to evaporation of water (Omonigho & Ikenebomeh, 2000). It also cannot be ruled out the possibility of accumulation of assimilates at the region of sampling. The samples were collected from the apical portion of the tuber or rhizome from which the sprouts originate. These apical portions are the centres of meristematic activity with high rate of metabolism requiring large quantities of soluble carbohydrates to trigger sprouting. As such the assimilates might be translocating to these regions from the other parts of the tuber thus causing a progressive increase in DW. Therefore, the method of sampling adopted in the present study also appears to be crucial in accounting for a gradual increase in DW.

The results on starch content showed a gradual decrease up to 5 WAS in tubers of *D. esculenta* and 6 WAS in rhizomes of *C. longa,* followed by a rapid decrease till sprouting and exhibited similar pattern of decrease in both the materials. The rate of decrease was also more or less same. Davis & Ross (1984) observed starch breakdown started at the time of sprouting in potato buds. The starch breakdown was first seen around the region of inner phloem and subsequent by spreading throughout the perimedula. Burton (1978) reported that starch breakdown started with the initiation of sprouts in potato tubers.

Analysis of the changes in starch and soluble sugars in sprouting potato showed that when a single sprout grows it draws upon the carbohydrates in every part of the tuber simultaneously. The breakdown of starch in potato tubers which starts when buds begins to grow, stops if the sprouts are removed. The sprouts control the utilization and translocation of food reserves from the tuber (Edelman *et al.,* 1969). In both the materials 2 or 3 WAS before the sprouts are visible starch breakdown was rapid. The starch breakdown in potato tuber starts at the end of dormancy apparently to a signal, probably hormonal, which seems to originate in the sprouts.

Some evidence suggests that gibberellins can hasten the breakdown of tuber reserves and it is easy to demonstrate the disappearance of starch from tuber tissue treated with gibberrellic acid (Morris, 1967). Isherwood (1975) showed starch was the only polysaccharide involved in carbohydrate changes. Without sprout growth the sweetening was not accompanied in the potato tubers (Isherwood, 1975). The results show that starch breakdown starts just prior to the initiation of sprouts.

The results on non-reducing and reducing sugar content clearly indicated a slight increase up to 5 WAS in the tubers of *D. esculenta* and up to 7 WAS in the rhizomes of *C. longa* followed by a rapid increase till sprouting in both the materials. The pattern of increase of both reducing and non-reducing sugar was similar for both the materials. Among the two materials sugar content was higher in the tubers of *D. esculenta* when compared to the rhizomes of *C. longa*. A comparative analysis of starch and sugars during dormant period till sprouting indicate that as starch content decreased the total sugars increased steadily as sprouting progressed. A similar trend was reported in potato tubers (Copp *et al.,* 2000) and in corms of *Crocus sativus* (Chrungoo & Farooq, 1985).

The results on qualitative study of sugar during the storage period "dormant period" the tubers of *D. esculenta* and rhizomes of *C. longa* show the presence of sucrose, glucose, fructose and maltose. It is quite interesting to note that maltose appeared from the 6 WAS in *D. esculenta* and 7 WAS in *C. longa*. α-Amylase activity was higher when the maltose appeared. Starch-sugar inter conversion has been studied in detail during storage period, before and after sprouting in potato tubers by Isherwood (1973). The results obtained in the present study with the two materials are similar to that of potato. Coursey (1967) noticed that the changes in sugar composition of yam tubers during storage need further investigation. The present study to a certain extent, gives detail about the sugar changes in one species of yam tubers and rhizomes of turmeric.

The results on quantitative estimation of individual sugars show a slight increase of sucrose in the initial period followed by a rapid increase in both the tubers and rhizomes. Glucose also exhibited a similar trend. On the other hand, increase in fructose was rapid in the "pre-sprouting period". The comparison clearly indicated the starch-sugar conversion during the storage period of yam tubers and turmeric rhizomes. Further the rapid decrease of starch during "pre-sprouting period" coincides with the rapid increase of sugars. In *D. rotundata* tubers sucrose was present in much higher amounts than glucose. A trace of fructose was also detected Coursey (1967).

A study on the results of sugar phosphates revealed the presence of glucose-1-phosphate and glucose-6-phosphate in the tubers and rhizomes during the "peak period of rest". Fructose-6-phosphate appeared later during the "pre-sprouting period". These three sugar phosphates were present at the time of sprouting in both the tuber and rhizome. In potato, a number of phosphate esters have been identified during starch-sugar intercomversion and the changes were related to changes in temperature of storage period (Isherwood, 1973). In the present work the phosphorylated sugars in relation to storage period till sprouting has been investigated.

Our results indicated the presence of OA in the tubers and rhizomes during storage period till sprouting. During the second phase of storage period *i.e.* "pre-sprouting period" succinic, malic and citric acid have been detected. Presence of citric acid in potato has been reported by Hughes (1963). The sugars present in the tubers may be the product of starch degradation and may be utilized in the metabolic pathways. The phosphate of sugar, glucose-6-phosphate can be utilized in the pentose phosphate pathway and OA may be the intermediates of the TCA cycle followed during dormancy of these organs.

We noticed a sharp increase in the rate of respiration in both tubers and rhizomes during "pre-sprouting period". In potato tubers there is a decrease of respiration during the initial period of storage followed by an increase of respiration during sprout growth (Blenkinsop *et al.,* 2002). The respireation of a sprouting tuber includes both that of the tuber and of the sprouts. Burton (1978) found approximately 50% increase in respiration in sprouted tubers. Respiration of potato during storage is increased by increasing temperature and oxygen concentration. Isherwood and Burton (1975) have shown that if the potato tubers are allowed to sprout normally, the respiration of the tubers plus sprouts increase considerably to about 4 to 5 times to that of desprouted tubers. The rate of respiration during the storage period coincides with the increased availability of sugars due to conversion of starch to sugars.

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