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Analysis of Biochemical Composition of Yams (*Dioscorea* spp.) Landraces from Southwest Ethiopia

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Abstract

Yams make a significant contribution to food security and medicinal importance in developing countries. In Ethiopia, there is insufficient scientific study on biochemical composition of Ethiopian yams. In order to fill the knowledge gap, this study was conducted to assess the biochemical composition of yams collected from Southwest Ethiopia. Flour from storage tuber of 36 yam landraces collected and the samples run in duplicates. Data on 14 biochemical traits were collected and subjected to various data analysis. Results of the analysis of variance indicated significant variation ($p \leq 0.01$) among the landraces on organic matter, total nitrogen, protein, fat, carbohydrate, total phosphorus, total energy, tannin and saponin contents. The flour moisture contents ranged from 17.75 to 27.47% with a mean of 22.03%. The ranges of dry matter (15.80 to 27.28%), organic matter (21.38 to 43.56%), ash (1.13 to 3.56%), organic carbon (0.63 to 1.98 g), crude fiber (0.41 to 2.05%), total nitrogen (1.00 to 1.32%), protein (6.25 to 8.28%), fat (0.09 to 0.65%), carbohydrate (12.71 to 33.94%), total phosphorus (23.7 to 53.0 mg/100 g), total energy (92.66 to 173.30 kcal/100 g DM), tannin (19.80 to 181.0 mg/100 g) and saponin (2.31 to 13.94 mg/100 g) contents. The cluster and distance analysis of biochemical traits showed the existence of eight divergent groups. The maximum inter cluster distance was found between clusters VI and VII (133.59), followed by clusters V and VI (109.19), clusters II and VI (105.22), clusters I and VI (100.42), and clusters III and VI (89.25) in order of magnitudes. Maximum genetic divergence between the clusters points out the fact that hybridization among the landraces included with them would produce potential and meaningful hybrids and desirable segregants. Besides, investigation of the existed yam landraces based on molecular marker analysis is vital for better assessment of genetic diversity of yams in Ethiopia.

Keywords: Cluster; Diversity; Food security; Nutritional composition; Storage tuber

Introduction

Yam (Dioscorea spp.) is the most important food crop since the time of immoral in the tropics and sub tropics [1]. It is highly linked with the human existence, endurance, and the socio economic history [2]. It is cultivated to a greater extent to combat the food security threats of the increasing population in the world [3]. The global production of yam in 2008 is estimated at 51.8 MT from 50 million hectares, of which 49.21 MT (95%) was produced in West Africa [4]. It is the third most important root crop in West Africa, after cassava (Manihot esculenta Crantz) and sweet potato (Ipomoea batatas (L.) Poir)[2,5]. From the nutritional standpoint, it is better than cassava on its higher vitamin C (40-120 mg/g edible portion) and crude protein content (40-140 g/kg dry matter) [6]. Moreover, during the off seasons, some people prefer using yams to solve their seasonal food shortage rather than cassava and sweet potato [7,8].

Yams have been domesticated and cultivated by over 60 million of people in tropical and sub-tropical regions [9-10]. In these regions, yams are well integrated into the social and cultural lifestyle of the people who cultivate and consume them and have significant contribution for food security, medicine and commercial value particularly in rural areas, where they are freely available [2,11,12]. Apart from providing basic food security and income source, yam is a rich source of carbohydrate, vitamins and minerals, especially where it is consumed in large amounts. The crop is estimated to provide more than 285 dietary calories per person per day for 300 million people in sub Saharan Africa [13-15].

In Ethiopia, yam is a highly valued crop, which provides food for household consumption and improves many livelihoods through the sale of harvested tubers [16]. Wild types of yam are also consumed by some farming communities in South and Southwest Ethiopia to overcome hunger and make a significant contribution in the diets of the people [17]. The tubers were found with a high amount of carbohydrates, fibers, and low level fats and protein, a good proportion of essential amino acids which make them a good dietary source and could be eaten as cooked vegetable, boiled yam, steamed, baked or fried in oil [18,19]. Conversely, the wider utilization of yam in Ethiopia is limited; due to information on the biochemical composition of yam is meager. Besides, yam in itself is not a balanced food and malnutrition occurs when yam is consumed alone as staple food [20]. Studies of nutritional composition on yam as a food are considerable significance since it may help to identify long forgotten food resource [21]. In this regards, few attempt was made to understand the proximate composition and anti-nutritional factors of the underutilized tubers of

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yam to make edible tubers as the safe food sources for mass consumption [22]. Moreover, many different forms and landraces of the edible yam species are available in different areas with variable in composition and nutritional values. In contrast to cultivated tubers, little is known about the proximate composition and reasons to expect that some of the species differ in composition from common agricultural varieties [23]. Furthermore, several species of yams also have medicinal properties and the tuber contains some pharmacologically active substances including dioscorine, saponin and sapogenin [24].

