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Original Article

The Comparison of the Chemical Composition, Sensory, Phenolic and Antioxidant Properties of Juices from Different Wheatgrass and Turfgrass Species

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Abstract

Wheatgrass juice is mainly derived from the common wheat *Triticum aestivum* L. The present study focused on the analysis of the potential of different perennial turfgrass species in grass juice production by determining certain compositional characteristics. The effects of fertilisers on the plants and the cutting time on some chemical constituents and antioxidant potential of grass juices were addressed. The juices from the different species of grasses, such as *T. durum*, *T. aestivum*, *Lolium perenne* L., *Festuca arundinacea* Schreb. were obtained by pressing. DPPH (1, 1diphenyl-2-picrylhydrazyl) radical scavenging activity, elemental composition, total chlorophylls, total carotenes, tocopherols, vitamin C, total phenols, viscosity and the colour profiles of the grass juice samples were analysed. Water-soluble dry matter, protein, total phenols, flavonoids and vitamin E (especially Durum cultivar) content were found to be higher in the juices of *Triticum* species as compared to the other grasses. Turfgrass species demonstrated higher concentrations of oil (in grass), vitamin C (unfertilised samples), chlorophyll (except *L. perenne* local) and major elements. The pressing of turfgrass was an easy process. Such perennial grass varieties have advantages over the *Triticum* species in terms of having higher concentrations of vitamin C (unfertilised samples) and major elements. The results of sensory analysis suggested that *L. perenne* (cultivar) is the most promising cultivar in terms of obtaining pressed grass juice.

Keywords: Biologically-active compounds, carotenoids, DPPH radical scavenging activity, flavonoid content, total oil content, total phenol contents

Introduction

Wheatgrass (*T. aestivum*) belonging to Poaceae family refers to young grass of the common wheat plant. Wheatgrass juice is a dietary supplement derived from common wheat; *T. aestivum* L. germinated over a period of 6-10 days. Wheatgrass juice is an aqueous form of the plant which is produced by juicing the young shoots, just before the jointing stage. The supplement is available commercially in liquid, powdered or concentrated forms, depending on the supplier and can be consumed on its own, or mixed with fruit juices. The juice is also known as "living food" and is a superior source of chlorophyll – appropriately referred to as the "green blood". In recent years, in many countries, wheatgrass, in the form of a ready-made juice is becoming more popular in the course of time and is being consumed as a 'health food' (Mujoriya, 2011). Although antioxidant activity of wheatgrass is well believed, more research is needed to reveal the reasons for it. A very few publications are available in literature on nutritive and antioxidant properties of wheatgrass juice where it is reported that these extracts contain high levels of antioxidants and inhibit the DNA oxidative damage and are effective in suppressing the superoxide radical (Kulkarni *et al.,* 2006; Rana, 2011). It has also shown antimutagenicity (Alitheen *et al.,* 2011; Arya and Kumar, 2011), antimicrobial (Ashok, 2011; Pallavi *et al*., 2011; Das *et al*., 2012), antiallergic (Padalia *et al.,* 2010) and diuretic (Popovič *et al.,* 2014) properties. Wheatgrass was also reported to be helpful incuring certain diseases such as thalassemia (Singh *et al.,* 2010), distal ulcerative colitis, anaemia, diabetes, eczema, constipation, and ulcerative

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colitis (Jaya and Gayathri, 2009). The scientific proof of bioactive properties of wheatgrass is still not well established (Ashok, 2011).

There are several factors, such as genetics, plant species, agronomic and environmental conditions, pH, light intensity, type of light, low and high temperatures, and minerals absorbed by the plant via roots, that affect different properties of the wheatgrass such as plant colour, oil, dry matter, °Brix, protein, total phenols, total flavonoids, vitamin C, DPPH, and macro element contents and radical scavenging activity (Kumar *et al.,* 2011; Devi Sowjanya *et al.,* 2015; Khampas *et al.,* 2015; Liu *et al.,* 2015; Rimple *et al.,* 2016).

Therefore, it is highly intriguing to report the data on wheatgrass juice in terms of its nutritive constituents, and chemical and physical properties in context to food science. Thus, we carried out this study to determine the chemical constituents and biological properties of several wheatgrass cultivars (*T. durum*, *T. aestivum*, *L. perenne* L. and *F. arundinacea* Schreb.) in order to exhibit the levels and biological activity of certain nutritive compounds and nutraceuticals. The consumer acceptance was also determined by hedonic sensory test. Though *Triticum* cultivars germinate rapidly and become ready for harvest in a short time, the turfgrass cultivars are still appealing in terms of their perennial characteristics and availability to multiple cuttings.

Besides, our study analysed the potential of perennial turfgrass species, which are generally used to feed animals or design landscapes, despite having the potential to be used for the production of the wheatgrass juice. The effect of fertiliser application to wheatgrass and turfgrass plants and the harvest time on some chemical constituents and antioxidant potential of grass juices was also studied.

Materials and Methods

Materials

The experiment was carried out in greenhouse facility at the Department of Field Crops at Selçuk University in Konya, Turkey (38°01'48.6"N 32°30'32.5"E). The grass seeds were sown on March 6, 2014, germinated and raised in pots under greenhouse conditions. The greenhouse was a Venlo-type with natural ventilation by side and ridge openings. The length, width and floor area of the greenhouse were 13.0 m, 33.0 m and 429 m^2, respectively. The experiment was set up as a completely randomised design with four replications per treatment, and six different Poaceae species were used: (CV1) durum wheat (*T. durum*) cultivar 'cesit 1252', (CV2) bread wheat (*T. aestivum*) cultivar 'Dagdas 94', (CV3) a 50:50 mixture of durum and bread wheat, (CV4) perennial ryegrass (*L. perenne*) cultivar 'Apple GL', (CV5) perennial ryegrass (*L. perenne*) local population, (CV6) tall fescue (*F. arundinacea*) cultivar 'Barlexas II' (Table 1).

