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# Potential of Indian potatoes for the management of hyperglycemia

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## ABSTRACT

**Potatoes are less favoured by health conscious people due to the notion that it has high glycaemic index. Anti-hyperglycemic and antioxidative potential of Indian potato cultivars were evaluated with the aim to remove the misconception. Glycaemic index was measured indirectly through estimating resistant starch, amylose content and activity of α-amylase and α-glucosidase inhibitors from cooked tubers of 46 Indian potato cultivars. The α-glucosidase inhibitory activity ranged from 0 to 52.8% and was observed only in 14 cultivars, *viz*., Kufri Anand, Kufri Arun, Kufri Khasigaro, Kufri Kuber, Kufri Kundan, Kufri Muthu, Kufri Naveen, Kufri Neela, Kufri Pushkar, Kufri Red, Kufri Sadabahar, Kufri Safed, Kufri Sutlej and Kufri Swarna. α-amylase inhibitory activity was found only in cultivar Kufri Frysona (20.5%). Resistant starch content ranged from 1.22 to 1.93 mg/100 mg DW with highest value in Kufri Garima (1.93 mg/100 mg DW). Amylose content ranged from 10.8 to 27.6 mg/100 mg DW and was the maximum in processing cultivar Kufri Chipsona-3 (27.6 mg/100 mg DW). The highest activities of α-glucosidase inhibitors along with considerable resistant starch content was observed in cultivars, *viz.* Kufri Kuber, Kufri Khasigaro, Kufri Muthu, Kufri Naveen and Kufri Pushkar. Therefore, these potato cultivars can be used as speciality potatoes as these attributes have potential to prevent hyperglycemia helping manage the incidence of type II diabetes.**

**Key words:** Antioxidants, α-amylase inhibitors, hyperglycemia, α-glucosidase inhibitors, potato.

## INTRODUCTION

Potato is a well-known carbohydrate rich food. Potatoes are added in our daily diets to supplement other vegetables or snacks and not due to its nutritional value. Although potatoes are full of nutrition, they are less favoured due to various misconceptions and also due to the notion that they are high glycaemic food (Livesey, 8). Glycaemic index (GI) of food depends on the type of carbohydrates present in it. Food with high amylose and high resistant starch (RS) generally has low GI due to the slow or incomplete digestion of carbohydrates (Miller *et al*., 10). Starch constitutes about 75-80% of the potato tuber dry weight, with amylose: amylopectin ratio of 1:3. Starches with higher content of amylose have superior nutritional qualities as the linear amylose chains form a compact structure that limits the accessibility of enzymes and hence rate of amylolysis, whereas, amylopectin being highly branched with several terminal endings is less ordered and hence easily accessible and digestible (Hallstorm *et al*., 3). In the recent past, bakeries have started the addition of high amylose products such as Hi-maize to provide the consumers with options beyond the basic fibre options intake without any change to food flavour (Raigond *et al*., 14).

Potatoes have the potential to develop RS during cooking and other forms of processing due to their high starch content (Raigond *et al*., 13). Formation of RS in starchy food depends on several factors including amylose content, amylose: amylopectin ratio, starch granule structure and size, amylose chain length and processing method as well as temperature during storage (Raigond *et al*., 14).

Major source of glucose from potato is starch. Before absorption in the intestine, starches are broken down to monosaccharides with the activity of hydrolytic enzymes 'α-glucosidases' such as sucrase, maltase, glucoamylase, dextrinase and pancreatic α-amylase. α-glucosidase is a membrane bound enzyme present in the epithelium of small intestine. This enzyme facilitates the absorption of glucose by small intestine by catalyzing the hydrolytic breakdown of oligosaccharides into absorbable monosaccharides (Kumar *et al*., 6). Inhibition of such enzymes can inhibit the breakdown of starch and hence can help in decreasing the postprandial enhancement in blood glucose. Literature is available on the presence of α-amylase and α-glucosidase inhibitors in food grade plants (Kwon *et al*., 7; Pinto *et al*., 12; Saleem, 15; Kumar *et al*., 6). Most of these food grade plants exhibit lower inhibitory effect against α-amylase activity and strong inhibitory effect against α-glucosidase activity. Such inhibitors are also present in potatoes (Saleem, 15). Even though α-amylase inhibitory activity has positive effects on prevention of hyperglycemia, linked to type II diabetes (Kwon *et al*., 7).

