

# Changes in Fruit Size, Fruit Dry Matter and Carbohydrate Composition at Different Stages in Developing Water Chestnut Fruit

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## ABSTRACT

Water chestnut (*Trapa bispinosa* Roxb.) is an important aquatic fruit crop in south east Asian countries like India, Bangladesh and Thailand. Apart from its use as fresh fruit, dry nut flour is a chief source of non-cereal carbohydrate diet. Five different water chestnut varieties, which included two green types and three red fruit types were grown under water logged condition and showed characteristic changes in composition of carbohydrates with the fruit age. Fruit size increased up to 14 days after fruiting initiation. The dry matter of fruits increased from 7 days to 14 days but after 21 days dry matter content almost doubled in all the five varieties compared to that at 14 days. Soluble carbohydrate, imparting sweetness to fruit was at its peak level at 7-day stage. By 14 days after fruiting initiation, the soluble carbohydrate was 49% and starch fraction was about 51%. In over-mature fruit, 21 days after fruit initiation, starch concentrations in all five varieties increased to 88 to 94% and soluble carbohydrate level decreased to 6 to 12%. For raw consumption 14-day stage was optimal for sweetness, dry matter and starch content as well as desirable nut size. Delayed harvest to 21 days subjected fruit to over-maturity and reductions in sweetness. But as dry matter and starch content after this stage increased considerably, fruits were more suitable for making into flour rather than using as fresh fruit.

*Key words:* *Trapa bispinosa*, carbohydrate, harvest stage, starch, water chestnut fruit.

## INTRODUCTION

The 'Singhara phal' or water chestnut is one of the few neglected but economically important aquatic crop grown in

different parts of India as well as south-east Asian countries like Bangladesh, Thailand, Myanmar. It is an annual, rooted aquatic plant with rosettes of floating leaves as well as submerged leaves. Floating leaves are simple with dentate margin while submerged leaves are pinnately compound and filiform lobes are with smooth margin. This aquatic herb is generally 0.5 to 2 m long but can grow up to 5 to 6m, depending upon depth of water, to keep the crown of rosette leaves afloat. The flowers are white and open above the surface of water. After pollination two-spine fruits 15 to 35g in size grow under water due to bending of pedicel (Srivastava and Vatsya 1986). In the states like Bihar, Uttar Pradesh and West Bengal the crop is popularly grown mainly in railway track side depressions or highway side depressions (Banerjee and Thakur 1980, Hazra et al. 1996, Ahmed and Singh 1999). The fruits are generally consumed as either fresh fruit or after boiling. Sometimes sun dried fruits are also peeled and powdered to prepare water chestnut flour as a non-cereal source of food supplement during fast or other ritual observations. The starch isolated from flour contains about 85% amylopectin and 15% amylose (Srivastava and Vatsya 1986). It has been found to be a suitable substitute for corn starch in ice-cream manufacturing and can be used for textile sizing (Srivastava and Vatsya 1986). Thus the nutritional composition of the fruit is important for its worthiness as a dietary supplement. Over-mature fruits are less preferred in the market due to their difficulty of peeling as well as the change in taste of fruit due to a reduction in sweetness. So determining the right stage of harvest to provide fruit that are ready for market is important. Relatively few reports are available about the nutrient composition of water chestnut fruit, particularly about changes occurring during maturity of the fruits (Gopalan et al. 1987, Poddar 2003). In this communication we report comparative changes in the composition of major constituents in water chestnut i.e. carbohydrate with aging fruit. This information will help to determine the right stage of harvest for water chestnut fruit depending upon intended use as fresh fruit or for making flour.

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## MATERIALS AND METHODS

### Plant Material

An experiment with water chestnuts was conducted at the Research Farm of Water Technology Centre for Eastern Region, Mendhasal from June 2000 to January 2001. Five local water chestnut varieties were grown in randomized block design with four replications (blocks). Six plants were planted in each block which subsequently ended up in several plants per block. Among the five varieties, three were red fruit types, 'KNP red', 'Haldipada red' and 'Balasore red'. The two green varieties were 'Balasore green' and 'Haldipada green'. Farm yard manure (FYM) compost was applied @ 8 t/ha. The N:P:K fertilizer @ 40:60:40 were applied in three splits. While 1/3 N and K with full P was applied as a basal treatment at planting, the remaining two-thirds of the N and K was applied in two splits 2 and 4 months after planting. Fruits appeared about 3.5 months after planting. At 100 days after planting, individual fruits from three randomly selected plants per replicate were marked with waterproof adhesive level at the base of the fruit stalk to mark the age and identity of particular fruit. The tagged fruits were then periodically harvested at 7, 14 and 21 days after appearance of small visible fruit.