The plants were grown under two treatments: with fertiliser and without fertiliser. Plastic pots of 22 × 20 cm were filled with 5 L sterilised peat up to 1 cm below the pot brim. The seeds were sown in pots on March 6, 2014. The properties of the peat were as follows: Texture = fine medium; pH=5.2-6.0; N=10–30 ppm, P_2O_5=10-30 ppm and K_2O=10-30 ppm. The nutrient solution was prepared from a fertiliser (Composition: N-NH_4=8%, N-NH_2=2%, P_2O_5=25%, K_2O=20%, SO_3=20%, Zn=4%, Cu=3%, Fe=5%, Fe=5%, Mn=3%, B=1.5% and Mo=0.5%) with a maximum 0.4-0.5% concentration in 100 L. Throughout the experiment, the plants were irrigated every day. The wheatgrass was cut twice. The first cutting was done on March 24, 2014, the second cutting was done on April 5, 2014, for wheatgrass, and on April 14, 2014, for the remaining varieties.

Production of grass juice

The grass juice was obtained by a manual wheatgrass juicer (Healthy Juicer, Lexen, California, USA). The freshly cut grass (200 g) from each cultivar was pressed to extract the juice, which was stored in amber glass bottles at 4 °C in a refrigerator until further use.

Moisture, protein, water soluble material (Brix)

In order to determine the moisture content, the samples of the grass were weighed before and after freeze-drying. The residual moisture was determined by drying at 105 °C overnight for 17 h. The nitrogen content of the samples was estimated by the boric acid method using a Kjeltec Auto 1030 analyser following the protocol suggested by the Association of Official Analytical Chemists (AOAC, 1980). The nitrogen content value was used to calculate the protein content of the samples by multiplying the results with 6.25. The total soluble solids were obtained by placing 2-3 drops of grass juice onto a digital refractometer (Atago™, Japan) calibrated in °Brix, and the means of the two ends were reported as water soluble material expressed as °Brix. All measurements were done in triplicate.

Table 1. Origin and name of the wheatgrass and turfgrass cultivars used of experiment

No	Name	Botanical Name	Cultivar	Company and Origin
CV1	Durum wheat	*T. durum*	'Cesit 1252'	Bahri Dagdas International Agricultural Research Center, Turkey
CV2	Bread wheat	*T. aestivum*	'Dagdas 94'	Bahri Dagdas International Agricultural Research Center, Turkey
CV3	Mix wheat (durum wheat 50% and bread wheat 50%)	*T. durum and T. aestivum*	'Cesit 1252' and 'Dagdas 94'	Bahri Dagdas International Agricultural Research Center, Turkey
CV4	Perennial ryegrass	*L. perenne*	'Apple GL'	Akademi Tohum (importing company) USA
CV5	Perennial ryegrass	*L. perenne*	Local population	Department of Field Crops, Faculty of Agriculture, Selcuk University, Turkey
CV6	Tall fescue	*F. arundinacea*	'Barlexas II'	Akademi Tohum (importing company) Netherlands

Determination of total phenol content in the juices

The total phenol content in the grass juices was determined using the Folin-Ciocalteu method (Singleton *et al.,* 1999). The results were expressed as milligrammes of gallic acid equivalents per litre of the sample (mg GAE/L). The calibration curve was prepared at concentrations ranging between 0 and 1000 (mg GA/L).

Determination of carotenoids

The pre-weighed samples of grass juices (20 mL) were incubated with ethyl acetate (1 mL). The extract obtained was centrifuged at 5000 ×g for about 10 min. The supernatant was separated and absorbance was measured at 400-700 nm by a UV spectrophotometer. The λ_{max} value for chlorophyll a is 662 nm, for chlorophyll b is 646 nm and for total carotene is 470 nm. The amounts of pigments present in the juice samples were calculated according to the formula given by Lichtentaler and Wellburn (Lichtenthaler and Wellburn, 1985):

$C_a = 10.05\ A_{662} - 0.766\ A_{644}$

$C_b = 16.37\ A_{644} - 3.140\ A_{662}$

$C_{x+c} = 1000\ A_{470} - 1.280\ C_a - 56.7\ C_b/230.$

Determination of vitamin C and vitamin E

The dried (vacuum evaporated + nitrogen) grass juice (100 mg) was extracted with 10 mL of 1% metaphosphoric acid for 45 min at room temperature and filtered through Whatman no. 4 filter paper. The filtrate (1 mL) was mixed with 9 mL of 2,6-dichlorophenolindophenol and the absorbance was measured within 30 min at 515 nm against blank. The content of ascorbic acid was calculated by using a standard plot of L-ascorbic acid for a concentration range of 0 to 55 ppm. The assays were carried out in triplicate and the results were expressed as milligrames of ascorbic acid per gramme of extract (mgAA/g) (Klein and Perry, 1982). The quantification of vitamin E was based on the molar absorption coefficient of the phosphomolybdenum complex. The linearity was established by obtaining calibration curves with multiple standards of the appropriate reducing species in parallel with the samples. The standardisation of the estimation of vitamin E in juice samples was based on the analysis of samples spiked with known quantities of γ-tocopherol (Prieto *et al.,* 1999).

The assessment of juice sample colour

A colourimeter (Minolta Chroma meter CR 400, Minolta Co., Osaka, Japan) was used to assess the colour of grass juice samples using the CIELAB colourimetric system. The colourimeter was calibrated against a standard calibration plate of a white surface and set to CIE Standard Illuminant C. To record the CIE (a lab coordinate reading), the instrument probe was immersed into a Petri dish (containing 20 mL of sample) placed on the white tile. The L^*, a^*, b^* values were obtained as an average of ten readings (Criado *et al.,* 2004).

DPPH radical scavenging activity

Five millilitres of 0.1 mM DPPH in methanol were added to 0.1 mL of wheatgrass juice. The tubes were allowed to stand at 27 °C for 20 min. The decrease in absorbance at 517 nm was recorded by a spectrophotometer (Shimadzu UV-Vis 1240). The radical scavenging activity was expressed as inhibition percentage and was calculated using the formula:

Percent radical scavenging activity = $(A_{sample} - A_{control} / A_{control}) \times 100$ (Singh *et al.,* 2002).

Determination of total oil content

The total oil content of grass was determined by the treatment with petroleum ether with a boiling range of between 40-60 °C using the Soxhlet procedure (Barthet *et al.,* 2002).

