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Phytochemical Composition of Selected Apple Lines for Processing

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Introduction

Intense interest in fruit has increased recently because of their potential for high antioxidant activity. Antioxidants help to neutralise free radicals, which are unstable molecules that are linked to the development of a number of degenerative diseases and conditions including cancer, cardiovascular disease, cognitive impairment, immune dysfunction, cataracts and macular degeneration (Van der Sluis et al. 2002; Folts 2002). Among the phytochemicals, phenols, have received a great deal of attention because of their antioxidant activity. Significant amounts of phenolic compounds frequently occur in foods and they importantly attribute to the sensory qualities (colour, flavour, taste) of fresh fruits, vegetables and their products (Van der Sluis et al. 2002). In addition, many phenolic phytochemicals have antioxidative, anticarcinogenic, antimicrobial, antiallergic, antimutagenic and anti-inflammatory activities (Kim et al. 2000).

The objectives of the present work are to quantify individual phenolic compounds of selected advanced apple lines and to quantify their total phenolic content and antioxidant activities compared to known cultivars. The future goal is to determine the effect of these chemical compositions on processing including the selection of lines for fresh cut apple (e.g. non browning apple for apple slice), cider, juice (e.g. non browning juice) and production of ice cider.

Materials and methods

The nineteen apple genotypes were collected at their commercial maturity during 2003 harvest season at the Agriculture and Agri-Food Canada experimental station, Quebec. Fruit samples, 2 batches of 10 apples per genotype were randomly selected, peeled, cored, cut into small pieces, frozen immediately in liquid nitrogen, and stored at -80 ° C until analysis. Ten grams (10 g) of frozen peel and flesh of each apple genotype were pooled separately, ground in liquid nitrogen and used for polyphenol analysis using HPLC, total phenolic content (TPC) by Folin-Ciocalteu method, and antioxidant capacity using ferric reducing antioxidant power (FRAP) as drescribed previousely (Khanizadeh et al. 2007; Tsao et al. 2005).

Conclusion

In general, apple peels possess a much higher contents than the flesh. Fourteen individual phenolics compounds were found in the apples studied, among which procyanidins were the most predominant group in both flesh and peel. Epicatechin and procyanidin B2 were the most abundant in the peel and chlorogenic acid was the most abundant in the flesh. Quercetin-3-rhaminoside was the only flavonols compounds found in the flesh whereas in the peel three others were also found. Among the dihydrochalcones compounds, phloridzin were detected in both flesh and peel, whereas phloretin-3-xyloglucoside was only found in flesh tissues. Cyanidin-3-galactoside was unique to and found only in red apple. These results clearly show that apples are an excellent source of phenolics and the antioxidant capacity, as well as the total phenolic contents and its compounds, varied significantly among the genotypes.

The variability of antioxidant capacity and phenolic compound in different lines can be used as a marker to breed specific apple for processing and or fresh market as reported previously (Tsao, et al. 2006; Khanizadeh et al. 2006)

Results and Discussion

Fourteen polyphenolic compounds belonging to five major polyphenolic groups were identified from the nineteen selected advanced apple lines and standard cultivars. They are chlorogenic acid, neochlorogenic acid and *p*-coumaroylquinic acid (hydroxycinnamic acids); catechin, epicatechin, procyanidins B1 and B2 (procyanidins); quercitin 3-galactoside, -xyloside, -arabinoside and -3-rhaminoside (flavonols); phloridzin and phloretin-3-xyloglucoside (dihydrochalcones) and cyanidin-3-galactoside (cyanidins). Mean total phenolic concentrations (TPI, total phenolic index measured by HPLC) of the peel was more than 2-fold greater compared to that of the flesh, with 'Floribunda Rosea' and 'Eden' a new release from Agriculture and Agri-Food Canada Research center (Khanizadeh et al. 2006) having the highest and the lowest TPI in both flesh and peel, respectively.

Among the five groups, procyanidins were the most predominant phenolic group and contributed to 49.7 and 48.7% of the TPI of flesh and peel, respectively. The total procyanidins ranged from 93.9 to 3989.7 µg g-1 in the peel and from 0 to 1928.5 µg g-1 in the flesh.

'Floribunda Rosea' had the highest total procyanidins concentrations, whereas 'Eden' had the lowest in both peel and flesh. 'Eden' was also the only apple selection that contained no measured procyanidins in its flesh.

In addition, only in certain apple genotypes ('Floribunda Rosea', 'Macspur' and 'Mcl. Summerland'), procyanidin B1 were detectable in the flesh. In all genotypes, epicatechin and procyanidin B2 (14.4%) were the most abundant phenolics compounds in the peel.

