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Biochemical, mineral and proximate composition of Indian cassava varieties

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Abstract
Cassava tuber, stem and leaves have got multifarious applications in food, feed and industry. Generally, it is believed that cassava is a poor man's crop with little nutritional quality. The ICAR-CTCRI, India has a collection of 1211 germplasm accessions of cassava and has released 20 varieties suited for direct consumption, starch extraction, other industrial applications, for disease resistance etc. The nutritional quality and composition of tuber, stem and leaf of all the important varieties have been systematically analysed in this study by using nineteen popular cassava varieties/landrace in India. The study showed large differences in biochemical, mineral and proximate composition. The crude protein content showed values ranging from 0.85 to 2.00%. Similarly, essential minerals such as K, Ca, Fe, Mn, Zn and Cu also showed large variations among the 19 varieties/landrace. There are varieties that could provide complete recommended dietary allowance from a meal of 150 g in the case of K, Fe and Mn. Present study suggests that there exist considerable variations in most of the properties studied and are genetic in nature which shows excellent opportunities available for exploiting these differences and further increasing them by breeding methods and bio fortification.

Keywords: Cassava, biochemical composition, mineral composition, proximate composition, energy value

Introduction
Cassava (*Manihot esculenta* Crantz), a dicotyledonous plant, belonging to the family Euphorbiaceae, is one of some 100 species of trees, shrubs and herbs of the genus *Manihot* (Howeler *et al*., 2013) [15]. Botanically, cassava is a woody perennial shrub, which grows from 1-5 m in height. It is believed to have been cultivated, mainly for its starchy roots, making it one of the oldest crops domesticated by humans (Fargette, 1990) [12]. Once seen as the 'food for the poor', cassava has emerged as a multipurpose crop for the 21st century; one that responds to the challenges of climate change (Sabitha *et al*., 2016) [31]. It is one of the most drought-tolerant crops, can be successfully grown on marginal soils, and gives reasonable yields where many other crops do not grow well. It is well adapted within latitudes 30° north and south of the equator, at elevations between sea level and 2,000 m above sea level, in equatorial temperatures, with rainfalls from 50 mm to 5 m annually, and to poor soils with a pH ranging from acidic to alkaline (4-9) (Howeler, 2013) [15]. It is the most important tuber crop and fourth most important source of food calories in the tropics and is a staple for more than 800 million people (Cock, 1985; Nasser *et al*., 2007) [9, 28]. Cassava can produce higher food calories @ 250 kcal/ha/day, as compared with 176 for rice, 110 for wheat and 200 for maize (El-Sharkawy, 2012) [11].

Under the changing climate scenario, cereal grain production in the tropics is predicted to decline (Rosenzweig and Parry, 1994; IPCC, 2006) [30, 16] and this will definitely reduce the dependence on crops like maize as main staple in regions like Sub-Saharan African countries. The most important alternative and suitable crop under such situations will be cassava which also has got varied uses in animal feed and many industries such as starch, alcohol and biofuel (Eke-Okoro *et al.*, 2009; Jansson *et al*., 2009; Jarvis *et al*., 2012; Johnston *et al*., 2009; Sabitha *et al*., 2016) [10, 18, 19, 20, 31]. Cassava tuber is a rich source of calorie and the calorie value mainly comes from sucrose which accounts for more than 69% of total sugar in tuber and 80% of carbohydrates is in the form of starch (Wholey and Cock, 1974; Gil *et al*., 2002) [33. 34]. Cassava tuber also contains small amount of polyphenols and they present a tonifying action because of their natural antioxidant properties as demonstrated *in vitro* (Block *et al*., 1994; Karakaya, 2001) [4, 22].

The lower nutritional value of cassava compared to cereals, legumes and other tuber crops such as yams has been reported by Latham (1969) [25]. Among minerals and vitamins, cassava contains reasonably good amounts of calcium and vitamin C and though the protein content is low (1-2%), its amino acid profile with high amounts of lysine and threonine is worth mentioning (Ceballos *et al*., 2006; Charles *et al*., 2006) [6, 7]. The cassava leaf has got wide applications in many areas such as animal feed and ornamental fish feed. The stem has got applications in particle boards and many other products, besides being used as planting material (ICAR-CTCRI, 2018) [32]. The ICAR-Central Tuber Crops Research Institute (CTCRI), India has released an array of varieties of cassava for various applications in food, feed and industry (Abraham *et al*., 2006; Sunitha *et al*., 2018) [1, 32]. A lot of variability exists in the biochemical, proximate and mineral composition of cassava varieties available in India. A systematic characterization of these varieties has not yet been attempted but is very important for meeting its requirement in food, feed and industry besides its application in crop breeding programmes such as bio fortification. Considering the above facts, the present study was conducted to quantify the variability in biochemical, mineral and proximate composition of important varieties of cassava cultivated in India.

Materials and Methods

Sample collection and preparation

Nineteen varieties of cassava were collected from the farm of ICAR-CTCRI, India. The ICAR-CTCRI has been catering to the needs of cassava farmers across the country by releasing suitable varieties since 1971 which include high starch varieties suitable for industrial applications, varieties with good culinary qualities for direct consumption especially in Kerala state and short-duration varieties that fit well into existing cropping systems prevalent in most of the growing areas (Sunitha *et al*., 2018) [32]. Seventeen varieties released by ICAR-CTCRI, one popular variety released by Kerala Agricultural University, India (Vellayani Hraswa) and a popular landrace (M-4) were used for the present study. Three replicate samples of each variety/cultivar were taken for different analysis. The samples were collected at the time of crop maturity and were separated into leaf, stem and tuber. The tubers were peeled and washed thoroughly, and tuber, stem and leaf samples were chopped into fine pieces and dried in a hot air oven at 105^0C for 48-72 hrs until constant weight was obtained. The dried samples were then powdered using stainless steel Wiley mill.