Flavonoid quantification

The flavonoid content was measured by the colourimetric assay as described by Zhishen (Zhishen *et al.,* 1999). The grass juice (1 mL) was poured into a 10-mL volumetric flask containing 4 mL of distilled water, followed by the immediate addition of 0.3 mL of 5% (w/v) $NaNO_2$, 0.6 mL of 10% (w/v) $AlCl_3$ after 5 min and 2 mL of 1 M NaOH after 6 min. The contents of each flask were then diluted with 2.4 mL of distilled water and mixed. The absorbance of the resulting pink coloured solution was measured at 510 nm against water. The samples were tested in triplicate and flavonoid content was expressed as milligramme catechin equivalents per gramme of sample in dry weight (mgCE/g DW).

Determination of the macro elements

About 0.2 mL of liquid sample or 0.5 g of dried and ground sample was accurately weighed into a container made of perfluoro alkoxy polymer, which was then placed in a microwave pressure vessel. After addition of 4 mL of nitric acid and 0.5 mL of hydrofluoric acid, the samples were digested by using microwave power progressively increasing up to 400W in 40 min. After cooling, the solutions were diluted to 100 mL with water. The concentrations were determined by Inductively Coupled Plasma Atomic Emission Spectrometer (ICP-AES) (Varian-Vista) (Moor *et al.,* 2001).

Sensory evaluation

The hedonic sensory evaluations were carried out to determine consumer acceptability of the tested grass juice samples (Staffolo *et al.,* 2004). Twenty-five untrained panellists involved in the sensory assessment were requested to taste each sample and to rate for its colour, odour and taste using a five-point Likert scale. The scores ranged from 1 = disliked to 5 = liked very much.

Statistical analysis

The results are reported as mean values of the three replicates along with standard deviations. One-way analysis of variance (ANOVA) was used to evaluate the cultivar and cutting time-dependent differences regarding the parameters that were analysed with or without transforming the data. The statistical analyses were carried out using the software SPSS 10.0 for Windows. A significant difference was defined as $P<0.05$. In the case of significance, differences between mean values were evaluated using Duncan's multiple range tests.

Results and Discussion

Dry matter and oil content in grass

The effect of sampling date and fertilisation on the dry matter and oil accumulation in grass shoots is shown in Table

2. The dry matter contents varied from 9.11% to 13.83% in wheatgrass juice and from 10.68% to 17.97% in turfgrass juice samples (Table 2). *L. perenne* contained the highest values of dry matter (average value 14.04%), while mixed *Triticum* wheat had the lowest value of dry matter (11.36%). Oil contents ranged from 1.49% to 1.69% in wheatgrass shoots and from 1.64% to 1.85% in the shoots of turfgrass species. The highest oil percentage was found in the shoots of *L. perenne,* while *T. aestivum L.* showed the lowest oil percentage in shoots. *Triticum* varieties had lower dry matter and oil content in shoots than that of turfgrass cultivars. Oil contents were found to be greater ($P<0.05$) in fertilised and second-cut wheatgrass samples in comparison to those in unfertilised and first-cut samples. The fertilisation had no statistically significant effect on the percentage of oil, while the oil contents after second-cut in the shoots of different cultivars were reduced.

Colour values of grass juice samples

The analysis of colour values showed that the value of lightness factor, L^*, in general, was lower in the juice of turfgrass as compared to the wheatgrass varieties with an exception of *T. durum L.*, as the juice from this variety showed the highest L^* value (30.09) (Table 3). The same trend was observed for a^* values; the juice samples from turfgrass and *T. durum* L. showed lowest a^* values. The b* values of *Triticum* samples were lowest in all the treatments. The juice of *L. perenne* (CV5) exhibited highest b* value, while the mixed *Triticum* juice demonstrated the lowest value of b*. The fertilisation did not exert any significant effect on L^* and a^* values; however, it decreased the b* values of the juice samples. L* and b* values of the juice samples obtained after second-cut were higher than that of the first-cut samples. The second-cut samples of all the species that were used in this study showed low a* values except *Triticum*, which showed high value for the second-cut fertilised samples.

Nutritive and bioactive compounds and macro elements in grass juice samples

Water-soluble dry matter (°Brix), total phenols, flavonoids, protein, DPPH radical scavenging activity and Cu, Fe and P were higher in the wheatgrass juice (Tables 4 and 5) than those were in the turfgrass juice. Chlorophyll concentration was similar in the juices from turfgrass and wheatgrass. Carotenoids, vitamin C, Ca, K, Mg, Mn, Ni and Zn were abundant with highest concentrations in the juice of turfgrass species, with the exception of mixed *Triticum* juice, which contained the same amount of vitamin C as in *L. perenne* (CV5). *T. aestivum L.* juice was richest in terms of °Brix and protein. *T. durum L.* juice contained highest levels of total phenols and DPPH radical scavenging activity but showed the lowest vitamin C level. The highest values of flavonoids, chlorophyll, carotenoids and vitamin C were observed in mixed *Triticum* juice, *L. perenne* (CV4), *F. arundinacea* (CV6) and *L. perenne* (CV5), respectively. On the other hand, °Brix, total phenol, flavonoids and chlorophylls were found to be lowest in the juice of *L. perenne* (CV5). *F. arundinacea* (CV6) had the lowest protein and DPPH radical scavenging activity. Carotenoids did not reach any significant levels in the juice obtained from *T. aestivum L.* An exceptional variation was observed between unfertilised first-cut samples of *Triticum* and turfgrass cultivars. The turfgrass cultivars contained almost half of the amount of phenols than that found in *Triticum* cultivars. However, the disparity found here in the total phenols content among the cultivars was not as substantial as that observed for the level of flavonoids.

Fertilisation led to an increase in °Brix, carotenoids and protein contents of juices, whereas it decreased the total phenols, DPPH, flavonoids, chlorophylls, and vitamin C levels. Ca, Fe, Mg, Mn, Na and Ni levels were observed to be higher in the juice obtained from unfertilised samples as compared to the fertilised samples. The juice of first cut samples had higher values of flavonoids, chlorophylls, carotenoids and proteins than those of second cut samples. The contents of vitamin C, total phenols, DPPH and most of the elements (except Cu, Fe, K and P) were higher in juices from second-cut samples. The different cutting times did not have any statistically significant effect on °Brix values.

