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BIOCHEMICAL CHARACTERIZATION OF PUNJAB CELERY 1 (*Apium graveolens* L.) LEAVES AND STALKS

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ABSTRACT

The present study entailed evaluation of temporal variation in biochemical composition of of leaf and stalk tissues in recently commercialized celery variety "Punjab Celery 1" during its vegetative growth. Tissues were harvested at 45, 60, 75, 90 and 105 days after transplantation. Carbohydrate, protein, fiber, ash, minerals, antioxidant and chlorophyll content were significantly affected by the tissue examined. Carbohydrates, protein, tocopherol, total phenols, carotenoid and chlorophyll contents were highest in leaves. Stalks had high values of fiber, ash and tannin content. Vitamin C was at par in leaves and stalks. Celery antioxidant system exhibited highly significant relationships between ascorbic acid, tocopherols, total phenols, carotenoids and tannins. A significant positive correlation was observed between all analyzed components in leaves and stalks except moisture. Conclusively, Punjab celery 1 greens are endowed with good biochemical composition and may be included in our daily diets as a nutritional delicacy.

Keywords: Antioxidants, Celery, Leaves, Pigments, Stalks

Celery (*Apium graveolens* L.), a monocarpic herb of Apiaceae (Umbelliferae) family, has its origin in the Mediterranean and the Middle East part of the world (Li *et al.,* 2020). Celery was cultivated first in Italy and later in France and England and then to USA in the 19th century (Sowbhagya, 2014). In 1930s, the crop was introduced in India. In India, celery was cultivated under area of 25000ha with production of 31000 MT in 2020-21 (https://agricoop.nic.in). Among Indian states, Punjab is the leading state cultivating celery in the districts of Amritsar, Tarn-Taran and Gurdaspur; covering an area of 4330ha and, 6100MT production in 2020-21 (https://agricoop.nic.in). Celery comprises three distinct cultivated taxonomic varieties, owing to the consumption of their different plant parts: *A. graveolens* var. *dulce* (common name celery), *A.* graveolens var. *rapaceum* (common name celeriac/ root celery) and *A. graveolens* var. *secalinum* (common name smallage/leaf celery) (Yang and Quiros, 1993; Domblides *et al.,* 2008; Bruznican *et al.,* 2020). It is a *rabi* crop that needs warm days, cool nights, low humidity and sun-shine for growth. All parts of celery plant are edible: leaves, stalks, roots and seeds, either fresh or canned, or dry as spices (Golubkina *et al.,* 2020). The leaves and stalks are consumed either raw in salad or cooked in soups. In blanched form, the leaf stalks are relished as a popular vegetable. Celery and celery extracts are endowed with anti-inflammatory, anti-microbial, anti-fungal, anti-bacterial, anti-virus, anti-cancer, anti-spasmodic, anti-diabetic, anti-platelet aggregation and anti-oxidant potential (Abdel-Moein *et al.,* 2011; Saini *et al.,* 2014; Khalil *et al.,* 2015; Li *et al.,* 2017; Saleh *et al.,* 2019). This potential may be attributed to the presence of series of bioactive compounds *viz*., phthalides, coumarins, carotenoids, chlorophyll, carotene, limonene, tannins, phenolic acids, flavonoids, volatile oil and antioxidants (Helaly *et al.,* 2015). Further, the antioxidant properties have been attributed to presence of flavonoids (apigenin, apiin, isoquercitrin), vitamin A and vitamin C (Yusni *et al.,* 2018). Other health promoting constituents in celery include dietary fiber, vitamins, minerals, tryptophan, protein etc. Overall, different types of celery plants are low-calorie vegetables and a reputable medicinal plant, rich in fibers, minerals (mainly Ca-0.23-0.30% and P-0.14-0.40%), vitamins (A-5800-7500IU and C-62.6mg/100g) and flavonoids (Fazal and Singla, 2012; Sowbhagya, 2014). Celery preparations were used as cure against various ailments *viz*., arthritis, nervousness, rheumatism, edema, headaches, insomnia, asthma, bronchitis etc. (Kolarovic *et al.,* 2010). The consumption of different celery preparations alters the biochemical composition in the body which ultimately helps in the treatment of the diseases (Abdel-Moein *et al.,* 2011; Saini *et al.,* 2014; Li *et al.,* 2017). Thus, inclusion of celery in diet could provide us with various health benefits.

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Punjab Celery 1 is the first systematically bred variety released for commercial cultivation in Punjab, by Punjab Agricultural University, Ludhiana in 2016. Aim of the present investigation was to characterize Punjab Celery 1 comprehensively at the biochemical level. During this study, Punjab celery 1 was investigated for proximate composition (moisture content, ash, minerals, crude fiber, crude protein and total soluble proteins), carbohydrates (total carbohydrates, total soluble sugars-TSS, reducing sugars-RS, non-reducing sugars and starch content), antioxidants (ascorbic acid, tocopherols, total phenols and tannins) and pigments (chlorophyll a, b & total and carotenoids).

MATERIALS AND METHODS

The plant material consisted of Punjab celery 1 leaf and stalk samples. The crop was raised in the Experimental Area, Department of Plant Breeding and Genetics, Punjab Agricultural University, Ludhiana, Punjab. About 60 days old seedlings were transplanted in field. The row to row spacing was kept at 45cm with plant-to-plant distance of 25cm. The leaf and stalk samples were collected at 45, 60, 75, 90 and 105 days after transplantation (DAT). All the collected samples were kept at -20°C till further analysis. In leaf and stalk tissues, moisture content, ash and minerals viz., P, K, Ca, Fe, crude fiber (AOAC, 1984), crude protein, total soluble proteins, total carbohydrates, total soluble sugars (TSS), reducing sugars (RS), starch content, ascorbic acid (Vitamin C), tocopherols (Vitamin E), total phenols, tannins, chlorophyll (a, b and total) & carotenoids were assessed by standardized methods (Kumar, 2010). Non-reducing sugars were estimated by taking the difference between total soluble sugars and reducing sugars.