Biochemical composition

Biochemical parameters such as starch, total sugar and polyphenol were estimated following standard procedures (Moorthy and Padmaja, 2002) [27]. The total N content was determined by digesting the samples in sulfuric acid (H_2SO_4) followed by analysis of total N by Kjeldahl method using a Kjeltec automatic N digestion and distillation system (Bremner and Mulvaney, 1982) [5].

Mineral composition

The plant samples were digested by wet digestion in triple acid mixture (HNO_3:$HClO_4$:H_2SO_4 in 10:4:1 ratio) (Jackson, 1972) [17]. Tissue P was determined by vanado-molybdo phosphoric yellow colour method after digestion with triple acid using uv-visible spectrophotometer and tissue K by flame photometer using the same digest (Jackson, 1972) [17]. Sulfur was estimated turbidimetrically using UV-visible spectrometer from the extractant obtained by diacid ((HNO_3: $HClO_4$) digestion (Kalra 1998) [23]. Other minerals such as Ca, Mg, Fe, Mn, Zn and Cu were determined from the extractant obtained by triple acid digestion using atomic absorption spectrophotometer (AAS) (Jones *et al*., 1991) [21]. Tissue boron was determined by dry ashing the sample at 550^0C for 6 hrs in a muffle furnace followed by azomethine-H method (Hou *et al*., 1994) [14].

Proximate composition

The proximate composition was determined by quantifying the moisture, crude protein, crude fibre and crude lipid contents. Moisture content was determined according to AOAC 1980) [3]. Ash content was determined by dry-ashing the samples in a muffle furnace at 525^0C for 24 h. The crude protein content was calculated by multiplying the nitrogen content determined as described in earlier section by a factor of 6.25 (Moorthy and Padmaja 2002) [27]. The crude fibre and crude lipid were estimated using the procedures of AOAC (1975) [2]. The energy content of the tubers was determined by multiplying the percentages of crude protein, crude lipid, starch and total sugars by the factors 17, 38, 17 and 16, respectively (Moorthy and Padmaja, 2002) [27].

The results of biochemical (except N) and proximate compositions are expressed on fresh weight basis whereas the nitrogen and mineral contents are expressed on dry weight basis as it is the conventional practice for food analysis.

Statistical analysis

Descriptive statistical analysis was done for interpretation of the results. Before descriptive statistical analysis, the data were tested for their normality using Kolmogorov-Smirnov (K-S) test as well as normal quantile-quantile (Q-Q) test. Since all data sets were found to be normally distributed, no transformation was done. The data sets were analyzed for their descriptive statistical parameters such as mean, minimum, maximum, median, standard deviation (SD), coefficient of variation (CV), skewness and kurtosis. The descriptive statistical analysis was performed using Excel 2007.

Results and Discussion

Biochemical composition

The results of analysis of biochemical composition and descriptive statistical analysis of the leaf, stem and tuber of 19 cassava varieties/landrace studied are given in Table 1. The starch content in the tuber ranged from 24 (H-165) to 40.91% (Sree Harsha) with a mean value of 28.59 %. The total sugar ranged from 0.74 (H-226) to 1.33% (Sree Prakash) with a mean value of 1.06%. Analysis of polyphenols showed a narrow range from 0.003% for Sree Reksha to 0.012% for Sree Jaya with a mean value of 0.012%. The nitrogen content (dry weight basis) in tuber varied from 0.413 (M-4) to 0.973% (H-97) with a mean value of 0.72%. The polyphenol/N ratio ranged from 0.004 (Sree Reksha) to 0.02 (Vellayani Hraswa) with a mean value of 0.01. Among the different biochemical parameters of tuber studied, the polyphenol had the highest variability as indicated by very high coefficient of variability (CV) value of 42.79%.

Table 1: Biochemical composition of cassava varieties (mean ± standard deviation)

