

Article

Influence of Polyphenols on the Resistance of Traditional and Conventional Apple Varieties to Infection by *Penicillium expansum* during Cold Storage

Ana-Marija Gotal Skoko ¹, Martina Skendrović Babojelić ², Bojan Šarkanj ³, Ivana Flanjak ¹, Ivana Tomac ¹, Antun Jozinović ¹, Jurislav Babić ¹, Drago Šubarić ¹, Michael Sulyok ⁴, Rudolf Krska ^{4,5}, Tihomir Kovač ¹ and Ante Lončarić ^{1,*}

- ¹ Faculty of Food Technology Osijek, Josip Juraj Strossmayer University of Osijek, Franje Kuhača 18, 31000 Osijek, Croatia; amgotal@ptfos.hr (A.-M.G.S.); ivana.flanjak@ptfos.hr (I.F.); ivana.tomac@ptfos.hr (I.T.); antun.jozinovic@ptfos.hr (A.J.); jbabic@ptfos.hr (J.B.); dsubaric@ptfos.hr (D.Š.); tihomir.kovac@ptfos.hr (T.K.)
 - ² Department of Pomology, Faculty of Agriculture, University of Zagreb, Svetošimunska 25, 10000 Zagreb, Croatia; mskendrovic@agr.hr
 - ³ Department of Food Technology, University Centre Koprivnica, University North, Trg dr. Žarka Dolinara 1, 48000 Koprivnica, Croatia; bsarkanj@unin.hr
 - ⁴ Department of Agrobiotechnology (IFA-Tulln), Institute of Bioanalytics and Agro-Metabolomics, University of Natural Resources and Life Sciences Vienna, Konrad Lorenzstr. 20, A-3430 Tulln, Austria; michael.sulyok@boku.ac.at (M.S.); rudolf.krska@boku.ac.at (R.K.)
 - ⁵ Institute for Global Food Security, School of Biological Sciences, Queen's University Belfast, University Road, Belfast BT7 1NN, UK
- * Correspondence: ante.loncaric@ptfos.hr; Tel.: +385-1224350

Abstract: This study investigates the impact of polyphenols on the susceptibility of traditional and conventional apple varieties to *Penicillium expansum* infection and subsequent patulin biosynthesis during cold storage. Traditional varieties, notably ‘Bobovec’, exhibit significantly higher levels of total polyphenols (650.56 ± 9.85 mg/L) and flavonoids (184.11 ± 1.48 g/kg dw) compared to conventional ones after six months of storage, accompanied by the identification of key polyphenols such as chlorogenic acid, epicatechin, phloridzin, quercetin and procyanidins B1 and B2. These traditional varieties demonstrate enhanced resistance to *P. expansum* infection, as evidenced by prolonged periods for colony formation, particularly ‘Bobovec’ with an average of 384 h. Furthermore, the traditional variety ‘Winter Banane’ and conventional varieties ‘Idared’ and ‘Fuji’ showed increased patulin biosynthesis postinoculation, indicating higher susceptibility to fungal infection. The findings underscore the potential of polyphenols from traditional apple varieties as natural defences against fungal infections, suggesting the importance of selecting or breeding varieties with higher polyphenol content to improve resistance to postharvest pathogens, thereby enhancing the quality and safety of stored apples.

Keywords: polyphenols; *Penicillium expansum*; storage; flavonoids; apple



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1. Introduction

Apples are one of the most economically important continental fruits worldwide, both in terms of production and consumption [1]. Apart from the fact that apples are consumed and produced in large quantities, they are also important because of their nutritional value and a considerable number of bioactive compounds such as polyphenols [2–4]. There are six main classes of polyphenols in apples, including catechins and epicatechins, anthocyanins, dihydrochalcones (phloretin and phlorizin), phenolic acids (gallic acid, chlorogenic acid), procyanidins and flavonol glycosides (flavonoids, quercetin, quercetin conjugates) [5]. All the polyphenols mentioned are contained in the flesh, seeds and peel of apples, and quercetin conjugates are the most important polyphenols in the peel. Moreover, their concentrations in the flesh are much lower than in the skin, with the exception of chlorogenic acid,

which is the main polyphenol in the flesh [6]. In addition to the peel and pulp, apple seeds are also a good source of polyphenols, especially phloridzin, chlorogenic acid, *p*-coumaroyl-quinic acid and epicatechin [7–9]. In addition, polyphenols have a variety of biological functions such as antiviral, antioxidant, anti-inflammatory, antifungal, antimicrobial and antihypertensive and hypoglycaemic properties [10–13]. On the other hand, apples are host to a wide range of diseases and pests due to their high nutrient and water contents.

One of the most important global problems for the food industry is the control of soft rot and blue mould caused by *Penicillium expansum* [14]. This fungus is a cause for great concern as it can produce various mycotoxins, in particular patulin [15–17]. Patulin is a mycotoxin that exhibits a broad spectrum of toxicity to animals and plants, including subacute toxicity, acute toxicity, embryotoxicity, teratogenicity and immunotoxicity [18,19]. Many studies have shown that some polyphenols can reduce the growth of *P. expansum* and inhibit patulin synthesis under certain conditions. For example, phloridzin, quercetin, quercetin-3-rutinoside and chlorogenic acid showed antifungal and antimicrobial activity [20–22]. The best way to avoid patulin contamination is to take pre- and postharvest measures that limit *P. expansum* infestation, such as biological control agents, fungicides, irradiation, etc. [23]. Therefore, scientists have turned to researching the composition of traditional apple varieties that have proven to be more resistant to *P. expansum* infection, resulting in less use of fungicides, pesticides, etc.

Traditional and conventional apple varieties have the same groups of polyphenols such as flavonols, dihydrochalcones, phenolic acids, anthocyanins and flavan-3-ols [24,25]. Despite the similarities, the traditional apple varieties proved to have a higher polyphenol content than the conventional varieties. Due to the higher content of polyphenols, the traditional apples are more resistant to plant diseases [20,26]. Traditional apple varieties are also richer in individual polyphenolic compounds such as quercetin-3-rutinoside, procyanidin B1, B2, epicatechin, chlorogenic acid, etc. [24,27–29]. Although the traditional apple varieties had a higher polyphenol content, it should not be forgotten that the stability of polyphenols is the most important nutritional value of food. Polyphenols are unstable and very susceptible to degradation and reactions with certain factors during processing and storage. The stability of polyphenols depends on various parameters such as temperature, metal ions, proteins, enzymes, oxygen, pH, light or interactions with other food components. The result of decreasing stability is a change in the structures and a decrease in the biological activities of the polyphenols [30,31]. The basis for maintaining the stability of the polyphenols and the quality of the fruit during storage is the reduction of the storage temperature, which increases the shelf life and maintains the quality of the apple [30].

The aims of this study were therefore to quantify, detect and determine polyphenols, flavonoids, anthocyanins and total polyphenols in traditional and conventional apple varieties and to compare the influence of polyphenols on the resistance of traditional and conventional apple varieties to infection by *P. expansum* during cold storage and consequential patulin biosynthesis.

2. Materials and Methods

2.1. Chemicals and Reagents

Folin–Ciocalteu reagent was purchased from Kemika (Zagreb, Croatia). Sodium carbonate anhydrous, sodium nitrite, sodium acetate anhydrous and potassium chloride were purchased from GRAM-MOL d.o.o. (Zagreb, Croatia). Methanol (MS grade), employed as extraction solvent, was supplied by Scharlaub (Chemie S.A., Barcelona, Spain), ultrapure water was produced in the laboratory with a Milli-Q gradient system (Millipore, Bedford, MA, USA) and formic acid was supplied by Merck (Darmstadt, Germany). Aluminium chloride 98%, extra pure, anhydrous powder was purchased from Alfa Aesar (Massachusetts, SAD). LC-MS grade acetonitrile was purchased from J.T. Baker (J.T. Baker, Deventer, The Netherlands). Sodium hydroxide was purchased from T.T.T d.o.o. (Sveta Nedelja, Croatia). Standard stock solutions (2000–8000 µg/mL) for determination of individual polyphenols were prepared in methanol using pure polyphenols, including idaein chloride, gallic acid,

trans-ferulic acid, chlorogenic acid, epigallocatechin, caffeic acid, procyanidin A2, catechin, p-coumaric acid, phloridzin, epicatechin, myricetin, rutin, quercetin-3-D-glucoside, procyanidin B1, oenin chloride, quercetin, procyanidin B2 and pelargonidin-3-glucoside, all of which were provided by Sigma-Aldrich (Chemie Check GmbH, Steinheim, Germany). From the prepared solutions, standard calibration curve solutions were then generated. For determination of patulin, patulin (CAS: 149-29-1, $\geq 98.0\%$) was obtained from Sigma-Aldrich (Chemie Check GmbH, Steinheim, Germany). Details for chemicals and standards used for patulin determination are given by Sulyok et al. [32].

2.2. Plant Material

The conventional apple varieties 'Jonagold', 'Idared', 'Golden Delicious', 'Fuji' and 'Granny Smith' were purchased in October 2022 at a local market at the ripening stage by OPG (family farm business) Pavičić, Petrijevci, Osijek, Croatia. The traditional apple varieties 'Wagener', 'Winter Banane', 'Kanadska Reneta', 'Zelenika' and 'Bobovec' were collected in October 2023 from OPG Horvatić, Cvetkovac, 38312 Rasinja (46°20'90.3" N 16°69'95.9" E), Croatia. The orchard is located in an area with a temperate continental climate and the soil type is loamy-clayey, pseudogley, slightly acidic to neutral. The varieties were grafted onto wild apple rootstocks and the trees were planted at a distance of about 6 m between rows and 5 m within rows. All apple varieties analysed were certified by a pomologist. Conventional and traditional apple varieties were stored in cold storage at 4 °C for 6 months. The extraction of bioactive substances was carried out using ultrasound. An average sample was taken from five apples of each variety, which had previously been freeze-dried (Christ, Osterode am Harz, Germany) and pulverised. An average of 250 mg per sample was mixed with 1.25 mL of the extraction solvent (80% aqueous methanol). Ultrasound-assisted extraction (UAE) was performed in an ultrasonic bath at 35 kHz for 15 min in 20 mL test tubes. Each extraction was performed in triplicate.