Table 2. Dry matter and total lipid content in shoots of wheatgrass and turfgrass cultivars

Parameter	Genotype	With fertiliser		Without fertiliser	
		First cut	Second cut	First cut	Second cut
Oil (%, in drymatter)	*T. durum L.* (CV1)	1.60±0.24^{b}*	1.61±0.30	1.49±0.37 ^{b}	1.58 ±0.26 ^{c}
	T. aestivum L. (CV2)	1.56 ±0.30 ^{b}	1.57±0.28	1.55±0.23 ^{b}	1.59±0.31 ^{b}
	mixed Triticum wheat (CV3)	1.69 ± 0.45 ^{a}	1.68±0.38	1.61±0.32 ^{ab}	1.60 ±0.25 ^{b}
	L. perenne (CV4)	1.82 ±0.49 ^{a}	1.66±0.21	1.82±0.42 ^{a}	1.65± 0.20 ^{ab}
	L. perenne (CV5)	1.75 ±0.40 ^{a}	1.70±0.36	1.85±0.53 ^{a}	1.69 ±0.25 ^{a}
	F. arundinacae (CV6)	1.74±0.37 ^{a}	1.68± 0.29	1.71±0.29 ^{ab}	1.64 ±0.34 ^{b}
Drymatter (%)	*T. durum L.* (CV1)	12.66±1.20 ^{a}	12.78±1.10 ^{cd}	13.62±0.84 ^{a}	13.83±0.74 ^{b}
	T. aestivum L. (CV2)	11.58±1.16 ^{b}	9.11±0.94 ^{e}	13.07±0.85 ^{ab}	13.80±0.80 ^{b}
	mixed Triticum wheat (CV3)	11.47±0.90 ^{b}	11.49±0.89 ^{d}	12.75±0.90 ^{abc}	11.05±0.70 ^{c}
	L. perenne (CV4)	11.47±0.85 ^{b}	16.19±1.23 ^{a}	12.15±0.90 ^{ab}	17.75±1.05 ^{a}
	L. perenne (CV5)	10.68±0.94 ^{b}	13.88±0.90 ^{bc}	12.36±0.82 ^{bc}	16.84±0.83 ^{a}
	F. arundinacae (CV6)	10.91±1.06 ^{b}	15.03±1.00 ^{ab}	11.76±0.75 ^{c}	17.97±0.96 ^{a}

*Mean value ± standard deviation

a, b, c, d, e: Mean values of the same harvest date and the same crop year with a different superscript differ significantly ($P\leq0.05$) [comparison between varieties]

*Comparison between fertiliser applications and cutting date were not shown in table, but related information was given in the text.

Table 3. Color indices of wheatgrass and turfgrass juice samples

Parameter	Genotype	With fertiliser		Without fertiliser	
		First cut	Second cut	First cut	Second cut
L*	*T. durum L.* (CV1)	24.52±0.87*	25.46±1.75 ^{c}	24.41±0.32 ^{b}	27.78 ±0.48 ^{b}
	T. aestivum L. (CV2)	25.83 ±0.79	26.22±0.11 ^{c}	23.12±0.78 ^{c}	27.91±0.70 ^{b}
	mixed Triticum wheat (CV3)	23.45 ± 0.80	24.90±0.26 ^{d}	24.39±1.15 ^{b}	28.23 ±0.25 ^{b}
	L. perenne (CV4)	24.61 ±0.85	28.68±0.92 ^{b}	24.00±0.26 ^{bc}	29.36± 0.54 ^{a}
	L. perenne (CV5)	28.30 ±0.40	28.23±0.13 ^{b}	27.32±0.38 ^{a}	29.42 ±1.07 ^{a}
	F. arundinacae (CV6)	25.54±0.74	30.51± 0.20 ^{a}	23.85±0.36 ^{bc}	30.00 ±0.38 ^{a}
a*	*T. durum L.* (CV1)	-4.45±0.19	-4.18±0.29 ^{b}	-4.30±0.15 a	-4.38±0.14 ^{ab}
	T. aestivum L. (CV2)	-4.03±0.18	-3.45±0.05 ^{a}	-4.40±0.14 ^{a}	-4.65±0.19 ^{bc}
	mixed Triticum wheat (CV3)	-3.82±0.20	-3.66±0.10 ^{a}	-4.71±0.11 ^{ab}	-4.15±0.33 ^{a}
	L. perenne (CV4)	-3.93±0.07	-4.89±0.12 ^{c}	-4.67±0.45 ^{ab}	-4.80±0.14 ^{c}
	L. perenne (CV5)	-5.55±0.07	-5.63±0.11 ^{d}	-4.88±0.30 ^{b}	-5.32±0.12 ^{d}
	F. arundinacae (CV6)	-4.46±0.32	-4.89±0.16 ^{c}	-4.35±0.18 ^{a}	-4.52±0.26 ^{abc}
b*	*T. durum L.* (CV1)	0.35±0.27 ^{c}	1.08±0.27 ^{c}	-0.03±0.12 ^{d}	1.15±0.09 ^{d}
	T. aestivum L. (CV2)	0.37±0.06 ^{c}	0.34±0.06 ^{d}	0.04±0.11 ^{d}	1.33±0.17 ^{d}
	mixed Triticum wheat (CV3)	-0.70±0.16 ^{d}	0.08±0.10 ^{d}	0.46±0.14 ^{c}	1.26±0.30 ^{d}
	L. perenne (CV4)	1.48±0.38 ^{b}	2.67±0.11 ^{b}	1.64±0.35 ^{b}	3.29±0.08 ^{b}
	L. perenne (CV5)	3.22±0.02 ^{a}	3.02±0.20 ^{a}	2.60±0.28 ^{a}	4.07±0.19 ^{a}
	F. arundinacae (CV6)	0.52±0.24 ^{c}	2.50±0.09 ^{b}	0.66±0.25 ^{c}	2.67±0.27 ^{c}

*Mean value±standard deviation
a, b, c, d, e: Mean values of the same harvest date and the same crop year with a different superscript differ significantly (P≤0.05) [comparison between cultivars]
Comparison between fertiliser applications and cutting date were not shown in table, but related information was given in the text.
When a colour is expressed in CIELAB, L* defines lightness, a* denotes the red/green value and b* the yellow/blue value.

The elements found in wheatgrass juice were similar to as reported earlier, such as 230.9 mg of Ca, 229.9 mg of Mg, 720.2 mg of P, 1406.6 mg of K, 98.7 mg of Na and 3.04 mg of Zn in 1 litre of wheatgrass juice (Lai, 1979).