Sl. No.	Variety	Tuber					Stem			Leaf		
		Starch %	Total Sugar %	Polyphenol %	Nitrogen (DW) %	Polyphenol/ Nitrogen	Polyphenol %	Nitrogen (DW) %	Polyphenol/ Nitrogen	Polyphenol %	Nitrogen (DW) %	Polyphenol/ Nitrogen
1	H-97	30.00±1.32	0.94±0.03	0.010±0.0008	0.97±0.03	0.010±0.0006	0.033±0.0011	0.78±0.03	0.041±0.0012	0.156±0.004	4.186±0.067	0.037±0.0015
2	H-165	24.00±1.64	0.83±0.03	0.004±0.0001	0.61±0.02	0.007±0.0002	0.019±0.0004	1.25±0.05	0.015±0.0008	0.127±0.007	4.459±0.083	0.028±0.0008
3	H-226	28.68±2.06	0.74±0.04	0.008±0.0003	0.54±0.07	0.015±0.0002	0.037±0.0003	1.08±0.04	0.035±0.0005	0.143±0.005	4.494±0.112	0.032±0.0009
4	Sree Visakham	27.00±1.14	1.24±0.02	0.004±0.0001	0.69±0.03	0.006±0.0002	0.028±0.0007	0.99±0.03	0.029±0.0003	0.136±0.008	4.361±0.231	0.031±0.0011
5	Sree Sahya	28.13±1.54	1.27±0.03	0.006±0.0002	0.92±0.03	0.007±0.0003	0.024±0.0008	1.19±0.04	0.020±0.0011	0.101±0.005	5.299±0.224	0.019±0.0011
6	Sree Prakash	30.91±1.07	1.33±0.04	0.009±0.0003	0.85±0.04	0.011±0.0001	0.032±0.0012	1.29±0.06	0.024±0.0009	0.055±0.005	5.107±0.221	0.011±0.0008
7	Sree Harsha	40.91±0.95	1.25±0.03	0.011±0.0008	0.86±0.05	0.013±0.0003	0.017±0.0006	0.80±0.03	0.022±0.0006	0.092±0.006	5.033±0.196	0.018±0.0009
8	Sree Jaya	26.00±1.47	1.07±0.04	0.012±0.0009	0.93±0.03	0.013±0.0004	0.026±0.0007	1.49±0.05	0.018±0.0007	0.105±0.004	4.165±0.188	0.025±0.0007
9	Sree Vijaya	30.50±1.34	0.99±0.03	0.007±0.0002	0.50±0.02	0.014±0.0002	0.017±0.0004	0.85±0.04	0.020±0.0008	0.070±0.003	4.067±0.211	0.017±0.0008
10	Sree Rekha	29.00±0.88	1.26±0.01	0.003±0.0001	0.55±0.02	0.005±0.0001	0.033±0.0001	0.99±0.03	0.033±0.0005	0.254±0.005	3.178±0.143	0.080±0.0023
11	Sree Prabha	30.00±0.78	0.96±0.02	0.007±0.0001	0.84±0.02	0.008±0.0002	0.028±0.0002	1.99±0.05	0.014±0.0003	0.154±0.004	3.815±0.116	0.040±0.0013
12	Sree Padmanabha	27.14±2.15	0.92±0.03	0.007±0.0002	0.61±0.02	0.011±0.0002	0.064±0.0001	1.67±0.04	0.038±0.0004	0.093±0.004	5.170±0.226	0.018±0.0008
13	Sree Athulya	28.13±1.34	0.92±0.04	0.007±0.0001	0.80±0.03	0.009±0.0004	0.040±0.0003	1.53±0.03	0.026±0.0003	0.141±0.006	3.619±0.178	0.039±0.0011
14	Sree Apoorva	29.13±0.67	0.93±0.04	0.005±0.0001	0.83±0.03	0.006±0.0002	0.020±0.0007	1.65±0.06	0.012±0.0004	0.160±0.006	3.749±0.145	0.043±0.0011
15	Sree Pavithra	26.47±2.31	1.01±0.03	0.006±0.0002	0.87±0.04	0.007±0.0001	0.020±0.0006	0.90±0.04	0.022±0.0001	0.111±0.004	4.725±0.133	0.023±0.0008
16	Sree Swarna	25.00±1.85	0.92±0.02	0.008±0.0004	0.87±0.04	0.009±0.0003	0.010±0.0005	1.49±0.04	0.007±0.0002	0.117±0.006	3.591±0.126	0.033±0.0006
17	Sree Reksha	30.00±1.33	1.15±0.03	0.002±0.0001	0.51±0.02	0.004±0.0002	0.015±0.0004	1.27±0.04	0.012±0.0003	0.110±0.005	5.705±0.236	0.019±0.0008
18	Vellayani Hraswa	28.13±0.94	1.07±0.03	0.002±0.0001	0.52±0.02	0.004±0.0002	0.016±0.0003	1.00±0.05	0.016±0.0006	0.142±0.008	3.472±0.118	0.041±0.0002
19	M-4	24.14±1.22	1.30±0.03	0.007±0.0002	0.41±0.02	0.017±0.0003	0.023±0.0004	1.22±0.05	0.019±0.0005	0.139±0.006	5.110±0.225	0.027±0.0005

The polyphenol content of cassava stem ranged from 0.01 (Sree Swarna) to 0.064% (Sree Padmanabha) with a mean value of 0.026% and showed highest variability as given by a very high CV value (45.97%). The nitrogen content (dry weight basis) of the stem ranged from 0.78 for H-97 to 1.99% for Sree Prabha with a mean value of 1.23%. The polyphenol/N ratio had a range of 0.01 for Sree Swarna to 0.04% for H-97 with an average value of 0.02%. The polyphenol content in cassava leaves ranged between 0.06% (Sree Prakash) and 0.25% (Sree Rekha) with a mean value of 0.13%. The nitrogen content (dry weight basis) was in the range of 3.18 (Sree Rekha) to 5.71% (Sree Reksha) with a mean value of 4.53%. The polyphenol/N ratio of cassava leaves ranged from 0.01 to 0.08 (mean 0.03) for Sree Prakash and Sree Rekha respectively.

Cassava has varied roles as human food, animal feed and in the manufacture of different industrial products. The results of the present study showed great variations in starch content of tubers and hence the varieties can be classified into high and low starch varieties and can be used for various applications. The highest starch content was reported in Sree Harsha which is a variety developed through triploidy breeding (Abraham *et al*. 2006) [1]. The total sugar content was lowest for H-226 which is a very popular variety in industrial areas of Tamil Nadu, India whereas Sree Prakash (1.33%) and M-4 (1.30%) had the highest sugar contents; Sree Prakash is a short duration and edible variety while M-4 is a popularly preferred variety for direct consumption by the people of Kerala state, India. The results of analysis of polyphenol contents showed high average values in leaves (0.13%) than stem (0.026%) and tuber (0.012%). Polyphenols are secondary metabolites of plants and are generally involved in defense against ultraviolet radiation or aggression by pathogens and have potential health benefits of dietary plant polyphenols as antioxidant. Epidemiological studies and associated meta-analyses strongly suggest that long term consumption of diets rich in plant polyphenols offer protection against development of cancers, cardiovascular diseases, diabetes, osteoporosis and neurodegenerative diseases (Pandey and Rizvi, 2009) [29]. Since cassava leaf and stem have got wide scope in composting, residues with high N concentration and low concentrations of polyphenol are categorized as high quality residues while those with low N concentration with high polyphenol contents are categorized as low quality residues (Mafongoya *et al*., 1998) [26]. Accordingly, the present study could find very wide variations in polyphenol/N ratio of cassava leaf and stem. Those varieties with low ratios could be very effectively utilized in preparation of good quality composts. The nitrogen content in cassava is in the order of leaf> stem> tuber with average values of 4.53, 1.23 and 0.72% respectively.