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Till date, the presence or absence of α-amylase and α-glucosidase inhibitors was not known in Indian potato cultivars. The aim of this study was to explore the potential of Indian potato cultivars to manage/ prevent hyperglycemia and to remove the misconception about nutritional value of potatoes through *in vitro* assays.

## MATERIALS AND METHODS

Freshly harvested medium sized tubers of forty six Indian potato cultivars, which were raised at CPRIC, Modipuram, India (29° 4' N, 77° 46' E, 237 masl) during 2013-14 using standard package of practices were used in the present study. Pressure cooking was done by cooking 1 kg of intact, washed and unpeeled tubers in 400 ml of water under 15 psi for 10 min., and 1×1 cm cylindrical pieces were prepared after pressure cooking. The cooked tuber pieces were dried and grinded to prepare powder. Amylose and RS content was estimated from the powdered samples. A total of 5 g of potato powder was stirred in 100 ml of 12% ethanol at 40°C for 2 h and cooled. The extract was centrifuged at 10,000 × g for 10 min. The supernatant was collected for analysis of α-glucosidase and α-amylase inhibitory activity, DPPH radical scavenging assay and total phenol content. This article does not contain any studies with human or animal subjects.

Resistant starch (RS) content was analyzed using the methodology described by Goni *et al*. (2) with slight modifications. Main steps involved were the sample (100 mg) incubation with pepsin (40°C, 60 min., pepsin in KCl-HCl buffer, pH 1.5) to make the sample protein-free, incubation with α-amylase (37°C, 16 h, α-amylase in Tris-maleate buffer pH 6.9) to hydrolyze digestible starch, incubation of residues with amyloglucosidase (60°C, 45 min.) to hydrolyze RS. Glucose was determined using glucose-peroxidase assay kit (Sigma Chem.). RS was calculated as glucose × 0.9.

The amylose content was determined from samples by using Amylose/ Amylopectin Assay Kit (Megazyme). Enzyme α-amylase inhibitory activity was measured with the modified method of Worthington (18). The α-amylase inhibitory activity was expressed as inhibition % and was calculated as follows:

$$\% \text{ inhibition} = \left( \frac{\text{Adsorbance}_{\text{Control}} - \text{Adsorbance}_{\text{Extract}}}{\text{Adsorbance}_{\text{Control}}} \right) \times 100$$

α-glucosidase inhibitory activity was determined with modified method of McCue *et al*. (9). Before and after incubation, absorbance readings were recorded at 405 nm through ELISA plate reader and compared to control which had 50 µl of buffer solution in place of the extract. The α-glucosidase inhibitory activity was expressed as % inhibition and was calculated with the same equation as for % inhibition of α-amylase activity. The total antioxidant activity of ethanol extracts of boiled potatoes was determined by the DPPH radical scavenging method modified from Kwon *et al*. (7). The total phenolic content was determined by an assay modified from Shetty *et al*. (17) using Folin-Ciocalteu reagent.

All the data (three replications of each treatment) was subjected to statistical analysis using MSTAT 4.0C software and ANOVA was calculated at 5% level of significance. The mean performance was analyzed on Microsoft Excel software 2007. The significance of means was compared using the Tukey's HSD test ($p < 0.05$). The dendrogram of biochemical traits were analyzed using XLSTAT software.