Benincasa *et al.* (2014) reported total phenol content of approximately 800 GAE/g FW in a 12-day old wheatgrass cultivar (*T. durum* cv. 'Creso'), as the highest among some *Triticum* cultivars including *T. spelta*, *T. monococcum*, *T. dicoccum* and *T. aestivum*.

It is presumed that wheatgrass is a rich source of vitamins, antioxidants, and minerals in a biologically available form**.** Wheatgrass contains vitamins C and E, β-carotene, ferulic acid and vanillic acid (Hanninen *et al.,* 1999). Chlorophyll, one of the active components in the wheatgrass extract, was found to be responsible for inhibition of metabolic activation of carcinogens (Lai, 1979). There are various studies that attribute the benefits (mainly anti-cancer effects) of wheatgrass juice to its high chlorophyll content. The beneficial effects of wheatgrass have been confirmed in human subjects after being tested in animal models.

Jangle and Padmanabhan (2016) reported the total phenol, total flavonoids and DPPH radical scavenging activity in wheatgrass juice as 301.74 μg gallic acid eq/g, 10.29 mg rutin eq/g, 12.87% inhibition (for 100 μg/mL), respectively.

Ca and Mg contents (mg/100 mL) and DPPH radical scavenging activity (% inhibition) in wheatgrass juice were reported to be in the range of 130-160, 21.3-36.2 and 89-96%, respectively (Agrawal *et al*., 2015). Our results for total phenol content are consistent with those reported by Jangle and Padmanabhan (2016), while the flavonoids reported in their study were extremely high in comparison to our observations. In a similar vein, the concentrations of elements reported by Agrawal *et al*. (2015) were higher than the values determined in the present study. Regarding the DPPH values, our findings are similar to those reported by Agrawal *et al*. (2015), whereas, the DPPH values of Jangle and Padmanabhan (2016) are incomparable.

There are very few published studies in the literature about the therapeutic effects of wheatgrass juice, and most of the information about composition available on the Internet is not from reliable scientific sources. One of the documents states that it contains 11.96 mg of chlorophylls, 18.60 g of protein, 34.83 mg of vitamin C in 1 litre of wheatgrass juice (Anonymous, 2015).

Sensory analysis

Fig. 1 shows the acceptable categories of sensory properties as a function of frequency, which corresponds to the number of panellists that chose a category over the total number of panellists (Staffolo *et al.,* 2004). The *Triticum* cultivars had the highest scores of colour, odour, and taste attributes, as all of the panellists graded colour, odour and taste of all *Triticum* samples as 5 (like very much). Almost more than 80% of the panellists graded colour and odour as 4 (like) for the juices of *L. perenne* (CV4) and *F. arundinacea* cultivars. The taste scores for *L. perenne* (CV4) cultivar juice mostly were 3 (neither like nor dislike), while *L. perenne* (CV5) and *F. arundinacea* cultivars had 80% of the scores below 2 (do not like).

Conclusions

The present study assessed the potential of turfgrass as an alternative to wheatgrass in obtaining pressed juice. For this, the levels of certain bioactive components in various cultivars at two different cutting times and under variable growth conditions were estimated. The juice of *Triticum* cultivars showed the best water-soluble dry matter, protein, total phenol, flavonoids and vitamin E (especially durum cultivar) contents, but relatively lower levels of oil (in grass), chlorophylls and trace elements in contrast to the turfgrass juices. The application of the fertiliser led to an increase in total carotenoids, water-soluble dry matter, protein, some trace elements (K and Zn) and DPPH radical scavenging activity (except *L. perenne* (CV4)) of juice samples and oil in shoots. The values of vitamin

Table 4. Concentration of some bioactive compounds and DPPH radical scavenging activity of wheatgrass and turfgrass juice samples