In spite of its food security and medicinal importance, to the best of our knowledge, there are no efforts so far done in the nutritional composition and medicinal value on Ethiopian yams and information on the biochemical composition of the landraces is scarce. Furthermore, the culinary attributes of the existing landraces have never been assessed and the nutritional importance of yam at country level is still unknown; which hinders the wider utilization and researchers to access the biochemical composition indigenous yam genetic resources in the country. Thus, exhaustive imagery of landraces based on biochemical composition and medicinal values in connection with farmers' indigenous knowledge and use have tremendous impact to make the genetic enhancement and sustainable use of yam genetic resource in Ethiopia. Consequently, the present study was designed to assess the biochemical composition of yams collected from Southwest Ethiopia for breeding and conservation.

Materials and Methods

Samples collection and preparation

A total of 36 yam landraces collected from major yam growing areas of Southwest Ethiopia. Names of the landraces and areas of collection are presented in Table 1. Yam tubers were weighed, peeled, cut into small pieces and dried at 65°C for 72 hours until constant weight was obtained (10%). The dried chips were then milled using an electric grinder [11,25], to obtain fine powder yam flour.

The flour was sieved through 1 mm sieve, measured and packed into airtight plastic bag and stored in the refrigerator until used for analysis. The proximate and mineral analysis was conducted at Ethiopian Institute of Agricultural Research Food and Nutrition Laboratory and the protein, phosphorus, tannin and saponin contents were analyzed at Jimma University College of Agriculture and Veterinary Medicine (JUCAVM) Animal Sciences Nutrition Laboratory.

Biochemical analysis

The analyses were carried out using the flour form the storage tuber of yam and the samples were run in duplicates and the mean value was used. The flour moisture, dry matter, organic matter, ash, organic carbon, crude fibre, tannin, nitrogen, phosphorus, crude fat, crude protein, saponin, carbohydrate and total energy contents were determined in accordance with the standard methods of the AOAC [26]. The flour moisture content was determined by the standard analytical method [27]. Duplicate flour samples (100 g) were weighed in aluminum dishes and oven dried at 65°C for three days. The dried samples were cooled in a desiccator's room temperature and weighed. The flour moisture content was determined by loss of weight due to drying was converted to percent flour moisture content as follows: Moisture %=(weight of moisture evaporated/weight of flour sample) x 100. The dry matter content of tuber was calculated by taking a representative duplicate sample of about 100 g (W1) prepared by thoroughly mixing sliced pieces of tubers was oven dried at 65°C for 72 hours and weighed (W2) and the value was expressed in percentage [28,29] The percentage dry matter content was calculated as:

No.	Name of landraces	Zone	District	Latitude	Longitude	Altitude
1	59/02	Jimma	Mana	07°40'37N	036°49'10E	1718
2	68/01	Jimma	Dedo	07°30'63N	036°53'45E	1774
3	6/02	Bench maji	Sheko	06°59'66N	035°34'11E	1728
4	75/02	Jimma	Kersa	07°40'43N	036°48'76E	1734
5	3/87	Jimma	Manna	07°40'58N	036°48'75E	1731
6	56/76	Jimma	Manna	07°41'89N	036°48'06E	1837
7	54/02	Bench maji	Sheko	07°02'03N	035°32'77E	1892
8	46/83	Jimma	Dedo	07°31'28N	036°53'59E	1771
9	08/02	Jimma	Kersa	07°40'46N	036°48'79E	1740
10	116	Jimma	Dedo	07°31'28N	036°53'63E	1683
11	01/75	Sheka	Yeki	07°11'30N	035°26'22E	1171
12	06/83	Jimma	Dedo	07°31'32N	036°53'64E	1692
13	17/02	Sheka	Yeki	07°11'27N	035°26'26E	1176
14	07/03	Jimma	Dedo	07°31'50N	036°53'60E	1733
15	45/03	Jimma	Mana	07°41'86N	036°48'08E	1810
16	27/02	Jimma	Seka chekorsa	07°35'06N	036°41'91E	1877
17	37/87	Jimma	Mana	07°41'87N	036°48'13E	1940
18	10/002	Bench maji	Sheko	07°02'91N	035°29'76E	1668
19	76/02	Jimma	Kersa	07°40'64N	036°48'84E	1728
20	06/200	Jimma	Seka chekorsa	07°35'43N	036°41'86E	1850
21	7/83	Jimma	Seka chekorsa	07°35'06N	036°41'91E	1898
22	58/02	Sheka	Yeki	07°11'22N	035°26'25E	1192
23	39/87	Jimma	Seka chekorsa	07°35'42N	036°42'94E	1885
24	32/83	Jimma	Shebe sombo	07°26'74N	036°24'°1E	1372
25	24/02	Jimma	Shebe sombo	07°26'75N	036°24'07E	1379
26	2/87	Jimma	Shebe sombo	07°26'76N	036°24'12E	1365
27	60/87	Sheka	Yeki	07°11'72N	035°26'48E	1199
28	15/2000	Bench maji	Sheko	07°04'13N	035°37'74E	1320
29	34/87	Jimma	Dedo	07°31'37N	036°53'44E	1911
30	21/02	Jimma	Seka chekorsa	07°36'48N	036°45'09E	1775
31	57/76	Bench maji	Sheko	07°02'88N	036°29'74E	1654
32	0001/07	Jimma	Shebe sombo	07°26'74N	036°24'12E	1367
33	0004/07	Jimma	Kersa	07°40'55N	036°48'75E	1741
34	7/84	Bench maji	Sheko	07°02'88N	036°29'74E	1661
35	7/85	Sheka	Yeki	07°14'30N	036°26'17E	1173
36	06/2001	Bench maji	Sheko	06°59'69N	036°34'09E	1387

Table 1: List of 36 yam landraces and their areas of collection.