2.3. Total Polyphenol Content Determination

The total polyphenol content in the conventional and traditional apple varieties was determined using the Folin–Ciocalteu method with some modifications according to the method found in work by Lončarić et al. [33]. The determination of the total polyphenol content was carried out using the spectrophotometric method. The absorbance was measured at 765 nm using a spectrophotometer (Jenway 6300, Bibby Scientific, Stone, UK). The average value of each sample was interpolated to a gallic acid calibration curve and expressed as g gallic acid equivalents per kg of extract (g/kg).

2.4. Flavonoid Determination

The content of flavonoids in the traditional and conventional apple varieties was determined using a method based on the reaction of flavones and flavonols with aluminium ions from the reaction mixture. The solution was prepared by mixing the sample volume (0.5 mL), 4 mL of deionised water and 0.3 mL of 5% NaNO₂. After five minutes, 0.3 mL of 10% AlCl₃ was added and after another five minutes, 2 mL of 1 mol/L NaOH and 2.4 mL of deionised water were added. The absorbance was measured at 510 nm using a spectrophotometer (Jenway 6300, Bibby Scientific, Stone, UK). The average value of the sample was interpolated to a catechin calibration curve and expressed as g catechin equivalent per kg of extract (g/kg) according to the method found in work by Lončarić et al. [34].

2.5. Determination of Anthocyanins

The content of anthocyanins in traditional and conventional apple varieties was determined using the pH differential method according to the method found in the work of Giusti and Wrolstadu [35]. Absorbance was measured at 510 and 700 nm using a spectrophotometer (Jenway 6300, Bibby Scientific, Stone, UK). The average value of the sample was expressed as mg anthocyanins per litre (mg/L).

2.6. Determination of Polyphenol Profile by HPLC Analysis

Individual polyphenolic compounds were quantified using high-performance liquid chromatography (HPLC) employing the Shimadzu HPLC instrument (Agilent, 1290 Infinity, Šestár ID: 2475). The mobile phase of 1% formic acid in water (98–100% pure) was used as solvent A and 1% formic acid in methanol as solvent B. The UV–Vis absorption spectra for both the standards and the test samples were recorded in the wavelength range from 190 to 600 nm. The injection volume of the sample was 10 µL and the flow rate of the mobile phase was 0.8 mL/min. Detection was carried out at 280, 320, 360 and 520 nm, depending on the component. The average value of the compound was expressed in units of micrograms per g (µg/g).

2.7. Determination of the Resistance of the Selected Apple Varieties to Infection by *Penicillium expansum*

The resistance of the apple varieties to *P. expansum* CBS 324.48 was determined by the following method described in Ballester et al. [36]. Investigated apple varieties were sterilised and cut into 1 cm thick apple slices. In the centre of each slice the core was removed using a plug hole puncher with 1 cm diameter, where the discs of a growing culture of 168 h old *P. expansum*, grown on potato dextrose agar in a Petri dish at 29 °C, were inserted. The inoculated apple samples were incubated at 29 °C. Fungal growth was measured and photographed every 24 h until the fungi had reached the edge of the apple slice. The infected apple sample was discarded and stored at −80 °C until it was subjected to the determination of the patulin concentration produced.

2.8. Patulin Determination

The determination of patulin in apple samples was carried out identically using the ‘dilute and shoot’ LC-MS/MS method established by Sulyok et al. [32], while the same QTrap 5500 MS/MS detector (Applied Biosystems, Foster City, CA, USA), equipped with a TurboV electrospray ionisation (ESI) source, and an Agilent 1290 binary UHPLC system (Agilent Technologies, Waldbronn, Germany) were used. For the separation of metabolite, the Gemini® C18 column (150 × 4.6 mm i.d., 5 µm particle size) was combined with the C18 Security Guard precolumn (4 × 3 mm i.d.) (Phenomenex, Torrance, CA, USA).

2.9. Statistical Analysis

Data presented in this work are expressed as the mean value ± standard error of measurement (SEM) from three separate experiments. The pooled datasets were checked for distribution normality by a Shapiro–Wilk test and compared by nonparametric statistics methods. Statistical analyses were performed using Statistica 13.5 (TIBCO Software Inc., Palo Alto, CA, USA) and differences were considered statistically significant when the *p*-value was <0.05. A correlogram was prepared by using Minitab Statistical Software 21.1 (Minitab LLC, State College, PA, USA).

3. Results and Discussion

In this study the content of total polyphenols, flavonoids and anthocyanins, individual polyphenolic compounds and resistance of selected traditional and conventional apple varieties to infection by *P. expansum* and consequential patulin biosynthesis during cold storage are investigated.

The content and ratio of identified polyphenols in traditional and conventional apple varieties are given in Table 1. The highest content of total polyphenols in traditional apple varieties during all six months of storage was detected in ‘Bobovec’ (609.74 ± 13.01, 654.83 ± 8.12, 650.56 ± 9.85 g/kg). On the other hand, the lowest content of total polyphenols in traditional apple varieties before and after six months of storage was detected in ‘Wagener’ (146.92 ± 12.69, 224.06 ± 8.37, 210.38 ± 5.09 g/kg). The highest content of total polyphenols in conventional apple varieties during all six months of storage was detected in ‘Granny Smith’ (462.74 ± 25.78, 526.20 ± 9.71, 531.75 ± 13.93 g/kg) and the

lowest content of total polyphenols was detected in ‘Idared’ (193.72 ± 13.60 , 364.44 ± 4.36 , 259.32 ± 2.96 g/kg). From data given in Table 1 it can be concluded that during the first three months of storage there was an increase in the content of total polyphenol in both traditional and conventional apple varieties. The greatest increase during first three months was recorded in ‘Zelenika’, where the content of polyphenols increased from 372.88 ± 15.86 to 641.15 ± 5.01 g/kg. An increase of total polyphenol content could be due to ethylene action which stimulates the activity of the main enzyme in polyphenol biosynthesis, phenylalanine ammonium lyase. At lower temperatures the phenylalanine ammonium lyase activity is higher [37]. Furthermore, the activity of enzyme polyphenol oxidase, which is responsible for polyphenol degradation, is lower [38]. These are some of the reasons that led to an increase in total polyphenol content during cold storage. On the other hand, the content of flavonoids decreased in all samples after storage (Table 2). The traditional variety ‘Bobovec’ had the highest flavonoid content after storage of 184.11 ± 1.48 g/kg dw. The highest content of flavonoids after storage in conventional apple varieties was detected in ‘Fuji’ at 126.56 ± 3.31 g/kg dw. Some studies [38,39] also reported decreases in the content of flavonoids during cold storage. It should be highlighted that traditional apple varieties had significantly higher content of total polyphenols and flavonoids both before and after storage than conventional ones. Moreover, the contents of flavonoids in traditional and conventional apple varieties during storage were significantly different ($p < 0.0001$).

Table 1. Total polyphenol content (g/kg) in traditional and conventional apple varieties during cold storage.

	Sample	TPC ¹ [mg/L]	TPC ² [mg/L]	TPC ³ [mg/L]
Traditional apple varieties	‘Wagener’	146.92 ± 12.69^g	224.06 ± 8.37^j	210.38 ± 5.09^i
	‘Winter Banane’	454.83 ± 19.66^b	491.58 ± 0.98^e	503.97 ± 15.87^d
	‘Kanadska Reneta’	604.09 ± 15.30^a	571.07 ± 7.06^c	600.13 ± 23.35^b
	‘Zelenika’	372.88 ± 15.86^c	641.15 ± 5.01^b	402.69 ± 8.88^e
	‘Bobovec’	609.74 ± 13.01^a	654.83 ± 8.12^a	650.56 ± 9.85^a
Conventional apple varieties	‘Jonagold’	250.77 ± 22.66^e	411.88 ± 3.76^f	399.49 ± 13.97^e
	‘Idared’	193.72 ± 13.60^f	364.44 ± 4.36^i	259.32 ± 2.96^h
	‘Golden Delicious’	330.68 ± 14.58^d	381.11 ± 11.05^h	283.25 ± 8.84^g
	‘Fuji’	333.89 ± 19.63^d	399.91 ± 1.33^g	337.31 ± 15.07^f
	‘Granny Smith’	462.74 ± 25.78^b	526.20 ± 9.71^d	531.75 ± 13.93^c
<i>p</i> -value		$p < 0.0001$	$p < 0.0001$	$p < 0.0001$

¹: after harvest, ²: after three months of storage, ³: after six months of storage. Mean $\pm$ SD based on three extracts each measured twice ($n = 6$). Data are presented as the mean $\pm$ SE with ANOVA *p*-value; means in columns followed by the same letter are not significantly different, $p < 0.0001$.

Table 2. The content of flavonoids (g/kg dw ^a) in traditional and conventional apple varieties during cold storage.

	Sample	Flavonoids ¹ [g/kg dw ^a]	Flavonoids ² [g/kg dw ^a]	Flavonoids ³ [g/kg dw ^a]
Traditional apple varieties	‘Wagener’	70.19 ± 1.62^i	51.36 ± 0.74^h	38.32 ± 0.00^g
	‘Winter Banane’	214.50 ± 3.98^d	134.60 ± 4.22^d	117.74 ± 4.62^c
	‘Kanadska Reneta’	374.89 ± 1.51^a	160.97 ± 5.29^c	183.91 ± 1.64^a
	‘Zelenika’	190.68 ± 3.69^e	195.38 ± 3.67^a	68.13 ± 1.19^e
	‘Bobovec’	359.30 ± 14.22^b	198.42 ± 0.45^a	184.11 ± 1.48^a
Conventional apple varieties	‘Jonagold’	130.77 ± 0.90^g	95.87 ± 2.95^f	76.56 ± 2.70^d
	‘Idared’	85.58 ± 4.42^h	76.66 ± 4.169^g	42.44 ± 5.60^g
	‘Golden Delicious’	129.01 ± 2.09^g	81.75 ± 1.22^g	48.91 ± 2.81^f
	‘Fuji’	165.28 ± 1.51^f	105.06 ± 4.07^e	126.56 ± 3.31^b
	‘Granny Smith’	235.87 ± 4.65^c	175.19 ± 2.90^b	71.17 ± 4.71^d
<i>p</i> -value		$p < 0.0001$	$p < 0.0001$	$p < 0.0001$

¹: after harvest, ²: after three months of storage, ³: after six months of storage. ^a: Dry weight. Mean $\pm$ SD based on three extracts each measured twice ($n = 6$). Data are presented as the mean $\pm$ SE with ANOVA *p*-value; means in columns followed by the same letter are not significantly different, $p < 0.0001$.

