Agrobiodiversity for Improving Nutrition, Health and Life Quality

Review

Importance of old and local apple cultivars

Iwona Szot[1], Inna Goncharovska*[2], Svitlana Klymenko[2], Petro Bulakh[2]

[1]University of Life Sciences, Faculty of Horticulture and Landscape Architecture, Institute of Horticultural Production, Subdepartment of Pomology, Nursery and Enology, Lublin, Poland
[2]M.M. Gryshko National Botanical Garden of the National Academy of Sciences of Ukraine, Kyiv, Ukraine

ORCID Iwona Szot: https://orcid.org/0000-0002-8433-677X
Inna Goncharovska: https://orcid.org/0000-0002-9949-7541
Svitlana Klymenko: https://orcid.org/0000-0001-6468-741X
Petro Bulakh: https://orcid.org/0000-0003-1415-7482

Article Details:
Received:2022-07-06
Accepted:2022-08-04
Available online:2022-11-30

DOI: https://doi.org/10.15414/ainhlq.2022.0017

Apples are among the most consumed fruits in the world. After China, the European Union is one of the biggest producers of apples. Due to the appropriate soil and climatic conditions, Poland is a leading producer of these fruits in the world and the European Union. Currently, the cultivar structure on the European market is limited to about 12 varieties. This leads to the genetic impoverishment and loss of many local cultivars, which, due to the unattractive external appearance of apples or the alternation of fruiting, are losing to the currently popular standards. The breeding of new cultivars is based on a limited number of ancestors, which poses the risk of reduced genetic diversity of the cultivars. The decline in biodiversity is also due to crop specialization. In every region of the world where apple cultivation has developed, there are many cultivars of unknown origin, which are referred to as local cultivars. They often have unique nutritional values or traits that enable them to survive. The preservation of these cultivars is justified due to the possibility of their use in breeding new cultivars, including those resistant to diseases. They can also be used in the food industry for the production of juices, cider, and high-percentage distillates, as well as a functional food. In addition, due to the higher content of some health-promoting ingredients, they are suitable for the production of, for example, anti-aging cosmetics. There are few native old cultivars in Poland. Before World War II, apple trees of English, French, German, Italian, Dutch, Belgian, Czech, Russian, and American origin predominated in Polish orchards. Old and local cultivars have remained only in home orchards, but due to the relatively short life of apple trees, they are in danger of becoming extinct. Poland undertook the protection of old and local cultivars by ratifying the Convention on Biological Diversity of Rio de Janeiro in 1992. The collection and preservation of these apple cultivars are carried out by research centres and Botanical Gardens, among others in Warsaw, Poznań, Bolestraszyce, Drawa, and Lublin.

Keywords: *Malus domestica*, biodiversity, apple domestication

***Corresponding Author:** Inna Goncharovska, M.M. Gryshko National Botanical Garden of the National Academy of Sciences of Ukraine, Timiryazevska 1, 01014 Kyiv, Ukraine
inna_lera@ukr.net

Introduction

The volume of apple production in the world and Poland

Apples are among the most consumed fruits in the world. After China, the European Union (EU) is one of the biggest producers of apples. Inside the EU, the biggest producers are Poland, Italy, France, and Germany (Jakobek et al., 2020). The dominant cultivars are Golden Delicious (21%), Gala (11%), and Idared (9%). Due to the appropriate soil and climatic conditions, Poland is a leading producer of these fruits in the world and the European Union. Apple is the national fruit of Poles due to its production volume and availability throughout the year. It is one of the most eaten fresh fruit and is a valuable raw material for processing. Apple yields in Poland amount to 83% of all fruit crops, and the area dedicated to apple cultivation is 62% of the area of all fruit plants. This makes apple cultivation monoculture, attracting the accumulation of harmful pests, especially those with a narrow range of hosts such as *Laspeyresia pomonella* (codling moths), *Aphis pomi* (apple aphid) or *Venturia inaequalis* fungi – the culprits of apple scab and *Podosphaera leucotricha* causing apple mildew. This is also intensified by the introduction of new, nobler cultivars, which often lack the defense mechanisms of their wild ancestors. The cultivar structure in the European market is limited to about 12 varieties (Hecke, 2006). Donno et al. (2012) stated that in Italy, 'Golden Delicious' is dominant in over 70% of the orchards. This leads to genetic impoverishment and the loss of many local cultivars, which, due to the unattractive external appearance of apples or the alternation of fruiting, lose to the currently popular standards (Jemrić et al., 2013).