The volume of five fruits were recorded from three randomly selected plants from each block *i.e.* three plants were randomly selected per replicate from which five fruits in total were collected to measure total volume of five fruits. The volume of whole fruit was determined through displacement of water by submerging these five fruits in a measuring cylinder.

### Measurement of Soluble Carbohydrate and Starch

The percentage dry matter content of the fruit was determined by separating the peel carefully without damaging the fruit. The fresh fruit was weighed then dried in an oven at 70°C to determine the dry weight.

The soluble as well as insoluble carbohydrate contents of 7, 14 and 21 days old fruit were measured with anthrone reagent (CTCRI 1983). The analysis of carbohydrate content was conducted by grinding 50 mg of kernel tissue with a mortar and pestle in 10 ml of 80% ethanol. The suspension was kept for 15 minutes at 80°C and was centrifuged at 5000 rpm for 15 minutes. The process was repeated with one residue three times. The collected supernatant was dried and was then diluted to 100 ml with distilled water. One ml of aliquot was taken and to it slowly added four ml of (0.2% w/v) an-

throne reagent. The anthrone reagent was prepared by dissolving 2 g of anthrone powder in 1.0 L of concentrated sulfuric acid. The test tubes were placed on boiling water bath for 5 minutes. After the mixture cooled to room temperature absorbance was measured at 630 nm using a UV-VIS spectro-photometer (Chemito, India).

The residue remaining in the centrifuge tube was dried in an oven at 80°C. Three ml of distilled water were added to the centrifuge tube to bring the dry residue into suspension and then placed in boiling water bath for 10 minutes. After allowing tube to cool, 2 ml of 9.2 M perchloric acid was added and stirred continuously for 10 minutes. The suspension was brought to 10 ml with distilled water and centrifuged. The supernatant was collected. Two ml of 4.6 M perchloric acid was added to the residue and the suspension was stirred for 15 minutes. Distilled water was added to bring the final volume to 10 ml and the suspension was centrifuged again. The combined supernatant was finally made up to 25 ml with distilled water. The insoluble carbohydrate content was analyzed for estimation of starch from this extract (Yoshida et al. 1976) by anthrone reagent similar to the estimation of soluble carbohydrate.

The analysis of variance and standard error of observations were calculated following Gomez and Gomez (1984).

## RESULTS AND DISCUSSION

The results of analysis of variance showed that fruit volumes, fruit dry matter, concentration of total and soluble carbohydrate as well as starch content were significantly influenced by varieties as well as age of the fruit (Table 1). As the interaction between age and variety was also significant, the varietal differences in all these fruit characters were significantly affected by the age of the fruit. The effect of age on the above five different fruit characters also differed significantly with five varieties tested (Table 1).

The volume of the fruit is a better quality index for market appeal than dry weight because harvested fruit is sold fresh in a wet condition. The volume of fruits in all the five varieties increased from 7 days to 14 days (Figure 1a). At 21 days there was marginal decrease in fruit volume in all varieties compared to the volume of the 14th day. At 7 and 14 days, the green varieties show fruit volume higher generally than the three red varieties. At all the three stages of fruiting, the variety 'Balasore red' consistently showed smaller fruit volume which may be attributed to varietal character.

The dry matter content of the fruits increased significantly by 14 days and 21 days after fruit initiation (Figure 1b). But

TABLE 1. STATISTICAL ANALYSIS USING ANALYSIS OF VARIANCE FOR REPLICATIONS, THREE STAGES (7-, 14- AND 21-DAY) AND FIVE VARIETIES OF WATER CHESTNUT FOR DIFFERENT CHARACTERISTICS OF FRUIT LIKE, FRUIT VOLUME, FRUIT DRY MATTER, TOTAL CARBOHYDRATE, SOLUBLE CARBOHYDRATE AND STARCH CONTENT. MEAN SQUARES (MSQ) AND PROBABILITY (P) ARE REPORTED FOR EACH CHARACTERISTICS. NS—NON SIGNIFICANT, \*\* SIGNIFICANT AT 0.01 LEVEL, \*\*\* SIGNIFICANT AT 0.001 LEVEL.

