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Chemical composition of French and Polish cloudy apple juices

By J. MARKOWSKI[1*], A. BARON[2], M. MIESZCZAKOWSKA[1] and W. PŁOCHARSKI[1]
[1]Research Institute of Pomology and Floriculture, Pomologiczna 18, 96-100 Skierniewice, Poland
[2]INRA, UR 117, Unité de Recherches Cidricoles, Biotransformation des Fruits et Legumes, F-35000 Rennes, France.
(e-mail: jmarkow@insad.pl) *(Accepted 31 August 2009)*

SUMMARY
Cloudy juices from six apple cultivars from Poland ('Ariwa', 'Gold Milenium', 'Florina', 'Melfree', 'Novamac', and 'Rajka') and four French cultivars ('Ariane', 'Chanteline', 'Judeline', and 'Judor') were produced and chemically characterised. The analyses encompassed 23 chemical parameters and phenolics profiles. The most important parameter, differentiating cloudy juice from clear juice, was turbidity. Cloudy juices were characterised by having an average total turbidity of 1,210 Nephelometric Turbidity Units (NTU) and a stability of turbidity of 42%. Some of the results deviated from the accepted ranges given in reference values for apple juices in the Code of Practice of the European Fruit Juice Association. This occurred in the cases of simple sugars and saccharose contents of the Polish apple juices (e.g., up to 56.9 mg l^{-1} of saccharose *vs.* a maximum value of 30 mg l^{-1}), and for some mineral compounds in the French apple juices (e.g., sodium values up to 10 mg l^{-1}). Large variations were found in case of important health-conferring components. Water-soluble pectin contents varied from 205 mg l^{-1} for 'Chanteline', to 1,289 mg l^{-1} for 'Gold Milenium'; while, in the case of phenolic compounds, the range was from 85.7 mg l^{-1} for 'Novamac', to 524.8 mg l^{-1} for 'Melfree'.

Two major problems in modern societies are cardiovascular diseases (CVD) and cancer. An increased consumption of fruits and vegetables may help to reduce the risk of CVD (Bazzano *et al*., 2003; Boyer and Liu, 2004) and some types of cancers (Knekt *et al*., 2002; Lambert *et al*., 2005; Barth *et al*., 2005). However, the data on cancer hazards and fruit and vegetable consumption are still ambiguous (Williamson and Manach, 2005).

Consumption of fresh fruit is often replaced by the intake of fruit juices, due to their convenience and ability to quench thirst. According to EU Regulation 1924/2006, it is expected that fresh fruits will be exempt from health and nutritional claims, it is therefore important to evaluate their chemical composition and biological value.

In Europe, apple juice is a highly-consumed product, in second place after orange juice (Kay-Shuttleworth, 2008). Among the most important constituents of apple juice are polyphenolics that have the ability to increase its anti-oxidant potential. Polyphenolics also affect lipid methabolism (Akazone, 2004) and the absorption of cholesterol (Aprikian *et al*., 2001). Some authors have suggested that apple juice can reduce some forms of cancer (Barth *et al*., 2005); however, such an effect was only found for cloudy apple juice.

Most apple juice is still consumed as clear juice, which is characterised by having a low phenolics content (Markowski and Płocharski, 2005) due to the clarification process which leads to dramatic changes in the profile of phenolic compounds compared to whole fruit (Dietrich, 2004; Hubert *et al*., 2007). Clear juice is also deprived of pectins. As a form of soluble fibre, pectic substances may play an important role in the prevention of obesity, arteriosclerosis (Gallisteo *et al*., 2008), and diabetes (Giacco *et al*., 2002). Current research has shown some advantages of consuming cloudy apple juice compared to clear juice (Barth *et al*., 2005; Markowski *et al*., 2007; Oszmiański *et al*., 2007), indicating that this product may be more beneficial to human health than clear apple juice.

Cloudy juice processing technology affects the quality of the final product (Cliff *et al*., 1991). Juices produced by simple pressing contain low amounts of phenolic compounds (van der Sluis *et al*., 2002), whereas the addition of ascorbic acid prevents their oxidation (Markowski, 1998). To obtain high quality, cloudy juice, it is important to restrict the oxidation of phenolic compounds by the enzyme, polyphenol oxidase. This may be done by excluding air during grinding and pressing (Hamatschek and Pecoroni, 1998), or by the addition of ascorbic acid (Welter *et al*., 1991). Special modifications of the processing equipment (e.g., grinders, Bucher presses, decanters) should be made to process the product under an inert (N2) atmosphere.