Furthermore, the contents of anthocyanins in traditional and conventional apple varieties were also determined. Anthocyanins are coloured water-soluble pigments responsible for the colour of fruit and vegetables, such as blue, purple and red [40]. Besides the colour, anthocyanins play an important role in the response to abiotic and biotic stressors and scavenging oxygen free radicals [41]. In this study the content of anthocyanins increases during storage (Figure 1). One of the reasons is the ability of apples in acidic medium and at lower temperature to produce more anthocyanins [39,41]. The highest content of anthocyanins before and after storage was in conventional variety ‘Jonagold’ (15.78 ± 0.52 , 20.79 ± 0.00 , 27.30 ± 0.00 mg/L). It should be noted that the stability of anthocyanins depends on the light intensity, temperature, pH, oxygen level and the action of enzymes [41]. Moreover, the increase in polyphenol oxidase and peroxidase activity during storage can result in the degradation of anthocyanins which leads to loss of antioxidant activity and discoloration [25,42]. In some cases, the content of anthocyanins decreased during storage. Obtained results are in correlation with results reported by other authors [43,44].

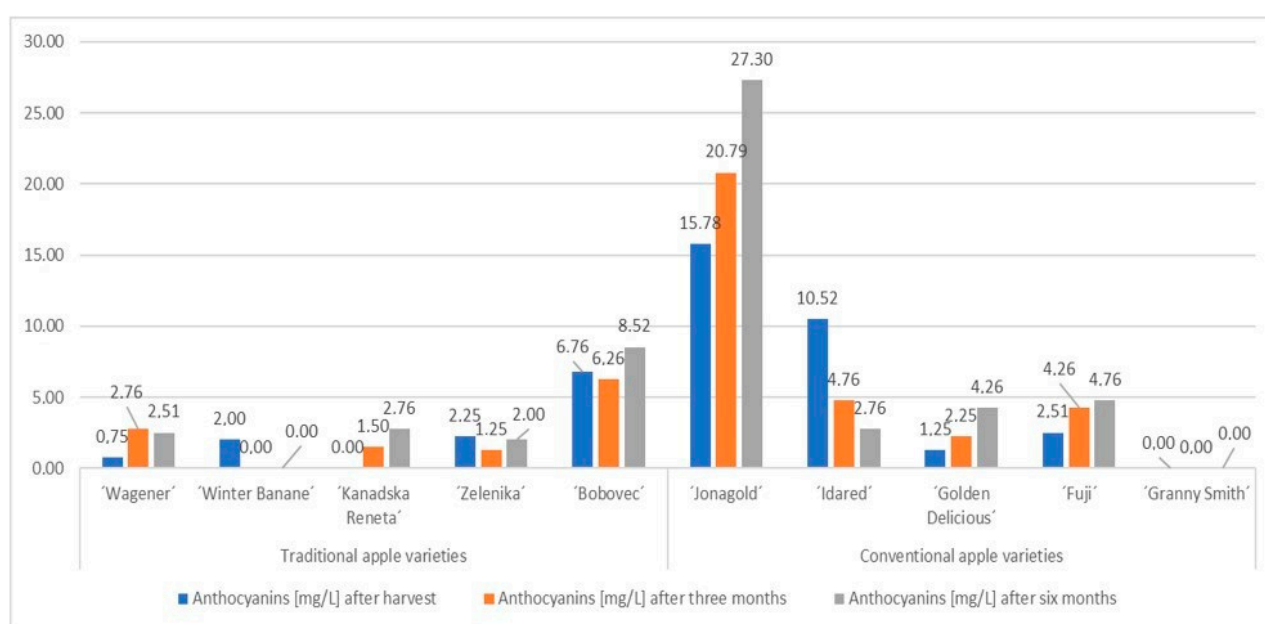


Figure 1. The content of anthocyanins (mg/L) in traditional and conventional apple varieties during cold storage.

The results of individual polyphenols in traditional and conventional apple varieties obtained by HPLC during storage are shown in Tables 3–5. The contents of individual polyphenols in traditional and conventional apple varieties during storage were significantly different. The most dominant individual polyphenols in investigated apple varieties were chlorogenic acid, procyanidin B2, phloridzin and epigallocatechin. The results suggest that the amount of individual polyphenols had decreased during cold storage (gallic acid, *trans*-ferulic acid, caffeic acid, catechin, rutin, quercetin-3-rutinoside, epigallocatechin, quercetin-3-D-glucoside and phloridzin), while the proportion of some individual polyphenols increased (idaein chloride, chlorogenic acid, procyanidin A2, procyanidin B1, epicatechin, oenin chloride, *p*-coumaric acid, myricetin, procyanidin B2 and pelargonidin-3-glucoside). The greatest increases were recorded for chlorogenic acid in variety ‘Winter Banane’ (2452–3755 $\mu\text{g/g}$), procyanidin B1 in ‘Granny Smith’ (195–676 $\mu\text{g/g}$) and procyanidin B2 in ‘Jonagold’ (769–1207 $\mu\text{g/g}$). On the other hand, the greatest decreases were recorded for epigallocatechin and phloridzin in ‘Kanadska Reneta’ (1187–524 $\mu\text{g/g}$ and 580–465 $\mu\text{g/g}$, respectively). In general, the contents of individual polyphenols in the majority of analysed traditional apple varieties were higher than for conventional ones. The obtained results are in correlation with other studies [45–47].

Table 3. The statistical significance ($p < 0.0001$) and the content of individual polyphenol compounds ($\mu\text{g/g}$) of the investigated apple varieties after harvest.

	Sample	IDC	GA	FA	CHA	EGC	CA	PA2	CAT	pCA	PHL	EPI	MY	RU	Q3G	PB1	ODC	QUE	PB2	P3G
Traditional apple varieties	‘Wagener’	n.d.	n.d.	0.37 $\pm$ 0.13 ^c	653.64 $\pm$ 4.72 ^g	n.d.	0.88 $\pm$ 0.02 ^f	1.06 $\pm$ 0.12 ^c	9.24 $\pm$ 1.03 ^h	0.27 $\pm$ 0.16 ^d	325.89 $\pm$ 2.83 ^b	23.26 $\pm$ 1.14 ⁱ	11.46 $\pm$ 0.07 ^h	64.85 $\pm$ 0.33 ^f	21.75 $\pm$ 0.22 ^f	n.d.	n.d.	0.22 $\pm$ 0.05 ^f	81.87 $\pm$ 4.02 ^h	n.d.
	‘Winter Banane’	8.07 $\pm$ 2.62 ^d	0.62 $\pm$ 0.11 ^c	1.11 $\pm$ 0.04 ^a	2452.22 $\pm$ 70.76 ^a	18.24 $\pm$ 3.94 ^d	2.47 $\pm$ 0.07 ^b	1.38 $\pm$ 0.05 ^c	42.58 $\pm$ 0.38 ^f	0.47 $\pm$ 0.01 ^c	126.84 $\pm$ 3.45 ^{cd}	440.80 $\pm$ 13.94 ^d	41.91 $\pm$ 1.86 ^c	369.66 $\pm$ 10.13 ^a	145.42 $\pm$ 4.91 ^a	n.d.	n.d.	0.86 $\pm$ 0.01 ^b	1306.58 $\pm$ 48.22 ^d	n.d.
	‘Kanadska Reneta’	n.d.	n.d.	0.65 $\pm$ 0.04 ^b	2234.35 $\pm$ 56.29 ^c	1186.69 $\pm$ 97.34 ^a	5.72 $\pm$ 0.13 ^a	41.30 $\pm$ 9.51 ^a	206.86 $\pm$ 8.59 ^a	0.89 $\pm$ 0.04 ^a	580.41 $\pm$ 97.44 ^a	791.70 $\pm$ 29.20 ^b	16.06 $\pm$ 0.32 ^g	50.34 $\pm$ 1.19 ^g	14.40 $\pm$ 0.43 ^g	n.d.	n.d.	0.16 $\pm$ 0.02 ^{fg}	2590.49 $\pm$ 114.90 ^b	n.d.
	‘Zelenika’	n.d.	9.67 $\pm$ 3.81 ^b	0.67 $\pm$ 0.03 ^b	1259.42 $\pm$ 38.64 ^d	18.54 $\pm$ 4.03 ^d	1.40 $\pm$ 0.04 ^{de}	9.11 $\pm$ 0.74 ^b	62.11 $\pm$ 0.50 ^d	0.66 $\pm$ 0.02 ^b	142.17 $\pm$ 4.41 ^c	290.22 $\pm$ 7.80 ^f	14.80 $\pm$ 0.46 ^g	136.40 $\pm$ 4.06 ^d	50.26 $\pm$ 1.54 ^d	n.d.	n.d.	0.45 $\pm$ 0.05 ^e	776.57 $\pm$ 32.01 ^f	n.d.
	‘Bobovec’	62.58 $\pm$ 0.90 ^b	n.d.	0.56 $\pm$ 0.04 ^b	2327.41 $\pm$ 12.48 ^b	379.13 $\pm$ 19.93 ^b	1.46 $\pm$ 0.01 ^d	6.64 $\pm$ 0.46 ^b	126.09 $\pm$ 4.17 ^b	0.93 $\pm$ 0.02 ^a	147.50 $\pm$ 2.69 ^c	972.55 $\pm$ 19.92 ^a	55.62 $\pm$ 0.50 ^a	323.76 $\pm$ 1.76 ^b	78.59 $\pm$ 0.69 ^c	128.70 $\pm$ 10.78 ^b	0.60 $\pm$ 0.03 ^b	0.66 $\pm$ 0.03 ^c	2687.72 $\pm$ 46.61 ^a	n.d.
Conventional apple varieties	‘Jonagold’	141.48 $\pm$ 2.45 ^a	5.26 $\pm$ 1.82 ^b	0.31 $\pm$ 0.02 ^c	1163.73 $\pm$ 27.96 ^e	8.01 $\pm$ 0.19 ^d	1.31 $\pm$ 0.02 ^{de}	1.08 $\pm$ 0.04 ^c	50.19 $\pm$ 0.57 ^e	0.16 $\pm$ 0.03 ^{ef}	145.49 $\pm$ 2.34 ^c	248.10 $\pm$ 4.03 ^g	9.67 $\pm$ 0.16 ⁱ	36.65 $\pm$ 0.60 ^h	9.09 $\pm$ 0.13 ^h	n.d.	1.04 $\pm$ 0.05 ^a	0.60 $\pm$ 0.02 ^{cd}	768.72 $\pm$ 4.20 ^f	7.41 $\pm$ 0.08 ^a
	‘Idared’	3.70 $\pm$ 0.77 ^e	9.37 $\pm$ 2.25 ^{ab}	0.15 $\pm$ 0.03 ^d	469.04 $\pm$ 16.18 ^h	12.69 $\pm$ 2.72 ^d	1.25 $\pm$ 0.38 ^{de}	0.85 $\pm$ 0.43 ^c	12.65 $\pm$ 0.25 ^h	0.12 $\pm$ 0.00 ^f	65.93 $\pm$ 1.69 ^e	161.92 $\pm$ 4.76 ^h	18.90 $\pm$ 1.02 ^f	25.54 $\pm$ 0.78 ⁱ	7.16 $\pm$ 0.38 ^h	n.d.	n.d.	0.57 $\pm$ 0.01 ^d	527.44 $\pm$ 15.98 ^g	n.d.
	‘Golden Delicious’	n.d.	9.67 $\pm$ 3.81 ^a	0.67 $\pm$ 0.03 ^c	1259.42 $\pm$ 38.64 ^f	18.54 $\pm$ 4.03 ^d	1.40 $\pm$ 0.04 ^c	9.11 $\pm$ 0.74 ^c	62.11 $\pm$ 0.50 ^h	0.66 $\pm$ 0.02 ^d	142.17 $\pm$ 4.41 ^{cd}	290.22 $\pm$ 7.80 ^g	14.80 $\pm$ 0.46 ^d	136.40 $\pm$ 4.06 ^e	50.26 $\pm$ 1.54 ^e	n.d.	n.d.	0.45 $\pm$ 0.05 ^g	776.57 $\pm$ 32.01 ^f	n.d.
	‘Fuji’	18.34 $\pm$ 1.03 ^c	n.d.	0.42 $\pm$ 0.01 ^c	1107.89 $\pm$ 9.92 ^e	45.95 $\pm$ 1.36 ^{cd}	2.00 $\pm$ 0.01 ^c	0.88 $\pm$ 0.08 ^c	33.15 $\pm$ 0.77 ^g	0.23 $\pm$ 0.03 ^{de}	109.79 $\pm$ 0.90 ^{cde}	334.51 $\pm$ 5.04 ^e	25.54 $\pm$ 1.08 ^e	139.06 $\pm$ 1.15 ^d	28.16 $\pm$ 0.44 ^e	n.d.	0.36 $\pm$ 0.02 ^c	0.15 $\pm$ 0.03 ^g	967.11 $\pm$ 6.46 ^e	n.d.
	‘Granny Smith’	n.d.	12.48 $\pm$ 2.99 ^a	0.32 $\pm$ 0.09 ^c	340.43 $\pm$ 2.33 ⁱ	76.12 $\pm$ 2.55 ^c	1.19 $\pm$ 0.01 ^e	1.28 $\pm$ 0.05 ^c	93.81 $\pm$ 0.71 ^c	0.87 $\pm$ 0.02 ^a	81.44 $\pm$ 0.61 ^{de}	522.75 $\pm$ 4.48 ^c	45.20 $\pm$ 0.81 ^b	228.00 $\pm$ 1.14 ^c	82.94 $\pm$ 0.29 ^b	195.46 $\pm$ 11.15 ^a	n.d.	1.21 $\pm$ 0.07 ^a	1470.84 $\pm$ 6.83 ^c	n.d.