Mineral composition

Table 2 gives the mineral composition of tubers of 19 cassava varieties/landrace studied. The P in tuber ranged from 0.03 (Sree Visakham) to 0.131% (Sree Prabha) with a mean value of 0.08%. The K is the most abundant mineral present in cassava tuber and it ranged from 0.327 (Sree Prabha) to 1.087% (Sree Pavithra) with an average value of 0.65%. The second most abundant mineral in cassava tuber is calcium and it ranged from 1083 to 1858 ppm for M-4 and Sree Vijaya, respectively. The average Ca content was 1502 ppm. The Mg in cassava tuber showed a range of 540 (Sree Swarna) to 895 ppm (Sree Sahya) with a mean content of 740 ppm. The average S content in cassava tuber was 0.11% and it ranged from 0.100 (H-165 and Sree Padmanabha) to 0.129% (Sree Reksha). Iron varied from 68 ppm for Sree Rekha to 248 ppm for Sree Athulya having an average Fe concentration of 120.46 ppm. The Mn content ranged from 15.40 ppm for Sree Rekha to 33.2 for Sree Swarna with an average concentration of 21.96 ppm. The content of Zn ranged from 15.00 ppm to 28.2 ppm for Sree Reksha and H-97, respectively (mean: 15.00 ppm) and Cu ranged from 2.2 ppm for Sree Prabha and H-97, and 4.2 ppm for H-226 (mean: 3.18 ppm). The boron content ranged from 4.12 (H-97) to 7.62 ppm (Sree Sahya) and the average value observed was 5.69 ppm.

Table 2: Mineral composition of cassava tuber (mean ± standard deviation)

Sl. No.	Variety	P (%)	K (%)	Ca (ppm)	Mg (ppm)	S (%)	Fe (ppm)	Mn (ppm)	Zn (ppm)	Cu (ppm)	B (ppm)
1	H-97	0.111±0.006	0.567±0.012	1800±65	825±2 9	0.103±0.006	138±6	22.0±1.2	28.2±1.2	2.2±0.11	4.12±0.11
2	H-165	0.088±0.002	0.835±0.025	1692±47	895±42	0.100±0.004	113±5	22.8±1.5	21.4±0.9	3.4±0.12	5.85±0.22
3	H-226	0.073±0.002	0.757±0.026	1428±39	715±46	0.101±0.003	130±6	16.2±0.8	18.8±0.8	4.2±0.13	5.22±0.19

4	Sree Visakham	0.030±0.001	0.523±0.018	1615±51	605±21	0.101±0.005	129±7	18.6±0.8	17.8±0.7	4.0±0.12	6.98±0.23
5	Sree Sahya	0.096±0.003	0.400±0.011	1400±72	895±38	0.102±0.005	137±6	28.2±1.1	24.0±1.4	3.8±0.09	7.62±0.22
6	Sree Prakash	0.073±0.004	0.498±0.007	1116±68	730±42	0.119±0.006	102±6	25.8±1.3	20.4±1.0	3.6±0.08	5.14±0.16
7	Sree Harsha	0.032±0.002	0.358±0.008	1516±59	870±38	0.104±0.007	100±7	17.4±0.8	15.6±0.8	3.4±0.08	4.98±0.15
8	Sree Jaya	0.084±0.003	0.919±0.031	1768±82	710±43	0.109±0.004	112±6	23.8±0.7	24.0±1.3	2.6±0.06	4.23±0.11
9	Sree Vijaya	0.041±0.002	0.438±0.008	1858±38	745±39	0.108±0.004	103±7	15.8±0.8	17.6±0.9	3.6±0.05	4.24±0.15
10	Sree Rekha	0.075±0.003	0.337±0.011	1659±41	605±38	0.106±0.004	68±5	15.4±0.9	17.8±0.8	2.6±0.06	5.57±0.21
11	Sree Prabha	0.131±0.006	0.327±0.009	1570±43	770±47	0.102±0.005	118±9	21.4±1.0	15.2±0.6	2.2±0.05	5.67±0.22
12	Sree Padmanabha	0.111±0.007	0.843±0.013	1415±62	730±51	0.100±0.006	93±6	27.8±1.4	22.2±1.0	3.4±0.06	6.45±0.32
13	Sree Athulya	0.109±0.006	0.622±0.022	1263±55	800±38	0.103±0.005	248±11	21.0±1.2	19.8±1.0	3.0±0.06	6.23±0.32
14	Sree Apoorva	0.099±0.004	0.869±0.019	1710±49	815±47	0.100±0.005	121±8	18.0±0.9	19.2±1.1	2.6±0.11	4.60±0.22
15	Sree Pavithra	0.099±0.003	1.087±0.042	1386±62	680±45	0.105±0.004	99.8±7	23.8±1.2	17.2±0.7	4.0±0.09	7.50±0.21
16	Sree Swarna	0.094±0.004	0.977±0.041	1440±57	540±37	0.101±0.005	102.4±6	33.2±1.6	16.6±1.0	3.8±0.08	5.43±0.32
17	Sree Reksha	0.045±0.002	0.578±0.022	1400±68	735±61	0.129±0.007	144±9	23.2±1.5	15.0±0.7	2.4±0.08	6.62±0.34
18	Vellayani Hraswa	0.071±0.003	0.943±0.034	1425±47	740±38	0.106±0.006	126.4±7	19.0±0.9	16.2±0.8	3.0±0.08	6.54±0.27
19	M-4	0.073±0.003	0.511±0.027	1083±51	655±41	0.105±0.006	104.2±5	23.8±1.2	16.6±0.8	2.6±0.09	5.11±0.26

Results of analysis of the mineral composition of the cassava stem are shown in Table 3. The P content in the stem varied from 0.07% for Sree Visakham to 0.29% for H-226 and the average content was 0.16%. The mean K content was 0.85% with minimum and maximum values of 0.43% (Sree Harsha) and 1.41% (Sree Padmanabha). The average Ca content was 14577.11ppm and it ranged from 11025 ppm for M-4 to 18850 ppm for Sree Vijaya. The Mg content varied from 2180 ppm for Sree Visakham to 5220 ppm Sree Sahya with an average value of 3755.53 ppm. The average S content was found to be 0.22% with minimum and maximum values of 0.13 and 0.29% observed for Vellayani Hraswa and Sree Prabha respectively. The Fe content ranged from 77.8 ppm for Sree Visakham and 144 ppm for Sree Jaya with a mean value of 114.08 ppm. The Mn content ranged from 86.4 ppm for Sree Visakham to 127 ppm for Sree Sahya with a mean value of 104.2 ppm. The Zn concentration ranged from 38.8 ppm (Sree Jaya) to 57 ppm (Sree Prabha) having a mean value of 47.95 ppm. The Cu content ranged from 9.4 ppm for Sree Reksha, Sree Rekha and H-165 to 14.2 ppm for H-226. The average Cu content across all 19 varieties/landrace studied was 11.27 ppm. The B content varied from 9.23 ppm (M-4) to 19.24 ppm (Sree Sahya) with a mean value of 13.04 ppm.