The quality of cloudy juice depends strongly on the apple cultivar used for processing (Cliff and Dever, 1990; Eisele and Drake, 2005) as phenolic compounds contents may vary over a wide range (Podsędek *et al*., 2000; Guyot *et al*., 2003). Some apple cultivars introduced to orchards are scab-resistant (Czynczyk *et al*., 2005) and require a reduced number of sprays during fruit growth, thereby decreasing production costs and pesticide residues in the fruit and fruit products. Some of these cultivars may be suitable for apple juice production; however, it is important to evaluate the quality of the cloudy juice produced, in order to meet customer expectations. Moreover, an important question is the effect of fruit

*Author for correspondence.

cultivar and source on juice quality, as these may affect the composition of the juice. Juice composition can easily be analysed using novel laboratory methods (Rossman, 2006). Thus the aim of these experiments was to compare the quality of cloudy apple juices from many different cultivars produced in France and in Poland using comparable technology in order to evaluate the nutritional value of each juice.

MATERIALS AND METHODS

Juice production

Production of all cloudy apple juices took place in Poland, at the Department of Storage and Processing, Research Institute of Pomology and Floriculture (Skierniewice), and in France at the Unité de Recherches Cidricoles, Biotransformation des Fruits et Légumes, INRA (Rennes). In Poland six scab-resistant apple cultivars were chosen for processing: 'Ariwa', 'Gold Milenium', 'Florina', 'Melfree', 'Novamac' and 'Rajka'. Selection of these apple cultivars in Poland was based on the results of previous laboratory tests in which 28 scab-resistant apple cultivars were processed into juice on a small scale. These juices were then evaluated on the basis of their soluble solids content (SSC), titratable acidity (TA), and sensory scores. Juice production from the six most promising cultivars was then conducted at a larger scale. In France, juices from four scab-resistant cultivars ('Ariane', 'Chanteline', 'Judeline', and 'Judor') were produced. 'Ariane' is a recent apple selection by INRA, with a major gene for scab-resistance and a high sensory quality of fruit. 'Chanteline', 'Judor', and 'Judeline' were selected for their high quality juices, with a good balance between total sugar content and TA.

A common production protocol was established (Figure 1) with only one deviation resulting from differences in the fruit processing facilities in Poland and France. Juices produced in Poland were centrifuged using a continuous-flow, disk-stack centrifuge at 1,500 rpm (377 × *g;* LAB 102B-25, Alfa Laval, Brentford, UK), while juices produced in France were simply decanted after storage at 10°C for 12 h. All juices were hot-filled into 0.35 l bottles at 96° – 98°C and cooled down to ambient temperature with tap water, 10 min after bottling.

Juice analyses

Most of the methods used for the determination of juice compositions (IFU) were as described in detail in the International Federation of Fruit Juice Producers (IFFJP) Manual, (http://www.ifu-fruitjuice.com/). In cases of differences in equipment, or in the application of different methods, details are given below.

Relative density (IFU 1) was determined using a DE 50 density meter (Mettler-Toledo). The results were expressed as the ratio of sample density to the density of water at 20°C. Soluble solids contents (SSC) were determined by the indirect refractometric method (IFU 8) using a RE 50 refractometer (Mettler-Toledo, Tokyo, Japan). The results were expressed as percentages. Titratable acidity (IFU 3) was determined by titration with an automatic titration unit (DL 58; Mettler-Toledo, Greifensee, Switzerland). The results were expressed as anhydrous citric acid equivalents, in g l^{-1} juice.

Turbidity was determined using a HACH turbidimeter (Hach Company, Loveland, CO, USA). Stable turbidity, and the stability of turbidity, were determined according to Stähle-Hamatschek and Gierschner (1989) after the juices had been centrifuged at 4,200 × *g* for 15 min at room temperature.