IDC: idaein chloride; GA: gallic acid; FA: trans-ferulic acid; CHA: chlorogenic acid; EGC: epigallocatechin; CA: caffeic acid; PA2: procyanidin A2; CAT: catechin; pCA: p-coumaric acid; PHL: phloridzin; EPI: epicatechin; MY: myricetin; RU: rutin; Q3G: quercetin-3-D-glucoside; PB1: procyanidin B1; ODC: oenin chloride; QUE: quercetin; PB2: procyanidin B2; P3G: pelargonidin-3-glucoside; data are presented as the mean $\pm$ SE with ANOVA p -value, means in columns followed by the same letter are not significantly different, $p < 0.0001$; n.d.: not detected.

Table 4. The content of individual polyphenol compounds ($\mu\text{g/g}$) of the investigated apple varieties after three months of cold storage.

	Sample	IDC	GA	FA	CHA	EGC	CA	PA2	CAT	pCA	PHL	EPI	MY	RU	Q3G	PB1	ODC	QUE	PB2	P3G
<i>Traditional apple varieties</i>	‘Wagener’	n.d.	n.d.	0.29 $\pm$ 0.01 ^c	976.48 $\pm$ 9.54 ^h	n.d.	0.98 $\pm$ 0.01 ^e	0.68 $\pm$ 0.05 ^c	7.28 $\pm$ 0.10 ^h	0.30 $\pm$ 0.02 ^d	399.34 $\pm$ 2.20 ^b	43.68 $\pm$ 0.60 ⁱ	15.19 $\pm$ 0.06 ^g	72.87 $\pm$ 0.21 ^f	27.80 $\pm$ 0.09 ^f	5.42 $\pm$ 0.93 ^d	n.d.	0.20 $\pm$ 0.06 ^d	133.31 $\pm$ 3.41 ^j	n.d.
	‘Winter Banane’	18.01 $\pm$ 0.12 ^d	n.d.	0.81 $\pm$ 0.14 ^b	3184.54 $\pm$ 9.86 ^a	27.14 $\pm$ 1.12 ^{de}	3.40 $\pm$ 0.03 ^b	2.14 $\pm$ 0.06 ^c	41.50 $\pm$ 0.51 ^f	0.33 $\pm$ 0.03 ^d	198.22 $\pm$ 0.98 ^d	539.31 $\pm$ 2.73 ^d	35.95 $\pm$ 1.35 ^c	285.18 $\pm$ 2.67 ^a	85.74 $\pm$ 0.43 ^a	n.d.	n.d.	0.32 $\pm$ 0.13 ^c	1519.36 $\pm$ 2.76 ^e	n.d.
	‘Kanadska Reneta’	n.d.	n.d.	1.18 $\pm$ 0.18 ^a	2995.60 $\pm$ 2.00 ^b	1206.47 $\pm$ 91.43 ^a	2.29 $\pm$ 0.02 ^c	50.40 $\pm$ 5.23 ^a	183.29 $\pm$ 9.48 ^a	0.81 $\pm$ 0.02 ^c	474.15 $\pm$ 2.53 ^a	644.83 $\pm$ 11.27 ^c	18.00 $\pm$ 0.84 ^f	58.88 $\pm$ 0.08 ⁱ	15.09 $\pm$ 0.49 ⁱ	684.88 $\pm$ 7.46 ^a	n.d.	3.36 $\pm$ 0.09 ^a	1957.22 $\pm$ 24.70 ^b	n.d.
	‘Zelenika’	n.d.	n.d.	0.79 $\pm$ 0.29 ^b	2062.34 $\pm$ 4.23 ^d	45.40 $\pm$ 0.62 ^{de}	4.32 $\pm$ 0.02 ^a	10.38 $\pm$ 0.47 ^b	94.78 $\pm$ 0.63 ^d	1.28 $\pm$ 0.20 ^b	290.72 $\pm$ 0.29 ^c	533.66 $\pm$ 2.02 ^d	20.93 $\pm$ 0.03 ^e	120.87 $\pm$ 0.55 ^d	56.81 $\pm$ 0.39 ^b	n.d.	n.d.	0.41 $\pm$ 0.02 ^c	1445.47 $\pm$ 4.74 ^f	n.d.
	‘Bobovec’	61.36 $\pm$ 1.50 ^b	n.d.	0.30 $\pm$ 0.04 ^c	2484.39 $\pm$ 23.54 ^c	97.82 $\pm$ 5.54 ^{bc}	1.79 $\pm$ 0.02 ^{cd}	12.01 $\pm$ 2.24 ^b	146.26 $\pm$ 0.21 ^b	1.49 $\pm$ 0.07 ^a	171.47 $\pm$ 0.80 ^f	1233.02 $\pm$ 8.70 ^a	37.80 $\pm$ 0.06 ^b	110.06 $\pm$ 0.08 ^e	35.50 $\pm$ 0.18 ^d	79.78 $\pm$ 4.95 ^{cd}	0.73 $\pm$ 0.03 ^b	0.18 $\pm$ 0.02 ^d	3409.56 $\pm$ 10.62 ^a	n.d.
<i>Conventional apple varieties</i>	‘Jonagold’	223.72 $\pm$ 0.11 ^a	13.93 $\pm$ 3.01 ^b	0.38 $\pm$ 0.01 ^c	1616.92 $\pm$ 11.89 ^e	7.96 $\pm$ 0.75 ^e	2.10 $\pm$ 0.01 ^{cd}	2.27 $\pm$ 0.59 ^c	68.39 $\pm$ 0.37 ^e	0.36 $\pm$ 0.07 ^d	126.92 $\pm$ 1.26 ^g	385.23 $\pm$ 9.70 ^f	17.55 $\pm$ 0.10 ^f	40.09 $\pm$ 0.16 ^j	14.73 $\pm$ 0.20 ⁱ	221.54 $\pm$ 1.41 ^{bc}	1.59 $\pm$ 0.10 ^a	0.17 $\pm$ 0.02 ^d	1596.95 $\pm$ 29.43 ^d	12.06 $\pm$ 0.12 ^a
	‘Idared’	13.54 $\pm$ 1.72 ^e	n.d.	0.25 $\pm$ 0.03 ^c	973.13 $\pm$ 19.42 ^h	40.87 $\pm$ 7.12 ^{de}	1.78 $\pm$ 0.07 ^{cd}	1.15 $\pm$ 0.36 ^c	16.72 $\pm$ 0.65 ^g	0.25 $\pm$ 0.04 ^d	83.90 $\pm$ 0.05 ⁱ	281.90 $\pm$ 2.03 ^h	40.90 $\pm$ 0.10 ^a	67.57 $\pm$ 0.23 ^g	20.01 $\pm$ 0.15 ^h	n.d.	n.d.	1.21 $\pm$ 0.01 ^b	921.68 $\pm$ 10.75 ⁱ	n.d.
	‘Golden Delicious’	n.d.	16.62 $\pm$ 0.31 ^a	0.31 $\pm$ 0.01 ^c	1058.42 $\pm$ 2.14 ^g	17.12 $\pm$ 6.06 ^e	2.36 $\pm$ 0.01 ^c	0.63 $\pm$ 0.02 ^c	16.40 $\pm$ 0.39 ^g	0.26 $\pm$ 0.00 ^d	180.63 $\pm$ 1.03 ^e	330.54 $\pm$ 0.17 ^g	37.11 $\pm$ 0.22 ^b	64.07 $\pm$ 0.32 ^h	24.47 $\pm$ 0.18 ^g	n.d.	n.d.	0.16 $\pm$ 0.03 ^d	1019.72 $\pm$ 3.21 ^h	n.d.
	‘Fuji’	30.32 $\pm$ 0.53 ^c	n.d.	0.78 $\pm$ 0.23 ^b	1480.48 $\pm$ 23.40 ^f	70.28 $\pm$ 1.69 ^{cd}	4.32 $\pm$ 1.39 ^a	2.06 $\pm$ 0.38 ^c	41.66 $\pm$ 0.59 ^f	0.29 $\pm$ 0.05 ^d	182.69 $\pm$ 0.22 ^e	491.77 $\pm$ 0.25 ^e	21.93 $\pm$ 0.04 ^d	130.24 $\pm$ 0.07 ^c	28.43 $\pm$ 0.14 ^e	n.d.	0.32 $\pm$ 0.01 ^c	0.16 $\pm$ 0.04 ^d	1403.48 $\pm$ 5.07 ^g	n.d.
	‘Granny Smith’	n.d.	6.80 $\pm$ 0.46 ^c	0.93 $\pm$ 0.05 ^b	376.38 $\pm$ 0.34 ⁱ	130.16 $\pm$ 3.61 ^b	1.49 $\pm$ 0.00 ^{de}	9.62 $\pm$ 1.04 ^b	117.92 $\pm$ 0.51 ^c	0.72 $\pm$ 0.02 ^c	115.73 $\pm$ 0.30 ^h	655.08 $\pm$ 1.05 ^b	40.36 $\pm$ 0.09 ^a	155.75 $\pm$ 0.27 ^b	54.42 $\pm$ 0.06 ^c	273.33 $\pm$ 20.52 ^b	n.d.	0.33 $\pm$ 0.03 ^c	1710.71 $\pm$ 5.33 ^c	n.d.