Table 3: Mineral composition of cassava stem (mean ± standard deviation)

Sl. No.	Variety	P (%)	K (%)	Ca (ppm)	Mg (ppm)	S (%)	Fe (ppm)	Mn (ppm)	Zn (ppm)	Cu (ppm)	B (ppm)
1	H-97	0.105±0.002	0.641±0.022	12745±432	3510±124	0.141±0.005	99.8±8.5	118.8±12.5	42.8±5.4	12.4±2.4	15.90±1.94
2	H-165	0.109±0.008	0.804±0.031	16035±364	2720±96	0.283±0.005	91.4±8.8	95.8±10.4	40.6±5.2	9.4±2.2	11.16±1.43
3	H-226	0.289±0.006	1.392±0.072	15830±723	4670±174	0.282±0.007	99.0±10.3	97.8±12.4	55.2±6.2	14.2±1.9	11.15±2.11
4	Sree Visakham	0.069±0.004	0.553±0.023	16910±632	2180±118	0.281±0.006	77.8±11.2	86.4±13.5	42.6±5.7	10.2±2.8	17.94±1.63
5	Sree Sahya	0.169±0.007	0.662±0.034	17430±476	5220±216	0.214±0.005	107.2±12.4	127±21.5	53.8±6.9	12.6±3.1	19.24±1.44
6	Sree Prakash	0.161±0.009	0.691±0.047	13625±538	4860±225	0.224±0.008	79.2±10.5	93.8±15.8	51.8±7.3	10.4±2.9	12.13±1.19
7	Sree Harsha	0.276±0.011	0.433±0.024	13895±552	3970±118	0.182±0.007	78.6±9.5	94.8±16.9	54.2±6.5	13.0±1.7	10.52±1.55
8	Sree Jaya	0.175±0.012	0.867±0.043	11245±472	2315±230	0.214±0.007	194.6±18.6	95.8±21.8	38.8±7.2	11.2±1.8	15.68±1.66
9	Sree Vijaya	0.111±0.008	0.524±0.035	18850±631	5005±326	0.242±0.006	163.8±15.5	119.4±21.5	56.4±7.5	11.4±1.7	12.71±1.98
10	Sree Rekha	0.114±0.006	0.61±0.027	18000±532	3920±154	0.282±0.007	110.2±17.8	91.6±18.2	42.4±7.9	9.4±1.8	13.1±1.52
11	Sree Prabha	0.197±0.012	0.706±0.042	14695±375	4915±341	0.286±0.008	124.6±13.5	110.2±22.5	57.0±6.5	10.4±2.1	14.72±1.55
12	Sree Padmanabha	0.193±0.021	1.411±0.061	11620±352	4895±236	0.165±0.005	131.4±20.8	98.6±18.6	51.0±10.5	12.2±1.5	12.45±1.32
13	Sree Athulya	0.219±0.008	1.062±0.063	17300±483	4075±195	0.194±0.005	78.2±11.5	118.2±24.7	52.0±12.4	12.4±1.6	13.74±1.47
14	Sree Apoorva	0.219±0.012	1.291±0.072	11815±458	3670±165	0.282±0.006	95.0±10.6	99.6±22.4	44.8±15.2	11.6±2.2	10.12±1.22
15	Sree Pavithra	0.131±0.008	1.362±0.084	11285±556	3075±138	0.215±0.006	120.6±14.5	116.2±18.9	45.8±11.4	12.0±1.8	11.64±1.44
16	Sree Swarna	0.210±0.011	1.061±0.083	18175±525	3130±172	0.226±0.007	100±15.8	106±22.4	55.2±12.5	10.2±1.6	14.39±1.43
17	Sree Reksha	0.114±0.008	0.601±0.034	12800±475	3920±215	0.185±0.008	110.2±14.6	91.6±17.5	42.4±14.8	9.4±2.3	11.11±1.22
18	Vellayani Hraswa	0.099±0.007	0.802±0.024	13685±480	2595±167	0.133±0.008	168.2±21.8	103±21.5	43.2±15.2	10.0±2.4	10.84±1.23
19	M-4	0.126±0.008	0.702±0.045	11025±382	2710±148	0.184±0.009	137.8±22.5	115.4±22.6	41.0±9.5	11.8±2.1	9.23±2.15

Table 4 shows the mineral composition of the leaves of 19 varieties/landrace of cassava. The P content was found to be between 0.13 and 0.38% (average: 0.26%) for Sree Jaya and Sree Reksha respectively. The K ranged from 0.57% for Sree Apoorva to 1.62% for H-226 showing an average value of 1.11%. The Ca content ranged from 9035 ppm for Sree Rekha to 18215 ppm for H-97. The average Ca content across 19 varieties/landrace studied was 12275.8 ppm. The Mg content ranged from 2085 ppm for M-4 to 3940 ppm for H-226 with an average value of 2919.47 ppm. The S content varied from 0.13% (Sree Swarna) to 0.38% (Sree Apoorva) with an average of 0.31 %. The Fe content ranged from 179.8 ppm for Sree Prabha to 280 ppm for Sree Athulya with an average value of 212.67 ppm. The Mn content ranged from 109 ppm for H-226 to 329 ppm for Vellayani Hraswa and the mean content was 260.96 ppm. The content of Zn ranged from 54.2 ppm to 129 ppm for Sree Apoorva and Sree Rekha, respectively (mean: 102.05 ppm). The Cu concentration ranged from 9.8 ppm (Sree Prabha) to 16.4 ppm (Sree Jaya) and the average value was 12.42 ppm. The B content ranged from 18.26 ppm (Sree Vijaya) to 47.93 ppm (H-226) with an average concentration of 34.3 ppm.