## RESULTS AND DISCUSSION

The content of RS, *i.e.* RS I is high in raw potato tubers and decreased in cooked tubers due to increased digestibility of starch. RS III is the main form of RS present in cooked potatoes and is mainly derived from retrograded amylose. RS content in cooked tubers of Indian potato cultivars ranged from 1.22 to 1.93 mg/100 mg DW with highest value exhibited by Kufri Garima (1.93 mg/100 mg DW) followed by Kufri Giriraj (1.90 mg/100 mg DW), Kufri Girdhari (1.86 mg/100 mg DW) and Kufri Swarna (1.84 mg/100 mg DW) with the mean value of 1.53 mg/100 mg DW (Table 1). In accordance with our results, Raigond *et al.* (14) reported higher RS content in boiled tubers of cultivar Kufri Sindhuri (1.24%), followed by Kufri Jyoti (1.22%) and least in Kufri Bahar (1.04%). RS content in boiled tubers is approximately 1% (Goni *et al*., 1). RS content in nine cultivars of freshly cooked New Zealand potatoes ranged from 3.0 to 6.45% on dry weight basis, which is much higher than in Indian potato cultivars used under the study (Monro *et al*., 11). This difference in RS content could be due to the fact that formation of resistant starch depends on several factors including amylose content, amylose: amylopectin ratio, starch granule structure and size, amylose chain length and processing method as well as temperature during storage (Raigond *et al*., 14). Amylose content in cooked tubers of Indian potato cultivars ranged from 10.8 to 27.6 mg/100 mg DW (Table 1). Amylose content was the maximum in processing cultivars, *viz*., Kufri Chipsona-3 (27.6 mg/100 mg DW) followed by Kufri Himsona (24.2 mg/100 mg DW), Kufri Chipsona-1 (24.1 mg/100 mg DW) and Kufri Chipsona-4 (23.6 mg/100 mg