IDC: idaein chloride; GA: gallic acid; FA: trans-ferulic acid; CHA: chlorogenic acid; EGC: epigallocatechin; CA: caffeic acid; PA2: procyanidin A2; CAT: catechin; pCA: p-coumaric acid; PHL: phloridzin; EPI: epicatechin; MY: myricetin; RU: rutin; Q3G: quercetin-3-D-glucoside; PB1: procyanidin B1; ODC: oenin chloride; QUE: quercetin; PB2: procyanidin B2; P3G: pelargonidin-3-glucoside; data are presented as the mean $\pm$ SE with ANOVA *p*-value; means in columns followed by the same letter are not significantly different, *p* < 0.0001; n.d.: not detected.

Table 5. The content of individual polyphenol compounds ($\mu\text{g/g}$) of the investigated apple varieties after six months of cold storage.

	Sample	IDC	GA	FA	CHA	EGC	CA	PA2	CAT	pCA	PHL	EPI	MY	RU	Q3G	PB1	ODC	QUE	PB2	P3G
Traditional apple varieties	‘Wagener’	n.d.	n.d.	0.57 $\pm$ 0.21 ^{bcd}	1052.72 $\pm$ 12.92 ^g	n.d.	0.35 $\pm$ 0.13 ^g	0.58 $\pm$ 0.07 ^d	4.56 $\pm$ 0.19 ^g	0.32 $\pm$ 0.02 ^{ef}	384.33 $\pm$ 1.50 ^b	20.48 $\pm$ 0.21 ⁱ	32.88 $\pm$ 0.06 ^h	93.19 $\pm$ 0.43 ^h	29.87 $\pm$ 0.52 ^f	131.69 $\pm$ 24.02 ^{bc}	n.d.	0.37 $\pm$ 0.08 ^c	84.78 $\pm$ 3.58 ⁱ	n.d.
	‘Winter Banane’	8.90 $\pm$ 0.84 ^d	n.d.	0.81 $\pm$ 0.10 ^b	3754.50 $\pm$ 6.95 ^a	140.43 $\pm$ 2.46 ^c	2.39 $\pm$ 0.03 ^b	3.08 $\pm$ 0.10 ^{bcd}	36.93 $\pm$ 0.84 ^e	0.68 $\pm$ 0.05 ^d	180.09 $\pm$ 2.06 ^d	486.27 $\pm$ 9.82 ^d	56.85 $\pm$ 0.15 ^c	304.83 $\pm$ 0.76 ^a	103.49 $\pm$ 0.97 ^a	n.d.	n.d.	0.15 $\pm$ 0.01 ^e	1612.11 $\pm$ 25.12 ^c	n.d.
	‘Kanadska Reneta’	n.d.	n.d.	1.22 $\pm$ 0.44 ^a	2937.83 $\pm$ 12.91 ^b	524.13 $\pm$ 41.93 ^a	4.73 $\pm$ 0.02 ^a	13.09 $\pm$ 7.32 ^{ab}	99.25 $\pm$ 8.33 ^b	1.40 $\pm$ 0.02 ^b	465.31 $\pm$ 4.18 ^a	771.92 $\pm$ 6.93 ^b	44.54 $\pm$ 0.14 ^f	193.14 $\pm$ 0.69 ^d	42.58 $\pm$ 0.91 ^e	109.37 $\pm$ 22.97 ^c	n.d.	0.20 $\pm$ 0.04 ^{de}	2571.75 $\pm$ 20.13 ^b	n.d.
	‘Zelenika’	n.d.	n.d.	0.42 $\pm$ 0.01 ^{cde}	1596.39 $\pm$ 2.13 ^e	35.41 $\pm$ 1.87 ^e	1.60 $\pm$ 0.01 ^d	18.60 $\pm$ 0.64 ^a	53.13 $\pm$ 1.09 ^d	0.84 $\pm$ 0.04 ^{cd}	180.68 $\pm$ 1.77 ^d	350.39 $\pm$ 12.48 ^f	47.33 $\pm$ 0.05 ^e	137.88 $\pm$ 0.35 ^e	51.21 $\pm$ 0.60 ^d	n.d.	n.d.	0.22 $\pm$ 0.03 ^{cde}	969.06 $\pm$ 18.02 ^f	n.d.
	‘Bobovec’	80.28 $\pm$ 0.87 ^b	n.d.	0.44 $\pm$ 0.21 ^{cde}	2658.52 $\pm$ 19.26 ^c	164.42 $\pm$ 3.78 ^b	1.40 $\pm$ 0.02 ^e	10.46 $\pm$ 3.97 ^a	134.55 $\pm$ 3.37 ^a	2.21 $\pm$ 0.01 ^a	137.55 $\pm$ 1.11 ^f	1077.84 $\pm$ 7.87 ^a	69.26 $\pm$ 0.41 ^a	230.39 $\pm$ 1.82 ^c	59.76 $\pm$ 0.81 ^c	186.32 $\pm$ 19.93 ^{bc}	0.87 $\pm$ 0.05 ^b	0.25 $\pm$ 0.02 ^{cde}	2989.49 $\pm$ 11.72 ^a	n.d.
Conventional apple varieties	‘Jonagold’	276.10 $\pm$ 12.75 ^a	n.d.	0.43 $\pm$ 0.07 ^{cde}	1758.28 $\pm$ 1.93 ^d	5.69 $\pm$ 0.15 ^{fg}	1.23 $\pm$ 0.01 ^f	3.36 $\pm$ 0.07 ^{bcd}	101.40 $\pm$ 2.12 ^b	0.91 $\pm$ 0.31 ^c	216.41 $\pm$ 0.39 ^c	305.46 $\pm$ 1.45 ^g	52.11 $\pm$ 0.11 ^d	122.71 $\pm$ 0.59 ^f	23.23 $\pm$ 0.24 ^d	156.32 $\pm$ 28.26 ^b	2.14 $\pm$ 0.03 ^a	0.15 $\pm$ 0.00 ^e	1207.07 $\pm$ 11.70 ^d	16.56 $\pm$ 0.05 ^a
	‘Idared’	20.54 $\pm$ 2.14 ^c	n.d.	0.10 $\pm$ 0.01 ^e	634.04 $\pm$ 3.26 ^j	32.50 $\pm$ 2.15 ^e	1.17 $\pm$ 0.01 ^f	1.54 $\pm$ 0.11 ^{cd}	13.45 $\pm$ 0.50 ^f	0.35 $\pm$ 0.01 ^{ef}	74.20 $\pm$ 2.25 ^h	211.10 $\pm$ 4.39 ^h	26.83 $\pm$ 0.11 ⁱ	43.96 $\pm$ 0.19 ^j	14.45 $\pm$ 0.14 ^j	n.d.	n.d.	0.95 $\pm$ 0.04 ^a	709.98 $\pm$ 4.25 ^h	n.d.
	‘Golden Delicious’	n.d.	n.d.	0.11 $\pm$ 0.01 ^e	936.46 $\pm$ 18.09 ^h	31.39 $\pm$ 1.29 ^{ef}	1.80 $\pm$ 0.02 ^c	0.51 $\pm$ 0.04 ^d	9.25 $\pm$ 0.12 ^{fg}	0.48 $\pm$ 0.00 ^e	90.05 $\pm$ 0.45 ^g	221.61 $\pm$ 0.87 ^h	24.22 $\pm$ 0.13 ^j	52.38 $\pm$ 0.32 ⁱ	21.08 $\pm$ 0.12 ⁱ	n.d.	n.d.	0.14 $\pm$ 0.01 ^e	874.30 $\pm$ 5.40 ^g	n.d.
	‘Fuji’	12.72 $\pm$ 0.88 ^d	n.d.	0.32 $\pm$ 0.19 ^{de}	1403.07 $\pm$ 32.91 ^f	79.47 $\pm$ 1.54 ^d	1.57 $\pm$ 0.08 ^d	0.99 $\pm$ 0.04 ^d	36.48 $\pm$ 0.19 ^e	0.21 $\pm$ 0.01 ^f	165.98 $\pm$ 0.92 ^e	447.38 $\pm$ 7.09 ^e	41.79 $\pm$ 0.41 ^g	97.18 $\pm$ 0.34 ^g	27.42 $\pm$ 0.60 ^g	n.d.	0.23 $\pm$ 0.03 ^c	0.16 $\pm$ 0.03 ^{cd}	1178.23 $\pm$ 15.41 ^e	n.d.
	‘Granny Smith’	n.d.	n.d.	0.71 $\pm$ 0.28 ^{bc}	756.65 $\pm$ 4.68 ⁱ	153.26 $\pm$ 11.52 ^{bc}	1.21 $\pm$ 0.02 ^f	7.77 $\pm$ 1.74 ^{abc}	85.14 $\pm$ 0.49 ^c	1.29 $\pm$ 0.01 ^b	92.04 $\pm$ 1.93 ^g	595.98 $\pm$ 9.19 ^c	65.98 $\pm$ 0.43 ^b	245.70 $\pm$ 0.94 ^b	99.21 $\pm$ 1.23 ^b	676.37 $\pm$ 19.43 ^a	n.d.	0.58 $\pm$ 0.01 ^b	1621.35 $\pm$ 10.59 ^c	n.d.