Organic acids contents (malic and citric acid) were determined by reversed-phase HPLC on an HP 1100 system (Hewlett-Packard, Waldbronn, Germany) equipped with a Diode Array Detector (DAD) using two Supelco LC-18 columns (25 cm x 4.6 mm) with a particle size of 5 µm. A 1% (v/v) water solution of KH_2PO_4 buffer at pH 2.5 was used as the mobile phase. The column temperature was kept at 30°C with a flow rate of 0.8 ml min^{-1}. Detection of organic acids was by absorbance at 210 nm, with a bandwidth 6 nm. The results were expressed in g l^{-1} or mg l^{-1}. Ascorbic acid (AA) contents were determined under identical conditions to those used for organic acids. Samples for AA determinations were dissolved in 6% (w/v) HPO4. Detection of AA was at 244 nm, with a bandwidth of 6 nm.

Saccharose, simple sugars, and sorbitol contents were determined with a modification of the EN 12630 method using an Agilent HPLC Model HP 1100 (Hewlett-Packard) equipped with an RI detector. Before injection into the analytical column (HPX 87C; 300 mm × 5 mm; particle size 5 µm; Bio-Rad, Reinach, Switzerland), samples were purified on a 0.8 cm × 4 cm PolyPrep column (Bio Rad, Hercules CA, USA) containing AG-1 X8 anion exchange resin. Results were expressed in g l^{-1}.

Formol index number (IFU 30) was determined using a DL 58 titrator (Mettler-Toledo, Greifensee, Switzerland). The results were expressed in ml 0.1M NaOH 100 ml^{-1} juice.

Potassium (K), calcium (Ca), magnesium (Mg), sodium (Na), and phosphorus (P) levels were determined using ICP methods after mineralisation in a microwave oven. All results were expressed in mg l^{-1} juice.

Sugar-free extract was determined according to the instructions in the Code of Practice (AIJN, 2007) by subtraction of the sum of the glucose, fructose, and saccharose contents from the SSC. The results were expressed in g l^{-1} juice.

Phenolics determinations were carried out on an HPLC (HP 1100; Hewlett-Packard) system equipped with a DAD detector. Samples of cloudy apple juices

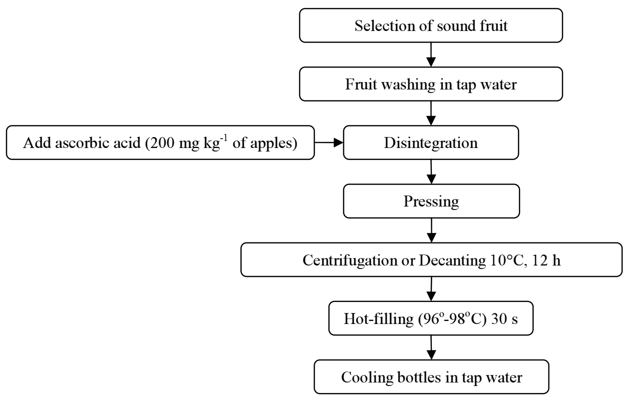

FIG. 1
Flowchart of the technology for cloudy apple juice production. Details are given in the text.

were extracted with 70% (v/v) methanol in an ultrasonic water bath (Model 6CT, Warsaw, Poland) for 10 min, then filtered. This treatment was omitted for samples of clear apple juice. Before HPLC analysis, all samples were diluted 1:3 (v/v) with sodium acetate buffer (solvent A). Phenolics were determined by a modified version of the HPLC method of Tsao and Yang (2003) using a Phenomenex® Fusion RP column (250 mm × 4.6 mm; particle size 4 µm) with a guard column. The mobile phase consisted of 10.2% (v/v) acetic acid in 2 mM sodium acetate (solvent A) and acetonitrile (solvent B). The flow rate was kept constant at 0.5 ml min^{-1} for a total run time of 73 min at 25°C. The system was run with a gradient programme: 3% (v/v) B (0 – 20 min); 3 – 17% (v/v) B (20 min); 17 – 40% (v/v) B (25 min); 40 – 90% (v/v) B (3 min); 90 – 90% (v/v) B (4 min); and 90 – 0% (v/v) B (1 min).

RESULTS AND DISCUSSION

All analytical data from the French and Polish apple juices are summarised in Table I. The average SSC of all juices investigated was close to 13.5%. Similar values were observed for the French (13.4%) and Polish (13.6%) juices. The range of SSC values in the Polish juices was larger than in the French juices. The minimum SSC value was found in 'Novamac' (11.6%), whereas the highest was in 'Rajka' (17.0%). Results for the relative densities of juices showed a similar pattern to the SSC, due to the strong correlation between these characteristics (R^2 = 0.83). The average relative density of all juices was 1.055. Values for the French and Polish juices were 1.055 and 1.056, respectively. All these data fulfilled the minimum requirements for authentic apple juices given in the AIJN Code of Practice, Section A – Absolute Quality Requirements (AIJN, 2007).