**Table 1.** Mean performance of potato cultivars.

| Cultivar | Amylose (mg/100 mg DW) | Resistant starch (mg/100 mg DW) | Total phenols (mg/100 g DW) | DPPH scavenging activity (%) |
|---|---|---|---|---|
| Kufri Alankar | 14.5$^{c-f}$ | 1.58$^{c-j}$ | 121.0$^{b}$ | 78.80$^{ghi}$ |
| Kufri Anand | 20.8$^{a-e}$ | 1.62$^{c-h}$ | 76.8d$^{e}$ | 81.71$^{d-h}$ |
| Kufri Arun | 19.9$^{a-f}$ | 1.61$^{c-i}$ | 76.0$^{e}$ | 86.75$^{a-d}$ |
| Kufri Ashoka | 19.9$^{a-f}$ | 1.40$^{h-o}$ | 94.3$^{c}$ | 18.79$^{q}$ |
| Kufri Badshah | 20.9$^{ad}$ | 1.32$^{l-o}$ | 100.1$^{c}$ | 85.81$^{a-f}$ |
| Kufri Bahar | 19.8$^{af}$ | 1.22$^{o}$ | 45.1$^{k-q}$ | 80.77$^{e-h}$ |
| KCM | 21.6$^{ad}$ | 1.35$^{k-o}$ | 61.9$^{e-j}$ | 35.21$^{n}$ |
| Kufri Chipsona-1 | 24.1$^{ab}$ | 1.48$^{g-n}$ | 42.5$^{l-s}$ | 72.91$^{j}$ |
| Kufri Chipsona-2 | 21.6$^{ad}$ | 1.35$^{l-o}$ | 67.7$^{e-h}$ | 24.96$^{op}$ |
| Kufri Chipsona-3 | 27.6$^{a}$ | 1.39$^{i-o}$ | 29.4$^{rst}$ | 49.06$^{m}$ |
| Kufri Chipsona-4 | 23.6$^{abc}$ | 1.39$^{i-o}$ | 56.3$^{g-l}$ | 20.26$^{pq}$ |
| Kufri Chamatkar | 20.9$^{a-e}$ | 1.46$^{g-n}$ | 137.3$^{a}$ | 18.72$^{q}$ |
| Kufri Deva | 20.5$^{ae}$ | 1.48$^{g-n}$ | 34.2$^{o-t}$ | 56.33$^{l}$ |
| Kufri Frysona | 16.7$^{b-f}$ | 1.50$^{f-n}$ | 55.1$^{g-l}$ | 7.27$^{rs}$ |
| Kufri Garima | 12.4$^{def}$ | 1.93$^{a}$ | 144.9$^{a}$ | 2.74$^{s}$ |
| Kufri Gaurav | 11.5$^{ef}$ | 1.46$^{g-n}$ | 91.6$^{cd}$ | 82.65$^{c-h}$ |
| Kufri Girdhari | 20.1$^{a-f}$ | 1.86$^{ab}$ | 26.8$^{t}$ | 19.91$^{pq}$ |
| Kufri Giriraj | 10.8$^{f}$ | 1.90$^{a}$ | 63.2$^{e-i}$ | 86.24$^{a-e}$ |
| Kufri Himalini | 16.9$^{b-f}$ | 1.52$^{e-m}$ | 53.2$^{h-n}$ | 85.99$^{a-f}$ |
| Kufri Himsona | 24.2$^{ab}$ | 1.52$^{e-m}$ | 38.8$^{n-t}$ | 81.45$^{d-h}$ |
| Kufri Jawahar | 14.4$^{c-f}$ | 1.46$^{g-n}$ | 91.0$^{cd}$ | 80.17$^{f-i}$ |
| Kufri Jyoti | 15.2$^{b-f}$ | 1.29$^{no}$ | 117.6$^{b}$ | 11.88$^{r}$ |
| Kufri Kanchan | 15.2$^{bf}$ | 1.50$^{f-n}$ | 39.9$^{m-t}$ | 84.96$^{a-f}$ |
| Kufri Khasigaro | 21.3$^{a-d}$ | 1.60$^{c-j}$ | 42.8$^{l-s}$ | 83.59$^{a-h}$ |
| Kufri Khyati | 14.4$^{cf}$ | 1.74$^{a-e}$ | 76.7$^{de}$ | 83.42$^{b-h}$ |
| Kufri Kuber | 20.4$^{ae}$ | 1.58$^{c-j}$ | 68.7$^{efg}$ | 26.75$^{o}$ |
| Kufri Kumar | 18.6$^{a-f}$ | 1.58$^{c-j}$ | 35.8$^{o-t}$ | 85.56$^{a-f}$ |
| Kufri Kundan | 17.2$^{b-f}$ | 1.57$^{c-k}$ | 34.6$^{o-t}$ | 54.19$^{lm}$ |
| Kufri Lalima | 19.4$^{af}$ | 1.48$^{g-n}$ | 43.5$^{l-r}$ | 89.32$^{a}$ |
| Kufri Lauvkar | 21.1$^{a-d}$ | 1.60$^{c-j}$ | 45.0$^{k-q}$ | 83.68$^{a-h}$ |
| Kufri Megha | 20.8$^{a-e}$ | 1.51$^{f-n}$ | 30.2$^{q-t}$ | 49.66$^{m}$ |
| Kufri Muthu | 19.9$^{a-f}$ | 1.50$^{f-n}$ | 54.2$^{g-m}$ | 87.69$^{abc}$ |
| Kufri Naveen | 19.7$^{a-f}$ | 1.52$^{d-m}$ | 47.6$^{j-p}$ | 74.58$^{ij}$ |
| Kufri Neela | 22.7$^{abc}$ | 1.53$^{d-l}$ | 34.9$^{o-t}$ | 62.14$^{k}$ |
| Kufri Pukhraj | 16.2$^{b-f}$ | 1.60$^{c-j}$ | 63.7$^{eh}$ | 88.72$^{ab}$ |
| Kufri Pushkar | 21.7$^{a-d}$ | 1.65$^{b-g}$ | 37.6$^{o-t}$ | 55.82$^{l}$ |
| Kufri Red | 20.1$^{a-f}$ | 1.71$^{a-f}$ | 53.9$^{g-m}$ | 88.12$^{abc}$ |
| Kufri Sadabhar | 20.2$^{a-e}$ | 1.74$^{a-d}$ | 94.7$^{c}$ | 84.02$^{a-g}$ |
| Kufri Safed | 19.3$^{a-f}$ | 1.31$^{mno}$ | 33.1$^{p-t}$ | 26.16$^{o}$ |
| Kufri Shailja | 15.1$^{b-f}$ | 1.45$^{g-n}$ | 59.4$^{f-k}$ | 80.60$^{e-h}$ |
| Kufri Sheetman | 21.0$^{a-d}$ | 1.39$^{i-o}$ | 71.6$^{ef}$ | 87.01$^{a-d}$ |
| Kufri Sherpa | 21.7$^{a-d}$ | 1.40$^{h-o}$ | 44.0l$^{m-r}$ | 87.86$^{abc}$ |