Statistical analysis

The biochemical data is presented as the mean±S.E. of the biological triplicates and was analyzed using analysis of variance to determine the significant difference ($P < 0.05$) in the levels of biochemicals among DATs. The significance of differences was calculated by post-hoc analysis (Duncan's test) at the confidence level of $P<0.05$. The Pearson correlation coefficient (R) was used to establish association between various parameters ($P<0.05$ and $P<0.01$). Statistical analysis was performed according to instructions given in SPSS 22.0 (SPSS Inc., Chicago, IL). Probability values of $P<0.05$ and $P<0.01$ were considered statistically significant and extremely significant, respectively.

RESULTS AND DISCUSSION

Celery (*Apium graveolens* L.) is one of the widespread aromatic vegetables with a high nutraceutical value, (i.e. an excellent source of antioxidants and other health promoting constituents viz. dietary fiber; the vitamins, minerals and the amino acids etc.) that is beneficial to human health and is widely used in traditional medicine and ethnoscience (Hassanen *et al.,* 2015; Tashakori-Sabzevar *et al.,* 2016; Golubkina *et al.,* 2020). In recent years, consumption of celery greens has increased steadily, largely owing to the appreciable amounts of natural bioactive components contained within celeries (Helaly *et al.,* 2015, Ramachandraiah and Chin, 2017; Liu *et al.,* 2020). Frequent consumption of these natural components might reduce the risk of oxidative damage, inflammatory response, cardiovascular disease and tumors among other conditions (Li *et al.,* 2017).

In the present study, analysis of variance ($P<0.05$) revealed the significant variability amongst all studied biochemical components in leaves and stalks except total chlorophyll in stalks. Although ANOVA revealed significant variability for mean values, but post-hoc analysis provided insignificant variability for certain biochemicals at some of the DAT. viz. moisture, crude fibre, crude protein, total carbohydrates, non-reducing sugars, total phenolics, tannins, carotenoids in leaves and moisture, crude fibre, phosphorus, calcium, iron, total carbohydrates, reducing sugars, tocopherols, total phenolics, tannins, carotenoids in stalks. An extremely significant positive correlation ($P<0.01$) (Table 1) was observed between all analyzed biochemical components in leaves and stalks indicating a close relationship between the different biochemical components except moisture which was significant but negatively correlated. Further, a positive correlation between ash content and antioxidants viz. vitamin C, tocopherol, tannins etc. may suggest the participation of mineral elements in the plant antioxidant system (Golubkina *et al.,* 2020; 2021).

Proximate analysis

The proximate composition in leaves and stalks of Punjab celery 1 is presented in Table 2. Among the proximate composition, moisture percentage was higher in leaves (92.42%) as compared to stalks (88.88%) and it varied significantly across DATs. The content decreased from 45-105 DAT in both leaves and stalks. The percent crude fiber content increased from 45 DAT to 105 DAT in both leaf (4.08-16.60%) and stalk tissues (7.65-20.80%) though higher in stalks. Amongst tissues, our results were in line with Qureshi *et al.,* (2014). Ingestion of foods rich in dietary fiber is associated with many health benefits like reduction in serum cholesterol, increase in stool bulk, improvement of laxation etc. (Schneeman, 1999; Slavin, 2005; Sowbhagya *et al.,* 2011) and it helps to reduce the risk of heart attack and colon cancer. The crude protein (%) and total soluble proteins (mg/g

Table 1. Correlation analysis of biochemical components between leaves and stalks

	Moisture	CF	ASH	P	K	Ca	Fe	CP	TSP
SMoisture	.811**								
SCF	-.898**	.996**							
SASH	-.731**	.955**	.922**						
SP	-.857**	.997**	.951**	.749**					
SK	-.767**	.921**	.900**	.754**	.907**				
SCa	-.802**	.944**	.952**	.694**	.928**	.921**			
SFe	-.891**	.995**	.960**	.733**	.969**	.858**	.976**		
SCP	-.877**	.936**	.906**	.714**	.922**	.784**	.945**	.962**	
STSP	-.891**	.879**	.807**	.645**	.843**	.658**	.894**	.965**	.975**

Table 1 Continued….

	TC	TSS	RS	NRS	St	VITC	TOC	TP	TAN	CHLA	CHLB	TCHL	CAR
STC	.966**												
STSS	.946**	.895**											
SRS	.977**	.956**	.950**										
SNRS	.953**	.894**	.989**	.862**									
SSt	.867**	.834**	.956**	.801**	.893**								
SVITC	.859**	.850**	.874**	.811**	.898**	.951**							
STOC	.732**	.716**	.832**	.749**	.753**	.750**	.740**						
STP	.934**	.903**	.845**	.898**	.792**	.891**	.738**	.922**					
STAN	.946**	.941**	.882**	.923**	.816**	.915**	.756**	.920**	.907**				
SCHLA	.892**	.917**	.838**	.925**	.817**	.872**	.721**	.863**	.867**	.835**			
SCHLB	.879**	.923**	.801**	.908**	.799**	.916**	.785**	.843**	.841**	.772**	.833**		
STCHL	.673**	.772**	.695**	.763**	.698**	.695**	.645**	.815**	.682**	.591*	.771**	.671**	
SCAR	.834**	.808**	.775**	.790**	.781**	.867**	.810**	.689**	.842**	.720**	.706**	.695**	.721**

