

Post Harvest Assessment and Nutritional Evaluation of Different Cultivars of Taro (*Colocasia esculenta* L. Schott) Grown in the Alluvial Soils of West Bengal, India

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Authors' contributions

This work was carried out in collaboration among all authors. Author MCM performed the experiments, designed the study and performed the statistical analysis and wrote first draft of the manuscript. Author ARJ helped author MCM in laboratory analysis of the samples and author SM managed the literature searches. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/CJAST/2021/v40i1431397

Editor(s):

(1) Dr. Michael Ignatius Ferreira, Western Cape Department of Agriculture, South Africa.

Reviewers:

(1) Rabo Younoussou, Niger.

(2) Behailu Asrat, Arba Minch University, Ethiopia.

Complete Peer review History: <http://www.sdiarticle4.com/review-history/69530>

Original Research Article

Received 10 April 2021
Accepted 14 June 2021
Published 18 June 2021

ABSTRACT

Aims: The aim of the study was to evaluate the nutritional content of various cultivars of taro acquired from All India Co-ordinated Research Project (AICRP) on tuber crops.

Study design: Completely randomized design (CRD) at 5% level of significance.

Place and duration of study: Department of Post Harvest Technology, faculty of Horticulture, Bidhan Chandra KrishiViswavidyalaya, West Bengal, India, between December 2019 and February 2020.

Methodology: 8 cultivars of taro were evaluated for their nutritional contents in this study and their physical attributes such as cormel girth, length, specific gravity, number of cormels per plant and weight of cormel as well as yield per hectare was calculated. Chemical attributes such as titratable

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acidity, starch, ascorbic acid, total phenol and total sugar as well as reducing sugar content in each cultivar was also studied.

Results: Analysis of variance showed significant variation among all the tested cultivars. Moisture content, total sugar and starch was recorded to be highest in the cultivar TTR-17-6 (72.233 %, 5.007 % and 31.805 % respectively). Total phenol (188 mg GAE 100 gm⁻¹) and reducing sugar (2.817%) was found to be highest in TTR-17-5. Total soluble solids was highest in TTR-17-7 (3.867 °Brix). Dry matter content was highest in TTR-17-4 (37.333 %) and ascorbic acid was highest in TTR-17-2 (70.093 mg 100 gm⁻¹).

Conclusion: The eight cultivars of taro studied were found to be rich in sugars, ascorbic acid, total phenols and starch. They were observed to vary in cormel girth, length, weight, specific gravity, yield, moisture, dry matter content, TSS and titratable acidity. The cultivar TTR-17-6 was found to be very high in starch, total sugar and moisture content. Therefore, this cultivar may be of considerable importance in ameliorating malnutrition in poorly resourced areas of the developing countries. Cultivar TTR-17-2 was found to be high in ascorbic acid and hence can be further used by the plant breeders to develop more cultivars of taro that are rich in such phytochemicals.

Keywords: Phenols; physical attributes; sugars; starch; taro; titratable acidity; TSS.

1. INTRODUCTION

Taro belongs to the family *Arecaceae* and the genus *Colocasia* and is produced worldwide for its underground corms [1]. *Colocasia* is cultivated globally in an area of around 2.0 million ha with an annual production of 12.0 mt and an average yield of 6.5 t ha⁻¹[2]. It serves as a staple source of diet for people around the world and it is the fourteenth most consumed vegetable worldwide [3]. Nigeria is the largest producer of taro in the world with an annual production of 2.8 million metric tons which accounts for 27% of the world's total production. China, Japan, Thailand, and the Philippines are the major producers of taro in Asia; while in Oceania, production is dominated by Papua New Guinea, Fiji, Solomon Islands, Samoa, and Tonga [2].

In India, the major taro growing states are Manipur, Assam, Nagaland, Orissa, Meghalaya, Gujarat, Maharashtra, Kerala, Andhra Pradesh, Tamil Nadu, West Bengal, Uttar Pradesh, and Bihar. The commercial development in taro is very less. However, it is important in the diet of many people around the world, especially in underdeveloped countries, and has the potential to develop as a commercial crop for specialty foods. *Colocasia* is a hardy plant and can withstand drought to a great extent. It is also a well known and high source of starch and major components of the diet *viz.*, proteins, minerals, and vitamins. All parts of the plant including corm, cormels, rhizome, stalk, leaves, and flowers are edible and contain abundant starch [4].