*Contd...*

*Table 1 Contd...*

| Cultivar | Amylose (mg/100 mg DW) | Resistant starch (mg/100 mg DW) | Total phenols (mg/100 g DW) | DPPH scavenging activity (%) |
|---|---|---|---|---|
| Kufri Sindhuri | 23.0$^{abc}$ | 1.39$^{i-o}$ | 43.7$^{l-r}$ | 78.21$^{hij}$ |
| Kufri Surya | 19.3$^{a-f}$ | 1.51$^{f-n}$ | 64.0$^{e-h}$ | 88.72$^{ab}$ |
| Kufri Sutlej | 20.2$^{a-e}$ | 1.78$^{abc}$ | 48.2$^{i-o}$ | 81.79$^{d-h}$ |
| Kufri Swarna | 23.3$^{abc}$ | 1.84$^{ab}$ | 27.9$^{st}$ | 24.19$^{opq}$ |
| Mean | 19.3 | 1.53 | 61.30 | 63.14 |

Different letters indicate significant differences between cultivars ($p<0.05$)

DW) compared to table cultivars. Amongst the table cultivars Kufri Swarna (23.3 mg/100 mg DW), Kufri Sindhuri (23.0 mg/100 mg DW), Kufri Neela (22.7 mg/100 mg DW), Kufri Pushkar (21.7 mg/100 mg DW) and Kufri Chandramukhi (21.6 mg/100 mg DW) exhibited higher amylose content. Amylose is digested slowly compared to amylopectin, due to the formation of compact structure by linear chains of amylose (Hallstorm *et al*., 3). From health point of view, potato cultivars containing high RS and/or amylose content are superior due to the slow rise in blood sugar level. In type II diabetes, breakdown of food becomes slow or improper due to the deficiency of insulin, which leads to sugar level spikes immediately after a meal. Therefore, ideal potato cultivars for diabetics are those which lead to slow release of sugars into the blood so that they do not cause any blood sugar spikes. GI is inversely related to amylose and RS content (Miller *et al*., 10). Therefore, potato cultivars with high content of amylose or RS or both can be considered as low glycaemic.

The natural forms of α-glucosidase and α-amylase inhibitors that one ingest through our daily diet have potential to prevent hyperglycemia helping manage the incidence of type II diabetes. These inhibitors reduce the activity of α-glucosidase and α-amylase and prevent or delay the absorption of glucose. The *in vitro* α-glucosidase inhibitory activity ranged from 0.0 to 52.8% in Indian potato cultivars and a large scale of variation has been observed amongst the 46 cultivars. In all cultivars, the α-glucosidase inhibitory activity was observed only in 14 table purpose potato cultivars, *viz.*, Kufri Anand, Kufri Arun, Kufri Khasigaro, Kufri Kuber, Kufri Kundan, Kufri Muthu, Kufri Naveen, Kufri Neela, Kufri Pushkar, Kufri Red, Kufri Sadabahar, Kufri Safed, Kufri Satlej and Kufri Swarna and the activity was 17.6, 1.7, 46.0, 52.8, 0.6, 40.5, 35.7, 26.7, 31.6, 7.8, 8.8, 8.5, 0.3 and 16.3%, respectively. The α-glucosidase inhibitory activity was the maximum in Kufri Kuber, followed by Kufri Khasigaro and Kufri Muthu. In 54 of Chilean potato varieties, α-glucosidase inhibitory activity ranged from 0 to 59% (Saleem, 16). α-amylase inhibitory activity was found only in cultivar Kufri Frysona (20.5%) amongst all the tested cultivars. Saleem (16) could not find α-amylase inhibitory activity in any of the cultivars out of 54 tested cultivars. These inhibitors inhibit the breakdown of starch after consumption and absorption of glucose in the small intestine, respectively, and therefore, contribute towards management of hyperglycemia, linked to type II diabetes.