CF-Crude Fibre, P-Phosphorus, K-Potassium, Ca-Calcium, Fe-Iron, CP-Crude protein, TSP-Total Soluble Protein (In leaves), TC-Total carbohydrates, TSS-Total Soluble Sugars, RS-Reducing sugars, NRS-Non-reducing sugars, St-Starch, VITC-Vitamin C, TOC-Tocopherols, TP-Total Phenolics, TAN-Tannins, CHLA-Chlorophyll A, CHLB-Chlorophyll B, TCHL-Total Chlorophyll, CAR- Carotenoids (In leaves)

SCF-Crude Fibre, SP-Phosphorus, SK-Potassium, SCa-Calcium, SFe-Iron, SCP-Crude protein, STSP-Total Soluble Protein (In stalks), STC-Total carbohydrates, STSS-Total Soluble Sugars, SRS-Reducing sugars, SNRS-Non-reducing sugars, SSt-Starch, SVITC-Vitamin C, STOC-Tocopherols, STP-Total Phenolics, STAN-Tannins, SCHLA-Chlorophyll A, SCHLB-Chlorophyll B, STCHL-Total Chlorophyll, SCAR- Carotenoids (In stalks)

**-significance at P (0.01) and *- significance at P (0.05)

FW) were much higher in leaves (11.64% & 7.80 mg/g FW) as compared to stalks (1.35% & 0.71 mg/g FW). ANOVA revealed significant variation in total soluble protein among different tissues, but among DAT, non-significant variation was observed at 90-105 DAT. Further, in transition from 45 to 105 DAT, the ash content almost doubled in both the tissues i.e. leaves (4.20-8.69%) and stalks (5.48-10.28%), though higher in stalks. On the contrary, Golubkina *et al.,* (2020) reported decreased ash content in celery petioles and roots as compared to leaves. Use of particular agro-technical technique and the growing conditions, such as soil and climatic factors, exposure to light, and the type of species or varieties may affect the ash content (Weber, 2017). Mineral analysis comprised both macro- and micro-minerals. In celery leaves and stalks, the mineral composition reflects its nutritional significance, resilience against biotic and abiotic stresses that might impact the nutritional value of the produce. Among the macro-minerals, the major element revealed was phosphorus (P) in both leaves (50.53±0.49 ppm) and stalks (65.99±2.12 ppm). Other observed macro- and micro-minerals with significant values were potassium (K) followed by calcium (Ca) and iron (Fe). P, Ca and Fe contents were higher in stalks when compared to leaves while K depicted reverse trend. Analysis of variance depicted significant variability in transition from 45 to 105 DAT for all minerals, except for potassium in 60 to 75 DAT. In leaves, the phosphorus content

Table 2. Proximate composition in leaves and stalk tissue of Punjab Celery 1

Traits	DAT	Leaves	Stalks
Moisture (%)	45	^{d} 92.42 ± 0.01	^{e} 88.88 ± 0.39
	60	^{c} 86.63 ± 0.35	^{d} 87.38 ± 0.23
	75	^{c} 86.54 ± 0.53	^{c} 85.08 ± 0.53
	90	^{b} 85.36 ± 0.08	^{b} 83.17 ± 0.02
	105	^{a} 84.11 ± 0.06	^{a} 79.08 ± 0.04
Crude fiber (%)	45	^{a} 4.08 ± 0.01	^{a} 7.65 ± 0.09
	60	^{b} 7.01 ± 0.02	^{b} 11.64 ± 0.04
	75	^{c} 9.67 ± 0.04	^{c} 14.30 ± 0.11
	90	^{d} 14.20 ± 0.06	^{d} 18.61 ± 0.11
	105	^{e} 16.60 ± 0.32	^{e} 20.80 ± 0.06
Crude protein (%)	45	^{a} 6.55 ± 0.19	^{a} 0.58 ± 0.02
	60	^{b} 10.10 ± 0.06	^{b} 1.03 ± 0.09
	75	^{c} 12.63 ± 0.12	^{c} 1.54 ± 0.12
	90	^{d} 14.17 ± 0.18	^{c} 1.67 ± 0.11
	105	^{e} 14.77 ± 0.09	^{d} 1.95 ± 0.03
Total soluble protein (mg/g FW)	45	^{a} 4.33 ± 0.08	^{a} 0.31 ± 0.01
	60	^{b} 6.30 ± 0.11	^{b} 0.57 ± 0.04
	75	^{c} 8.75 ± 0.00	^{c} 0.86 ± 0.05
	90	^{d} 9.75 ± 0.03	^{c} 0.89 ± 0.02
	105	^{d} 9.88 ± 0.02	^{c} 0.90 ± 0.03
Ash content (%)	45	^{a} 4.20 ± 0.06	^{a} 5.48 ± 0.04
	60	^{b} 5.52 ± 0.29	^{a} 5.61 ± 0.10
	75	^{c} 6.19 ± 0.21	^{b} 6.60 ± 0.18
	90	^{c} 6.72 ± 0.08	^{c} 8.46 ± 0.03
	105	^{d} 8.69 ± 0.10	^{d} 10.28 ± 0.23
Phosphorus (ppm)	45	^{a} 48.91 ± 0.07	^{a} 55.51 ± 0.18
	60	^{a} 48.96 ± 0.39	^{b} 60.41 ± 0.23
	75	^{ab} 50.84 ± 0.64	^{c} 64.33 ± 0.06
	90	^{ab} 51.29 ± 1.04	^{d} 72.27 ± 0.09
	105	^{b} 52.65 ± 1.26	^{e} 77.42 ± 0.27
Potassium (ppm)	45	^{a} 17.39 ± 0.03	^{a} 15.32 ± 0.06
	60	^{b} 18.84 ± 0.02	^{ab} 15.58 ± 0.28
	75	^{b} 18.96 ± 0.04	^{b} 15.80 ± 0.13
	90	^{c} 20.42 ± 0.31	^{c} 16.32 ± 0.01
	105	^{d} 21.27 ± 0.12	^{c} 16.76 ± 0.02
Calcium (ppm)	45	^{a} 12.35 ± 0.03	^{a} 12.20 ± 0.01
	60	^{b} 13.25 ± 0.03	^{b} 13.23 ± 0.04
	75	^{b} 13.25 ± 0.01	^{c} 14.23 ± 0.01
	90	^{b} 13.25 ± 0.01	^{d} 15.25 ± 0.14
	105	^{c} 15.25 ± 0.03	^{e} 17.92 ± 0.60
Iron (ppm)	45	^{a} 2.53 ± 0.01	^{a} 2.20 ± 0.06
	60	^{b} 3.23 ± 0.01	^{b} 3.32 ± 0.01
	75	^{c} 4.10 ± 0.06	^{c} 4.20 ± 0.06
	90	^{c} 4.19 ± 0.03	^{d} 5.25 ± 0.03
	105	^{d} 5.21 ± 0.04	^{e} 6.23 ± 0.10