Source	df	Fruit volume		Fruit dry matter		Total Carbohydrate		Soluble Carbohydrate		Starch	
		MSQ	P	MSQ	P	MSQ	P	MSQ	P	MSQ	P
Block	3	2.1	NS	1.8	NS	1106.4	NS	377.3	NS	684.7	NS
Stage	2	27280.3	***	3428.4	***	193518.3	***	491991.3	***	1157458.2	***
Variety	4	8811.3	***	44.5	***	35175.6	***	24399.7	***	5359.2	**
Stage × Variety	8	725.9	***	11.9	***	13583.4	***	2708.7	**	10988.9	***
Error	42	4.6		1.2		2233.1		701.6		1133.4	

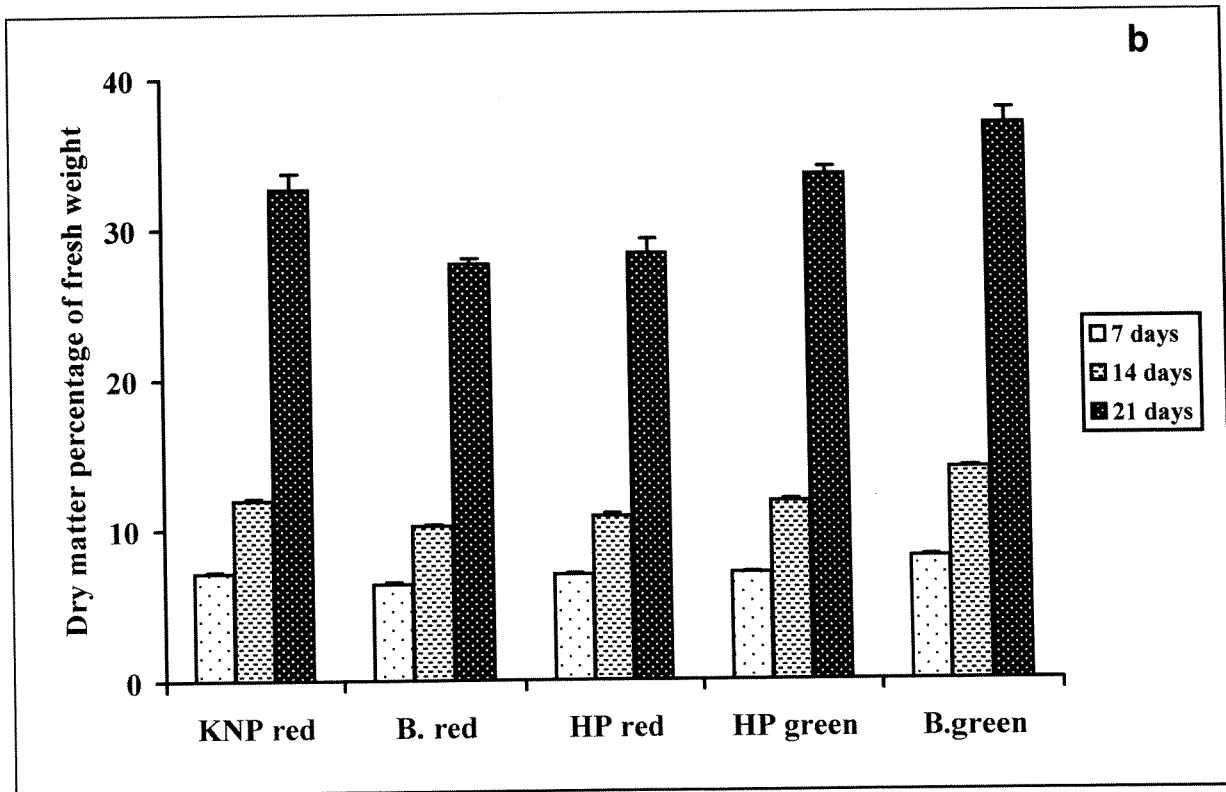
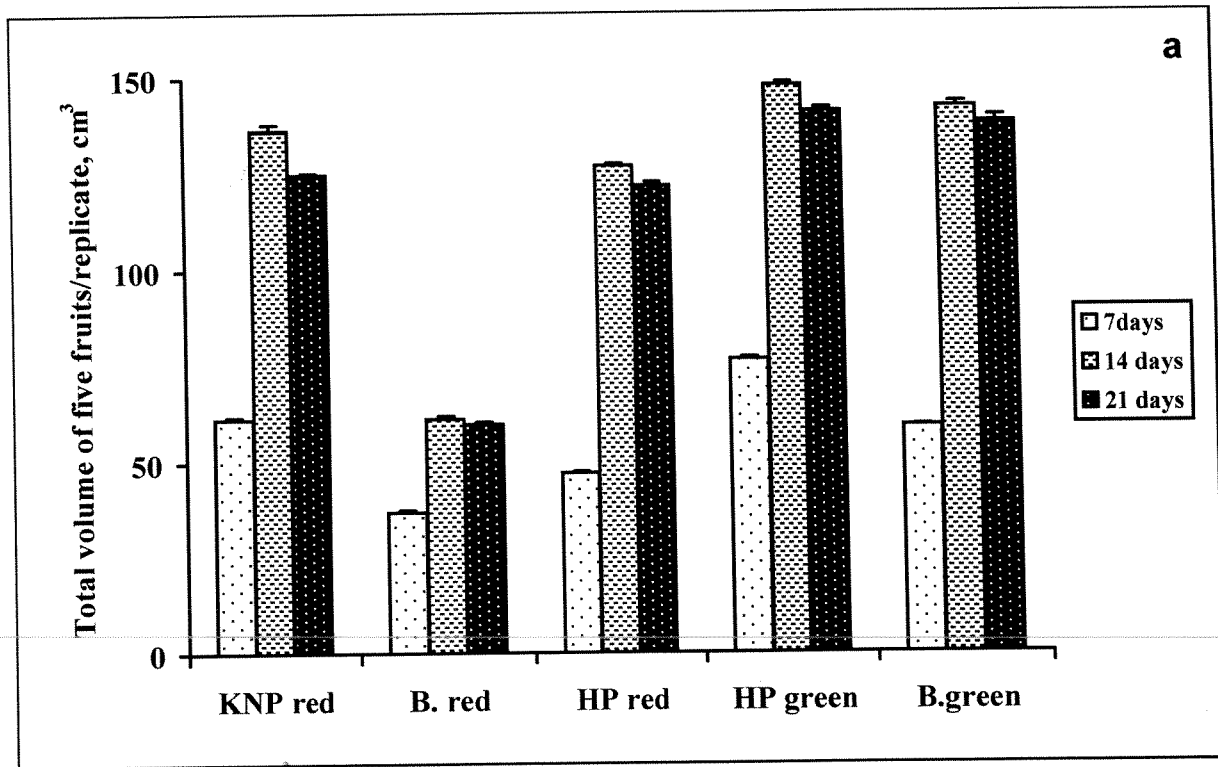