% Dry matter= (W2/W1) × 100.

Or

% Dry matter=100 - % moisture content.

The ash content was determined by following the instruction of AOAC [26] was adhered. Crucibles were rinsed and dried in hot air oven (SM9053) maintained for 30 minutes at 105°C. These were cooled in desiccators and weighed. Five gram of the sample was burnt on a heater inside a fume cupboard to get rid of smoke. The samples were moved to preheated muffle furnace (SM9080) maintained at 550°C until such a time when a light grey ash was noticed. The crucibles were cooled in desiccators and weighed. The ash content was calculated as:

$$\%Ash = \frac{(weight\ of\ crucible + Ash) - weight\ of\ empty\ crucible}{weight\ of\ sample} \times 100$$

The organic matter content was determined by subtract the percent ash from percent total dry matter and the value was expressed in percentage. The % organic matter content was calculated;

Organic matter content (%)=% DM – % ash.

Similarly, the amount of organic carbon is determined by divide weight of ash by sample weight. That is, Organic carbon (g)=weight of ash/sample weight.

The crude fiber of the sample was determined according to AOAC [26]. Two gram of the sample was defeated with petroleum ether. The defeated sample was boiled in reflux for 30 minutes with 200 ml of a solution contain 1.25 g of H_2SO_4 per 100 ml of solution. The solution was then filtered through linen on a fluted funnel. Then the sample was washed with hot water, using a two-food muslin cloth to trap the particles, the washed sample was transferred quantitatively back to the flask and boiled again in 200 ml of 1.25 g of carbonate free NaOH per 100 ml for 30 minutes and washed before it transferred to a weighed Gooch crucible and dried in the oven at 105°C for three hours. After cooling in desiccators it was re-weighed. Then the percentage crude fiber was calculated as:

$$\%CF = \frac{(weight\ of\ sample + Crucible) - (weight\ of\ crucible + Ash)}{weight\ of\ sample} \times 100$$

The fat contents were determined by using fat extractor with automated control unit (FOSS Soxtec 2055) according to AOAC [26]. The equipment has six extraction units with each unit carry a thimble which accommodates the samples and aluminum cups for collection of the extracted fat. These units enable six samples to be analyzed within 75 minutes. Percentage of fat was considered as, the difference between weight of the pre weighed cups and after extraction. One gram of the sample was weighed into the thimble and its mouth plugged with defatted cotton wool, after which it was inserted into the extraction unit. Eighty ml of petroleum ether was dropped into each cup and maintained at 135°C. Each cup was aligned with its corresponding thimble. The extraction and rinsing were done for 30 minutes each, after which the sample was aerated for 15 minutes and crude fat calculated as:

$$\%Fat = \frac{(W3 - W2)}{W1} \times 100$$

Where: W_1=weight of sample, W_2= weight of empty cup and W_3= weight of cup with the extracted oil.

The saponin content was determined by following spectrophotometric method of Brunner [30]. Two grams of the sample was put into a 250 ml beaker and 100 ml of ISO butyl alcohol added. A shaker was used to shake the mixture for 5 hours to ensure uniform mixing. The mixture was then filtered using the No.1 Whatman filter paper into a 100 ml beaker containing 20 ml of 40% saturated solution of magnesium carbonate ($MgCO_3$). The obtained mixture was filtered again through No.1 filter paper to obtain a clean colorless solution and was taken to a 500 ml volumetric flask using a pipette made to mark with the distilled water. It was allowed to stand for 30 minutes for the need color to develop. The absorbance was read after the color development on the spectrophotometer at 350 nm. The saponin content was calculated as: (absorbance sample/concentration of sample) x absorbance of standard sample.

The analysis of crude protein content was conducted with an aid of micro Kjedhal system in accordance with AOAC [26]. A small quantity of the yam flour sample (1 g) was introduced into the digestion tube (Kjeltec 2200 FOSS) and, a catalyst (2 tablets of 5g K_2SO_4 and 5 mg of Se) and 12 ml of concentrated tetra oxo-sulphate VI acid (H_2SO_4) were added. The digestion was run for one hour at 42°C. Eighty (80 ml) and 40 ml of water and sodium hydroxide (NaOH) respectively were used in the distillation using 2200 FOSS distillation unit and the distillate was collected in 4% Boric acid. The percentage nitrogen (N) was calculated as:

$$\%N = \frac{(a-b)}{s} \times n \times 0.014 \times 100 \times mcf$$

Where; a=ml of H_2SO_4 required for titration of sample, b=ml of H_2SO_4 required for titration of blank, S=air-dry sample weight in mg, n=normality of H_2SO_4 (0.1 N), 0.014=meq weight of nitrogen in g and mcf=moisture correction factor. Then the protein content of the sample was estimated by percent nitrogen multiplied protein coefficient (6.25). The protein content calculated as 'N' × 6.25. [31-33].