Hydroxycinnamic acids were the second highest group in the flesh in abundance with 44.0% of total phenolics, ranging from 37.0 to 1607.5 µg g-1. In the peel, hydroxy-cinnamic acids accounted for only 11.8 % and ranged from 33.4 to 831.3 µg g-1. 'Floribunda Rosea' present the richest composition in the flesh and the peel. Three hydroxycinnamic acids compounds were found in these apple genotypes, and their concentrations generally followed the order of chlorogenic acid (35.4% of TPI in the flesh and 8.6% of TPI in the peel), *p*-coumaroylquinic acid (5.9 and 1.5%) and neochlorogenic acid (2.7% and 0.9%). In all genotypes, chlorogenic acid was the most abundant phenolics compounds in the flesh (35.4%), ranging from 15.6 µg g-1 ('Eden') to 1374.7 µg g-1 ('Floribunda Rosea'). Flavonols represent the second highest group in concentration of apple peel with 21.7% of TPI. The values of total flavonols in the peel varied between 90.6 and 487.6 µg g-1, with 'Primevert CBR4T29' and 'Reinette Russet' showing the highest and lowest concentrations, respectively. The dominating flavonols in the peel were quercetin 3-galactoside (5.8%), but considerate amounts of quercetin 3-rhamnoside (2.7%), quercetin 3-arabinoside (2.5%), and quercetin 3-xyloside (2.3%) were also present. Quercetin 3-rhamnoside, the single detected compound of the flavonols class in the flesh, was below the detection in some genotypes ('Cortland', 'Mcl. Summerland' and 'Spartan'). Dihydrochalcones were found in only minor amounts, which consisted of 12.0% and 5.4% of TPI in the peel and the flesh, respectively. In all genotypes, the amount of total dihydrochalcones varied between 10.5 and 113.1 µg g-1 in the flesh and between 45.5 and 1286.7 µg g-1 in the peel. 'Floribunda Rosea' and 'Reinette Russet' had the highest dihydrochalcones in the flesh and peel, respectively. The lowest dihydro-chalcones was for 'SJCA16R5A15' in both flesh and peel. Phloretin-3-xyloglucoside and phloridzin were both found in flesh tissues, whereas in the peel, phloridzin and phloretin derivatives were detected. Cyanidins were almost exclusively found in the peel and represented less than 6% of TPI. 'Floribunda Rosea' was the only genotype that contained detectable Cyanidins in the flesh. Cyanidins content in the peel ranged from 0 to 280.0 µg g-1 and the highest concentration being observed for 'SJC649' cultivar.

'Floribunda Rosea' had the highest TPC, whereas 'Eden' had the lowest TPC with less than 300 µg g-1. The remaining genotypes were intermediate with TPC varying between 458.1 and 1147.6 µg g-1. In the flesh, the TPCs ranged between 45.5 to 4426.4 µg g-1, with the highest amounts being recorded in 'Floribunda Rosea' and the lowest amount being measured in 'Eden'. Great differences among genotypes were found in their antioxidant capacity of the apple genotypes expressed as FRAP (µg g-1). The ferric reducing ability of the peels was greater than that of the flesh for all genotypes. 'Floribunda Rosea' peel showed the greatest antioxidant capacity, with 6680.9 µg g-1; compared with 'Eden' (517.1 µg g-1). In the flesh, the greatest antioxidant capacity were also found for 'Floribunda Rosea', with a FRAP value of 729.1 µg g-1, while 'Eden' had the lowest activity with 102.9 µg g-1.

Total phenolic content and antioxidant capacity (FRAP) of 19 advanced apples lines and cultivars.

Genotype	Total phenolic content[a] (µg/g)		FRAP - AAE[b] (µg/g)	
	Flesh	Peel	Flesh	Peel
Cortland	76.2	695.7	322.3	1158.7
Eden	45.5	228.2	102.9	517.1
Elstar	162.0	719.8	295.1	999.6
Florib. Rosea	4426.4	12358.7	729.1	6680.9
Gala	155.2	881.0	355.3	1299.9
Golden Delicious	147.5	737.3	385.6	1250.0
GoldRush	178.2	1029.4	415.3	1700.8
Macspur	181.7	671.7	333.6	778.6
Summerland	197.1	688.6	411.2	1235.3
Paula Red	213.2	497.1	444.9	1209.5
Primevert	175.4	1147.6	388.8	1869.5
Reinette Russet	381.6	1092.7	592.3	1535.8
SJC649	107.5	881.0	358.4	1589.6
SJC7123-1	136.7	472.1	354.3	1033.5
SJC7713-1	164.3	869.9	374.2	1294.2
SJC8234-1	188.6	806.9	542.6	1536.6
SJCA16R5A15	96.7	487.2	326.5	979.7
Spartan	153.4	585.4	398.0	898.7
SuperMac	102.9	458.1	267.6	723.4
$LSD_{0.05}$	69.0	280.4	47.8	406.5

Values are means of 4 replicates.

[a] Total phenols expressed as µg gallic acid equivalent (GAE) per gram fresh-frozen weight.

[b] FRAP: Ferric-Reducing Antioxidant Power expressed as µg ascorbic acid equivalent per gram fresh-frozen weight.

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