The history of apple domestication

All apple cultivars belong to the conventional apple tree species (*Malus* × *domestica* Borkh.), which does not occur in its natural state. It was created to systematize the cultivars developed over the centuries. Initially, the species found in the Caucasus was considered to be the ancestor of apple trees: *M. pumila* Mill. (Figure 1). and common throughout Europe *M. sylvestris* Mill. It is currently believed that many apple cultivars arose from the hybridization of the mentioned species with *M. sieversii* (Ledeb.) M.Roem., *M. orientalis* Uglitzk. and *M. baccata* (L.) Borkh.

Plants from the rosacea family (Rosacae), and the pome subfamily (Pomoideae), to which the apple tree (*Malus*) belongs, did not differentiate for 50 million years of their existence (DeVore and Pigg, 2007). The first differentiation took place only in the Oligocene (Xiang et al., 2016), and large-fruited forms *Malus*, *Pyrus*, and *Cydonia* evolved only in the late Miocene, i.e. 11.6–5.3 million years ago. Climate changes from the late Miocene to the Pleistocene caused fluctuations in the range of many plant species. The trees were not allowed to cross the glacier barriers during the peak ice age. The northern temperate apple tree has a very fragmented population, limited to its place of occurrence, as many of its seed distributors have ceased to exist as a result of glaciation (Pollegioni et al., 2017). Spreading of genetic form of apple trees is more effective by dispersing the seeds than pollen. Pollen may be carried up to a maximum of 10.7 km from the mother plant (Reim et al., 2015). Thus, the spread of apple trees was favoured by the development of fruit-eating megafauna: bears, deer, and humans. A breakthrough stage in the formation of the present apple tree cultivars was the beginning of the migrationrelated to the Silk Road in the late Holocene. Migrant people began to carry apples or apple seedlings, which caused different apple populations to spread across two continents. Hybridization of species was made possible by pollinating insects, and humans, through the selection of valuable plants and their further vegetative reproduction, contributed to the emergence of *M.* × *domestica*. Thus, the emergence of over 10 thousand existing apple cultivars took about 3,000 years (Splenger, 2019).

Figure 1 Apple fruits of *Malus pumila* Mill.

The primary method of apple domestication was by moving plants with valuable traits to the neighborhood of homes. Over time, humans have learned to reproduce plants vegetatively through grafting or budding. They described the techniques of grafting in their tracts: Hippocrates 424 BC (Mudge et al., 2009), Theophrastus (371–287 BC), Katon (234–149 BC) and Pliny the Elder (234–149 BC) (Juniper and Mabberley, 2006). The Greeks and Romans spread the "*domestica*ted apples" across the European continent (Coart et al., 2006). The simplest breeding method was the selection of seedlings obtained by natural pollination. Then, man learned to cross-breed or search for mutations. Some of the cultivars were grown locally, while others were distributed over larger geographic areas in Europe (Hartmann, 2015).

The greatest diversity of apple cultivars occurred in Europe in the 19th century, where, with intensive cultivation, various cultivars were cultivated in many small orchards. At that time, over 2500 cultivars were known in England, and in the Soviet Union countries, there were 6000. Also on the American continent, starting from the 18th century, the breeding of apple cultivars began on a large scale (Dziubiak, 2006). Before Europeans conquered America, this continent was inhabited by wild forms of apple trees. The first apple trees from Europe are believed to have been planted in Jamestown, Virginia in 1607, and others – in 1629 – in the Massachusetts Bay Colony. From the first half of the 17th century, the production of apples increased and it was immediately accompanied by the production of cider. One of the American folk heroes, Johnny Appleseed, traveling around America in the years 1792–1842, spread apple seeds, thereby increasing the biodiversity of this species, some of which were characterized by prominent productivity. However, the selection of these cultivars was focused on the production of cider, so the taste and appearance of the apples were of secondary importance (Juniper and Mabberley, 2006; Goncharovska, 2021, 2022). In the years between 1804 and 1904 in the United States, more than 7,000 apple cultivar names were recorded, although some of them may be synonyms. Gayle and Henk (2016) report that 56% of the old cultivars found in the United States (before 1830) come from wild seedlings there. The other varieties come from England (27%), France (7%), Germany (3%), and Russia (3%).