The tannin content was determined by using a method Pearson [34]. One gram of each sample was weighed into a centrifuge tube with 2 ml of distilled water. It was centrifuged at 1500 rpm for 10 minutes. The centrifuge samples were then poured out into a beaker and the supernatant (extract) dispersed. One ml of $NaCO_3$ and Folin Denis reagent was added in the beaker and allowed to settle. The readings were taken using a spectrophotometer. Tannin content was calculated as follows:

$$Tannin(mg/100g) = \frac{(An \times C \times Vf)}{As\,W\,Va}$$

Where; An= absorbance test sample, As= absorbance of standard sample, C= concentration of standard solution, W= weight of sample, Vf= total filtrate volume and Va=volume of filtrate analyzed.

The phosphorus content of each sample was determined by the dry ash extraction method following specific mineral element [35]. Five grams of the sample was burnt to ashes in a muffle furnace (SM9080) at 500°C. After complete ashing, the ash was diluted with 1% Hydrochloric (HCl) acid, then filtered into a 100 ml standard flask, and made up to the mark with deionized water. The solution was read with UV-visible spectrophotometer machine (model No: UV-1600, Shimadzu Corporation, Japan) for the determination of phosphorus in mg/100 g. The carbohydrate content of the sample was determined by estimation using arithmetic difference [36]. The energy value was calculated by application of the thermal coefficients of Atwater and Rosa [37] with 4 calories for 1 g of carbohydrates; 4 calories for 1 g of protein and 9 calories for 1 g of crude fat. The available carbohydrate (CHO) and energy value were determined by using the formula as given below; CHO=[100 - (% moisture+% crude protein+% crude fat+crude fibre+% ash)]. Total energy (kcal)=[(% CHO × 4)+(% CP × 4)+(% CF × 9)]. Where; CHO, CP and CF are; carbohydrate, crude protein and crude fat, respectively [38-40].

Data analysis

The data was subjected to analysis of variance (ANOVA) using SAS statistical software package [41]. The entire dataset was standardized by dividing each variable with its respective range, and was subjected to clustering based on Un-weighted Pair Group Method of Arithmetic mean (UPGMA) and cluster distance and principal component analysis (PCA) was analyzed to assess correlations between components and the parameters measured.

Results and Discussion

Analysis of variance

The result on the analysis of variance indicated, mean squares due to landraces were highly significant ($p \leq 0.01$) for organic matter, total nitrogen, protein, fat, carbohydrate, total phosphorus, total energy, tannin and saponin contents indicating the existence of sufficient genetic variability of these traits within yam landraces from Southwest Ethiopia (Table 2). The variability among landraces also revealed wide chance of developing yam varieties possessing desirable biochemical traits. While, mean squares due to the flour moisture content, dry matter, ash, organic carbon and crude fiber contents showed non-significant difference.

Range and mean performance biochemical traits

The descriptive value of the landraces based on biochemical characters was showed (Table 3). The mean values of different biochemical traits revealed remarkable differences among the landraces. The flour moisture and dry matter contents ranged from 17.75 to 27.47% and 15.80 to 27.28% with a mean of 22.03% and 21.76%, respectively. The mean dry matter content of 21.76% found in this study is comparable with the value of 23.1% and 19.9% reported by Megh et al. [11] on Dioscorea triphylla and Dioscorea versicolor species, but different from the value reported by Abera [42]. On contrary, the result obtained from this study was lower than the flour and dry matter contents reported from the wild yam species collected from the South pacific region [43]. The differences observed between the result of this study and the report of other researchers might be due to experimental methods of analysis and the inherent character of Dioscorea species. The range of organic matter and ash contents were 21.38 to 43.56% and 1.13 to 3.56% with a mean of 31.13 and 2.61%, respectively. The result obtained for ash content in this study is consistent with the result of Coursey and Abera [42,44], but lower than the value (3.41%) reported by Princewill-Ogbonna and Ibeji [45]. The value of organic carbon and crude fiber varies from 0.63 to 1.98 g and 0.41 to 2.05% with a mean and standard deviation of 1.45 ± 0.35 and 1.28 ± 0.39, respectively (Table 3). The crude fiber content obtained from this study was almost similar to the reported value of 1.5% by Wanasundera and Ravindran [46], 1.5% Megh et al. [11] and 1.13%, Udensi et al. [47] on yam. The mean crude fiber content obtained from this study was lower than the value 1.68% reported by Abera [42] and 1.98% by Princewill-Ogbonna and Ibeji [45]. This difference might be due to climate condition, the level of soil fertility where the yams are grown, varietal differences and the age of harvested storage tuber.