Table 4: Mineral composition of cassava leaves (mean ± standard deviation)

Sl. No.	Variety	P (%)	K (%)	Ca (ppm)	Mg (ppm)	S (%)	Fe (ppm)	Mn (ppm)	Zn (ppm)	Cu (ppm)	B (ppm)
1	H-97	0.195±0.008	0.908±0.034	18215±523	2695±134	0.344±.011	271.8±15.4	287.8±17.5	119.8±9.5	11.2±1.3	32.46±2.31
2	H-165	0.300±0.011	1.091±0.056	14135±341	2680±125	0.284±.008	206.8±12.7	189.8±21.4	97.0±8.4	12.0±0.9	27.30±1.94
3	H-226	0.270±0.008	1.618±0.084	11545±286	3940±145	0.359±.012	216.4±13.4	109.0±12.5	109.8±9.8	10.8±1.4	47.93±2.33
4	Sree Visakham	0.212±0.008	1.151±0.073	9295±355	3460±162	0.323±.010	203.6±15.5	163±14.3	92.8±6.9	12.4±1.6	39.55±2.16
5	Sree Sahya	0.345±0.013	0.992±0.047	9480±421	3010±150	0.269±0.006	189±12.6	221.2±19.6	128.8±10.2	10.8±1.2	40.20±1.94
6	Sree Prakash	0.229±0.007	0.938±0.041	9925±375	3550±167	0.309±0.009	217.4±14.5	260.4±21.5	92.0±9.1	13.2±1.1	31.81±2.15
7	Sree Harsha	0.316±0.009	0.932±0.044	9685±368	3050±153	0.359±0.008	243.2±20.6	271.8±18.8	122.0±11.5	11.8±1.0	27.29±1.19
8	Sree Jaya	0.126±0.008	0.992±0.038	17770±552	2490±137	0.353±0.009	204.2±17.8	287.6±20.4	123.0±15.6	16.4±1.4	41.48±2.24
9	Sree Vijaya	0.240±0.012	0.945±0.041	9390±375	2775±132	0.300±0.011	240.6±14.5	325.2±24.5	86.4±9.0	15.0±1.7	18.26±1.92
10	Sree Rekha	0.263±0.011	0.970±0.052	9035±368	2870±144	0.233±0.005	191.6±21.4	294±21.5	129.0±12.5	12.2±1.1	36.97±2.11
11	Sree Prabha	0.356±0.014	0.700±0.033	10585±435	3120±151	0.311±0.007	179.8±20.5	314.6±25.4	107.8±10.5	9.8±1.2	34.38±2.32
12	Sree Padmanabha	0.320±0.013	1.590±0.088	11415±426	2575±130	0.351±0.006	196.2±22.4	282.0±14.2	126.0±17.8	10.8±1.5	38.57±2.45
13	Sree Athulya	0.300±0.012	1.375±0.075	13125±531	2900±146	0.176±0.005	280.0±17.9	314.6±15.3	57.8±9.2	10.0±1.4	39.54±1.88
14	Sree Apoorva	0.203±0.008	0.571±0.025	9930±557	3380±186	0.379±0.005	222.2±16.8	249.0±20.5	54.2±8.4	14.2±1.4	34.39±2.54
15	Sree Pavithra	0.259±0.008	1.334±0.066	18025±476	2640±168	0.224±0.007	194.6±13.5	322.6±19.6	123.2±8.5	15.6±1.9	36.31±2.31
16	Sree Swarna	0.236±0.008	1.345±0.049	15185±465	2725±142	0.132±0.007	196.6±15.4	250.2±21.5	73.4±6.9	14.4±1.6	24.07±3.28
17	Sree Reksha	0.379±0.009	1.121±0.066	11715±378	2945±155	0.362±0.008	184.4±11.4	282.0±19.5	102.6±11.5	11.0±2.1	22.78±1.67
18	Vellayani Hraswa	0.195±0.011	1.487±0.055	14275±535	2580±138	0.357±0.009	204.2±13.5	329.0±27.6	98.0±9.5	10.8±2.0	37.61±1.94
19	M-4	0.156±0.013	0.979±0.039	10510±451	2085±115	0.371±0.008	198.2±15.5	204.4±15.6	95.4±6.9	13.6±0.9	40.83±2.33

The results of the present study showed large variabilities in mineral contents among 19 varieties/landrace studied. The recommended dietary allowances (RDA) for an Indian male of moderate activity weighing 60 kg according to Krishnaswamy (2011) [24] has been used to calculate the amounts of various nutrients provided by 150 g (dw basis) serving of cassava. An analysis of the results shows that a serving of certain varieties of cassava can supply complete RDA in case of K, Fe and Mn, while 70, 47, 35 and 28% of RDA of Cu, Ca, Zn and P respectively could be provided by some of the cassava varieties. This is an important finding of the study since cassava is dubbed as a climate smart future crop (Sabitha *et al*. 2016) [31] and could be able to meet the food and nutritional security of many tribal and backward population across the globe especially in Sub- Saharan Africa, Asia and Latin America.

Proximate composition

Table 5 gives the proximate composition of 19 varieties/landrace of cassava. The moisture content of cassava tuber varied from 56.67% (Sree Harsha) to 70.19 % (M-4) with a mean value of 66.67%. The ash content ranged from 2.07% (H-97) to 2.00% (H-97) with an average value of 2.78%. The crude protein content of cassava tubers ranged from 0.85% (M-4) to 2.00% (H-97) with an average value of 1.49%. The average crude fibre of cassava tuber was 0.19% and it ranged from 0.08% (Sree Padmanabha) to 0.39 % (Sree Jaya). The crude lipid content varied from 0.15% (Sree Jaya, Sree Swarna and Sree Apoorva) to 0.37 % (H -97) with a mean value of 0.26%.