Classification of apple cultivars

People differ in their preferences regarding the taste and appearance of apples (Bonany et al., 2014), but nowadays taste and crumbly flesh are the basic features that prove their high quality (Yue and Trong, 2011). Intensive breeding work over the centuries contributed to the creation of over 10 thousand cultivars. Pomologists tried to systematize them. The different cultivars can be distinguished by their typical external and internal characteristics. The Diel-Lucas classification, popular at the turn of the 19th and 20th centuries, was based on the morphological features of apples and distinguished 15 classes (Lucas and Medicus, 1878). The aforementioned classification was based, for example, on the shape of apples, so in the Calvia class there were cultivars with a characteristic narrow ribbing around the calyx, renets had a dry russet skin and coarse-grained flesh with a wine taste, and the Rambury's were large, flattened and asymmetrical. With time, many new cultivars were created, especially the American ones, for which the Diel-Lucas classification was outdated. Also, the development of nursery techniques and the introduction of dwarf rootstocks have led to major changes in the morphology and physiology of the cultivars improved on them. It is also influenced by the climatic and soil conditions as well as the cultivation treatments used in orchards. Moreover, it is difficult to introduce specific systematics here, because all cultivars constitute the same botanical species. Currently, pomologists classify cultivars according to the date of ripening and shelf life (Rejman, 1994).

In the last 20 years, molecular tools to characterize the diversity of apple cultivars have been implemented (Guilford et al., 1997; Hokanson et al., 1998). Such methods consist of direct analysis of DNA that can be isolated from the plant tissue independently of the phenological stage of the tree and is not influenced by the environment. The most commonly used technique is the analysis of simple sequence repeats (SSRs) or microsatellite markers, which due to their repeatability have been used to describe the genetic resources of apples in many countries (Patzak et al., 2012; Baric et al., 2020). Ordrige et al. (2018), used the Diversity array technology (DarT) markers of genetic diversity to compare 2,000 cultivars. Using the Jaccard similarity coefficient, they proposed several new varietal origins than were previously documented. For example, for the cultivar James Grieve, whose origin was described as a free pollination seedling from 'Potts seedling', they indicated that it was a cross between 'Potts seedling' and 'Cox's Orange Pippin'. Migicovsky (2016) used the correlation of traits between individual phenotypes of cultivars, based on which they were able to characterize apples from the Old World or New World, with a basic skin colour (green/yellow), used for cider or other purposes (dessert/cooking), late (October/November) and early (August/September). For example, New World apples were generally larger than Old World apples. Old World cultivars were less red and more russet. This proves that the breeding program of the New World cultivars was aimed at obtaining cultivars with larger, better-colored fruit, and less sensitivity to russeting. They also found that the fruits of the cider cultivars were smaller and their flesh oxidized faster than that of dessert/kitchen apples. Although many breeding programs have been developed since the 1920s to obtain new apple cultivars, still very important in the structure of the current orchards, cultivars such as 'Golden Delicious', Red Delicious, and 'Granny Smith' were created as seedlings. It is only in recent decades that the cultivation of new cultivars, obtained through deliberate breeding, has become more important. However, this breeding is based on a limited number of ancestors, which creates the risk of reduced genetic diversity in cultivars (Noiton and Shelbourne, 1992). Based on the available literature, Noiton and Alspach (1996) analyzed how 439 new cultivars were created, i.e., those that appeared in production since the 1970s. They found that the creation of 64% of these varieties is based on 5 clones: 'McIntosh', Golden Delicious', 'Jonathan', 'Cox's Orange Pippin' and 'Red Delicious'. The use of only these five valuable cultivars may be due to a lack of information about other valuable germplasm cultures and a reluctance to test unknown parents.

Validity of preserving old cultivars

The importance of biodiversity. As a result of crop specialization, there has been a decline in biodiversity, which also applies to apple trees (Fowler and Mooney, 1990). There is a decline in the number of commonly cultivated varieties around the world. Miller (2014) reports that out of 15,000–16,000 apple cultivars in North America, now only 3 thousand are available in horticulture, but also over 80% of these cultivars are threatened with extinction. Only a few nurseries offer the sale of these cultivars. Nowadays, many experimental programs promote the conservation of biodiversity. Biodiversity is the diversification of life at all levels of an organization. Since 1992, the protection of the natural environment and biodiversity has been an integral part of the Common Agricultural Policy. Biodiversity is fundamental to the evolution and durability of life support systems in the biosphere. The higher the biological diversity of a given ecosystem, the more resistant it is to various natural disasters (droughts, floods, diseases, hailstorms, etc.) and artificial ones (chemical and radioactive contamination, the introduction of alien species, noise, global warming, etc.). To protect biodiversity, it is necessary to anticipate, prevent and combat the causes of its decline or disappearance. The importance of biodiversity protection results primarily from the need to maintain a balance in nature.

Old cultivars are gene pools the use of which can be of great economic importance. Promoting the preservation of old cultivars, as a rule, attention is paid to the protection of genetic resources and saving vanishing genotypes.