Biochemical traits	Mean square			
	Landrace	Error	CV	R^2
	DF:35	DF:35	(%)	
Flour moisture content (%)	0.015	0.02	15.49	0. 48
Dry matter (%)	0.002	0.02	15.3	0.68
Organic matter (%)	0.07**	0.001	2.47	0.84
Ash (%)	0.01	0.005	9	0.68
Organic carbon (g)	0.004	0.005	9.13	0.43
Crude fiber (%)	0.045	0.015	16.2	0.75
Total N (%)	0.006**	0.002	3.13	0.75
Protein	0.24**	0.07	3.6	0.75
Fat (%)	0.03**	0.005	7.72	0.98
Carbohydrate (%)	0.015**	0.003	4.44	0.8
Total P (mg/100g)	0.008**	0.001	0.65	0.99
Total Energy (kcal/100g)	0.006**	0.001	1.89	0.79
Tannin (mg/100g)	3244.92**	0.003	0.01	1
Saponin (mg/100g)	0.046**	0.007	10.62	0.85

Table 2: Analysis of variance of different biochemical traits of yams from Southwest Ethiopia.

No.	Quantitative character	Mean ± Se	Range
1	Flour moisture content (%)	22.03 ± 2.40	17.75-27.47
2	Dry matter (%)	21.76 ± 3.16	15.80-27.28
3	Organic matter (%)	31.13 ± 4.30	21.38-43.56
4	Ash (%)	2.61 ± 0.63	1.13-3.56
5	Organic carbon (g)	1.45 ± 0.35	0.63-1.98
6	Crude fiber (%)	1.28 ± 0.39	0.41-2.05
7	Total nitrogen (%)	1.25 ± 0.06	1.00-1.32
8	Protein %	7.82 ± 0.34	6.25-8.28
9	Fat (%)	0.32 ± 0.14	0.09-0.65
10	Carbohydrate (%)	21.84 ± 4.13	12.71-33.94
11	Total phosphorus (mg/100g)	39.0 ± 0.07	23.7-53.0
12	Total Energy (kcal/100g DM)	130.19 ± 16.84	92.66-173.30
13	Tannin (mg/100g)	64.67 ± 40.28	19.80-181.00
14	Saponin (mg/100g)	5.91 ± 3.72	2.31-13.94

Table 3: Mean standard deviation and ranges of 14 biochemical traits of *Dioscorea* spp.

The range of total nitrogen content was 1.00 to 1.32% and a mean of 1.25%. The total nitrogen content in the studied yam tubers were higher than reported value of 0.48% by Abera [42] and comparable with the reported value of 1.08%, [48]. The crude protein content of yam tubers ranged from 6.25 to 8.28% with a mean of 7.82%. This value was consistent with the value of 8.31% reported by Udensi et al. [48] on water yam and Tamiru [17] on yams from South Ethiopia collections. The higher protein content indicated its higher total nitrogen in the storage tuber of yams. The protein content was varying with different species of yams. For example, the mean and standard deviation of the crude protein content of Dioscorea bulbifera was 3.1 ± 0.03 g/100 g, Dioscorea deltoidea was 1.6 ± 0.06 g/100 g, Dioscorea versicolor 1.7 ± 0.02 g/100 g and Dioscorea triphylla 2.3 ± 0.05 g/100 g [11]. Similarly, the crude protein content of yam was different in wet 1.68 to 3.00 g/100 g and dry 2.89 to 6.36 g/100 g processing methods, respectively [42]. The crude fat content ranged from 0.09 to 0.65% with a mean of 0.32%. This value is higher than reported value (0.20) for Cameroonian yam species [49] and wild yams tubers from the central region of Nepal [11]. Comparatively, this result was consistent with the report of FAO [50] and Wanasundera and Ravindran [46] on yams. On contrary, the mean fat content presented in this study by far lower than the reported value (2.24%) by Princewill-Ogbonna and Ibeji [45] on three cultivars of Dioscorea bulbifera. The distribution of fat in different yams tuber showed the peel contained higher levels than tissue [51,42]. The carbohydrate content ranged from 12.71 to 33.95% and the energy values ranged from 92.66 to 173.30 kcal/100 g with a mean value of 21.84% and 130.19 kcal/100 g, respectively. This result in agreement with those reported for yam [11,42,52], but lower than the reported value of 82.50% and 359.81 kcal/100 g) of Udensi et al. [48]. The variation of carbohydrate content between yam species might be due to the genetic factor, maturity and management of yams.

The phosphorous content varied between 23.7 mg/100 g and 53.0 mg/100 g with a mean of 39.0 mg/100 g. This result was consistent with the report of Megh et al. [11] on different yam species for example, 61.61 mg/100 g for Dioscorea bulbifera, 33.1 mg/100 g for Dioscorea deltoidea, 40.8 mg/100 g for Dioscorea versicolor and 56.6 mg/100 g for Dioscorea triphylla. On contrary, the results of this study by far lower than the reported value ranged from 120-340 mg/100 g on Dioscorea alata by Udensi et al. [48]. The observed disparity between

the results could be explained on the basis of the species difference and the environmental conditions upon which the tuber was grown.