Parameter	Genotype	With fertiliser		Without fertiliser	
		First cut	Second cut	First cut	Second cut
Brix (soluble dry matter)	*T. durum L.* (CV1)	9.5±0.3 ^{ab*}	9±0.2 ^{b}	9±0.25 ^{a}	9.5±0.3 ^{a}
	T. aestivum L. (CV2)	10±0.4 ^{a}	10±0.3 ^{a}	9±0.25 ^{a}	9.75±0.25 ^{a}
	mixed Triticum wheat (CV3)	10±0.4 ^{ab}	10.5±0.4 ^{a}	8±0.2 ^{b}	8±0.2 ^{b}
	L. perenne (CV4)	9.5±0.3 ^{ab}	9±0.3 ^{b}	8.5±0.2 ^{b}	8.5±0.2 ^{b}
	L. perenne (CV5)	9±0.25 ^{ab}	9±0.2 ^{b}	9±0.25 ^{a}	8±0.25 ^{b}
	F. arundinacae (CV6)	9±0.25 ^{b}	9±0.25 ^{b}	9±0.25 ^{a}	8.5±0.25 ^{b}
Protein (%)	*T. durum L.* (CV1)	2.9±0.2 ^{ab}	2.7±0.4 ^{b}	2.7±0.3 ^{a}	2.5±0.3 ^{ab}
	T. aestivum L. (CV2)	3.1±0.3 ^{a}	3±0.2 ^{a}	2.8±0.3 ^{a}	2.6±0.2 ^{a}
	mixed Triticum wheat (CV3)	3.3±0.3 ^{a}	3.1±0.3 ^{a}	2.5±0.2 ^{b}	2.4±0.2 ^{abc}
	L. perenne (CV4)	2.5±0.4 ^{c}	2.3±0.2 ^{c}	2.4±0.2 ^{bc}	2.2±0.2 ^{c}
	L. perenne (CV5)	2.8±0.4 ^{b}	2.6±0.2 ^{b}	2.3±0.2 ^{cd}	2.3±0.2 ^{bc}
	F. arundinacae (CV6)	2.4±0.3 ^{c}	2.3±0.2 ^{c}	2.2±0.2 ^{d}	2.3±0.3 ^{bc}
Total phenolics (mg GAE/L)	*T. durum L.* (CV1)	334±42 ^{a}	359±31 ^{a}	443±35 ^{a}	422±45 ^{a}
	T. aestivum L. (CV2)	293±37 ^{bc}	289±24 ^{c}	324±31 ^{b}	342±35 ^{c}
	mixed Triticum wheat (CV3)	335±34 ^{a}	364±43 ^{ab}	346±40 ^{b}	376±35 ^{b}
	L. perenne (CV4)	288±29 ^{c}	299±24 ^{abc}	214±29 ^{c}	398±41 ^{b}
	L. perenne (CV5)	316±33 ^{ab}	321±43 ^{abc}	166±19 ^{d}	347±37 ^{c}
	F. arundinacae (CV6)	286±22 ^{d}	322±45 ^{bc}	191±19 ^{d}	392±32 ^{b}
Total flavonoids (mg/L)	*T. durum L.* (CV1)	447.5±33.4 ^{b}	324.7±30.7 ^{ab}	496.5±38.5 ^{bc}	383.9±39.3 ^{b}
	T. aestivum L. (CV2)	356.2±25.6 ^{b}	302.7±22.8 ^{ab}	598.7±30.2 ^{ab}	568.6±47.4 ^{a}
	mixed Triticum wheat (CV3)	666.2±41.9 ^{a}	399.2±27.8 ^{a}	748.2±44.3 ^{a}	674.8±43.1 ^{a}
	L. perenne (CV4)	175.0±20.4 ^{c}	170.6±12.6 ^{b}	312.3±34.8 ^{cd}	302.6±32.6 ^{b}
	L. perenne (CV5)	139.8±21.3 ^{c}	137.5±21.3 ^{b}	215.6±22.7 ^{d}	300.8±34.0 ^{b}
	F. arundinacae (CV6)	200.6±22.1 ^{c}	173.1±25.9 ^{b}	427.92±30.6^{bcd}	375.3±25.6 ^{b}
Vitamin C (mg/L)	*T. durum L.* (CV1)	33.6±4.3 ^{b}	36.2±4.0 ^{b}	31.9±4.1 ^{d}	36.8±2.9 ^{b}
	T. aestivum L. (CV2)	37.6±5.3 ^{b}	36.4±3.9 ^{b}	38.9±3.5 ^{c}	37.1±4.2 ^{b}
	mixed Triticum wheat (CV3)	48.8±4.2 ^{a}	50.4±4.4 ^{a}	37.6±3.3 ^{c}	32.6±3.3 ^{b}
	L. perenne (CV4)	27.3±3.7 ^{c}	33.5±3.8 ^{b}	45.9±4.5 ^{ab}	52.8±3.5 ^{a}
	L. perenne (CV5)	35.8±3.1 ^{b}	36.2±3.7 ^{b}	46.9±3.8 ^{a}	50.6±4.0 ^{a}
	F. arundinacae (CV6)	33.2±4.0 ^{b}	34.7±3.2 ^{b}	40.2±3.0 ^{bc}	57.3±3.6 ^{a}
Vitamin E (mg/L)	*T. durum L.* (CV1)	18.8±2.5 ^{a}	14.6±1.4 ^{a}	20.3±1.8 ^{a}	16.5±1.4 ^{a}
	T. aestivum L. (CV2)	13.8±1.8 ^{c}	10.2±1.1 ^{c}	16.5±1.3 ^{a}	14.1±1.3 ^{b}
	mixed Triticum wheat (CV3)	16.5±1.6 ^{b}	14.3±1.6 ^{a}	16.8±1.1 ^{a}	14.7±1.3 ^{b}
	L. perenne (CV4)	16.05±2.0 ^{b}	12.2±1.5 ^{b}	15.4±1.0 ^{b}	13.2±0.8 ^{c}
	L. perenne (CV5)	10.5±1.3 ^{d}	10.7±0.9 ^{c}	17.4±1.6 ^{a}	13.9±1.5 ^{b}
	F. arundinacae (CV6)	13.3±1.7 ^{c}	12.8±1.5 ^{b}	16.3±1.5 ^{a}	14.3±0.9 ^{b}
total carotenoids (mg/ 100 mL)	*T. durum L.* (CV1)	3.2±0.5 ^{a}	2.3±0.6	3.2±0.7 ^{ab}	2.5±0.5
	T. aestivum L. (CV2)	2.5±0.4 ^{b}	2.6±0.7	2.9±0.6 ^{b}	2.3±0.3
	mixed Triticum wheat (CV3)	3.6±0.7 ^{a}	2.5±0.5	2.4±0.4 ^{b}	2.1±0.5
	L. perenne (CV4)	3.2±0.6 ^{a}	2.7±0.5	3.3±0.5 ^{ab}	2.7±0.6
	L. perenne (CV5)	3.0±0.4 ^{ab}	3.±0.6	2.2±0.4 ^{b}	2.4±0.4
	F. arundinacae (CV6)	3.2±0.5 ^{a}	2.9±0.4	3.8±0.8 ^{a}	2.9±0.4
Total chlorophylls (mg/100mL)	*T. durum L.* (CV1)	29.6±0.4 ^{b}	25.0±0.5 ^{ab}	33.3±0.6 ^{ab}	28.3±0.4 ^{c}
	T. aestivum L. (CV2)	27.9±0.5 ^{b}	25.5±0.5 ^{b}	27.0±0.4 ^{b}	25.4±0.4 ^{c}
	mixed Triticum wheat (CV3)	42.1±0.8 ^{a}	27.4±0.7 ^{ab}	39.4±0.7 ^{ab}	28.3±0.5 ^{c}
	L. perenne (CV4)	46.2±0.8 ^{a}	37.8±0.4 ^{a}	44.6±0.7 ^{a}	43.3±0.5 ^{ab}
	L. perenne (CV5)	28.6±0.6 ^{b}	27.4±0.6 ^{b}	36.6±0.6 ^{ab}	31.7±0.6 ^{bc}
	F. arundinacae (CV6)	48.8±0.5 ^{a}	38.1±0.4 ^{a}	40.7±0.5 ^{a}	46.8±0.8 ^{a}
DPPH (% inhibition)	*T. durum L.* (CV1)	94.1±9.7 ^{a}	94.4±7.2 ^{a}	92.6±8.5 ^{a}	93.7±10.0 ^{a}
	T. aestivum L. (CV2)	94.4±10.5 ^{a}	90.3±8.3 ^{a}	91.4±8.3 ^{a}	93.5±8.6 ^{ab}
	mixed Triticum wheat (CV3)	93.6±9.0 ^{a}	94.4±10.4 ^{a}	93.5±7.7 ^{a}	91.7±7.5 ^{c}
	L. perenne (CV4)	74.5±8.3 ^{b}	62.4±9.1 ^{b}	92.8±5.8 ^{a}	93.1±9.0 ^{ab}
	L. perenne (CV5)	92.2±11.4 ^{a}	92.5±7.5 ^{a}	90.9±8.0 ^{b}	91.8±8.4 ^{ab}
	F. arundinacae (CV6)	93.7±8.5 ^{a}	92.8±10.2 ^{a}	85.2±7.4 ^{c}	92.2±8.3 ^{b}