- Local cultivars of crops: increase the species and varietal diversity of crops, which prevents the simplification of crop rotation and ensures the diversity of habitats,
- In general, they have lower cultivation requirements, what allows to limit the use of fertilization and plant protection products,
- Some of them are especially useful in extensive production systems and for keeping agricultural production in marginal lands.

Preserving plant gene resources is the only way to guarantee their availability now and in the future. It is difficult to predict changes in the environment and all human needs, so it is necessary to maintain the widest possible genetic variability of plants. The more genetically diverse the plant material, the greater the chance of finding forms with useful features in plant breeding and plant production.

In every region of the world where the cultivation of apple trees has developed, there are many varieties of unknown origin, which are referred to as local cultivars. They are often characterized by unique nutritional values or qualities that enable them to survive (Király et al., 2020). In some countries, e.g. Hungary (Király et al., 2020), Bosnia-Herzegovina (Stanivuković et al., 2017), Montenegro (Božović et al., 2013), the United States (Miller, 2014), Iran (Damyar et al., 2007), the presence of so-called local cultivars, i.e. those that can adapt to the conditions prevailing in a given region, is noted. For many years, they have been grown on a small scale for local markets.

One way to preserve the old cultivars is to create embryonic plasma repositories to prevent the future narrowing of the genetic base (Way et al., 1990). The next step is to use this diverse germ plasma in breeding programs rather than relying only on inbreeding (Noiton and Shelbourne, 1992). In many countries, repositories in the form of orchards are established based on the accumulated old and local cultivars. It is necessary to identify and evaluate genotypes based on the morphometrical and biochemical traits in various conditions, as evidenced by the many authors (Ivanišová et al., 2017; Grygorieva et al., 2017a,b, 2018a,b; Fatrcová Šramková et al., 2019; Vergun et al., 2020; Horčinová Sedláčková et al., 2020, 2021). In England, there is an increased interest in setting up a lot of small community orchards with 100-old trees. The Newquay community orchard in Cornwall was founded in 2015 with a £66,000 crowdfunding appeal. More than 2,000 trees, including 120 local heritage cultivars, have been planted on land donated by the Duchy of Cornwall. In Lithuania, an attempt was made to establish a modern orchard based on the oldest cultivar there: Ničnera zemeņu (Edrbeerapfel Nitschners) and Trebū sēklaudzis and Mālābele, on a semi-dwarf rootstock MM 106. Experience shows that the tested varieties require refinement of harvesting technology and care work. The cv. Mālābele, as a late summer variety, needs to be harvested several times. The cv. Trebū sēklaudzis, due to its strong growth, requires a wider spacing in the row (1.5–2.0 m) and the formation of crowns in slender spindle, as well as thinning of buds, to improve the quality of the fruit (Rubauskis and Borisova, 2021).

Nutritional and health-promoting characteristics of old and local cultivars

Apple, as a fruit, provides man with many valuable chemicals such as carbohydrates, vitamins, mineral compounds and fibres, pectin and various polyphenols, while it is characterized by a low concentration of protein and fat.

Currently, in many countries, studies are being carried out on the quality characteristics of the fruits of old and local cultivars. Unfortunately, determining what the old and new cultivar is not unambiguous. 'Golden Delicious' in some experiments is considered an old cultivar (Wojdyło et al., 2008; Mitre et al., 2009), and in some as a representative of new cultivars (Kschonsek et al., 2018; Morresi et al., 2018; Király et al., 2020; Ceci et al., 2021). This is probably due to the fact that although this cultivar was bred in the nineteenth century, its share in the varietal structure of many countries is still significant.

Oszmiański et al. (2018), while determining the chemical composition of 22 old cultivars, noted that the dry matter content was from 1.30 to 17.12 g.100 g^{-1}, soluble solids content from 10.50 to 14.70 Bx, fructose from 3.96 to 8.52 g.100 g^{-1} f.w. glucose from 0.94 to 2.96 g.100 g^{-1} f.w., sucrose from 0.06 to 2.72 g.100 g^{-1} f.w., total sugar from 7.41 to 11.99 g.100 g^{-1} f.w., total acidity from 0.17 to 1.07 g.100 g^{-1}, pectin content from 0.65 to 2.24 g.100 g^{-1}. The concentration of polyphenols in 22 apple cultivars ranged from 1,348.40 to 4,310.52 mg.100 g^{-1} d.m. in the fruits of the Altländer Pfannkuchenapfel and Roter Trier Weinapfel cultivars; triterpenoids ranged from 466.30 to 3,753.60 μg.g^{-1} d.m. in the fruits of the Gelber Richard and Wintergoldparmane cultivars. The highest ABTS and FRAP test values were observed for the cv. Wintergoldparmane (124.71 and 80.15 μmol Trolox.g^{-1} dm) and Horneburger Pfannkuchenapfel (117.93 and 78.63 μmol Trolox.g^{-1} dm).