Values are means of three replicates ± standard error; a,b,c,d,e symbols depicts the significant variability at 5% amongst DATs

varied from 48.91-52.65 ppm whereas in stalks, the change was higher with increase of 19% (55.51-77.42 ppm). Likewise, the contents of K, Ca and Fe were (17.39-21.27 ppm), (12.35-15.25 ppm) and (2.53-5.21 ppm), respectively in leaf tissue and the corresponding values in stalks were (15.32-16.76 ppm), (12.20-17.92 ppm) and (2.20-6.23 ppm), respectively. The mineral elements play crucial roles in various biological processes for both plants as well as for human beings (Scherz and Kirchhoff, 2006; Maathuis, 2009; Golubkina *et al.,* 2020). Qureshi *et al.,* (2014) reported highest amount of K, P and Ca in roots of celery and minimum level of Fe, Mn and Zn in leaves however, we observed higher P, Ca and Fe in stalks and K in leaves of the celery plant. This could be attributed to the reason that macro element distribution between leaves and petioles in celery may significantly vary depending on the cultivar and the applied fertilizer (Kalembasa *et al.,* 2014).

Carbohydrates

Carbohydrates serve as fuel, energy stores and building materials, as well as play role in cell-cell recognition and information transmission. Sugars (reducing & non-reducing) and starches are carbohydrates involved in energy transport and storage. Petioles are the storage parts in leafy, stalk and to a lesser extent in root celery plants. In the present study, during vegetative growth, the accumulation of total carbohydrates, total soluble sugars, reducing, non-reducing sugars and starch were observed from 45 to 105 DAT, in both leaves as well as in stalks; though the contents were much higher in leaves (Table 3). From 45 to 105 DAT, the content of total carbohydrates increased by 32% in leaves whereas it was 51% in stalks, however, the total soluble sugars increased 1.8 and 2.7 times in leaves and stalks, respectively. Golubkina et al., (2020) reported significant variability in contents of

Table 3. Carbohydrate composition in leaves and stalks of Punjab Celery 1

Traits	DAT	Leaves	Stalks
Total carbohydrates (mg/g FW)	45	[a] 75.75 ± 0.05	[a] 27.15 ± 0.03
	60	[b] 80.07 ± 0.04	[b] 30.59 ± 0.07
	75	[c] 86.16 ± 0.07	[c] 32.45 ± 0.51
	90	[d] 92.99 ± 3.01	[d] 35.21 ± 0.14
	105	[e] 100.99 ± 0.37	[e] 40.89 ± 0.49
Total soluble sugars-TSS (mg/g FW)	45	[a] 7.13 ± 0.15	[a] 3.43 ± 0.13
	60	[b] 8.50 ± 0.34	[b] 4.84 ± 0.07
	75	[b] 9.80 ± 0.07	[c] 6.58 ± 0.11
	90	[c] 11.50 ± 0.20	[d] 8.86 ± 0.03
	105	[d] 13.99 ±0.84	[d] 9.29 ± 0.46
Reducing sugars (mg/g FW)	45	[a] 0.51 ±0.09	[a] 0.25 ± 0.07
	60	[b] 0.71 ± 0.02	[b] 0.36 ± 0.01
	75	[c] 0.93 ± 0.01	[c] 0.48 ± 0.01
	90	[d] 1.17 ± 0.01	[d] 0.57 ± 0.01
	105	[d] 1.21 ± 0.02	[e] 0.75 ± 0.02
Non reducing sugars (mg/g FW)	45	[a] 6.62 ± 0.16	[a] 3.18 ± 0.07
	60	[ab] 7.79 ± 0.49	[b] 4.49 ± 0.07
	75	[bc] 8.87 ± 0.09	[c] 6.10 ± 0.00
	90	[c] 10.33 ± 0.08	[d] 8.30 ± 0.18
	105	[d] 12.79 ± 0.92	[d] 8.54 ± 0.35
Starch (mg/g FW)	45	[a] 5.95 ± 0.19	[a] 3.40 ± 0.40
	60	[b] 7.07 ± 0.08	[b] 5.81 ±0.15
	75	[c] 9.60 ± 0.05	[b] 6.06 ± 0.02
	90	[d] 11.19 ± 0.61	[c] 8.78 ± 0.33
	105	[d] 11.21 ±0.30	[c] 8.69 ± 0.54