Table 5: Proximate composition of cassava

		Tuber					Stem					Leaf				
Sl. No	Variety	Moisture %	Ash %	Crude protein %	Crude fibre %	Crude lipid %	Moisture %	Ash %	Crude protein %	Crude fibre %	Crude lipid %	Moisture %	Ash %	Crude protein %	Crude fibre %	Crude lipid %
1	H-97	65.57±2.25	2.07±0.08	2.00±0.06	0.19±0.004	0.37±0.017	69.57±3.21	3.03±0.12	1.71±0.08	2.49±0.19	1.60±0.11	78.43±1.49	2.69±0.15	7.85±0.31	1.75±0.07	1.25±0.09
2	H165	69.84±2.25	2.97±0.11	1.26±0.10	0.19±0.005	0.20±0.004	65.92±1.96	2.98±0.11	2.73±0.15	3.99±0.24	1.05±0.07	75.87±1.51	2.86±0.13	8.36±0.37	1.84±0.06	1.67±0.08
3	H226	67.44±1.33	2.58±0.12	1.11±0.07	0.21±0.007	0.33±0.014	70.81±2.47	2.96±0.17	2.36±0.13	4.52±0.22	2.20±0.13	76.21±1.78	2.80±0.24	8.43±0.40	1.94±0.09	2.05±0.15
4	Sree Sahya	67.15±1.21	2.47±0.13	1.42±0.08	0.26±0.013	0.32±0.014	71.30±2.32	2.85±0.15	2.17±0.10	5.02±0.32	2.95±0.18	75.49±2.02	2.70±0.22	8.18±0.36	2.06±0.11	1.69±0.14
5	Sree Visakham	66.52±1.28	2.54±0.14	1.90±0.06	0.19±0.009	0.31±0.014	67.35±1.96	2.97±0.15	2.60±0.11	2.63±0.31	2.40±0.16	77.22±1.95	2.86±0.19	9.94±0.47	1.97±0.06	1.75±0.14
6	Sree Prakash	65.31±2.04	2.46±0.12	1.75±0.09	0.15±0.007	0.30±0.012	65.03±2.03	2.94±0.17	2.82±0.12	4.15±0.22	2.65±0.22	79.14±1.56	2.77±0.17	9.58±0.48	1.90±0.07	1.81±0.09
7	Sree Harsha	56.67±2.34	2.47±0.13	1.77±0.10	0.29±0.008	0.30±0.013	63.54±1.77	2.86±0.16	1.75±0.09	4.79±0.67	2.00±0.15	76.34±1.76	2.74±0.22	9.44±0.45	1.02±0.13	1.41±0.08
8	Sree Jaya	68.88±1.24	3.00±0.14	1.92±0.11	0.39±0.011	0.15±0.006	65.53±1.89	3.01±0.21	3.26±0.12	3.33±0.31	2.00±0.16	77.91±1.98	2.81±0.09	7.81±0.35	1.68±0.09	1.62±0.07
9	Sree Vijaya	67.56±1.33	2.85±0.09	1.03±0.08	0.34±0.012	0.30±0.009	72.50±1.55	3.04±0.01	1.86±0.09	3.38±0.33	2.85±0.19	77.98±1.48	2.89±0.08	7.63±0.36	2.91±0.16	1.65±0.15
10	Sree Rekha	65.34±1.65	2.94±0.12	1.13±0.09	0.17±0.007	0.35±0.016	64.60±2.33	3.04±0.13	2.17±0.09	3.50±0.33	2.70±0.26	74.80±2.03	2.81±0.11	5.96±0.27	2.89±0.18	1.57±0.12
11	Sree Prabha	64.98±1.54	2.94±0.14	1.73±0.11	0.28±0.007	0.32±0.014	66.50±1.95	2.88±0.15	4.35±0.15	4.53±0.29	2.10±0.22	79.04±1.65	2.87±0.13	7.15±0.35	1.99±0.08	1.81±0.13

12	Sree Padmanabha	67.88±1.97	2.97±0.15	1.26±0.12	0.08±0.03	0.25±0.11	69.21±2.02	3.01±0.21	3.65±0.13	4.71±0.45	2.90±0.30	80.72±1.67	2.87±0.16	9.69±0.45	1.89±0.08	1.42±0.11
13	Sree Athulya	64.75±1.57	3.02±0.16	1.65±0.13	0.22±0.04	0.25±0.13	66.52±1.55	2.89±0.18	3.35±0.17	2.78±0.29	2.20±0.21	76.88±1.98	2.67±0.08	6.79±0.33	1.60±0.14	1.47±0.12
14	Sree Reksha	67.32±1.45	2.79±0.17	1.71±0.08	0.20±0.05	0.17±0.09	72.42±2.21	2.97±0.22	3.61±0.19	4.84±0.47	2.70±0.15	80.88±1.07	2.78±0.06	7.03±0.32	1.82±0.12	1.56±0.13
15	Sree Pavithra	65.98±1.32	3.02±0.14	1.79±0.09	0.10±0.08	0.25±0.13	67.96±1.44	2.86±0.14	1.97±0.09	4.37±0.31	2.55±0.14	77.10±1.45	2.85±0.04	8.86±0.41	2.72±0.10	1.61±0.13
16	Sree Swarna	69.84±1.28	2.86±0.13	1.79±0.10	0.09±0.05	0.15±0.06	65.31±1.27	2.90±0.13	3.26±0.13	4.58±0.29	2.20±0.17	78.16±1.43	2.83±0.07	6.73±0.26	2.36±0.69	1.88±0.11
17	Vellayani Hraswa	67.32±1.43	3.01±0.16	1.05±0.05	0.13±0.05	0.19±0.10	71.28±1.82	2.97±0.16	2.78±0.12	3.49±0.23	2.00±0.19	74.38±1.76	2.81±0.09	10.70±0.38	2.06±0.76	1.72±0.08
18	Sree Apoorva	66.34±1.56	2.94±0.17	1.07±0.06	0.16±0.07	0.15±0.07	63.73±1.37	2.98±0.19	2.19±0.10	3.68±0.33	2.50±0.16	80.64±1.87	2.68±0.23	6.51±0.31	2.31±0.79	1.90±0.09
19	M-4	70.19±1.78	2.99±0.08	0.85±0.03	0.09±0.03	0.25±0.13	65.54±2.48	3.02±0.11	2.67±0.10	3.70±0.28	2.60±0.21	81.67±1.98	2.88±0.19	9.58±0.42	2.66±0.16	1.89±0.07