Wojdyło et al. (2008) draw attention to the content of health-promoting ingredients such as polyphenols, including anthocyanins, flavanols, phenolic acids, flavonols, vitamin C content, etc. Analysis of the phenolic profile in apples indicates that the main groups are procyanidins, flavan-3-ols, and chlorogenic acid, while anthocyanins and ploridzin are the smallest groups. The antioxidant activity of apples depends on the content of polyphenols, especially on the content of procyanidins/flavan-3-ols (Wojdyło et al., 2008). In the study Kschonsek et al. (2018), the pulp of new cultivars such as Elstar or Jonagold was characterized by a lower content of major phenolic groups and vitamin C compared to the pulp of old cultivars such as Ontario, Oldenburger, Goldparmäne, Berlepsch. They showed that the antioxidant capacity depends on the content of flavonols in the peel, not vitamin C. In contrast, in the pulp, the content of vitamin C determines the antioxidant properties of apples. Therefore, it is worth consuming fruits with peel. Wojdyło et al. (2008), comparing the content of polyphenols among old and new cultivars, found that new cultivars such as Ozark Gold, Julyred and Jester, were characterized by the same or higher content of bioactive ingredients compared to the old cultivar: Golden Delicious, Idared, and Jonagold.

Božović et al. (2013), assessing the apples of old cultivars growing in Montenegro, found that they ripened from mid-July to mid-October. Extremely large fruits were characterized by 'Ilinjača'' (167.50 g), 'Dunjka' (170.15 g) and 'Moračka Krstovača krupna' (182.34 g). It is noted that early fruiting cultivars such as 'Šarena petrovača' and 'Ilinjača' and late-ripening cultivars such as Aleksandrija, Limunjača and Rebrača can be used for kitchen use. In addition, cultivars with a high soluble solids content: Aleksandrija (16%), Rebrača (15.5%), Jolovača (14.6%) and Dunjka (14.5%) can be used as dessert fruits, for direct consumption.

Jakobek and Barron (2016) found that the polyphene profile of several old Croatian cultivars was similar to the American cultivars (Cortland and Russet). Some of the old autumn cultivars like 'Zimnjara' can be a good source of polyphenols due to the particularly high content of total polyphenols and dihydrochalcone

ISSN 2585-8246

content. The cv. Adamova zvijezda was characterized by the highest values of quercetin derivative and flavanol content in the skin. They observed that parenchymal cultivar with a high proportion of phenolic acid is characterized by a low content of flavanol and vice versa.

Passafiume et al. (2021) compared the quality of fruits of old and new cultivars bred in Italy and grown in the mountainous conditions of Sicily. They found that both old and new clones are characterized by high fruit quality. The new clones are more attractive in the dessert fruit market, where the consumer is looking for apples that are better coloured and sweeter. However, the old genotypes had more vitamins: thiamine, B_5, B_2, E and C, so they can satisfy not only the niche market.

Donno et al. (2012) compared 9 local ancient cultivars: Bella di Barge, Buras, Contessa, Dominici, Gamba Fina, Grigia di Torrian, Losa, Magnana, and Runsè with the control cv. Golden Delicious found that they were characterized by a higher content of vitamin C, total polyphenols and antioxidant activity.

Morresi et al. (2018) report that old cultivars of apple trees from the Marche region of Italy are characterized by high variability. They proved that a 150 g apple can provide, depending on the variety, from 12.5 mg (cv. Gelata) to more than 500 mg (cv. Calville White Winter) of total polyphenols.

Ceci et al. (2021), comparing the chemical composition of old cultivars, commonly grown (commercial), noted that the old cultivars were distinguished by the content of polyphenolic compounds and higher antioxidant capacity.

Sometimes apples can cause allergies, but it has been found that old cultivars are better tolerated by people who have developed intolerance compared to new cultivars (Kschonsek et al., 2019).

Apples of old cultivars contain higher amounts of dihydrochalcones than commercial cultivars. These compounds have the potential to lower blood glucose levels, which may hel prevent diabetes (Kobori et al., 2012; Mei et al., 2016).

Possibilities of using old cultivars of apple trees

Breeding cultivars resistant to diseases and pests. Perennial cultivation of apple trees in large areas caused the accumulation of diseases and pests. The most dangerous diseases include apple scab (*Venturia inaequalis* Cke.) and powdery mildew of apple (*Podosphaera leucotricha* Salm.), and pests: aphids, especially aphis pomi (*Aphis pomi*) and codling moth (*Cydia pomonella*). Until now, most resistance breeding has been based on the *Malus floribunda* type 821 × Rome Beauty cross, followed by reverse crosses with noble varieties to give the new variety valuable quality characteristics (Crosby et al., 1992).