The result of anti-nutritional factors such as tannin and saponin contents on yams from Southwest Ethiopia was presented in Table 3. The tannin content ranged from 19.80 to 181.0 mg/100 g with a mean value of 64.67 mg/100 g. This result was higher than the reported value for Dioscorea rotundata (20 mg/100 g), which implies that less protein may be available in studied landraces from Southwest Ethiopia than in Dioscorea rotundata due to protein-tannin complex formation [53]. However, it is important to note that heat treatment which is normally given to yams landraces before consumption will eliminate or reduce the level of tannin in the food system thereby making the protein available [54]. Comparatively, the result of this study was consistent with the work of Udensi et al. [47] who reported the tannin content ranged from 46.5 to 180.25 mg/100 g on Dioscorea alata. Similarly, the saponin contents of yams ranged from 2.31-13.94 mg/100 g with a mean of 5.91 mg/100 g. This result is almost similar with the reported values of saponin (8.49-14.03 mg/100 g) of other yam species [45].

Principal component analysis

The patterns of variation and the relative importance of each biochemical trait in explaining the observed variability was assessed through principal component analysis (PCA). The result of PCA grouped the variables into six components based on nine biochemical traits, among which the first three are significant (Eigen value > 1) and explained 73.9% of the total variability (Table 4). The first principal component (PC-1) accounted 35.10% of the total variation and was correlated positively with organic matter (0.545), total nitrogen (0.194), protein (0.194), carbohydrate (0.533) and total energy (0.540), while fat (-0.077), total phosphorus (-0.067), tannin (-0.204) and saponin (-0.012) contributed negatively. The second principal component (PC-2) accounted 24.5% of the total variability and mainly correlated with total nitrogen (0.597), protein (0.597), fat (0.324) and saponin (0.212) and negatively with the total phosphorus (-0.237), total energy (-0.137), carbohydrate (-0.181) and organic matter (-0.133). The third principal component (PC-3) had 14.30% of the total variation. The total phosphorus content contributed (0.525), tannin (0.504) and fat (0.395), while PC-4 accounted 10.30% of the variation and correlated with saponin (0.567), fat (0.537) and tannin (0.459). PC-5 accounted 8.20% of the variation and negatively correlated with total phosphorus content (-0.779) and saponin content (-0.540). Finally, PC-6 had 7.10% of the total variation and mainly correlated with the tannin content (0.617) and negatively with the fat content (-0.665).

Variable	PC1	PC2	PC3	PC4	PC5	PC6
Eigen value	3.159	2.206	1.319	0.923	0.738	0.626
Proportion	35.1	24.5	14.3	10.3	8.2	7.1
Cumulative	35.1	59.6	73.9	84.2	92.4	99.5
Organic matter (%)	0.545	-0.133	0.057	0.12	0.028	-0.003
Total nitrogen (%)	0.194	0.597	0.157	-0.201	-0.017	0.2
Protein	0.194	0.597	0.157	-0.201	-0.017	0.2
Fat (%)	-0.077	0.324	0.395	0.537	-0.042	-0.665
Carbohydrate (%)	0.533	-0.181	0.071	0.118	-0.011	0.042
Total P (mg/100g)	-0.067	-0.237	0.525	-0.226	-0.779	0.072
Total Energy (kcal/100g DM)	0.54	-0.137	0.059	0.141	-0.001	0.055
Tannin (mg/100g)	-0.204	-0.112	0.504	0.459	0.314	0.617
Saponin (mg/100g)	-0.012	0.212	-0.503	0.567	-0.54	0.296

Table 4: Eigen values, proportion, cumulative variance and component scores of the first six principal components for quality traits in 36 landraces of yams.

For proximate, anti-nutritive and mineral compositions, six principal components accounted for 99.5% of the total genetic variation where organic matter, total nitrogen, protein, fat, carbohydrate, total phosphorus, total energy, tannin and saponin contributed maximally to the PCs. This variation is attributable to environmental and genetic factors [55,56]. Plotting the first and second principal components (Figure 1) from the matrix showed majority of biochemicaltraits clustering together at the origin of the plot. On contrary, the fat, tannin and saponin showed as an outlier far from the rest.

Cluster analysis

Grouping of landraces based on their similarity is crucial. In the present study, this approach was adopted to cluster the 36 landraces into eight different groups based on nine bio chemical traits (Table 5). The distribution of the landraces was evident from different clusters. Among the clusters, Cluster I was the largest, having six landraces and 16.67% of the overall genetic similarity. Cluster II, III, IV, V and VI having five landraces of each and contributed 69.44% of the total variations. Cluster VII and VIII having the total of five landraces and contributed 11.11% and 2.78% of the total variation (Table 5).