IDC: idaein chloride; GA: gallic acid; FA: trans-ferulic acid; CHA: chlorogenic acid; EGC: epigallocatechin; CA: caffeic acid; PA2: procyanidin A2; CAT: catechin; pCA: *p*-coumaric acid; PHL: phloridzin; EPI: epicatechin; MY: myricetin; RU: rutin; Q3G: quercetin-3-D-glucoside; PB1: procyanidin B1; ODC: oenin chloride; QUE: quercetin; PB2: procyanidin B2; P3G: pelargonidin-3-glucoside; data are presented as the mean $\pm$ SE with ANOVA *p*-value; means in columns followed by the same letter are not significantly different, $p < 0.0001$; n.d.: not detected.

Resistance of investigated traditional and conventional apple varieties to infection by *P. expansum* during six months of cold storage was also determined (Figures 2–4). Many abundant polyphenols in apples are involved in the response to patulin attack through scavenging the free radicals that are induced by patulin [48]. After harvest the traditional ‘Bobovec’ (15 days) and conventional ‘Granny Smith’ (15 days) apple varieties had the highest resistance. Both varieties had the highest content of procyanidin B2, epicatechin and procyanidin B1. Other authors also observed that higher concentrations of epicatechin and procyanidins B1 and B2 play a significant role in blue mould resistance [48–50]. On the other hand, the traditional ‘Zelenika’ and ‘Kanadska Reneta’ (8 days) and conventional ‘Fuji’ (9 days) apple varieties had the lowest resistance. After three months of storage the traditional ‘Zelenika’ (19 days) and conventional ‘Jonagold’ and ‘Golden Delicious’ (19 days) apple varieties had the highest resistance, while the traditional ‘Bobovec’, ‘Wagener’ and ‘Kanadska Reneta’ (16 days) and conventional ‘Idared’ and ‘Granny Smith’ (10 days) apple varieties had the lowest resistance. All varieties with lower resistance had lower content of epicatechin. Furthermore, traditional apple varieties were more resistant than conventional ones after three months of storage. After six months of storage the traditional ‘Zelenika’ and ‘Bobovec’ (17 days) and conventional ‘Jonagold’ and ‘Idared’ (15 days) had the highest resistance to infection by *P. expansum*. All varieties with higher resistance had the highest contents of total polyphenols. On the other hand, the traditional ‘Wagener’ (8 days) and conventional ‘Fuji’ (9 days) apple varieties had the lowest resistance after six months of storage. Moreover, ‘Wagener’ and ‘Fuji’ had low contents of total polyphenols, procyanidin A2, procyanidin B1 (‘Fuji’) and procyanidin B2 (‘Wagener’).

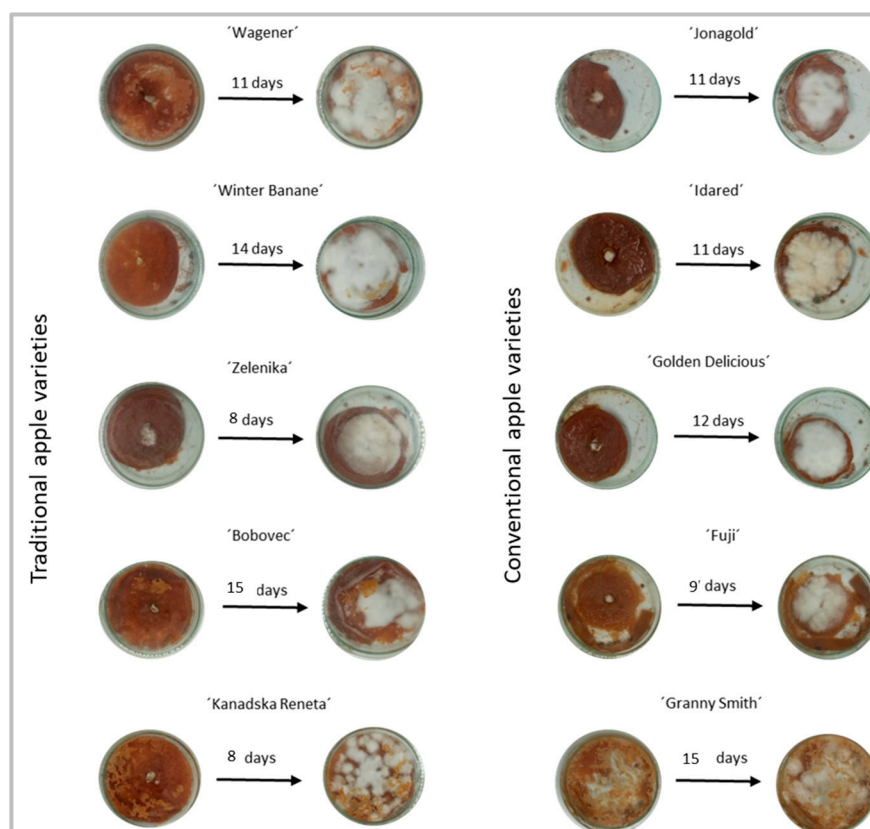


Figure 2. Resistance of investigated apple varieties to infection by *P. expansum* after harvest.

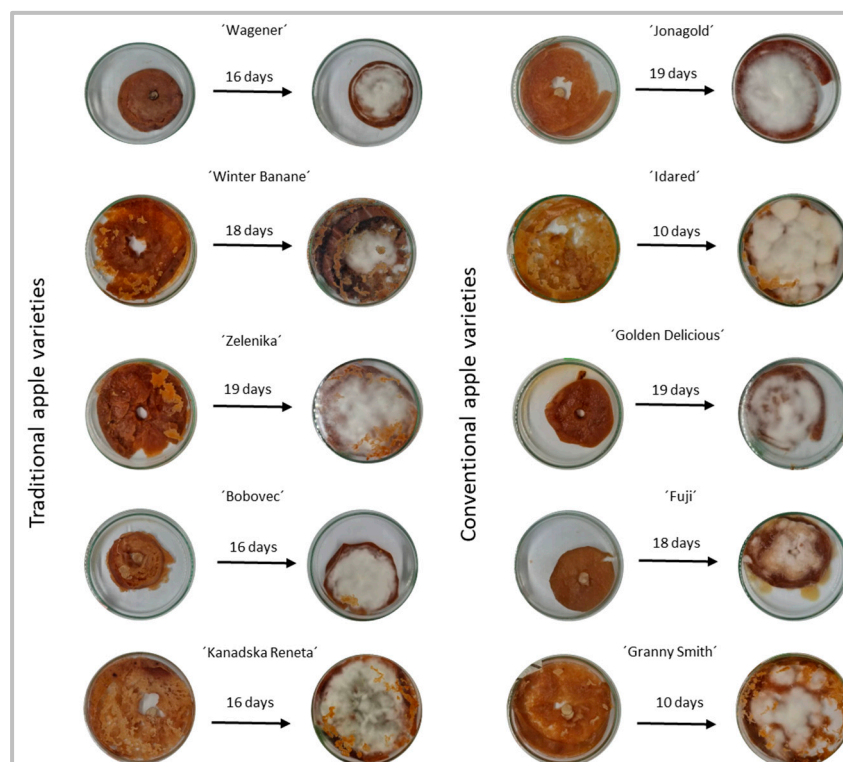


Figure 3. Resistance of investigated apple varieties to infection by *P. expansum* after three months of cold storage.

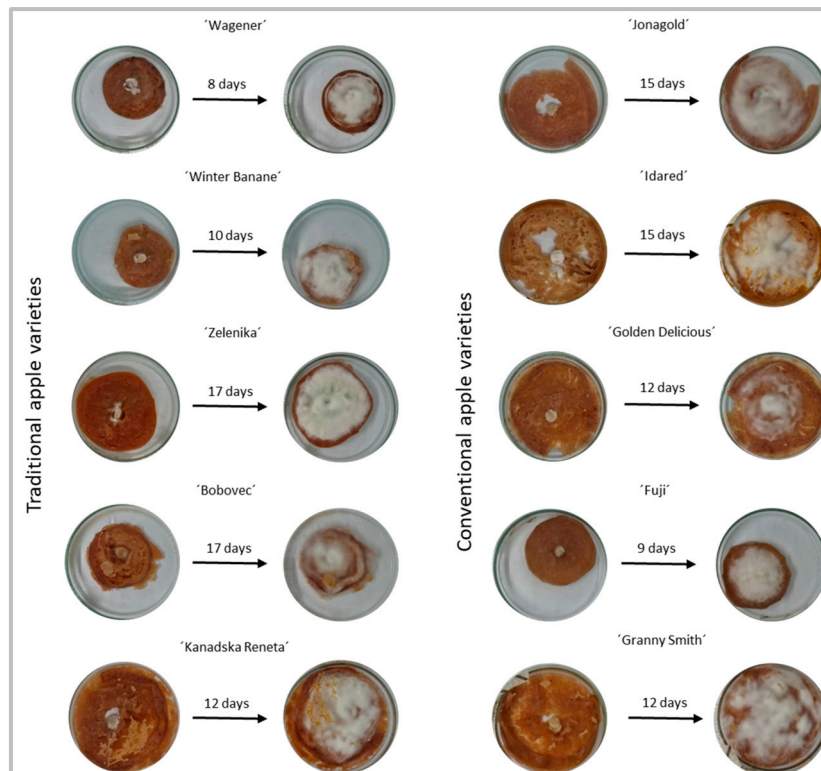


Figure 4. Resistance of investigated apple varieties to infection by *P. expansum* after six months of cold storage.