Figure 1. The changes total volume of five fruits per replicate (a) and in percentage of dry matter content (b) in water chest nut fruit at 7-day, 14-day and 21-day after initiation of the fruit in five different varieties. Each value is mean of four replications (each replicate is based on 5 fruits from 3 plants). Vertical bars are  $\pm$ SE. The symbols are as in figure.

between 14- and 21-day stage the dry matter content almost doubled in all the varieties. The increase in dry matter content in fruit was greatest in the variety 'Balasore red'.

In 7-day-old fruit, the total carbohydrate content was nearly similar in green and red varieties except 'Balasore red', which showed less total carbohydrate content, compared to other varieties (Figure 2a). The total carbohydrate content in 7-day-old fruit varied from 334 mg/gDW in 'Balasore red' to 462 mg/gDW in the 'Haldipada green' variety. The soluble carbohydrate fraction dominated at this stage. It varied from 242 mg/gDW in 'Balasore red' to as high as 416 mg/gDW in 'Haldipada green'. In both green varieties 'Balasore green' and 'Haldipada green' soluble carbohydrate in 7-day-old fruit was as high as 90% compared to other three red varieties which showed about 72 to 82% soluble carbohydrate.

In mature 14 day-old fruit, soluble sugar concentrations decreased considerably with concomitant increase in level of starch (Figure 2b). The green varieties in general showed higher total carbohydrate concentrations and significant increases since 7 day-old stage compared to red varieties at this stage. Both highest soluble carbohydrate as well as starch level was noted in variety 'Haldipada green' (353.87 mg/gDW and 373.44 mg/gDW, respectively). The relative contributions of soluble carbohydrate and starch were about 49% and 51% in the varieties 'Haldipada green' and 'Balasore green' at the 14 day stage. But the percentage of soluble carbohydrate in the red varieties varied between 40% and 58%. These soluble carbohydrate ratios were reflected in the taste of the varieties e.g., red varieties except 'Balasore red' being sweeter than green varieties at this stage.