Values are means of three replicates ± standard error; a,b,c,d,e symbols depicts the significant variability at 5% amongst DATs

total soluble solids and sugars of different celery types. For reducing and non-reducing sugars, two fold change was observed in leaves during growth from 45 to 105 DAT whereas, it was three fold in stalks. In present study, out of 87.19 mg/g FW leaves and 33.26 mg/g FW stalks total carbohydrates, reducing sugars (0.91 mg/g FW leaves and 0.48 mg/g FW stalks/petioles) were only a small part of carbohydrates. Our results are synchronous with Barros *et al.,* (2010) as they also reported total carbohydrates of 18g/100g in fennel leaves, with very low amount of reducing sugars (0.72g/100 g leaves). It may be due to the presence of abundant polysaccharides such as starch and cellulose that are major storage and structural polysaccharide used for energy storage in plant cells and as the major component of cell walls in plants, respectively (Zubay, 2006). To the best of our knowledge, till now, there are very few reports of carbohydrate estimation, especially total carbohydrates, reducing sugars, non-reducing sugars and starch in celery leaves and stalks. The starch content also increased from 45 DAT to 105 DAT in both leaf and stalk tissues but higher in leaves. A significant variability was observed amongst tissues, DAT and their interaction, for all carbohydrate components except for starch at 90 and 105 DAT.

Antioxidants

Antioxidants from herbs are a great group of bioactive compounds that consist of phenolic compounds, flavonoids, sulphur-containing compounds, alkaloids, tannins, phenolic diterpenes, and vitamins (El-Beltagi *et al.,* 2020). Punjab Celery 1 had antioxidant system of significant prevalence (ascorbic acid, phenols, tannins and tocopherols). The antioxidant content was determined on fresh weight basis in mg/g and the analyzed data values are tabulated in Table 4. The results indicated that, amongst antioxidants, higher levels of tocopherols and total phenols were observed in leaves whereas tannins were more in stalks; however, vitamin C level was at par in both the tissues. The contents of the estimated antioxidants increased with increased DAT. Duncan's multiple comparison test revealed no significant change for contents of vitamin C during transition from 45 to 60 DAT and from 75 to 90 DAT, for tocopherols at 75-105 DAT and for total phenols at 60-75 DAT. Tannins registered the average value of (12.35 & 16.48 mg/g FW) followed by total phenols (1.39 & 0.34 mg/g FW), tocopherols (0.39 & 0.24 mg/g FW) and vitamin C (0.34 & 0.33 mg/g FW) in leaves and stalks, respectively. Golubkina *et al.,* (2020) reported higher content of ascorbic acid in leaves as compared to

Table 4. Antioxidant composition in leaves and stalk tissue of Punjab Celery 1

Traits	DAT	Leaves	Stalks
Vitamin C (mg/g FW)	45	[a] 0.14 ±0.01	[a] 0.14 ± 0.01
	60	[a] 0.20 ± 0.01	[a] 0.16 ± 0.01
	75	[b] 0.38 ± 0.04	[b] 0.41 ± 0.09
	90	[b] 0.42 ± 0.09	[b] 0.43 ± 0.03
	105	[c] 0.57 ± 0.01	[b] 0.52 ± 0.01
Tocopherols (mg/g FW)	45	[a] 0.29 ± 0.01	[a] 0.19 ± 0.01
	60	[a] 0.33 ± 0.01	[b] 0.23 ± 0.01
	75	[b] 0.42 ± 0.04	[bc] 0.24 ± 0.01
	90	[b] 0.45 ± 0.02	[bc] 0.26 ± 0.02
	105	[b] 0.46 ± 0.02	[c] 0.26 ± 0.01
Total phenols (mg/g FW)	45	[a] 0.72 ± 0.02	[a] 0.08 ± 0.01
	60	[b] 1.04 ± 0.05	[ab] 0.15 ± 0.02
	75	[b] 1.24 ± 0.08	[b] 0.20 ± 0.03
	90	[c] 1.82 ± 0.12	[c] 0.44 ± 0.3
	105	[c] 2.11 ± 0.14	[e] 0.82 ± 0.06
Tannins (mg/g FW)	45	[a] 9.78 ± 0.15	[a] 13.18 ± 0.57
	60	[b] 11.23 ± 0.06	[a] 14.10 ± 0.18
	75	[c] 12.23 ± 0.17	[b] 15.23 ± 0.33
	90	[d] 13.92 ± 0.08	[c] 17.86 ± 0.16
	105	[e] 14.57 ± 0.38	[d] 22.01 ± 0.02

Values are means of three replicates ± standard error; a,b,c,d,e symbols depicts the significant variability at 5% amongst DATs