The presence of specific phenolic compounds can cause low susceptibility of apple fruits to the most important diseases. One such compound is phloridzin (a derivative of chalcone) which is a characteristic apple polyphenol. It is a phytolaexin that provides resistance to pathogens – *Venturia inaequalis* and *Erwinia amylovora* (Petkovsek et al., 2010). Other researchers (McClure et al., 2019) emphasize that flavan-3-ols are responsible for increasing resistance to *Venturia inaequalis*.

Old cultivars, due to their resistance to diseases, especially scab and powdery mildew, can be used in the expansion of such breeding programs. In addition, due to the high field resistance to these diseases, they are suitable for organic cultivation. Papp et al., 2015 studying resistance to apple scab, powdery mildew and fire blight among the old cultivars accumulated in Hungary distinguished those that can be recommended for organic cultivation: 'Batul', 'Vilmos renet', 'Pónyik', 'Sikulai', 'Tordai piros lálvil' and 'Szabadkai szeresika'. The old 'Batul' cultivar from the Carpathian Basin probably contains genes responsible for inheriting resistance to fire blight FB_MR5 and Scab Vh4Vh4. These observations are consistent with Halász et al., 2011, who indicate that the cv. Sikulai, Tordai piroskálvil, Batul, Vilmos renet, Zöld sóvári, are resistant to Ervinia amylovora and apple scab. They have S2 or S3 alleles (Broothaerts and Van Nerum, 2003). Some of these cultivars have been known in the Carpathian Basin for more than 200 years, and even date back to the time of the Turkish occupation of Transylvania. Militaru et al. (2015), comparing a dozen or so attics of Romanian cultivars, distinguished the cv. Gustaw durabil as resistant to apple scab, cv. Botane – resistant to apple mildew. In addition, the cv. Gustaw durabil and Pătul were not attacked at all by the aphis pomi, while cv. Verzi de Rădăşeni, Domneşti, Roşii de Geoagiu, Călugăreşti – by the codling moth.

Raw material in the food industry

The current consumer is looking for food produced and processed sustainably, making it safe, fresh and natural (Putnik et al., 2018). Many consumers appreciate the unique taste of old cultivars and are aware of their nutritional and health-promoting values. Thanks to this, old cultivars can be restored to the dessert fruit market. Donno et al. (2012) created a sensory profile of ancient cultivars and distinguished several interesting features based on a sensory analysis. They found that old cultivars such as Buras, Contesse, Grigia di Torriana and Runsè show good organoleptic quality, so they could expand the local apple market. Oszmiański et al. (2018) found that some old apple fruit cultivars, especially Roter Trier Weinapfel, Wintergoldparmane and Horneburger Pfannkuchenapfel, are characterized by the highest amount of bioactive compounds and antioxidant properties. They can therefore be chosen for their potential use in commercial cultivation for the production of fruits with a valuable health-promoting nutritional effect on human health. Therefore, old apple cultivars can be a promising source of health-promoting compounds with potential health benefits. Mitre et al. (2009), assessing the yield and quality of fruits of several old cultivars: Golden Delicious, Jonathan, Starkrimson, Wagener, Kaltherer Bőhmer in Transylvania conditions, concluded that due to the abundance of yield and high quality of fruits, they should continue to be maintained in commercial orchards. On the other hand, Jeremić et al. (2013) examined the usefulness of 9 old cultivars: Gelber Bellefleur, Carevic, Celenka, Crvena Jesenska Rebrača, Paradija, Paulaner Weinapfel, Perovnjaca, Winter Banana, and Zuccalmaggio, on the MM 106 rootstock, in Croatian conditions found that they are characterized by too little weight (80–120 g) and without special treatments such as fertilization, cutting and thinning, they do not meet market standards. Horčinová Sedláčková et al. (2020, 2021) stated that some local cultivars in Slovakia, that grow wild and represent spontaneous seedlings from free pollination have a set of economically important traits and are ready to be used as potential genetic resources for a breeding program.