By 21 days after fruit initiation, however, soluble carbohydrate content decreased substantially and starch content increased (Figure 2c). In red varieties the total carbohydrate content increased compared to 14 days, to 553-606 mg/g DW. Over this time period, total carbohydrate remained unchanged in 'Balasore green' whereas in 'Haldipada green' it decreased from 727 mg/g DW to 621 mg/g DW. By 21 days the soluble fraction of carbohydrate decreased in all the five varieties in old fruit to the level of 6 to 12% of total carbohydrate content with the starch fraction increased to between 88 to 94%. This resulted in a decrease in sweetness in mature fruits and reduced its market acceptability as fresh fruit.

With an increase in age, dry matter content and density of water chestnut fruits increased, especially after 2nd and 3rd week. This increased density helps fruits to settle at the bottom of the water body and is an adaptive feature of this aquatic plant. Comparing the three stages of harvest it was also clear that fruit maintain their sweetness, optimum firmness and size in the 2nd week. At a later stage (3rd week) dry matter content and starch content of fruit increased substantially so they were more suitable for making flour. The starch particle of the water chestnut kernel resembles that of potato in shape and size ranging between 15 to 39 micron in size (Qudrat-I-Khuda et al. 1960). Hence, to be used as fresh fruit the best stage of harvest of water chestnut fruit is 2nd week after fruit initiation, whereas for flour, fruits should be allowed to grow up to 3rd week for better starch recovery.

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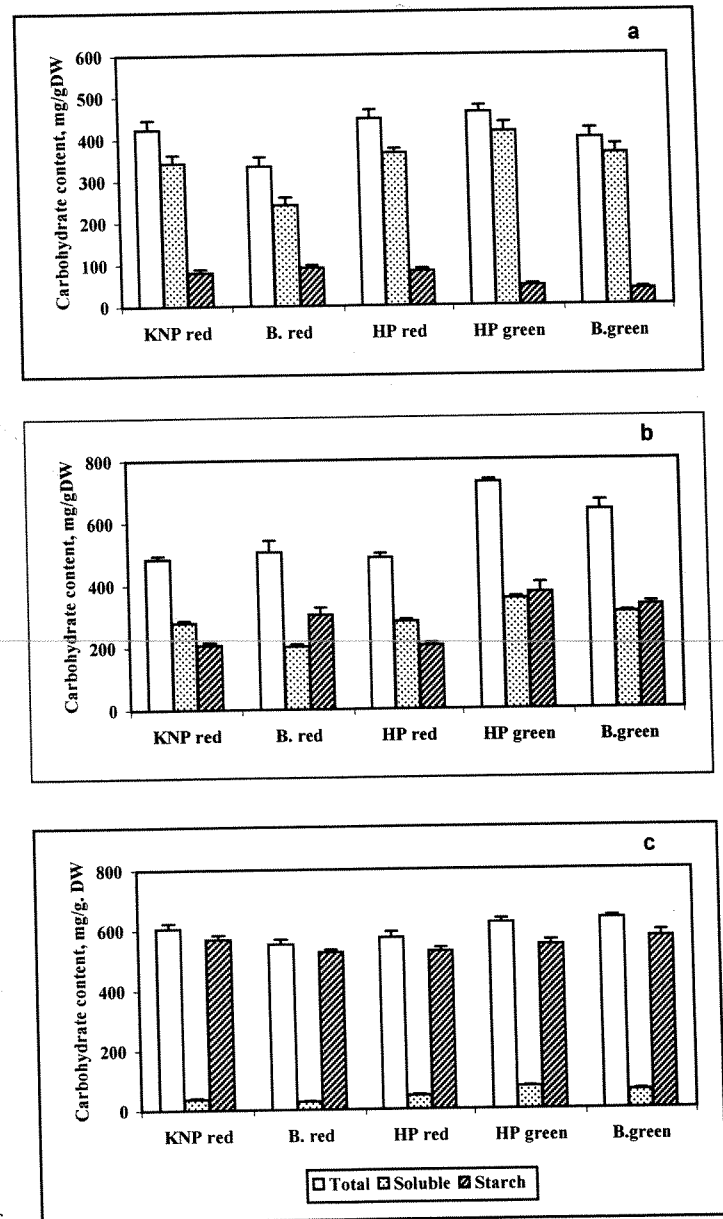


Figure 2. The total carbohydrate, soluble carbohydrate and starch content (the symbols are as in Fig. 2c) in five different varieties of water chestnut at 7-day- (a), 14-day- (b) and 21-day-old (c) water chestnut fruit. Each value is mean of four replications  $\pm$ SE.

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