The cluster mean for various traits revealed that considerable differences were noticed between the cluster means of different biochemical characters (Table 6). Landraces from cluster VII and II produced the highest organic matter (35.92 and 35.15%); total nitrogen (1.30 and 1.27%) and protein (8.125 and 7.92) contents. Landraces grouped in under clusters VIII and IV had highest fat (0.599 and 0.450) contents. Besides, landraces grouped under cluster III and VI had highest total phosphorus (0.438 and 0.411) and landraces in cluster VII and II produced highest total energy (146.7 and 146.514), cluster VI and VIII; highest tannin (151.32 and 97.0) content and saponin (8.829 and 7.584) contents in cluster I and II respectively. This implies that the landraces grouped under cluster IV and II (Figure 2) were found to be superior with regard to total biochemical traits than other clusters. For example, higher organic matter, total nitrogen, protein, fat, carbohydrate, total phosphorous, total energy and saponin contents. For emphasis, most of the landraces in cluster IV were obtained from Jimma zone, except 60/87 and 17/02 that were obtained from Yeki and Sheka zone.

This could inform importantly that the chances of environmental influences were reduced drastically with genetic factor playing an active role. On the contrary, cluster I and V, consisted of eleven landraces, and had 30.56% of the total variation and having the least performance for the majority of biochemical characters (Table 6). For example, the landraces grouped under these clusters gave the lower

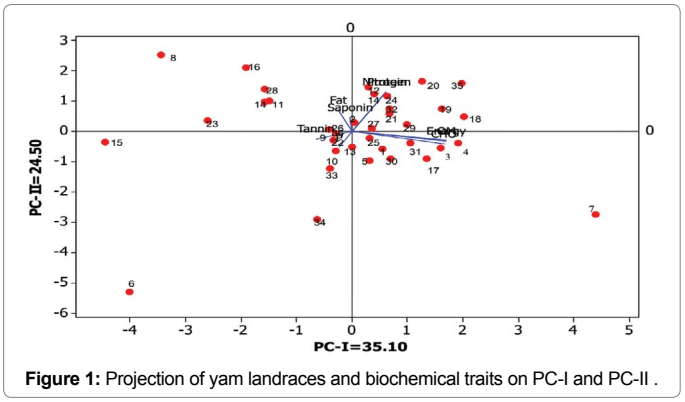

Figure 1: Projection of yam landraces and biochemical traits on PC-I and PC-II .

Clusters	Number of landraces in each cluster	Serial number	Name of landraces in each cluster	% of Contribution
I	6.0	33,11,34,5,8, and 1	0004/07, 01/75, 7/84, 3/87, 46/83 and 59/02	16.67
II	5.0	25,36,35,31and 4	24/02, 06/2001, 7/85, 57/76 and 75/02	13.89
III	5.0	30,32,24,12 and 2	21/02, 0001/07, 32/83, 06/83 and 68/01	13.89
IV	5.0	14,21,27,26 and 13	07/03, 7/83, 60/87, 2/87 and 17/02	13.89
V	5.0	22,10,29,28 and 9	58/02, 116, 34/87, 15/2000 and 08/02	13.89
VI	5.0	15,6,17,16 and 3	45/03, 56/76, 37/87, 27/02 and 6/02	13.89
VII	4.0	20,19,18 and 7	06/2000, 76/02, 10/002 and 54/02	11.11
VIII	1.0	23	39/87	2.78

Table 5: Distribution of 36 *Dioscore*a spp. into eight clusters based on biochemical traits.

Cluster	OM	N	Pro	Fat	CHO	P	Ene	Tan	Sap
I	25.97	1.22	7.62	0.3	16.63	0.37	108.63	57.05	8.83
II	32.47	1.26	7.87	0.28	23.23	0.39	135.76	39.61	6.03
III	32.67	1.23	7.67	0.31	23.58	0.4	137.59	135.2	3.66
IV	32.43	1.28	8	0.45	22.86	0.37	135.43	74.78	3.88
V	43.56	1.22	7.59	0.15	33.95	0.45	173.31	45.2	3.37
VI	21.39	1.23	7.69	0.35	12.72	0.52	92.67	170	2.54
VII	33.63	1.25	7.81	0.29	23.27	0.35	142.38	181	10.87
VIII	21.83	1.3	8.13	0.6	13.25	0.38	93	97	4.12
Mean	30.49	1.25	7.8	0.34	21.19	0.4	127.35	99.98	5.41
S.div	7.28	0.03	0.19	0.13	6.92	0.06	27.55	55.86	2.96

OM: Organic Matter (%); N: Total Nitrogen (%); Pro: Protein; Fat: Fat (%); CHO: Carbohydrate (%); P: Total Phosphorous (mg/100g); Ene: Total Energy (kcal/100g DM); Tan: Tannin (mg/100g) and Sap: Saponin (mg/100g); S. dev: Standard Deviation

Table 6: Cluster means for nine biochemical traits of *Dioscorea* spp. grown at Jimma.

organic matter, total nitrogen, carbohydrate and energy contents. The landraces grouped in the rest of clusters had moderate amounts of biochemical composition. Thus, use of landraces grouped under cluster IV and II would desirable to generate best landraces and having higher biochemical compositions.

Distance between clusters

The pair wise generalized square distances (D^2) between the clusters (Table 7) showed that the distance between clusters were highly significant ($p \leq 0.01$) suggesting diversity among landraces grouped into different clusters. The maximum inter cluster distance was found between clusters VI and VII (133.59), followed by clusters V and VI (109.19), clusters II and VI (105.22), clusters I and VI (100.42), and clusters III and VI (89.25) in order of magnitudes. Selection of parents from such clusters for breeding program would help to achieve novel recombinants in view of biochemical composition.