Malnutrition and food shortage among the poor rural population is highly evident and cultivation

of crops like *colocasia* will not only increase food production, but also provide balanced nutrition to the deprived sections of the society. As a consequence, popularizing taro cultivation and identifying suitable cultivars for nutritional value is important. However, taro remains a largely underutilized crop in our country and cultivated only in small pockets having very limited industrial uses. The main reason is due to the fact that the crop has high moisture content and respiration rate and there are almost no standard postharvest management techniques which leads the crop to deteriorate rapidly during storage due to mechanical injury sustained during postharvest handling.

Different varietal studies on *Colocasia* are lacking and only a few cultivars have been studied so far. Therefore, the main objective of this study was to evaluate different cultivars of taro for horticultural and nutritional parameters to provide information to the breeders to develop desirable types having high yield and better nutritional profile, and with aims to increase the demand of these cultivars in the market by evaluating some of the promising cultivars developed by the AICRP of tuber crops.

2. MATERIAL AND METHODS

The present investigation was conducted in the laboratory of Department of Post Harvest Technology of Horticultural Crops, faculty of Horticulture, Bidhan Chandra Krishi Viswavidyalaya, Mohanpur, Nadia District, West Bengal, India.

2.1 Data Collection

8 different cultivars of taro were acquired from the All India Coordinated Research Projects (AICRP) on tuber crops, Mondouri farm, West Bengal, which were planted in April 2019 and harvested during first week of January, 2020. The geographic coordinates of the experimental location is 23.5° North Latitude and 9.75° East Longitude with an elevation of 9.75 m above mean sea level. The name of the cultivars studied are as follows:

1. TTR-17-1
2. TTR-17-2
3. TTR-17-3
4. TTR-17-4
5. TTR-17-5
6. TTR-17-6
7. TTR-17-7
8. TTR-17-8

These cultivars were analyzed with 3 replications and different parameters were recorded from five randomly selected plants in each variety. Mature harvested cormels were selected for this experiment and the physical and chemical analysis were done fresh soon after procuring the samples from the field.

2.2 Parameters Studied

Physical parameters: Flesh colour, tuber length (cm), cormel girth (cm), specific gravity (Kg m^{-3}), Weight of cormel per plant (gm), number of cormels per plant, yield (t ha^{-1}).

Chemical parameters: Moisture content (%), dry matter (%), titratable acidity (%), TSS ($^{\circ}\text{Brix}$), ascorbic acid ($\text{mg } 100 \text{ gm}^{-1}$), starch (%), total sugar (%), reducing sugar (%) and total phenols ($\text{mg GAE } 100 \text{ gm}^{-1}$).

Moisture and dry matter content: Moisture content and dry-matter content in the samples were recorded by oven drying 10g of sample at 60°C , till a constant weight was obtained [5].

$$\text{Moisture}(\%) = \frac{\text{Initial value} - \text{Final value}}{\text{Initial value}} \times 100$$

$$\text{Drymatter}(\%) = \text{Initial value} - \text{Moisture content}$$

Total soluble solids (TSS): TSS were determined by using a hand refractometer. The reading was expressed as $^{\circ}\text{Brix}$ [6].

Titratable acidity: Titratable acidity were determined by titrating the sample extracted in distilled water against 0.1N NaOH titration method [6].

$$\text{Titratable acidity}(\%) = \frac{\text{Volume made up} \times \text{Equivalent weight of the sample} \times 0.1\text{N NaOH} \times \text{Titre value}}{\text{volume of aliquot taken for analysis} \times \text{weight of the sample}} \times 100$$

Ascorbic acid: Ascorbic acid content were estimated using 2, 6 dichloro-endophenol dye titration method [6]. Ascorbic acid reduces the 2, 6-dichlorophenol indophenols dye to a colorless leuco-base. The ascorbic acid gets oxidized to dehydro-ascorbic acid. Though the dye is blue colored compound, the end product is the appearance of pink color. The dye turns pink color in acidic medium. Metaphosphoric acid is used as the titrating agent.