Ethanol extracts of 46 Indian potato cultivars were evaluated for total phenolics and total antioxidant activity through DPPH radical scavenging assay to measure total antioxidative potential. The total phenolics content of Indian potato cultivars ranged from 26.8 to 144.9 mg/ 100 g of sample DW with an average content of 61.3 mg/100 g DW (Table 1). The total phenolics were the maximum in Kufri Garima (144.9 mg/100 g DW) followed by Kufri Chamatkar (137.3 mg/100 g DW) and Kufri Alankar (121.0 mg/100 g DW). Kufri Girdhari contained lower phenolic content (26.8 mg/100 g DW) followed by Kufri Swarna (27.9 mg/100 g DW) and Kufri Chipsona-3 (29.4 mg/100 g DW). Amongst 46 tested cultivars, total phenolics content was low in processing cultivars, *viz.* Kufri Chipsona-1 (42.5 mg/100 g DW), Kufri Chipsona-2 (67.7 mg/100 g DW), Kufri Chipsona-3 (29.4 mg/100 g DW), Kufri Chipsona-4 (56.3 mg/100 g DW), Kufri Frysona (55.1 mg/100 g DW) and Kufri Himsona (38.8 mg/100 g DW), which is a desirable traits for processing into chips and French fries. Most of the potato sample consisted of high phenolic content, which indicated the potential of Indian potato cultivars as a good source of phenolic antioxidant. Cultivar differences for total phenolics content were reported earlier also (Kumar, 4; Kumar *et al*., 5). In potato cultivars, contribution of total phenols to total antioxidant activity was reported to be up to 58 to 82% (Reddivari *et al*., 15). DPPH radical scavenging activity ranged from 2.74 to 89.32%, showing a large scale of variation in antioxidative potential of Indian

potato cultivars (Table 1). Activity was the maximum in Kufri Lalima (89.32%) and the minimum in Kufri Garima (2.74%) with the average activity of 63.14%. Along with Kufri Lalima, cultivars, *viz*. Kufri Muthu, Kufri Pukhraj, Kufri Red, Kufri Sheetman, Kufri Sherpa and Kufri Surya also exhibited high DPPH scavenging activity that ranged from 87 to 89%. Saleem (16) reported a range of 5.8 to 77% DPPH scavenging activity in 54 Chilean potato varieties.

Cluster analysis of amylose, RS, DPPH scavenging activity, total phenols, α-glucosidase and α-amylase inhibitors grouped the cultivars into three clusters (Fig. 1). Mean performance of cultivars in each cluster is depicted in Table 2. Highest RS and total phenolics content containing cultivars were grouped in cluster 3 that is constituted by three cultivars, *viz.* Kufri Garima, Kufri Chamatkar and Kufri Jyoti. Cluster 2 comprises of 12 cultivars, *viz*. Kufri Swarna, Kufri Safed, Kufri Girdhari, Kufri Deva, Kufri Chipsona-3, Kufri Megha, Kufri Kundan, Kufri Chipsona-2, Kufri Chandramukhi, Kufri Chipsona-4, Kufri Frysona and Kufri Ashoka that contained high amylose content and α-amylase inhibitory activity. Maximum cultivars come under cluster 1 (31 cultivars) that contained highest DPPH scavenging activity and α-glucosidase inhibitory activity.

The highest activities of α-glucosidase inhibitors along with considerable RS content could be observed in cultivars, *viz.* Kufri Kuber, Kufri Khasigaro, Kufri Muthu, Kufri Naveen and Kufri Pushkar. Hence, these cultivars may be considered better for consumption having low GI.