*Mean value±standard deviation

a, b, c, d, e: Mean values of the same harvest date and the same crop year with a different superscript differ significantly (P≤0.05) [comparison between cultivars]

*Comparison between fertiliser applications and cutting time were not shown in table, but related information was given in the text.

Table 5. Main elements in wheatgrass and turfgrass juice samples (mg/L)

Parameter	Genotype	With fertiliser		Without fertiliser	
		First cut	Second cut	First cut	Second cut
Ca	*T. durum L.* (CV1)	86.6±7.2 [b]	148.7±22.3 [d]	114.3±22.6 [e]	714.9 ±65.2 [b]
	T. aestivum L. (CV2)	39.2 ±5.3 [c]	145.5±28.0 [d]	33.8±5.8 [f]	412.3±34.3 [c]
	mixed Triticum wheat (CV3)	54.9 ± 4.4 [c]	125.6±35.6 [d]	217.9±30.3 [d]	519.5 ±50.5 [bc]
	L. perenne (CV4)	309.3 ±49.0 [a]	867.1±74.2 [a]	535.8±42.2 [c]	1306.9±148.5 [a]
	L. perenne (CV5)	145.3 ±20.4 [ab]	640.6±62.3 [b]	695.7±53.4 [b]	1199.4 ±126.4 [a]
	F. arundinacae (CV6)	159.9±22.7 [ab]	387.8± 42.7 [c]	832.3±51.8 [a]	1245.5 ±113.1 [a]
Fe	*T. durum L.* (CV1)	0.31±0.10 [c]	0.22±0.09 [bc]	0.50±0.08 [b]	0.69±0.11 b
	T. aestivum L. (CV2)	0.59±0.16 [ab]	0.14±0.05 [c]	1.02±0.18 [a]	0.24±0.05 [cd]
	mixed Triticum wheat (CV3)	0.45±0.19 [b]	0.16±0.08 [bc]	0.46±0.05 [c]	0.87±0.17 [a]
	L. perenne (CV4)	0.56±0.5 [b]	0.41±0.06 [a]	0.09±0.03 [d]	0.16±0.03 [d]
	L. perenne (CV5)	0.72±0.14 [a]	0.31±0.06 [b]	0.26±0.08 [c]	0.30±0.03 [c]
	F. arundinacae (CV6)	0.21±0.16 [c]	0.14±0.05 [bc]	0.28±0.05 [c]	0.23±0.06 [cd]
K	*T. durum L.* (CV1)	3373.0±115.4 [a]	2491.6±187.6 [c]	2421.5±203.5[c]	1978.0±105.3 [b]
	T. aestivum L. (CV2)	3383.4±120.7 [a]	2498.8±205.2 [c]	2943.1±187.9[b]	1924.1±118.0 [b]
	mixed Triticum wheat (CV3)	2828.6±247.2 [b]	1631.9±193.7 [d]	2246.3±240.3[cd]	2074.3±153.0 [b]
	L. perenne (CV4)	3430.9±188.6 [a]	4272.3±268.3 [a]	4313.9±166.2[a]	3624.0±248.8 [a]
	L. perenne (CV5)	3267.4±253.2 [ab]	3703.0±166.3 [b]	2959.8±215.1[b]	3486.3±237.9 [a]
	F. arundinacae (CV6)	3375.4±171.5 [a]	3932.3±234.0 [b]	2995.3±198.7[b]	3619.5±194.5 [a]
Mg	*T. durum L.* (CV1)	91.2±36.5 [b]	211.3±35.9 [b]	100.2±17.6[d]	228.4±24.7 [b]
	T. aestivum L. (CV2)	133.9±25.2 [ab]	210.3±28.3 [b]	153.0±1.3[c]	234.9±21.5 [ab]
	mixed Triticum wheat (CV3)	132.6±26.8 [ab]	183.1±37.1 [c]	146.5±22.4[c]	274.5±32.4 [ab]
	L. perenne (CV4)	130.3±30.1 [ab]	257.6±41.8 [ab]	183.5±32.7[b]	277.9±26.2 [ab]
	L. perenne (CV5)	147.3±29.7 [ab]	253.6±39.5 [ab]	188.3±29.1[b]	267.2±33.2 [ab]
	F. arundinacae (CV6)	140.8±18.4 [a]	270.5±24.0 [a]	257.6±37.2[a]	287.4±24.8 [a]
Na	*T. durum L.* (CV1)	279.1±29.3 [b]	807.1±63.4 [a]	458.0±37.7[c]	709.5±53.0 [b]
	T. aestivum L. (CV2)	68.3±14.0 [e]	187.3±25.6 [c]	130.6±21.5[d]	156.0±29.1 [c]
	mixed Triticum wheat (CV3)	115.3±16.5 [d]	350.1±44.7 [b]	200.5±28.1[d]	738.0±52.3 [b]
	L. perenne (CV4)	322.8±27.9 [a]	761.7±46.3 [a]	603.5±48.9[a]	1098.2±124.4 [a]
	L. perenne (CV5)	237.3±20.7 [c]	687.2±37.9 [a]	659.9±34.9[a]	953.5±117.8 [a]
	F. arundinacae (CV6)	121.6±22.3 [d]	205.2±32.2 [c]	529.5±46.6[b]	690.3±68.3 [b]
P	*T. durum L.*	1371.0±184.2 [a]	380.1±31.2 [bc]	563.8±29.8[b]	265.3±20.1[c] c
	T. aestivum L.	1216.9±137.8 [a]	402.3±34.0 [b]	767.8±33.2[a]	84.1±14.5 [e]
	mixed Triticum wheat	997.9±72.1 [b]	511.4±82.4 [a]	606.0±19.9[b]	183.2±21.4[d]
	L. perenne Apple	293.6±37.9 [c]	292.0±41.1 [d]	168.7±27.5[d]	434.8±36.8[a]
	L. perenne local	354.3±41.6 [c]	312.8±34.3 [c]	214.6±33.4[c]	385.9±35.2[a]
	F. arundinacae B 1	123.9±27.2 [c]	266.3±15.5 [d]	196.5±18.7[cd]	329.9±30.9[b] b
S	*T. durum L.* (CV1)	353.5±41.8 [c]	525.6±34.7 [d]	257.6±22.6[e]	474.4±35.8 [c]
	T. aestivum L. (CV2)	355.4±37.9 [d]	548.6±24.6 [cd]	279.1±29.6[d]	308.5±26.1 [f]
	mixed Triticum wheat (CV3)	252.7±31.3 [d]	597.2±48.7 [c]	221.9±26.7[e]	585.2±45.0 [d]
	L. perenne (CV4)	705.3±54.9 [a]	849.4±37.5 [a]	433.9±31.5[c]	996.1±46.2 [a]
	L. perenne (CV5)	509.9±37.4 [b]	727.7±32.2 [b]	613.0±52.8[a]	911.5±59.3 [b]
	F. arundinacae (CV6)	452.2±36.6 [b]	823.1±49.5 [a]	533.2±30.7[b]	745.9±33.7 [c]
Zn	*T. durum L.* (CV1)	0.81±0.12 [c]	1.52±0.41 [c]	0.59±0.10[e]	0.98±0.16 [b]
	T. aestivum L. (CV2)	0.64±0.20 [c]	0.95±0.25 [c]	0.92±0.22[d]	0.43±0.08 [b]
	mixed Triticum wheat (CV3)	0.66±0.18 [c]	1.24±0.20 [c]	0.67±0.15d[e]	0.69±0.17 [b]
	L. perenne (CV4)	7.16±1.63 [b]	11.12±2.13 [b]	2.05±0.64[c]	5.04±0.84 [a]
	L. perenne (CV5)	6.72±1.24 [b]	9.65±1.52 [b]	3.15±1.05[b]	5.36±0.76 [a]
	F. arundinacae (CV6)	9.02±1.30 [a]	17.24±3.20 [a]	3.62±0.81[a]	5.41±0.59 [a]