$$\text{Dyefactor} = \frac{0.5}{\text{Average burette reading for standardization of dye}}$$

$$\text{Ascorbic acid}(\text{mg per } 100\text{gm}) = \frac{\text{burette reading} \times \text{dye factor} \times \text{volume made up}}{\text{Volume of sample taken for estimation} \times \text{weight of sample}} \times 100$$

Sugars: Total sugar and reducing sugar level in the samples were estimated by the copper reduction method, using Fehling's solution and methylene blue indicator [6].

$$\text{Totalsugar}(\%) = \frac{\text{mg of invert sugar} \times \text{dilution} \times 100}{\text{Titre} \times \text{wt. or volume of sample} \times 100}$$

Phenols: Total phenols were estimated according to the procedure given by Swain and Hillis [7] and Walter and Purcell [8]. Reagents used are sodium carbonate (20%), folin-ciocalteau reagent, and ethyl alcohol (95%). A standard curve was drawn using gallic acid as standard. Different concentrations of gallic acid were prepared and optical density was read at 750 nm wavelength. The concentration of samples was calculated based on the standard curve.

$$\text{mg gallic acid equivalence per gram} = \frac{\text{O.D} \times \text{standard curve factor} \times \text{volume made up} \times \text{Dilution}}{\text{Aliquot taken} \times \text{weight of the sample}}$$

Starch: Amount of starch present in the samples were determined as per Rangana [6]. After the sugar present in the sample has been leached out starch is hydrolyzed using acid and estimated

as invert sugar. Starch (%) = % Reducing sugar × 0.9

2.3 Statistical Analysis

The data from different treatments were statistically analyzed by employing completely randomized design (CRD) at 5% level of significance adopted from the statistical procedure of Gomez and Gomez [9]. The data were analyzed with the help of a window-based computer package OPSTAT [10].

3. RESULTS AND DISCUSSION

3.1 Physical Attributes

Physical and yield attributing characters of cultivar, in fact, significantly influenced the productivity of taro. From the results, it appeared that out of eight cultivars, three namely TTR-17-2, TTR-17-4 and TTR-17-3 were superior to others if cumulative values of size (length, diameter), specific gravity, weight of cormels per plant and yield were accounted for as summarized in Table 1.

3.2 Cormel Girth and Length

Cormel girth in different cultivars studied was significantly different from one another. Among the taro cultivars studied, TTR-17-4 (224.90 mm) recorded highest average cormel girth followed by TTR-17-8 (213.620 mm) and TTR-17-7 (191.823 mm) recorded lowest average cormel girth. The average length of the cormels also varied significantly from one cultivar to another. TTR-17-7 had the average cormel length of 7.267 cm which was the highest among all cultivars followed by TTR-17-4 which had 7.167 cm and TTR-17-1 with 6.833 cm cormel length. The lowest average cormel length was recorded in cultivar TTR-17-8 (5.367 cm). The same parameters were observed by Angami et al., [11] and he found that the corm length and corm breadth/ girth varied significantly among different cultivars where the highest corm length (15.41 cm) and corm girth (107 mm) were found in the cultivar Panchmukhi and the lowest corm length and girth were observed in the cultivar BCC-1 (4.3 cm and 31.73 mm respectively).

3.3 Specific Gravity

Significant variation in specific gravity was also recorded among different taro cultivars. Highest

specific gravity was recorded in cultivar TTR-17-3 (1.073 Kg m⁻³) followed by TTR-17-7 (1.057 Kg m⁻³) and TTR-17-6 (1.023 Kg m⁻³) and the lowest specific gravity was recorded in TTR-17-1 with only 0.657 Kg m⁻³. According to Hollyer et al., [12] the specific gravity of raw taro corms varies in a narrow range of 0.94 – 0.98 Kg m⁻³, and more mature corms have higher value. According to this study the variation in specific gravity may be mainly due to inherited traits determined by the genetic makeup of a cultivar.