In the case of TA, the average value was 5.2 g l^{-1}. French juices were characterised by a higher mean TA compared to Polish juices; 6.2 *vs*. 4.6 g l^{-1}, respectively. This could be due to cultivar characteristics. The highest TA (7.3 g l^{-1}) was found for juice from 'Judor', while in 'Gold Milenium' the TA was only 2.7 g l^{-1}.

The turbidity of apple juices ranged from 298 NTU in juice from 'Ariane', to 3,309 NTU in juice from 'Gold Milenium'. These results indicate that the 'Gold Milenium' fruit might have been over-ripe, and that processing occurred too late. This may be confirmed by the low TA of this juice, which was below 3.0 g l^{-1}, the minimum value accepted for natural apple juice (AIJN, 2007). After excluding this cultivar from our comparisons, the average total turbidity was 446 NTU for the French juices, and 1,402 for the Polish juices. This could be an effect of the different juice processing technologies used (centrifugation *vs*. decanting). In all cases, juice turbidity values fulfilled the requirements given by Dietrich *et al*. (1996) for cloudy apple juices (i.e., ≥ 250 NTU).

Stable turbidity represents the amount of turbidity that remains unsettled after 1 year in storage at 20°C (Stähle-Hamatschek and Gierschner, 1989). These mean values were much higher in the Polish juices than in the French juices (at 550 and 220 NTU, respectively). The stability of turbidity (i.e., the percentage of settled total turbidity) was more directly comparable, with average values of 38% for the Polish and 48% for the French juices. Very high stabilities of turbidity were found for 'Judeline', 'Judor', and 'Rajka' juices. Water-soluble pectins are the main constituents that contribute to turbidity, thus their contents were correlated with both the total (R^2 = 0.685) and stable (R^2 = 0.764) turbidity values of the cloudy juices. The average pectins content was 673 mg l^{-1}. The highest content of pectins (1,284 mg l^{-1}) was found in juice from 'Gold Milenium'. The lowest content of pectins (205 mg l^{-1}) was found in 'Chanteline' juice. On average, French apple juices contained lower amounts of pectins, (421 mg l^{-1}) compared to Polish juices (841 mg l^{-1}). The data obtained agreed with Mollow *et al*. (2006), who found from 277 – 1,422 mg l^{-1} of pectic substances in juices, depending on apple cultivar and stage of maturity.