The content of patulin in investigated traditional and conventional apple varieties was determined at the end of the incubation period when the *P. expansum* colony reached the edge of the apple slice (Table 6). The extent of host contamination by *P. expansum* is the result of the interaction between fruit resistance and pathogen virulence [51]. Consequently, the production of patulin will be affected by quality parameters of the apple host and environmental conditions. After harvest the only variety with detected content of patulin was conventional apple variety ‘Idared’ ($10.9 \pm 0.2 \mu\text{g/kg}$). ‘Idared’ was also one of the varieties with the lowest resistance to infection by *P. expansum*. After three months of storage the concentration of patulin in apple varieties ‘Fuji’, ‘Idared’ and ‘Winter Banane’ was above the regulated level of $25 \mu\text{g/kg}$ for solid apple products [52]. These varieties also had the lowest storage resistances to infection by *P. expansum* and lowest content of procyanidins B1 and B2. After six months of storage the content of patulin was below the detection limit in every investigated apple variety.

Table 6. The content of patulin in investigated apple varieties. Mean $\pm$ SD based on three measurements ($n = 3$).

Apple Varieties	Patulin [$\mu\text{g/kg}$] after Cold Storage		
	0 months	3 months	6 months
‘WAGENER’ CONTROL	<LOD	<LOD	<LOD
‘WAGENER’ INOCULATED	<LOD	<LOD	<LOD
‘WINTER BANANE’ CONTROL	<LOD	<LOD	<LOD
‘WINTER BANANE’ INOCULATED	<LOD	1220 ± 50	<LOD
‘ZELENKA’ CONTROL	<LOD	<LOD	<LOD
‘ZELENKA’ INOCULATED	<LOD	<LOD	<LOD
‘BOBOVEC’ CONTROL	<LOD	<LOD	<LOD
‘BOBOVEC’ INOCULATED	<LOD	<LOD	<LOD
‘KANADSKA RENETA’ CONTROL	<LOD	<LOD	<LOD
‘KANADSKA RENETA’ INOCULATED	<LOD	<LOD	<LOD
‘JONAGOLD’ CONTROL	<LOD	<LOD	<LOD
‘JONAGOLD’ INOCULATED	<LOD	<LOD	<LOD
‘IDARED’ CONTROL	<LOD	<LOD	<LOD
‘IDARED’ INOCULATED	10.9 ± 0.2	62.1 ± 7.5	<LOD
‘GOLDEN DELICIOUS’ CONTROL	<LOD	<LOD	<LOD
‘GOLDEN DELICIOUS’ INOCULATED	<LOD	<LOD	<LOD
‘FUJI’ CONTROL	<LOD	<LOD	<LOD
‘FUJI’ INOCULATED	<LOD	35.5 ± 6.3	<LOD
‘GRANNY SMITH’ CONTROL	<LOD	<LOD	<LOD
‘GRANNY SMITH’ INOCULATED	<LOD	<LOD	<LOD

<LOD—below detection limit ($<5 \mu\text{g/kg}$).

4. Conclusions

From the obtained results, it may be concluded that traditional apple varieties had higher content of polyphenols and flavonoids than conventional ones, especially polyphenols such as phloridzin, quercetin, epicatechin and procyanidins B1 and B2, which could be responsible for apple resistance to fungal infections. The traditional apple variety ‘Bobovec’ had the highest content of polyphenols and flavonoids during six months of cold storage. Furthermore, traditional apple varieties proved to have higher resistance to infection by *P. expansum* during six months of cold storage than conventional ones, for example, ‘Bobovec’ had one of the longest growing periods of *P. expansum* colonies (384h, average). The results of patulin determination indicate that inoculation with *Penicillium expansum* resulted in increased patulin levels in certain apple varieties, such as ‘Winter Banane’, ‘Idared’ and

‘Fuji’, highlighting the susceptibility of these varieties to fungal infection and consequential biosynthesis of a higher amount of patulin.

Furthermore, the findings suggest that polyphenols in apples contribute to their resistance against fungal infections and patulin biosynthesis, emphasising the importance of breeding or selecting apple varieties with higher polyphenol content for improved resistance to postharvest pathogens. Overall, the obtained results should add to food safety and prevention of economic losses caused by *P. expansum*.

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References

1. Cornille, A.; Giraud, T.; Smulders, M.J.M.; Roldán-Ruiz, I.; Gladieux, P. The Domestication and Evolutionary Ecology of Apples. *Trends Genet.* **2014**, *30*, 57–65. [\[CrossRef\]](#)
2. Barreira, J.C.M.; Arraibi, A.A.; Ferreira, I.C.F.R. Bioactive and Functional Compounds in Apple Pomace from Juice and Cider Manufacturing: Potential Use in Dermal Formulations. *Trends Food Sci. Technol.* **2019**, *90*, 76–87. [\[CrossRef\]](#)
3. Wojdyło, A.; Oszmiański, J.; Laskowski, P. Polyphenolic Compounds and Antioxidant Activity of New and Old Apple Varieties. *J. Agric. Food Chem.* **2008**, *56*, 6520–6530. [\[CrossRef\]](#) [\[PubMed\]](#)
4. Wang, L.; Huang, J.; Li, Z.; Liu, D.; Fan, J. A review of the polyphenols extraction from apple pomace: Novel technologies and techniques of cell disintegration. *Crit. Rev. Food Sci. Nutr.* **2022**, *63*, 9752–9765. [\[CrossRef\]](#) [\[PubMed\]](#)
5. Oszmiański, J.; Wojdyło, A.; Kolniak, J. Effect of Enzymatic Mash Treatment and Storage on Phenolic Composition, Antioxidant Activity, and Turbidity of Cloudy Apple Juice. *J. Agric. Food Chem.* **2009**, *57*, 7078–7085. [\[CrossRef\]](#)
6. Golding, J. *Monitoring Natural Phenolics and Antioxidants in Processing Apple Juice*; Horticulture Australia Ltd., Ed.; NSW Department of Primary Industries: Sydney, Australia, 2012.
7. Kumar, M.; Barbhai, M.D.; Esatbeyoglu, T.; Zhang, B.; Sheri, V.; Dhumal, S.; Rais, N.; Radha; Said Al Masry, E.M.; Chandran, D.; et al. Apple (*Malus Domestica* Borkh.) Seed: A Review on Health Promoting Bioactivities and Its Application as Functional Food Ingredient. *Food Biosci.* **2022**, *50*, 102155. [\[CrossRef\]](#)
8. Xu, Y.; Fan, M.; Ran, J.; Zhang, T.; Sun, H.; Dong, M.; Zhang, Z.; Zheng, H. Variation in Phenolic Compounds and Antioxidant Activity in Apple Seeds of Seven Cultivars. *Saudi J. Biol. Sci.* **2016**, *23*, 379–388. [\[CrossRef\]](#)
9. Lu, Y.; Yeap Foo, L. Constitution of Some Chemical Components of Apple Seed. *Food Chem.* **1998**, *61*, 29–33. [\[CrossRef\]](#)
10. Joseph, S.V.; Edirisinghe, I.; Burton-Freeman, B.M. Fruit Polyphenols: A Review of Anti-Inflammatory Effects in Humans. *Crit. Rev. Food Sci. Nutr.* **2016**, *56*, 419–444. [\[CrossRef\]](#)
11. McGhie, T.K.; Hunt, M.; Barnett, L.E. Cultivar and growing region determine the antioxidant polyphenolic concentration and composition of apples grown in New Zealand. *J. Agric. Food Chem.* **2005**, *53*, 3065–3070. [\[CrossRef\]](#)
12. Daglia, M. Polyphenols as Antimicrobial Agents. *Curr. Opin. Biotechnol.* **2012**, *23*, 174–181. [\[CrossRef\]](#)
13. Chojnacka, K.; Skrzypczak, D.; Izydorczyk, G.; Mikula, K.; Szopa, D.; Witek-Krowiak, A. Antiviral Properties of Polyphenols from Plants. *Foods* **2021**, *10*, 2277. [\[CrossRef\]](#)
14. Wang, K.; Ngea, G.L.N.; Godana, E.A.; Shi, Y.; Lanhuang, B.; Zhang, X.; Zhao, L.; Yang, Q.; Wang, S.; Zhang, H. Recent Advances in *Penicillium expansum* Infection Mechanisms and Current Methods in Controlling *P. expansum* in Postharvest Apples. *Crit. Rev. Food Sci. Nutr.* **2023**, *63*, 2598–2611. [\[CrossRef\]](#)
15. Tannous, J.; Keller, N.P.; Atoui, A.; El Khoury, A.; Lteif, R.; Oswald, I.P.; Puel, O. Secondary Metabolism in *Penicillium expansum*: Emphasis on Recent Advances in Patulin Research. *Crit. Rev. Food Sci. Nutr.* **2018**, *58*, 2082–2098. [\[CrossRef\]](#)
16. Sohrabi, H.; Arbabzadeh, O.; Khaaki, P.; Khataee, A.; Majidi, M.R.; Orooji, Y. Patulin and Trichothecene: Characteristics, Occurrence, Toxic Effects and Detection Capabilities via Clinical, Analytical and Nanostructured Electrochemical Sensing/Biosensing Assays in Foodstuffs. *Crit. Rev. Food Sci. Nutr.* **2022**, *62*, 5540–5568. [\[CrossRef\]](#)