3.4 Number of Cormels

The number of cormels obtained varied significantly and a maximum average number of cormels was observed in the cultivar TTR-17-5 (84.33) followed by TTR-17-7 (83.33) while the least number of cormels was observed in TTR-17-2 (43.667) as seen in Table 1. Miyasaka et al., [13] also reported that inadequate rainfall during the time of greatest water need resulted in lower yield and percentage corm dry matter in taro.

3.5 Weight of Cormels

Weight of cormels per plant also varied significantly. Highest weight was recorded in TTR-17-4 followed by TTR-17-7 and TTR-17-6 i.e., 1.750 kg, 1.533 kg and 1.30 kg respectively. Lowest weight per plant was recorded in TTR-17-2 (0.643 kg) followed by TTR-17-1 (0.783 kg) which was found to be significantly at par with TTR-17-5 (0.760 kg). Similar results were found by Angami et al., [11] in which he stated that variation in weight of cormels may be due to accumulated storage of foods, the moisture content in the corm, etc, and thus have a direct bearing on crop yield.

3.6 Yield

Yield also varied significantly in different cultivars. Maximum yield in TTR-17-2 (10.32 t ha⁻¹) and lowest (4.20 t ha⁻¹) in TTR-17-7 was recorded (Table 1). This may be due to differences in planting date and temperature changes during the growth of taro as stated by Lu et al., [14]. Likewise, Pandey et al., [15] also observed wide range of variability among 31 genotypes for yield per plant, weight of mother cormels and weight of cormel. These findings are in close proximity with the results of Cheema et al., [16] who reported variability for number of leaves per plant, number of cormels per plant, corm weight and yield per plant. Similar findings

were also reported by Solanki et al., [17], Mukherjee et al., [18] and Singh et al., [19].

3.7 Dry Matter and Moisture Content

Dry matter content is an important determining factor for both processing and selling in fresh markets. Corms with higher dry matter content tend to be more susceptible to bruising and disintegrate more rapidly. There was a significant variation recorded in the dry matter content among various taro cultivars in the present study. TTR-17-4 recorded maximum dry matter content of 37.333 % followed by TTR-17-1 (36.933 %) which was significantly at par with TTR-17-7 (36.733 %). The lowest dry matter content was observed in TTR-17-6 *i.e.*, 27.80 % as shown in Table 2. The table also summarizes the moisture content of taro cultivars which was found to be significantly varied. As dry matter content was observed the least in TTR-17-6, this variety recorded the highest moisture content of 72.233 % followed by TTR-17-8 (69.933 %) and TTR-17-3 (69.133 %) which was statistically at par. Cultivar TTR-17-4 had the lowest moisture percentage (59.667 %). According to Huang et al., [20], moisture content of taro varies with variety, growth condition and harvest time and in general the moisture content of taro ranges from 60- 83 %. Angami et al., [11] also summarized in his findings that at harvest, dry matter content ranged from 27.50 % to 17.17 % and moisture content ranged from 82.83 % to 72.50 % in different cultivars that he studied. The moisture content obtained is also consistent with earlier research conducted in South Africa and Nigeria by Mwenye et al., [21] and Aregheore and Perera [22]. Both authors obtained moisture contents that were between 65% - 80%, the variation may be attributed to the cocoyam variety used, environmental factors and agronomic practices.

3.8 Titratable Acidity

Titrate acidity among the cultivars was found to be significant and three of the cultivars were recorded to be statistically at par with each other. All three cultivars TTR-17-1, TTR-17-4 and TTR-17-7 recorded the highest titratable acidity of 0.315 %. The lowest reading however was recorded by TTR-17-5 (0.084 %) (Table 2). Wills et al., [23] also found similar results in his study and concluded that the total acid content in taro cultivars grown in highlands of Papua New Guinea were 0.1 % - 5 %. Nevertheless, a study conducted by Panja et al., [24] observed that the titratable acidity in elephant foot yam (similar

tuber crop) varied from 0.144 % to 0.226 % in different cultivars, hence, indicating that the titratable acidity of tuber crops and corms are comparatively low as compared to other crops such as fruits and vegetables.