TABLE I
Basic composition of natural cloudy apple juices from France and Poland

	Apple cultivar									
Parameter (units)	'Ariane'	'Chanteline'	'Judeline'	'Judor'	'Ariwa'	'Gold Milenium'	'Florina'	'Melfree'	'Novamac'	'Rajka'
Soluble solids (%)	13.7	12.8	12.4	14.5	12.3	14.3	12.7	13.8	11.6	17.0
Density ($d_{20/20}$)	1.057	1.053	1.052	1.060	1.049	1.059	1.054	1.061	1.047	1.064
Titratable acidity (g l^{-1})	7.1	5.5	5.1	7.3	4.0	2.7	4.5	5.2	5.2	5.8
Turbidity – total (NTU)	298	345	736	406	1,038	3,309	1,127	1,379	1,507	1,959
Turbidity – stable (NTU)	130	164	380	208	297	1,169	382	545	567	961
Turbidity – stability (%)	44	48	52	51	29	35	34	39	38	49
Water-soluble pectin (mg l^{-1})	281	205	492	705	351	1,289	369	836	1,105	1,093
Formol index number (ml 0.1 M NaOH 100 ml^{-1} juice)	3.4	2.4	1.9	2.0	5.9	3.5	6.5	3.0	7.0	3.6
Malic acid content (g l^{-1})	11.2	7.4	6.9	8.9	5.9	4.5	6.6	7.0	7.2	8.4
Citric acid content (mg l^{-1})	86	48	22	75	100	143	124	175	53	166
Ascorbic acid content (mg l^{-1})	73	81	54	51	0	0	0	0	0	0
Glucose content (g l^{-1})	22.6	20.8	18.5	27.5	24.7	10.6	14.3	13.2	19.0	18.2
Fructose content (g l^{-1})	71.3	66.8	75.9	90.7	57.3	71.8	59.6	66.2	55.9	75.4
G/F ratio	0.32	0.31	0.24	0.30	0.43	0.15	0.24	0.20	0.34	0.24
Saccharose content (g l^{-1})	30.6	21.5	24.6	17.7	24.9	48.9	43.6	56.9	34.5	45.6
Sugar-free extract (g l^{-1})	23.2	28.6	14.9	19.9	19.3	21.5	22.4	21.7	13.4	25.9
Total soluble solids content (g l^{-1})	147.7	137.6	133.9	155.8	126.1	152.8	139.8	158.1	122.9	165.2
Sorbitol content (g l^{-1})	7.6	5.2	1.9	5.9	3.9	7.6	6.0	4.7	4.0	7.0
Ca (mg l^{-1})	35.0	26.0	33.0	43.0	73.0	n.d.	78.0	91.0	92.0	77.0
K (mg l^{-1})	1,308.0	1,080.0	1,019.0	1,099.0	1,173.0	n.d.	1,358.0	1,193.0	1,004.0	1688.0
Mg (mg l^{-1})	39.0	35.0	30.0	33.0	49.0	n.d.	46.0	49.0	48.0	52.0
Na (mg l^{-1})	5.0	9.0	9.0	10.0	2.9	n.d.	3.6	1.9	2.5	2.5
P (mg l^{-1})	60.0	77.0	68.0	87.0	77.0	n.d.	98.0	85.0	64.0	98.0

n.d., no data

Formol index number (FN) reflects the overall content of free amino acids in each juice. The average FN value was 3.9 ml 0.1 M NaOH 100 ml^{-1} juice. Amino acids were more abundant in Polish juices than in French juices, with average values of 4.9 and 2.4 ml 0.1 M NaOH 100 ml^{-1} juice, respectively. Such an effect could could be due to cultivar characteristics, or to nitrogen fertilisation (Link and Bangerth, 1972; Baron *et al*., 1977).

Malic acid contents were 8.6 g l^{-1} in the French, and 6.6 g l^{-1} in the Polish apple juices. Malic acid represents the major organic acid in apple juice and its content is correlated, to a high extent, with TA (R^2 = 0.884). Juices from 'Ariane', 'Judor', and 'Rajka' were most abundant in malic acid. In contrast to malic acid, the Polish juices contained more citric acid than the French ones, with average values of 127 mg l^{-1} and 58 mg l^{-1}, respectively. One exception was juice from 'Novamac', which contained a similar amount of citric acid to that in the French cultivars. However, all citric acid contents were within the range given in the Code of Practice (AIJN, 2007).

French apple juices contained, on average, 62 mg l^{-1} AA, while AA was not found in any of the samples from Poland. Differences in AA content probably reflect the processing technology used and the resulting oxidation of the juices during processing.

The average overall glucose content was 18.9 g l^{-1}. In general Polish apple juices contained lower amounts of glucose than French juices, at 16.7 and 22.3 g l^{-1}, respectively. However, 'Judor' and 'Ariwa' were characterised by having markedly higher glucose contents. Fructose contents were generally similar in the French and Polish juices; however, juices from 'Judor' and 'Rajka' had substantially higher contents. This phenomenon may be related to changes in fruit sugars during maturation and the relative accumulation rates of particular sugars (Blanco-Gomis *et al*., 1998; Silverman *et al*., 2004). Differences in glucose and fructose contents are reflected in the glucose:fructose ratio. The highest ratio (0.43) was found for 'Ariwa' juice, while in 'Gold Milenium' it was only 0.15.

The average saccharose content was 34.9 g l^{-1}. In French apple juices, the average saccharose content was 23.6 g l^{-1}, in agreement with published data for dessert apple cultivars (Wu *et al*., 2007) and for juices given by Eisele and Drake (2005). In Polish juices, produced from scab-resistant apple cultivars, the average saccharose content was 42.4 g l^{-1}. Only in juice from 'Ariwa' was the saccharose content below 30 g l^{-1}, which is the maximum given in the Code of Practice (CoP) for natural apple juices (AIJN, 2007).