17. Jimdjio, C.K.; Xue, H.; Bi, Y.; Nan, M.; Li, L.; Zhang, R.; Liu, Q.; Pu, L. Effect of Ambient pH on Growth, Pathogenicity, and Patulin Production of *Penicillium expansum*. *Toxins* **2021**, *13*, 550. [\[CrossRef\]](#)
18. Liu, X.; Wang, L.; Wang, S.; Cai, R.; Yue, T.; Yuan, Y.; Gao, Z.; Wang, Z. Detoxification of Patulin in Apple Juice by Enzymes and Evaluation of Its Degradation Products. *Food Control* **2023**, *145*, 109518. [\[CrossRef\]](#)
19. Puel, O.; Galtier, P.; Oswald, I. Biosynthesis and Toxicological Effects of Patulin. *Toxins* **2010**, *2*, 613–631. [\[CrossRef\]](#)
20. Lončarić, A.; Kovač, T.; Gotal, A.-M.; Celeiro, M.; Lores, M. Croatian Traditional Apple Varieties: Why Are They More Resistant to Plant Diseases? In Proceedings of the 2nd International Electronic Conference on Foods—“Future Foods and Food Technologies for a Sustainable World”, online, 15–30 October 2021; p. 21.
21. Sanzani, S.M.; De Girolamo, A.; Schena, L.; Solfrizzo, M.; Ippolito, A.; Visconti, A. Control of *Penicillium expansum* and Patulin Accumulation on Apples by Quercetin and Umbelliferone. *Eur. Food Res. Technol.* **2009**, *228*, 381–389. [\[CrossRef\]](#)
22. Baldisserotto, A.; Malisardi, G.; Scalambra, E.; Andreotti, E.; Romagnoli, C.; Vicentini, C.; Manfredini, S.; Vertuani, S. Synthesis, Antioxidant and Antimicrobial Activity of a New Phloridzin Derivative for Dermo-Cosmetic Applications. *Molecules* **2012**, *17*, 13275–13289. [\[CrossRef\]](#)
23. Wright, S.A. Patulin in Food. *Curr. Opin. Food Sci.* **2015**, *5*, 105–109. [\[CrossRef\]](#)
24. Jakobek, L.; García-Villalba, R.; Tomás-Barberán, F.A. Polyphenolic Characterisation of Old Local Apple Varieties from Southeastern European Region. *J. Food Compos. Anal.* **2013**, *31*, 199–211. [\[CrossRef\]](#)
25. Skoko, A.-M.G.; Vilić, R.; Kovač, M.; Nevistić, A.; Šarkanj, B.; Lores, M.; Celeiro, M.; Babojelić, M.S.; Kovač, T.; Lončarić, A. Occurrence of Patulin and Polyphenol Profile of Croatian Traditional and Conventional Apple Cultivars during Storage. *Foods* **2022**, *11*, 1912. [\[CrossRef\]](#) [\[PubMed\]](#)
26. Skłodowska, M.; Mikiciński, A.; Wielanek, M.; Kuźniak, E.; Sobiczewski, P. Phenolic Profiles in Apple Leaves and the Efficacy of Selected Phenols against Fire Blight (*Erwinia amylovora*). *Eur. J. Plant Pathol.* **2017**, *151*, 213–228. [\[CrossRef\]](#)
27. Goulas, V.; Kourdoulas, P.; Makris, F.; Theodorou, M.; Fellman, J.K.; Manganaris, G.A. Comparative polyphenolic antioxidant profile and quality of traditional apple cultivars as affected by cold storage. *Int. J. Food Sci. Technol.* **2014**, *49*, 2037–2044. [\[CrossRef\]](#)
28. Skoko, A.-M.G.; Šarkanj, B.; Lores, M.; Celeiro, M.; Babojelić, M.S.; Kamenjak, D.; Flanjak, I.; Jozinović, A.; Kovač, T.; Lončarić, A. Identification and Quantification of Polyphenols in Croatian Traditional Apple Varieties. *Plants* **2022**, *11*, 3540. [\[CrossRef\]](#) [\[PubMed\]](#)
29. Kaeswurm, J.A.H.; Senpio, R.; Manca, F.; Burandt, M.R.; Buchweitz, M. Analyzing Bioaccessibility of Polyphenols in Six Commercial and Six Traditional Apples (*Malus domestica* Borkh.) during In Vitro and Ex Vivo Oral Digestion. *Mol. Nutr. Food Res.* **2023**, *67*, 2300055. [\[CrossRef\]](#)
30. Deng, J.; Yang, H.; Capanoglu, E.; Cao, H.; Xiao, J. Technological Aspects and Stability of Polyphenols. In *Polyphenols: Properties, Recovery, and Applications*; Elsevier: Amsterdam, The Netherlands, 2018; pp. 295–323.
31. Lončarić, A.; Gotal Skoko, A.-M.; Flanjak, I.; Jozinović, A.; Babić, J.; Tomac, I.; Mihaljević Žulj, M.; Fruk, G.; Skendrović Babojelić, M.; Šarkanj, B.; et al. Influence of Cold Storage on Quality of Croatian Traditional Apple Cultivars. *Kem. Ind.* **2023**, *72*, 317–322. [\[CrossRef\]](#)
32. Sulyok, M.; Stadler, D.; Steiner, D.; Krska, R. Validation of an LC-MS/MS-based dilute and shoot approach for the quantification of >500 mycotoxins and other secondary metabolites in food crops: Challenges and solutions. *Anal. Bioanal. Chem.* **2020**, *412*, 2607–2620. [\[CrossRef\]](#)
33. Lončarić, A.; Matanović, K.; Ferrer, P.; Kovač, T.; Šarkanj, B.; Skendrović Babojelić, M.; Lores, M. Peel of Traditional Apple Varieties as a Great Source of Bioactive Compounds: Extraction by Micro-Matrix Solid-Phase Dispersion. *Foods* **2020**, *9*, 80. [\[CrossRef\]](#)
34. Lončarić, A.; Pichler, A.; Trtinjak, I.; Piližota, V.; Kopjar, M. Phenolics and antioxidant activity of freeze-dried sour cherry puree with addition of disaccharides. *LWT* **2016**, *73*, 391–396. [\[CrossRef\]](#)
35. Giusti, M.M.; Wrolstad, R.E. Characterization and Measurement of Anthocyanins by UV-Visible Spectroscopy. *Curr. Protoc. Food Anal. Chem.* **2001**, *1*, F1.2.1–F1.2.13. [\[CrossRef\]](#)
36. Ballester, A.R.; Norelli, J.; Burchard, E.; Abdelfattah, A.; Levin, E.; González-Candelas, L.; Droby, S.; Wisniewski, M. Transcriptomic response of resistant (Pi613981—*Malus sieversii*) and susceptible (“royal gala”) genotypes of apple to blue mold (*Penicillium expansum*) infection. *Front. Plant Sci.* **2017**, *8*, 1981. [\[CrossRef\]](#) [\[PubMed\]](#)
37. Leja, M.; Mareczek, A.; Ben, J. Antioxidant Properties of Two Apple Cultivars during Long-Term Storage. *Food Chem.* **2003**, *80*, 303–307. [\[CrossRef\]](#)
38. Awad, M.A.; de Jager, A. Flavonoid and Chlorogenic Acid Concentrations in Skin of ‘Jonagold’ and ‘Elstar’ Apples during and after Regular and Ultra Low Oxygen Storage. *Postharvest Biol. Technol.* **2000**, *20*, 15–24. [\[CrossRef\]](#)
39. Butkeviciute, A.; Viskelis, J.; Liaudanskas, M.; Viskelis, P.; Janulis, V. Impact of Storage Controlled Atmosphere on the Apple Phenolic Acids, Flavonoids, and Anthocyanins and Antioxidant Activity In Vitro. *Plants* **2022**, *11*, 201. [\[CrossRef\]](#)
40. Khoo, H.E.; Azlan, A.; Tang, S.T.; Lim, S.M. Anthocyanidins and Anthocyanins: Colored Pigments as Food, Pharmaceutical Ingredients, and the Potential Health Benefits. *Food Nutr. Res.* **2017**, *61*, 1361779. [\[CrossRef\]](#) [\[PubMed\]](#)
41. Shao, L.; Shu, Z.; Sun, S.-L.; Peng, C.-L.; Wang, X.-J.; Lin, Z.-F. Antioxidation of Anthocyanins in Photosynthesis Under High Temperature Stress. *J. Integr. Plant Biol.* **2007**, *49*, 1341–1351. [\[CrossRef\]](#)
42. Butkeviciute, A.; Viskelis, J.; Viskelis, P.; Liaudanskas, M.; Janulis, V. Changes in the Biochemical Composition and Physicochemical Properties of Apples Stored in Controlled Atmosphere Conditions. *Appl. Sci.* **2021**, *11*, 6215. [\[CrossRef\]](#)

43. Cavalcanti, R.N.; Santos, D.T.; Meireles, M.A.A. Non-Thermal Stabilization Mechanisms of Anthocyanins in Model and Food Systems—An Overview. *Food Res. Int.* **2011**, *44*, 499–509. [[CrossRef](#)]
44. Jakobek, L.; Barron, A.R. Ancient Apple Varieties from Croatia as a Source of Bioactive Polyphenolic Compounds. *J. Food Compos. Anal.* **2016**, *45*, 9–15. [[CrossRef](#)]
45. Donno, D.; Beccaro, G.L.; Mellano, M.G.; Torello Marinoni, D.; Cerutti, A.K.; Canterino, S.; Bounous, G. Application of sensory, nutraceutical and genetic techniques to create a quality profile of ancient apple cultivars. *J. Food Qual.* **2012**, *35*, 169–181. [[CrossRef](#)]
46. Morresi, C.; Cianfruglia, L.; Armeni, T. Polyphenolic compounds and nutraceutical properties of old and new apple cultivars. *J. Food Biochem.* **2018**, *42*, e12641. [[CrossRef](#)]
47. Kschonsek, J.; Wiegand, C.; Hipler, U.-C.; Böhm, V. Influence of Polyphenolic Content on the in Vitro Allergenicity of Old and New Apple Cultivars: A Pilot Study. *Nutrition* **2019**, *58*, 30–35. [[CrossRef](#)] [[PubMed](#)]
48. Zhong, L.; Carere, J.; Lu, Z.; Lu, F.; Zhou, T. Patulin in Apples and Apple-Based Food Products: The Burdens and the Mitigation Strategies. *Toxins* **2018**, *10*, 475. [[CrossRef](#)] [[PubMed](#)]
49. Sun, J.; Janisiewicz, W.J.; Nichols, B.; Jurick II, W.M.; Chen, P. Composition of Phenolic Compounds in Wild Apple with Multiple Resistance Mechanisms against Postharvest Blue Mold Decay. *Postharvest Biol. Technol.* **2017**, *127*, 68–75. [[CrossRef](#)]
50. Sanzani, S.M.; Schena, L.; Nigro, F.; De Girolamo, A.; Ippolito, A. Effect of quercetin and umbelliferone on the transcript level of *Penicillium expansum* genes involved in patulin biosynthesis. *Eur. J. Plant Pathol.* **2009**, *125*, 223–233. [[CrossRef](#)]
51. Yu, L.; Qiao, N.; Zhao, J.; Zhang, H.; Tian, F.; Zhai, Q.; Chen, W. Postharvest control of *Penicillium expansum* in fruits: A review. *Food Biosci.* **2020**, *36*, 100633. [[CrossRef](#)]
52. The European Parliament and the Council of the European Union Commission Regulation (EC). No 1881/2006, Maximum levels for certain contaminants in foodstuffs. *Off. J. Eur. Union* **2006**, *L364*, 5–24.

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