3.9 Total Soluble Solids (TSS)

Kamiloglu, [25] stated that TSS is a major quality parameter, which is correlated with the texture and composition. Significant variation in TSS content of different cultivars of taro was observed (Table 2). Cultivar TTR-17-6 recorded a maximum TSS content of 4.3 °Brix followed by TTR-17-7 (3.867 °Brix) followed by TTR-17-4 (3.333 °Brix) as summarized in Table 2. The least amount of TSS was recorded by cultivar TTR-17-1 (2.5 °Brix). Kandil et al., [26] explained that TSS in tuber crops is a function of the amount of pectin and the density of the finished products much of which is the ability to take up nutrients and convert sucrose to carbohydrate in tubers. Angami et al., [11] in his research on several varieties of taro corms reported a TSS range of 1.60 °Brix to 5.85 °Brix.

3.10 Starch

According to Njintanget al., [1] starch is the most important component (73- 80 %) of taro. In the present study, starch percentage in taro cultivars ranged from 31.805 % to 11.840 % as seen in Table 3. The highest of which was found in TTR-17-6 (31.805 %), followed by TTR-17-5 (29.463 %). However, cultivar TTR-17-7 showed a significantly lower starch content of 11.840 % as compared to other cultivars. Surajit and Tarafdar [27] also recorded similar variations in starch content (13.71 % to 18.36 %). A study conducted by Shellikeri et al., [28] in his study also reported that the starch content varied from 13.57 % to 24.13 %. According to Wills et al., [23] the taro cultivars grown in highlands of Papua New Guinea were found to have starch content ranging from 20% to 35.1%.

3.11 Ascorbic Acid

Ascorbic acid was also found to be present in taro corms showing various degrees of significant variation among the cultivars. The highest amount of ascorbic acid was recorded in the cultivar TTR-17-2 with 70.093 mg 100 gm⁻¹ of ascorbic acid followed by TTR-17-7 which contains 56.780 mg 100 gm⁻¹ of ascorbic acid and is statistically at par with TTR-17-6 which recorded 56.223 mg 100 gm⁻¹ of ascorbic acid.

Table 1. Physical attributes of different cultivars of taro

CULTIVAR	Flesh colour	Cormel girth (mm)	Length (cm)	Specific gravity(Kg m⁻³)	No. of cormels (per plant)	Weight of cormels perplant(in kg)	Yield (t ha⁻¹)
TTR-17-1	White	203.257	6.833	0.657	55	0.783	7.323
TTR-17-2	White	207.383	5.667	0.817	43.667	0.643	10.32
TTR-17-3	White	208.18	5.4	1.073	73.667	0.8	9.477
TTR-17-4	White	224.9	7.167	0.85	71.333	1.75	9.14
TTR-17-5	White	205.88	5.5	0.938	84.333	0.76	9.783
TTR-17-6	White	211.253	6.367	1.023	74	1.3	9.11
TTR-17-7	White	191.823	7.267	1.057	83.333	1.533	4.2
TTR-17-8	White	213.62	5.367	0.95	73.333	0.883	9.323
MEAN		208.287	6.196	0.920	69.833	1.056	7.313
S.Em ±		1.588	0.270	0.037	1.969	0.037	0.364
C.D at 5%		4.801	0.817	0.113	5.952	0.112	1.100

(S.Em ± is the Standard error mean and C.D is the critical difference at 5% level)

Table 2. Dry matter (%), Moisture (%), Titratable acidity (%) and TSS (^oBrix) of taro

Cultivars	Dry matter (%)	Moisture (%)	Titratable acidity (%)	TSS (^oBrix)
TTR-17-1	36.933	63.067	0.315	2.5
TTR-17-2	33.133	66.867	0.147	2.7
TTR-17-3	31.533	69.133	0.115	2.733
TTR-17-4	37.333	59.667	0.315	3.333
TTR-17-5	35.067	64.933	0.084	3
TTR-17-6	27.8	72.233	0.294	4.3
TTR-17-7	36.733	63.267	0.315	3.867
TTR-17-8	30.067	69.933	0.21	3.267
Mean	33.574	66.137	0.224	3.212
S.Em±	1.659	1.096	0.026	0.290
CD at 5%	5.016	3.316	0.079	0.878

Table 3. Starch (%), Ascorbic acid (mg 100gm⁻¹), Total sugar (%), Reducing sugar (%) and Phenol (mg GAE 100gm⁻¹) of taro