The moisture content of cassava stem ranged from 63.54% for Sree Harsha to 72.50% for Sree Vijaya (mean: 67.61%). The ash content of cassava stem ranged from 2.85% (Sree Sahya) to 3.04% (Sree Vijaya and Sree Rekha) with mean value of 2.96%. The crude protein content varied from 1.71% (H-97) to 4.35% (Sree Prabha) with a mean value of 2.70%. The average crude fibre content was 3.92% which ranged from 2.49% (H-97) to 5.02% (Sree Sahya). The crude lipid content ranged from 1.05% reported for H-165 to 2.95% for Sree Sahya with an average content of 2.32%.

The moisture content in cassava leaf ranged from 74.38% to 81.67% for Vellayani Hrawsa and M-4 respectively and the average moisture content was 77.83%. The ash content ranged from 2.67 (Sree Athulya) to 2.89% (Sree Vijaya) with mean value of 2.80 %. The crude protein content ranged from 5.96% for Sree Rekha to 10.70% for Vellayani Hraswa and mean value was 8.22%. The crude fibre content ranged from 1.02% for Sree Harsha to 2.91% for Sree Vijaya and the average of 19 varieties/landrace was 2.07%. The crude lipid content ranged from 1.25% to 2.05% for H-97 and H-226, respectively with an average value of 1.67%.

Energy content of cassava tuber

Figure 1 shows the energy content of 19 varieties/landrace of cassava tuber. The results indicated that Sree Harsha had highest energy content (756.96 kJ/100g of fresh weight) whereas the lowest value was recorded for H-165 (450.30 kJ/100g). Energy content varied from 503.10 KJ $100g^{-1}$ (H-226) to 839.90 KJ $100g^{-1}$. Mean energy content of cassava tuber studied was 538.05 kJ/100g.

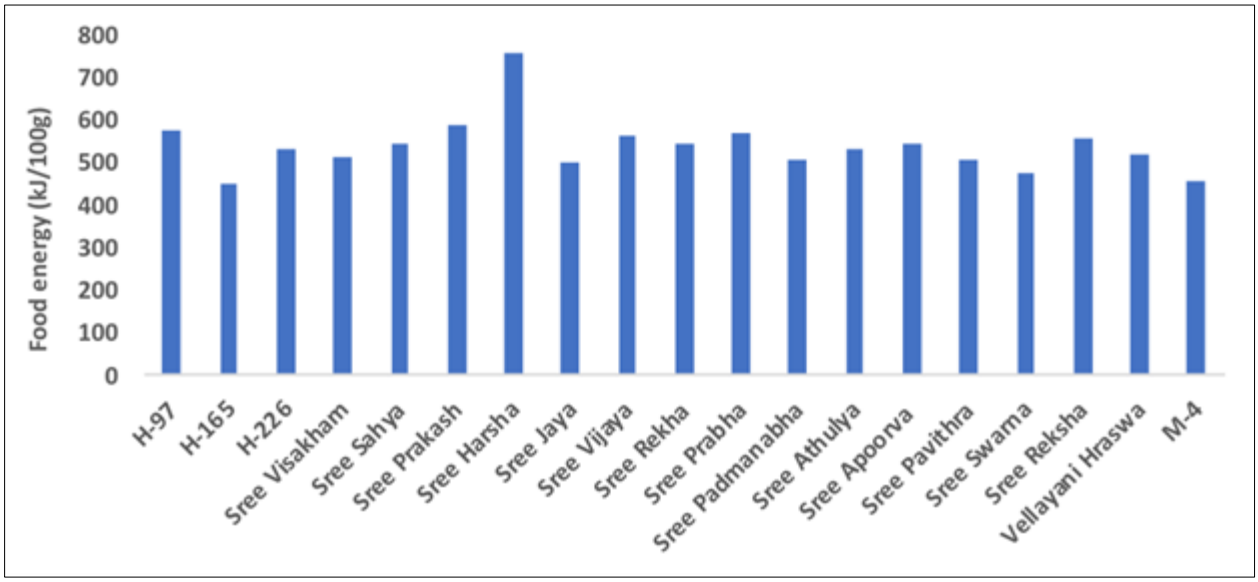

Fig 1: The energy content of 19 cassava varieties/landrace

Conclusion

Cassava is an important reserve of food energy because of its high starch content and the 19 varieties/landrace studied include all important varieties released in India during the past more than 40 years for various purposes such as starch extraction, good culinary traits, suitability in existing cropping systems and disease resistance. The present study showed these varieties/landraces vary greatly in biochemical, mineral and proximate composition. The present research has characterized all parts of cassava such as tuber, stem and leaf and has showed that different varieties have got applications in different sectors such as direct food consumption, starch extraction, other industrial applications, value addition, animal feed sector etc. The varieties of cassava studied vary in their biochemical, mineral and proximate composition in tuber, leaf and stem and also among the varieties. The results reveals the importance of cassava as food as well as fodder. Many cassava varieties are good sources of minerals such as K, Ca, Fe, Mn and Cu and can be popularized to alleviate such nutritional problems in socially marginalized tribal and backward population. It should be highlighted that the present study quantified the composition of only released and popular

cassava varieties and the results of the study indicate that a systematic analysis of cassava germplasm of 1211 available at ICAR-CTCRI will help in finding excellent cassava clones with high crude protein and essential minerals and can be used in future breeding and biofortification research programmes. This also has got applications in developing cultivars suitable for animal feed industries as well as for various industrial applications.

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