Table 5. Pigments in leaves and stalk tissue of Punjab Celery 1

Traits	DAT	Leaves	Stalks
Chlorophyll a (mg/g FW)	45	^{a} 0.98 ± 0.10	^{a} 0.09 ± 0.02
	60	^{a} 1.22 ± 0.05	^{b} 0.12 ± 0.01
	75	^{a} 1.28 ± 0.05	^{b} 0.13 ± 0.01
	90	^{b} 1.78 ± 0.15	^{b} 0.15 ± 0.01
	105	^{c} 2.14 ± 0.07	^{d} 0.20 ± 0.01
Chlorophyll b (mg/g FW)	45	^{a} 0.10 ± 0.02	^{a} 0.01 ± 0.01
	60	^{a} 0.12 ± 0.01	^{a} 0.01 ± 0.00
	75	^{b} 0.21 ± 0.02	^{b} 0.02± 0.00
	90	^{bc} 0.25 ± 0.00	^{b} 0.03 ± 0.01
	105	^{c} 0.27 ± 0.01	^{c} 0.04 ± 0.01
Total chlorophyll (mg/g FW)	45	^{a} 1.12 ± 0.04	^{a} 0.15 ± 0.02
	60	^{b} 1.25 ± 0.03	^{ab} 0.17 ± 0.02
	75	^{bc} 1.31 ± 0.02	^{ab} 0.18 ± 0.01
	90	^{c} 1.38 ± 0.01	^{ab} 0.21 ± 0.02
	105	^{c} 1.39 ± 0.01	^{b} 0.23 ± 0.02
Carotenoids (mg/g FW)	45	^{a} 0.21 ± 0.01	^{a} 0.03 ± 0.01
	60	^{b} 0.30 ± 0.04	^{ab} 0.04 ± 0.01
	75	^{c} 0.42 ± 0.03	^{bc} 0.06 ± 0.01
	90	^{cd} 0.47 ± 0.03	^{bc} 0.07 ± 0.01
	105	^{d} 0.53 ± 0.02	^{c} 0.08 ± 0.01

Values are means of three replicates ± standard error; a,b,c,d,e symbols depicts the significant variability at 5% amongst DATs

petioles of all celery genotypes whereas in present investigation, ascorbic acid content was at par in leaves and stalks. Low levels of vitamin C in Punjab celery 1 could be justified as it may depend on multiple factors, such as cultivar, cultivation method, biotic and abiotic stress, harvest date and storage, access to light, water and nitrogen fertilizers (Kyriacou *et al.,* 2019; Wojdylo *et al.,* 2020), along with the time of germination, as the most intense synthesis of L-ascorbic acid occurs within a few days after sowing, and then its content is maintained at a constant level (Marton *et al.,* 2010; Xiao *et al.,* 2012). Huang *et al.,* (2016) also observed variable levels of vitamin C in different cultivars. Thus, different cultivars and also the different tissues of the same cultivar may have variable vitamin C level (Bruznican *et al.,* 2020). Phenolic compounds in plant materials have been claimed to contribute to the antioxidant activities of the plants (Yao *et al.,* 2010). Ghosh, (2015) reported that tannins possess potent antioxidant activity and radical scavenging activity. Wolski *et al.,* (2002) recorded 3-fold more tannin in stalks of leaf type celery than in blades which is in line to present study's results.

Pigments

The pigment variability in different tissues of Punjab Celery 1 is depicted in Table 5. In both leaves and stalks, the contents of chlorophyll a, b as well as of total, increased during vegetative growth, with highest at 105 DAT. In leaves, the content of chlorophyll a, chlorophyll b and total chlorophyll ranged from 0.98-2.14 mg/g FW, 0.10-0.27 mg/g FW and 1.12-1.39 mg/g FW, respectively; however, in stalks, the contents were much lower i.e. 0.09-0.20 mg/g FW, 0.01-0.04 mg/g FW and 0.15-0.23 mg/g FW, respectively. Our study demonstrated an increase in carotenoid levels from 45 to 105 DAT. High carotenoid content was registered in leaves with maximum of 0.53 mg/g FW at 105 DAT however in stalks; the content was much less i.e. 0.06 mg/g FW. The effect of tissues proved to be significant for the pigments, however, DAT effect was non-significant for chlorophyll a at 60-75 DAT, chlorophyll b at 45-60 DAT & 75-90 DAT, total chlorophyll at 60-75 DAT & 90-105 DAT and carotenoids at 75-90 DAT. Chlorophyll, a green pigment found in most of the plants, is used as a direct index of photosynthetic potential of a plant and as an indirect index for assessing the nutrient status of the plant. A higher concentration of chlorophyll might indicate the production of more energy nutrients in the plants. Leaves are rich source of chlorophyll. We have observed 2 (leaves) to 4-fold (stalks) accumulation in chlorophyll a and b during vegetative growth from 45-105 DAT in Punjab Celery 1 and the total chlorophyll was accumulated around 1.5 times. For carotenoids, this accumulation was around 2.5-3.0-fold in both leaves and stalks. Chl b content in our study is in line with previous study of Mezeyova *et al.* (2018); however total chlorophyll content is much higher. Higher contents of chlorophyll a, b and total in leaves than stalks of Punjab Celery 1 validates the previous findings of Golubkina *et al.* (2020) thus, suggesting the nutraceutical prospects of leaves for human utilization. In our study, the content of chlorophyll b was quite less as compared to cholorophyll a. This could be attributed to the reason that the primary photosynthetic pigment is chlorophyll a and chlorophyll b is not necessary for photosynthesis to occur, and, therefore, not all cells that perform photosynthesis contain chlorophyll b. An increase in the content of chlorophyll b results from adaption to shade, as it allows a plant to absorb a broader range of light wavelengths. Carotenoids are also important antioxidants (Weber, 2017) and phytonutrients and can play a major role in the protection of plants against photo-oxidative processes and in the protection of humans against cancers of e.g., liver, colon, lung, pancreas or prostate (Mir *et al.,* 2017). Consumption of carotenoid-rich products has been demonstrated to bring health benefits in the form of ameliorating degenerative and cardiovascular diseases (Wojdylo *et al.,* 2018, 2020).