Cultivars	Starch (%)	Ascorbic acid (mg 100gm ⁻¹)	Total Sugar (%)	Reducing sugar (%)	Phenol (mg GAE 100gm ⁻¹)
TTR-17-1	12.097	49.543	2.943	1.347	31.966
TTR-17-2	14.06	70.093	2.99	2.5	120.53
TTR-17-3	18.607	52.327	3.6	1.56	114.57
TTR-17-4	24.167	53.997	3.28	1.903	172.00
TTR-17-5	29.463	47.873	3.547	2.817	188.00
TTR-17-6	31.805	56.223	5.007	1.45	164.07
TTR-17-7	11.84	56.780	2.08	0.997	101.87
TTR-17-8	16.803	55.667	2.45	2.373	87.270
Mean	19.855	55.312	3.237	1.868	122.533
S.Em±	1.031	3.765	0.090	0.041	1.243
CD at 5%	3.116	11.385	0.272	0.124	3.757

Among the cultivars TTR-17-5 had the lowest ascorbic acid content of 47.783 mg 100 gm⁻¹ (Table 3). FAO [29] also states that vitamin C (ascorbic acid) and vitamin B complex (niacin, riboflavin and thiamin) which are important constituents of human diet, are present in appreciable quantity in corms and leaves of taro.

3.12 Sugars

Sucrose is the most important sugar found in taro, but fructose, maltose, glucose and raffinose are also present Wills et al., [23]. Sugar content is also an important factor accounting for their usability in processing. Table 3 also represents the comparison of total sugar and reducing sugar content in various taro cultivars. Both total sugar and reducing sugar showed significant variation. The highest total sugar was found in TTR-17-6 (5.007 %) followed by TTR-17-3 (3.6 %) and TTR-17-5 (3.547 %). The lowest 2.080 % was found in TTR-17-1. Reducing sugar was recorded highest in the cultivar TTR-17-5 (2.817 %) followed by TTR-17-2 (2.5 %). Lowest reducing sugar was recorded in TTR-17-7 (0.997 %). Angami et al., [11] also reported a similar finding in his work where he tested several different cultivars of taro in the North eastern region of India and found that the total sugars ranged from 5.58 % in cultivar Nainital and lowest was found in BCC-1A with only 1.60 % of total sugar content.

3.13 Total Phenol

According to Dai and Mumper [30] phenolic compounds have potent antioxidant properties and expressed marked effects in the prevention of numerous oxidative stress associated

diseases such as cancer. In this experiment phenol content was measured in mg gallic acid equivalent per 100gm. The cultivars showed wide significant variation among each other and the highest total phenol content was observed in TTR-17-5 (188 mg GAE 100 gm⁻¹) followed by TTR-17-4 (172 mg GAE 100 gm⁻¹). Lowest phenol content was observed in TTR-17-1 (31.96 mg GAE 100 gm⁻¹) as shown in Table 3. The findings in this research are in partial agreement with Alcantara et al., [31] who found similar variations in phenolic content of raw taro corms ranging from 34 mg 100 gm⁻¹ to 78 mg 100 gm⁻¹. Similarly, Njintang et al., [1] observed total phenol content of taro corms varied from one variety to another in different countries.

4. CONCLUSION

The eight cultivars of taro studied were found to be rich in sugars, ascorbic acid, total phenols and starch. They were observed to vary in cormel girth, length, weight, specific gravity, yield, moisture, dry matter content, TSS and titratable acidity. The cultivar TTR-17-6 was found to be very high in starch, total sugar and moisture content. Therefore, this cultivar may be of considerable importance in ameliorating malnutrition in poorly resourced areas of the developing countries. Cultivar TTR-17-2 was found to be high in ascorbic acid and hence can be further used by the plant breeders to develop more cultivars of taro that are rich in such phytochemicals. The study also revealed sufficient genetic variability for quantitative traits among the varieties, which can be exploited for varietal improvement and can be further used as a source material to develop promising varieties in colocasia.

ACKNOWLEDGEMENTS

No funding was received from any source for this study. However, we would like to thank All India Co-ordinated Project on Tuber crops West Bengal, India for providing their valuable taro cultivars for this study.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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