Sugar-free extracts represent the content of all water-soluble, non-sugar compounds and values were calculated by subtraction of the total sugars content from the SSC. In general, these values were within the CoP range (18 – 29 g l^{-1}), with the exception of juices from 'Judeline' and 'Novamac', at 14.9 and 13.5 g l^{-1}, respectively. This could present a problem during authenticity evaluation of these juices.

Sorbitol is a typical constituent of apple juice. Its average content in all the juices investigated was 5.4 g l^{-1}. French juices contained slightly lower amounts of sorbitol (5.2 g l^{-1}) compared to Polish juices (5.5 g l^{-1}). The maximum observed value, 7.6 g l^{-1}, was found for both 'Ariane' and 'Gold Milenium' juices; whereas juice from 'Judeline' contained only 1.9 g l^{-1} sorbitol, which agrees with data presented by Eisele and Drake (2005), who found a sorbitol range of 1.4 – 14.0 g l^{-1}. However, values ≥ 7.0 g l^{-1} exceed the maximum value given in the CoP (AIJN, 2007), values which may (falsely) suggest the addition of pear juice.

Large differences between juices were found for the contents of particular mineral compounds. The calcium content of the French apple juices was, on average, 34.3 mg l^{-1}; while in the Polish juices it was 82.2 g l^{-1}. Similarly, the magnesium content of French juices was lower compared to Polish ones, at 34.3 mg l^{-1} and 48.8 mg l^{-1}, respectively. These differences could arise from the varieties used as well as the different soil and cultivation conditions between countries, as observed in the case of the FN values.

The average overall potassium content was 1,214 mg l^{-1}. Almost no cultivar differences were observed for potassium contents. Only juice from 'Rajka' contained a markedly higher potassium content (1,688 mg l^{-1}). Phosphorus contents were, on average, 75.7 mg l^{-1}, with no differences found when comparing French and Polish juices. Low phosphorus contents were found in juices from 'Ariane' and 'Novamac'.

Sodium contents in apple juices are, as a rule, low. The average sodium content in all the juices investigated was 5.2 mg l^{-1}. However, the French apple juices had a higher average sodium content (8.3 mg l^{-1}) than the Polish juices (2.7 mg l^{-1}). Such results support the thesis that mineral fertilisation, or soil characteristics, can markedly influence the mineral content of the product.

A Principal Components Analysis (PCA) of these data was carried out in order to identify potentially different groups of fruit juices, according to their various chemical compositions. Four Principal Components were extracted in order to explain 89% of the variance. Values of AA content were discarded from this computation because they were related to the differences in the French and Polish methods of juice extraction. However, the juices from each country were easily distinguished by the first two Principal Components (Figure 2A). Each analytical variable made almost the same contribution to the variance (Figure 2B). The highest modulus of the vectors was 0.40 (sugar-free extract), and the lowest was 0.27 (total extract). Each juice was strongly correlated to one particular analytical variable.

The results from the chemical composition analysis of phenolics contents are presented in Table II. Four main groups of phenolics were determined. The flavan-3-ols group consisted of catechin, epicatechin, and oligomeric procyanidins. The dihydrochalcones group contained phloretin xyloglucoside and phloridzin. Two hydroxycinnamic acids were determined: chlorogenic acid and *p*-coumarylquinic acid. Flavonols were expressed as the sum of the five quercetin glycosides detected. No free quercetin was found in any of the juices investigated.

Large variations in phenolic compounds were found in relation to the apple cultivar used, and its origin. Juice from 'Novamac' contained only 85.7 mg l^{-1} of total phenolics, while juice from 'Melfree' contained 524.8 mg l^{-1}. Polish juices had higher levels of total phenolics (271.5 mg l^{-1}) than French juices (185.2 mg l^{-1}), which could be a result of differences in the cultivars used, or in the juicing technology (i.e., centrifugation for