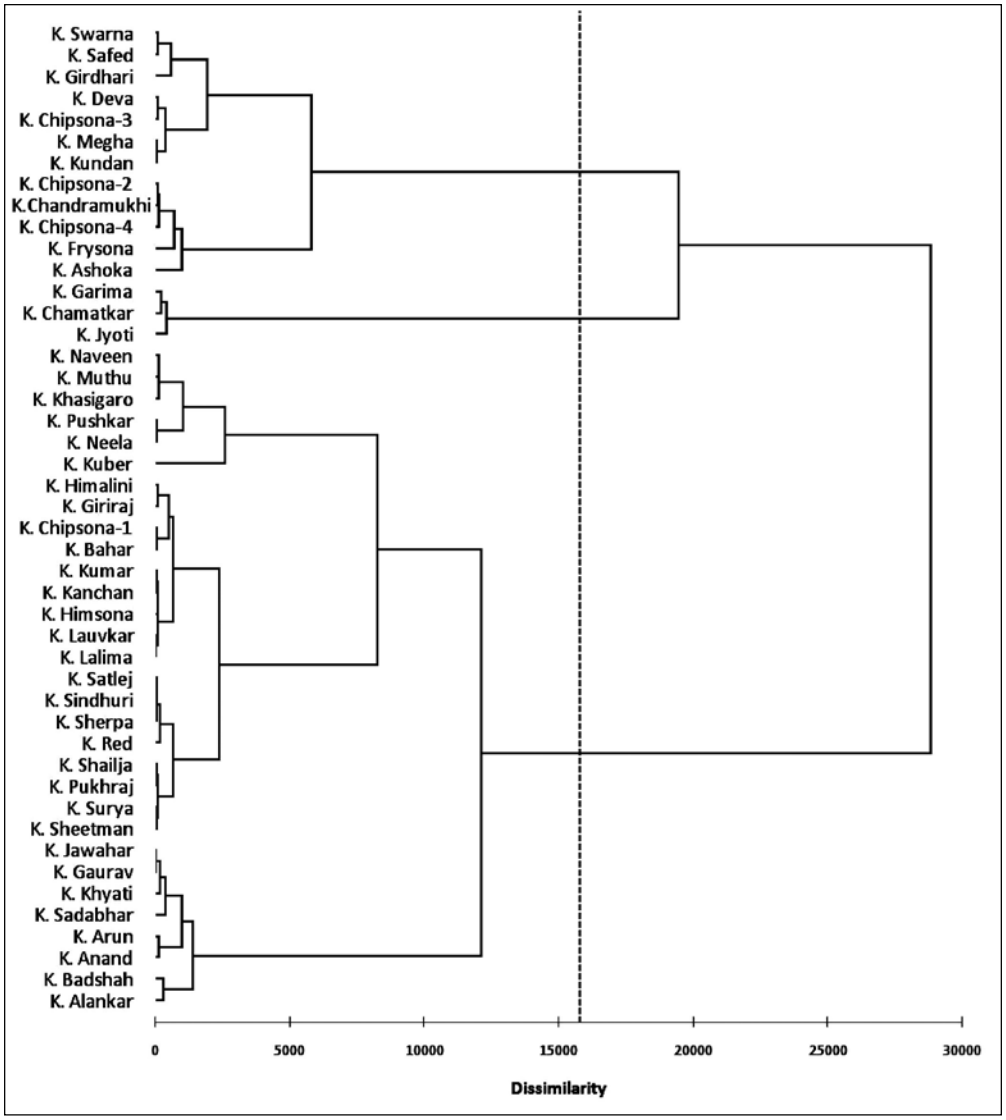


**Fig. 1.** Clustering of potato cultivars based on biochemical attributes.

**Table 2.** Means of biochemical traits in three groups formed by cluster analysis of 46 Indian potato cultivars.

| Class | No. of cultivar(s) | Resistant starch | Amylose | Total phenols | DPPH radical scavenging activity | α-glucosidase Inhibitory activity | α-amylase inhibitory activity |
|---|---|---|---|---|---|---|---|
| Cluster 1 | 31 | 1.55 | 19.0 | 60.3 | 80.19 | 8.69 | 0.00 |
| Cluster 2 | 12 | 1.50 | 21.0 | 46.0 | 32.10 | 2.12 | 1.71 |
| Cluster 3 | 3 | 1.56 | 16.2 | 133.3 | 11.11 | 0.00 | 0.00 |

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