Apples of old cultivars are suitable for the production of valuable juices (Jakobek and Barron, 2016). Many valuable ingredients characteristic of apples are also found after their processing in juice. Iaccarino et al. (2019) studying the chemical composition of juices from ancient cultivars found that it is similar to popular apple juices. The extract content ranged from 8.1 to 14.2 3 gL^{-1}. The predominant sugar was fructose (from 30.1–78.3 gL^{-1}). The glucose content was 5.4–20.7 gL^{-1} and sucrose from 8.5 to 63.2 gL^{-1}. The dominant acid was malic acid (on average 8.8 gL^{-1}). The ratio of sugars to acids ranged from 5.5–33.1, with the values of this coefficient of 15–16 being shown to give the desired balance of sweet taste and acidity. The juice of four cultivars: Gadeskovæble, Ingersæble, Bodil Neergaard, and Barritskov Madæble were particularly rich in polyphenols, while apple juice of the cv. Mormorsæble and Antonius were characterized by a very specific smell and taste like apricot and peach. Thus, cultivars distinguished by special taste qualities can be used for the production of single-variety juices, the so-called 'vintage', which diversify the juice menu in restaurants.

Recently, the processing industry in Poland has been dynamically developing, in the production of cider. In Poland, the intensive development of this industry took place in 2013, when the Association of Fruit Growers of the Republic of Poland began to look for ways of developing industrial apples other than apple concentrate. The refinement of the Excise Tax Act, which reduces excise duty on low-percentage alcohol, encouraged many entrepreneurs to develop apples in the form of cider. The embargo introduced by Russia on Polish apples in 2014 meant that the production of these beverages amounted to 800,000 litres in 2013, in 2014 increased to 2 million litres, and in the following year to 15 million litres (Nosecka and Bugała, 2019). The development of cider production in Poland may be affected by a change in taxes, which assumed a 10% increase in excise duty on wine, beer and vodka from January 1, 2020. According to the EU Agriculture Outlook (EC 2019), there may be an increase in cider consumption in new markets from Central and Eastern Europe. Craft ciders focused on consumers looking for innovative and unique flavours have great potential (Reiss et al., 2012). The quality of cider largely depends on the quality of the apples. It is assumed that the juice for the production of cider should contain about 15% sugars, 0.2% tannins and 0.3–0.5% acids. Therefore, in Poland, different cultivars of apples are mixed to obtain the expected chemical composition of the juice. To increase the acidity of the juice, 20% juice of wild apples is added to the basic apple raw material. You can also reach for older cultivars of apples with a sour aftertaste, with a hint of bitterness, such as: 'Berner Rose', 'Reneta Landsberska', 'Żeleźniak', 'Sztetyna Czerwona', 'Kardynalskie', 'Kalwila Czerwona', 'Kazachstanskoje Jubilinnoje'. Jemrić et al. (2013) studying the quality of old apple cultivars indicated the cv. Perovnjača characterized by the highest acidity and less than 20 SSC:TA ratio, which makes it suitable for cider production.

Apples can also be used to make fruit distillates. Fruit distillates are popular spirits because of their unique taste. The taste of fruit distillates depends primarily on the fruit (primary taste), fermentation (secondary taste), distillation (tertiary taste) and ripening (quaternary flavour). Very important is the presence of suitable volatile organic compounds that affect the overall sensory characteristics of the product. Spaho et al. (2021) studied in Bosnia and Herzegovina the suitability of old cultivars for the production of fruit distillates found that products from the cv. Prijedorska zelenika and Masnjača had an intense fruity-sour aroma that surpassed the control cv. Golden Delicious. In contrast, distillates from apples of the cv. Žuja in terms of chemical composition and sensory quality were similar to those of the cv. Golden Delicious. The alcohol obtained from the apples of the cv. Šarenika was distinguished by its aroma, but it still needs to be specially purified during distillation. Apples of the cv. Samoniklica, due to the high content of terpenes, can be a valuable flavouring additive. However, apples of the cv. Ljepocvjetka, Bobovec and Sarija are not suitable for the production of distillates due to the lack of an aromatic contribution.

Old cultivars, due to their outstanding health-promoting properties, can also be a raw material for the production of functional food (Duralijo et al., 2021). The consumption of such foods as part of a varied diet has beneficial effects that go beyond the basic nutritional values. An example of such products is functional drinks, which are, for example, a mixture of apple juice and tea (De Souza et al., 2020). Thanks to improved physicochemical properties, increased nutritional or health-promoting properties and sensory attractiveness, they can find interest among athletes, convalescents, etc. There are attempts to create flour from apple pomace, as a gluten-free product that would replace wheat flour for people with celiac disease. Flour with has a lower protein content (1.25%) and more fibre (56%) than wheat and rice flour. The total phenol content in apple flour is 4 times higher than in wheat and 7 times higher than in rice. Cakes made of such flour, despite being harder, meet the expectations of consumers (Azari et al., 2020).