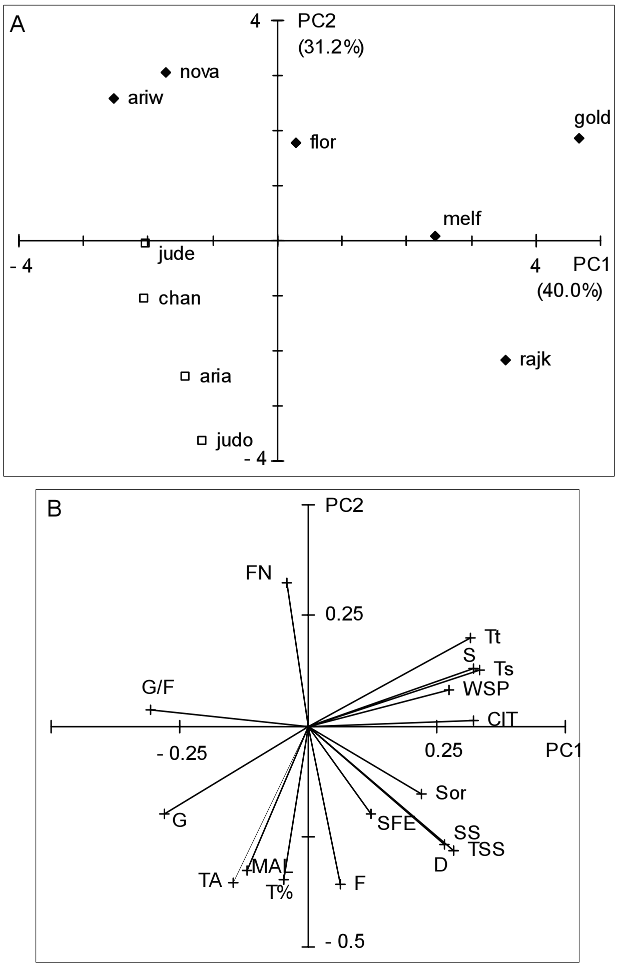

FIG. 2.
Principal Components Analysis (PCA) of the analytical characteristics of Polish and French cloudy apple juices. Axes: PC1, principal component 1; PC2, principal component 2. Panel A, cultivar parameters: 'Ariane' (aria), 'Chanteline' (chan), 'Judeline' (jude), 'Judor' (judo), 'Ariwa' (ariw), 'Gold Milenium' (gold), 'Florina' (flor), 'Melfree' (melf), 'Novamac' (nova), 'Rajka' (rajk). Open symbols, French juice; closed symbols, Polish juice. Panel B, Analytical variables:soluble solids content (SS), density (D), titratable acidity (TA), turbidity total (Tt), stable turbidity (Ts), turbidity stability (T%), water soluble pectin (WSP), formol number (FN), malic acid (MAL), citric acid (CIT), glucose (G), fructose (F), glucose-fructose ratio (G/F), saccharose (S), total soluble solids (TSS), sugar-free extract (SFE), and sorbitol (Sor).

Polish juices *vs*. passive sedimentation for French juices) that affects the oxidation conditions during processing. In the Polish juices all the AA was oxidised during production preventing the oxidation of phenolics by polyphenol oxidase. All these factors could modify the phenolics content and explain the difference between Polish and French juices.

In most cases, the main phenolics constituent was chlorogenic acid. On average, all juices contained 47% (w/w) chlorogenic acid in their total phenolics. For French juices, the value was 42%, and for Polish ones it was 51%. The maximum content of this compound in French juices was in 'Judor' (165.7 mg l^{-1}) and, in Polish juices, it was 232.1 mg l^{-1} in 'Gold Milenium'.

Some juices were abundant in flavan-3-ols. On average, their share of total phenolics was 37%. Juices from the French cultivars 'Judor' and 'Chanteline' contained ≤ 70% and 55% of flavan-3-ols in their total phenolics, respectively. In the Polish cultivars, the highest content of flavan-3-ols was found in juices from 'Florina' (51%) and 'Melfree' (49%). Surprisingly, juices from 'Novamac', 'Ariva', and 'Judeline' were low in these compounds.

On average, dihydrochalcones represented 10% of total phenolics. The average content of dihydrochalcones in French juices was 9.7 mg l^{-1}, while in Polish juices it was 29.4 mg l^{-1}. These compounds are present mainly in apple seeds (Thielen *et al*., 2005) and the use of a disc-mill during juice production in Poland resulted in greater seed disintegration, thereby introducing more dihydrochalcones into the juices.

Quercetin glycoside contents in Polish juices ranged from 4.7 – 19.6 mg l^{-1}, while in French juices it ranged from 1.5 – 3.8 mg l^{-1}. The proportion of quercetin glycosides in phenolics was 1% for French juices and 4% for Polish ones. Flavonols are present in apple skin (Awad *et al*., 2000) and are only transferred to juice to a small extent. It is not clear if the difference in flavonols contents between Polish and French apple juices was a result of cultivar differences or processing technology.