*Mean value±standard deviation
a, b, c, d, e : Mean values of the same harvest date and the same crop year with a different superscript differ significantly (P≤0.05) [comparison between cultivars]
*Comparison between fertiliser applications and cutting date were not shown in table, but related information was given in the text.

E, total flavonoids, phenol (*Triticum* cultivars), chlorophyll (except *T. aestivum*), Ca and Na and colour indices were significantly decreased due to fertilisation. The second-cut samples showed higher levels of dry matter (turfgrass cultivars), phenol and some elements (Na, Ca, Mg, S, Zn), and lower levels of oil (turfgrass cultivars), protein, chlorophyll and carotenoid pigments and flavonoids. The pressing of turfgrass did not encounter any difficulties. Moreover, these varieties have advantages over the *Triticum* cultivars, in terms of having higher concentrations of vitamin C (unfertilised samples) and major elements Ca, K, Na, S and Zn as well as being perennial. The sensory analysis results suggested the potential use of *L. perenne* (CV4) cultivar in pressed grass juice; however, the low levels of protein, vitamin E, carotenoids and DPPH radical scavenging activity in these cultivars might be regarded as the disadvantages. The results of our study indicate that wheatgrass

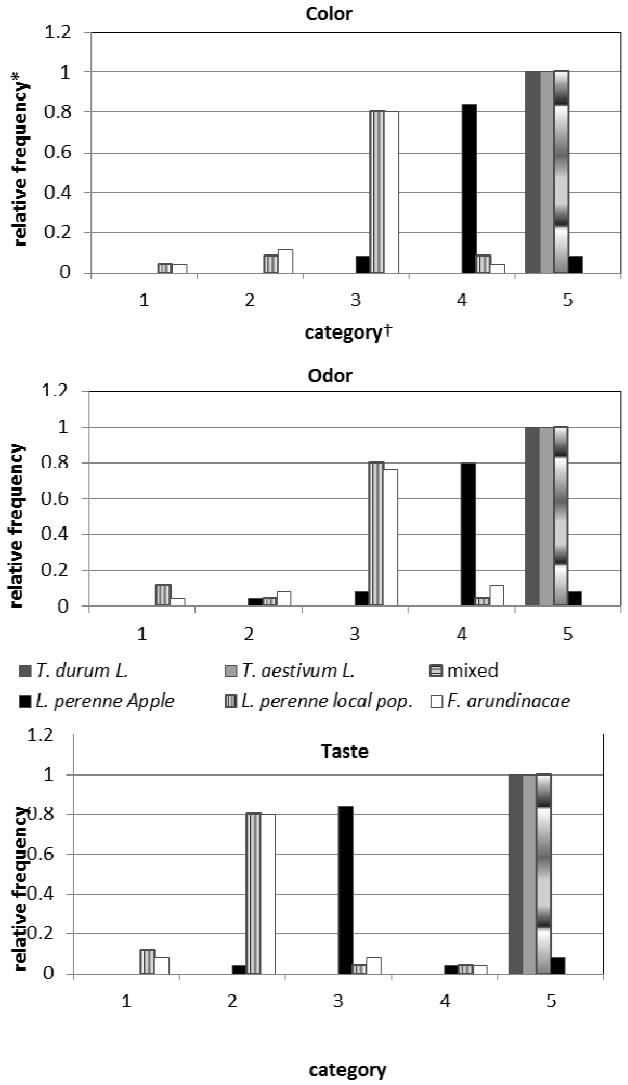

Fig. 1. Results of sensory analysis using a hedonic scale for wheatgrass and turfgrass juice samples

*Relative frequency: number of panelists that choose a category/total number of panelists (25). †Category: 1-dislike; 2-do not like; 3-neither like nor dislike; 4-like; 5-like very much.

and turfgrass cultivars may be selected for the production of pressed juices owing to their optimal contents of biologically active compounds.

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