This is the first report on biochemical profiling of Punjab Celery 1 leaves and stalks. The data generated by this research is likely to provide a scientific basis for evaluating the biochemical status (carbohydrate, protein, fiber, antioxidant, pigments) of Punjab celery 1 in leaves and stalks. Variability in tissues and leaf harvesting time (DAT) was shown to have a significant effect on biochemical profile of Punjab Celery 1. The results revealed that the leaves of the plant possess high level of total carbohydrates, total soluble sugars and antioxidants whereas crude fiber, ash and tannins were found more in stalks. Also, the maximum amount of crude & soluble protein, chlorophylls and carotenoids were found in leaves. However, since growing, harvesting and postharvest handling conditions may have a considerable impact on the synthesis and degradation of various biochemicals, further studies may be needed to evaluate the effect of these agricultural practices on biochemical profile. Thus, inclusion of celery in diet could provide us with various health benefits; however, the amount to be consumed in diet needs to be determined. In conclusion, Punjab Celery 1 is abound in minerals & antioxidants and may be included in daily diets as salads or in cooked form and its potential could be exploited in culinary industry.

Authors' contribution

Conceptualization and designing of the research work (MKS, DP, UN); Execution of field/ lab experiments and data collection (HSG); Analysis of data and interpretation (SG, SS); Preparation of manuscript (SG, MKS)

LITERATURE CITED

Abdel-Moein N M, Abdel-Moniem E A, Mohamed D A and Hanfy EA 2011. Evaluation of the anti-inflammatory and anti-arthritic effects of some plant extracts. *Grasas Aceites* **62**: 365-74.

AOAC 1984. *Official Method of Analysis*. 14th Edn, Association of Official Analytical Chemists, Washington, D.C. USA.

Barros L, Carvalho A M and Ferreira I C F R 2010. The nutritional composition of fennel (*Foeniculum vulgare*): Shoots, leaves, stems and inflorescences. *LWT Food Sci Technol* **43**: 814-18.

Bruznican S, De Clercq H, Eeckhaut T, Van Huylenbroeck J and Geelen D 2020. Celery and Celeriac: A Critical View on Present and Future Breeding. *Front Plant Sci* **10**: 1699.

Davis J M and Loescher W H 1991. Diurnal pattern of carbohydrates in celery leaves of various ages. *Hort Sci* **26**: 1404-06.

Domblides A, Domblides H and Kharshenko V 2008. Discrimination between celery cultivars with the use of RAPD markers. *Proc Latvian Acad Sci (Section B)* **62**: 219-22.

El-Beltagi H S, Dhawi F, Aly A A and El-Ansary A E 2020. Chemical compositions and biological activities of the essential oils from gamma irradiated celery (*Apium graveolens* L.) seeds. *Not Bot Horti Agrobo* **48**: 2114-33.

Fazal S S and Singla R K 2012. Review on the pharmacognostical and pharmacological characterization of *Apium graveolens* Linn. *Indo Glob J Pharm* **2**: 36-42.

Ghosh D 2015. Tannins from foods to combat diseases. *Int J Pharma Res Rev* **4**: 40-44.

Golubkina N A, Kharchenko V A, Moldovan A I, Koshevarov A A, Zamana S, Nadezhkin S et al. 2020. Yield, growth, quality, biochemical characteristics and elemental composition of plant parts of celery leafy, stalk and root types grown in the northern hemisphere. *Plants* **9**: 484.

Golubkina N A, Kharchenko V A, Moldovan A I, Zayachkovsky V, Stepanov V, Pivovarov V et al. 2021. Nutritional value of apiaceae seeds as affected by 11 species and 43 cultivars. *Horticulturae* **7**: 57.

Hassanen N H, Eissa A M F, Hafez S A M and Mosa E A 2015. Antioxidant and antimicrobial activity of celery (*Apium graveolens*) and coriander (*Coriandrum* *sativum*) herb and seed essential oils. *Int J Curr Microbiol Appl Sci* **4**: 284-96.

Helaly A A D, Back J P, Mady E, Eldekashy M H Z and Craker L 2015. Phytochemical analysis of some celery accessions. *J Med Act Plants* **1**: 1-7.

Huang W, Wang G L, Li H, Wang F, Xu ZS and Xiong AS 2016. Transcriptional profiling of genes involved in ascorbic acid biosynthesis, recycling and degradation during three leaf developmental stages in celery. *Mol Genet Genomics* **291**: 2131–43.

Kalembasa S, Malinowska E, Kalembasa D, Symanowicz B and Pakuła K 2014. Effect of foliar fertilization with tytanit on the content of selected macroelements and sodium in celery. *J Elem* **19**: 683-96.

Khalil A, Nawaz H, Ghania J B, Rehman R and Nadeem F 2015. Value added products, chemical constituents and medicinal uses of celery (*Apium graveolens* L.) - A review. *Int J Chem Biol Sci* **8**: 40-48.

Kolarovic J, Popovic M, Zlinska J, Trivic S and Vojovic M 2010. Antioxidant activities of celery and parsley juices in rats treated with doxorubicin. *Molecules* **15**: 6193-6204.

Kumar 2010. Evaluation of different okra (*Abelmoschus esculentus* l. *Moench*) genotypes for nutritional and antinutritional components. M.Sc. Thesis. Punjab Agricultural University, Ludhiana, Punjab, India. http://krishikosh.egranth.ac.in/handle/1/5810081053

Kyriacou M C, El-Nakhel C, Graziani G, Pannico A, Soteriou G A, Giordano M et al. 2019. Functional quality in novel food sources: Genotypic variation in the nutritive and phytochemical composition of thirteen microgreens species. *Food Chem.* **277**: 107–18.