These results on phenolics contents support the thesis that the main source of variation was fruit cultivar (Guyot *et al*., 2003). In general, the phenolics profiles of cloudy French apple juice were comparable to those of Polish apple juices (Figure 3) with chlorogenic acid dominating, followed by flavan-3-ols (Eisele and Drake, 2005).

CONCLUSIONS

Cloudy apple juices produced from French or Polish apple cultivars showed a wide range of variations in the

TABLE II
Composition of phenolic compounds (in mg l^{-1}) in natural cloudy apple juices from France and Poland*

Origin	Cultivar	CAT*	ECT	PRO	PXG	PHL	CHL	PCQ	QGL	Total phenolics
France	'Ariane'	3.1	16.6	33.7	3.7	6.6	84.0	3.5	1.5	152.6
	'Chanteline'	10.5	25.6	75.6	2.8	3.4	74.6	5.6	3.1	201.3
	'Judeline'	2.6	19.6	43.4	4.0	4.2	18.2	0.4	1.9	94.3
	'Judor' 5.2	27.4	63.9	6.8	7.2	165.7	12.4	3.8	292.5	
Poland	'Ariwa'	1.8	21.7	17.6	5.5	20.0	145.6	2.8	6.8	221.7
	'Florina'	0.0	41.8	67.8	9.1	13.6	72.2	2.4	10.1	216.9
	'Gold Milenium'	5.7	28.2	24.3	17.6	30.9	232.1	2.8	19.6	361.4
	'Melfree'	19.0	121.9	117.5	16.8	21.6	200.3	12.4	15.2	524.8
	'Novamac'	0.0	0.0	0.0	10.1	12.1	55.3	3.5	4.7	85.7
	'Rajka'	0.0	49.3	53.8	8.9	10.1	83.7	6.2	6.7	218.7
	Average	4.8	35.2	49.8	8.5	13.0	113.2	5.2	7.4	237.0
	Minimum	0.0	0.0	0.0	2.8	3.4	18.2	0.4	1.5	85.7
	Maximum	19.0	121.9	117.5	17.6	30.9	232.1	12.4	19.6	524.8

*CAT, (+)catechin; ECT, (–)epicatechin; PRO, oligomeric procyanidins; PXG, phloretin xyloglucoside; PHL, phloridzin; CHL, chlorogenic acid; PCQ, *p*-coumarylquinic acid; and QGL, quercetin glycosides.

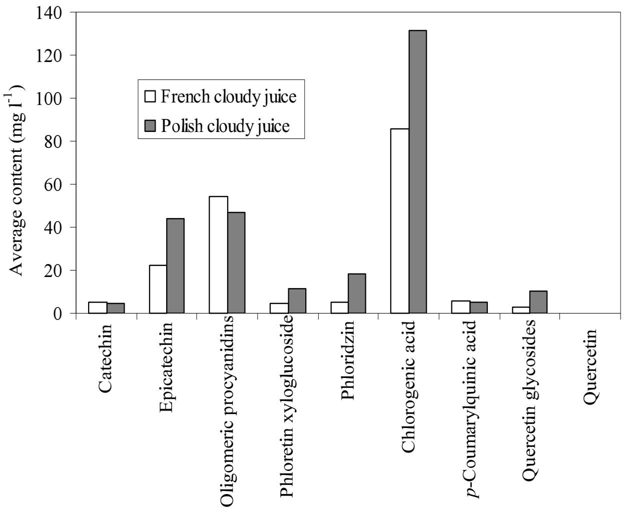

FIG. 3.
Average contents of major phenolic compounds in French and Polish cloudy apple juices.

chemical parameters investigated. For basic chemical parameters, except turbidity, these differences were due to the combined effects of apple cultivar and origin of the juice. In the case of phenolics contents, a cultivar effect was observed. Extremely high differences in phenolics contents were found between juice from 'Novamac' (85.7 mg l^{-1}) compared to juice from 'Melfree' (524.8 mg l^{-1}). To produce apple juices with a high health-giving value, it is important to select apple cultivars such as 'Melfree', 'Gold Milenium', 'Judor', or 'Ariwa', that provide high levels of phenolics in their juice.

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