The clustering pattern suggested that landraces of the same origin were distributed into different groups, indicating that there was no parallelism between clustering pattern and geographic distribution of landraces. This might be due to difference in adoption, selection pressure and environmental conditions. For example, in the present study, crossing of landraces falling in the most distant clusters i.e., VI (6/02) from Bench maji and VII (39/87) from Jimma zones could result in maximum hybrid vigor and eventually may give rise to desirable recombinants. The minimum inter cluster distance was recorded between clusters II and VII (7.27), followed by clusters II and III (8.38) and clusters II and V (8.94). Thus, the landraces lines belonging to the distant clusters could be used for breeding program to obtaining a wider range of variability [57].

The result of the present study showed that the genetic distances between representatives landraces in different clusters was generally

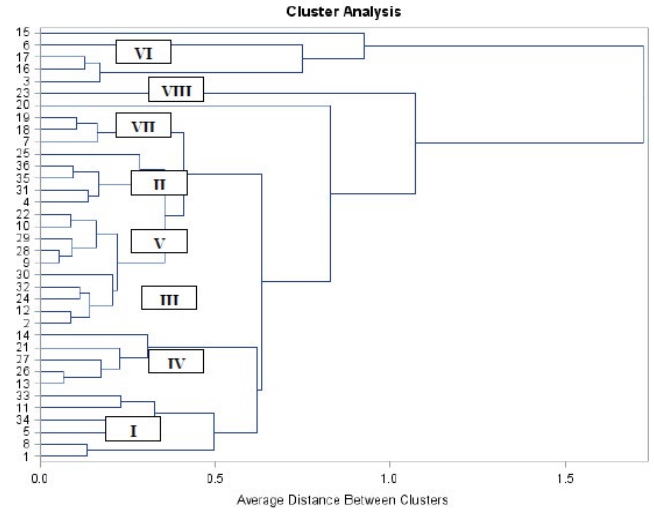

Figure 2: Dendrogram showing hierarchical clustering patterns of 36 *Dioscorea* spp. landraces (UPGMA) based on nine biochemical traits.

not wide as compared to the result of Mulualem [58]. Importantly, the low divergence among landraces studied indicates the possibility of the landraces originated from the different genetic background. Padulosi [59] reported high level of resemblance among yam landraces, which was attributed to their cross pollinating nature. Though cluster analysis grouped together landraces with higher proximate, anti-nutritive and mineral differences together in the present work, the cluster analysis necessarily include all landraces from the same geographical sites. It is probable that the lack of differentiation among regions is an indication of both high level of gene flow between regions as well as lack of

Cluster	I	II	III	IV	V	VI	VII	VIII
I	-	22.97**	16.83*	30.25**	15.92*	100.42**	28.04**	44.96**
II		-	8.38	19.54**	8.94	105.22**	7.27	65.81**
III			-	17.15*	9.01	89.25**	13.24	49.83**
IV				-	22.06**	51.13**	29.89**	28.42**
V					-	109.19**	11.74	55.48**
VI						-	133.59**	47.72**
VII							-	80.21**
VIII								-

*: Significant at 0.05 probability level (x^2_7: 14.07)
**: Highly significant at 0.01 probability level (x^2_7: 18.47)

Table 7: Pair wise generalized squared distances between eight clusters of *Dioscorea* spp. collected from Southwest Ethiopia.

sufficient time for significant genetic differentiation along geographical lines. Sulnathi et al. [60] demonstrated that genetic drift and selection pressure under different environments would have caused greater divergence rather than geographical distance.

Conclusion

The result of analysis of variance indicated significant variation ($p \leq 0.01$) among the landraces for organic matter, total nitrogen, protein, fat, carbohydrate, total phosphorus, total energy, tannin and saponin contents indicating the existence of sufficient genetic variability of these traits within yams landraces collected from Southwest Ethiopia. The principal component analysis grouped the variables into six components based on nine biochemical traits among which the first three are significant (Eigen value > 1) and explained 73.90% of the total variability. For proximate, anti-nutritive and mineral compositions, six principal components accounted for 99.50% of the total genetic divergence, where organic matter, total nitrogen, protein, fat, carbohydrate, total phosphorus, total energy, tannin and saponin contributed maximally to the PCs. This variation is attributed to environmental and genetic factors.

The cluster and pair wise generalized squared clusters distances analysis of biochemical traits revealed, the existence of eight divergent groups. The maximum distances obtained between cluster VII and VIII. Thus, crossing between landraces grouped under these clusters may give desirable recombinants for high biochemical composition; due to widest inter cluster distance. The results obtained from this study confirmed the existence of potential for selection of nutritionally superior landraces of yams from Southwest Ethiopia. The variability in the biochemical composition and functional properties of yams landraces are vital for plant breeders that may select landraces with high nutritional compositions of yams. From the results of the present investigation concluded that, different collections of yams vary greatly for their dry matter, protein, fat, ash and crude fiber content.

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