Li M Y, Feng K, Hou X L, Jiang Q, Xu Z S, Wang G L et al. 2020. The genome sequence of celery (*Apium graveolens* L.), an important leaf vegetable crop rich in apigenin in the Apiaceae family. *Hortic Res* **7**: 9.

Li M Y, Hou X L, Wang F, Tan G F, Xu Z S and Xiong A S 2017. Advances in the research of celery, an important Apiaceae vegetable crop. *Crit Rev Biotechnol* **38**: 172-83.

Liu D K, Xu C C, Zhang L, Ma H, Chen X J, Sui YC et al. 2020. Evaluation of bioactive components and antioxidant capacity of four celery (*Apium graveolens* L.) leaves and petioles. *Int J Food Prop* **23**: 1097-1109.

Maathuis F J 2009. Physiological functions of mineral macronutrients? *Curr Opin Plant Biol* **12**: 250–58.

Marton M, Mandoki Z, Csapo J and Guba S 2010. The role of sprouts in human nutrition: A review. Acta Universitatis Sapientiae: *Alimentaria* **3**: 81-117.

Mezeyova I, Hegedusova A, Mezey J, Slosar M and Farkas J 2018. Evaluation of quantitative and qualitative characteristics of selected celery (*Apium graveolens* var. dulce) varieties in the context of juices production. *Potr S J F Sci* **12**: 173-79.

Mir S A, Shah M A and Mir M M 2017. Microgreens: Production, shelf life, and bioactive components. *Crit Rev Food Sci Nutr* **57**: 2730–36.

Qureshi K, Farrukh T, Neelam M A, Muhammad Z A and Muhammad Z 2014. Investigation of mineral constituents of *Apium graveolens* L. available in Khyber Pakhtunkhwa Pakistan. *J Pharmacog Phytochem* **3**: 234-39.

Ramachandraiah K and Chin K 2017. Impact of drying and micronization on the physico-chemical properties and antioxidant activities of celery stalk. *J Sci Food Agr* **97**: 4539-47.

Saini N, Singh G K and Nagori B P 2014. Spasmolytic potential of some medicinal plants belonging to family Umbelliferae: A review. *Int J Res Ayurveda Pharm* **5**: 74-83.

Saleh S, Liu G, Liu M, Liu W, He H and Abdelhamid MT 2019. Do NH_4:NO_3 ratio and harvest time affect celery (*Apium graveolens*) productivity and product quality? *Folia Hortic.* **31**: 343-53.

Scherz H and Kirchhoff E 2006. Trace elements in foods: Zinc contents of raw foods—a comparison of data originating from different geographical regions of the world. *J Food Compos Anal* **19**: 420-33.

Schneeman B O 1999. Fiber, inulin and oligofructose: Similarities and differences. *J Nutr* **129**: 1424-27.

Slavin J L 2005. Dietary fiber and body weight. *Nutrition* **21**: 411-18.

Sowbhagya H B 2014. Chemistry, technology and nutraceutical functions of celery (*Apium graveolus* L.). *Crit Rev Food Sci Nutr* **54**: 389-98.

Sowbhagya H B, Mahadevamma S and Indrani S P 2011. Physicochemical and micro-structural characteristics of celery seed spent residue and influence of its addition on quality of biscuits. *J Texture Stud* **42**: 369-76.

Tashakori-Sabzevar F, Razavi B M, Imenshahidi M, Daneshmandi M, Fatehi H, Sarkarizi YE et al. 2016. Evaluation of mechanism for antihypertensive and vasorelaxant effects of hexanic and hydroalcoholic extracts of celery seed in normotensive and hypertensive rats. *Rev Bras Farmacogn* **26**: 619-26.

Weber C F 2017. Broccoli Microgreens: A mineral-rich crop that can diversify food systems. *Front Nutr* **4**: 1-9.

Wojdyło A, Nowicka P and Babelewski P 2018. Phenolic and carotenoid profile of new goji cultivars and their anti-hyperglycemic, anti-aging and antioxidant properties. *J Funct Foods* **48**: 632–42.

Wojdylo A, Nowicka P, Tkacz K and Turkiewicz IP 2020. Sprouts vs. microgreens as novel functional foods: Variation of nutritional and phytochemical profiles and their *in vitro* bioactive properties. *Molecules* **25**: 4648.

Wolski T, Dyduch J and Najda A 2002. Evaluation of content and composition of phenolic acids and tannins in leaf dry matter of two celery cultivars (*Apium graveolens* L. Var. *Dulce* Mill. Pers.). *Electron J Pol Agric Univ* **5**: 1.

Xiao Z, Lester G E, Luo Y and Wang Q 2012. Assessment of vitamin and carotenoid concentrations of emerging food products: edible microgreens. *J Agric Food Chem* **60**: 7644-51.

Yang X and Quiros C 1993. Identification and classification of celery cultivars with RAPD markers. *Theor Appl Genet* **86**: 205-12.

Yao Y, Sang W, Zhou M J and Ren G X 2010. Phenolic composition and antioxidant activities of 11 celery cultivars. *J Food Sci* **75**: C9–13.

Yusni Y, Zufry H, Meutia F and Sucipto K W 2018. The effects of celery leaf (*Apium graveolens* L.) treatment on blood glucose and insulin levels in elderly pre-diabetics. *Saudi Med J* **39**: 154.

Zubay G 2006. Biochemistry. USA: WMC Brown Publishers.