Due to the high content of polyphenols, apples can also be used in the production of anti-ageing cosmetics. Morresi et al. (2018) proved that glycoxidation is responsible for skin ageing, and the polyphenols contained in apples of old varieties effectively prevent this. Barreira et al. (2019) suggests that phenolic compounds from apples can be used in skin preparations due to several beneficial properties such as antioxidant or antimicrobial effects.

Old cultivars in Poland

In Poland, horticulture developed thanks to monks and gardeners working in castle gardens. In the Middle Ages, several noble varieties of apple trees were grown, imported mainly from Germany and France. The travelling nobility also brought interesting plant specimens from foreign countries. Soldiers returning from wars smuggled valuable plants. From the mid-nineteenth century, when the commodity production of apples in peasant farms began to develop, it was modelled on German and French fruit growing and apple cultivars were still imported from these countries. However, in Poland, due to the lack of schools focused on the development of horticultural sciences, purposeful breeding did not develop (Jankowski, 1923). Records of nursery catalogues from the early 30s of the twentieth century indicate Polish cultivars: Bukówka, Bursztówka Polska, Kalwaryjska, Kosztela, Ksawerówka, Papierówka Podlaska, Piękna z Rept, Profesor Jankowski, Rapa Zielona (Figure 2), Rarytas Śląski, Tyrolka Krynicka, Węgierczyk, Złota Kwidzyńska. The cv. Kosztela is associated with a legend explaining the origin of this name. Kosztela was probably bred by the Cistercians in the sixteenth century in Czerwińsk as Wierzbówka Zimowa. Planted in the palace garden of Jan III Sobieski in Wilanów, it bore fruit alternately. In the year of poor yield, Queen Marysieńka, collecting fruit from under the apple tree, assessed the crop as "kosz tylko?" (the basket only). With time, Wierzbówka adopted the name Kosztylka, and finally Kosztela (Smardzewski, 1917–1932).

Figure 2 Cultivar Rapa Zielona

The Polish people often cultivated cultivars from neighbouring countries, such as Lithuanian: Pineapple Berżenicki, Cukrówka Litewska, Malinówka Berżenicka, Reneta Litewska, Strumiłówka, Śmietankowe; Russian: Antonówka zwykła, Antonówka Półtorafuntowa, Antonówka Kamienna (Figure 3 (A)), Antonówka Kołowa (Figure 3 (B)), Charłamowska, Kandil Sinap (Figure 3 (C)); Ukrainian: Aporta; German: Kaiser Wilhelm, Grochówka (Figure 3 (D)), Żeleźniak

Figure 3 Cultivars of apples
A – Antonówka Kamienna; B – Antonówka Kołowa; C – Kandill Sinap; D – Grafsztynek Inflancki; E – Grochówka; F – Żeleźniak

(Figure 3 (E)), from the Baltic countries: Grafsztynek Inflancki (Figure 3 (F)), Oliwka Inflancka, Glogierówka (synonym Pepina Litewska).

As a result of the search for valuable cultivars before World War II, cultivars of apple trees of English, French, German, Italian, Dutch, Belgian, Czech, Russian and American origin prevailed in Polish orchards. Cultivars of apple trees imported from other countries often had names that were difficult to mention and spell, so they were changed to more familiar-sounding ones. For example, Kronselska (Figure 4a A) with the foreign-language name Pomme de Croncels or Transparente de Croncelles has settled in Poland. Other old cultivars from countries not directly bordering Poland are: Grafsztynek Prawdziwy, Fameuse (Figure 4a B), Hibernal, Glockenapfel (Figure 4a C), Golden Delicious, Granny Smith (Figure 4a D), Jonatan, Kantówka Gdańska (Figure 4b E), Kardynalskie (Figure 4b F), Koksa Pomarańczowa (Figure 4b J), Królowa Renet (Figure 4b K), Krótkonóżka Królewska (Figure 4b L), Książę Albrech Pruski, Książęca, Malinowa Oberlandzka, Reneta Landsberska (Figure 4b M), Pepina Saffron, Signe Tillisch, Piękna z Boskoop, Piękna of Barnak.

In the interwar period, there were several cultivars of apple trees in commercial production, but none came from Polish breeding. During this period, the first American cultivars were imported, e.g. Jonathan, and after the Second World War: McIntosh, Lobo, Cortland, Bankroft. The dominant varieties in orchards at that time were: Boskoop, Cesarz Wilhelm, Oliwka Żółta, Landsberska, Grochówka and summer cultivars. A clear breakthrough in the efficiency and quality of apple production occurred after 1995 when most of the trees in the orchards were replaced by cultivars on dwarf rootstocks.

Old and local cultivars have remained only in home orchards, but due to the relatively short life of apple

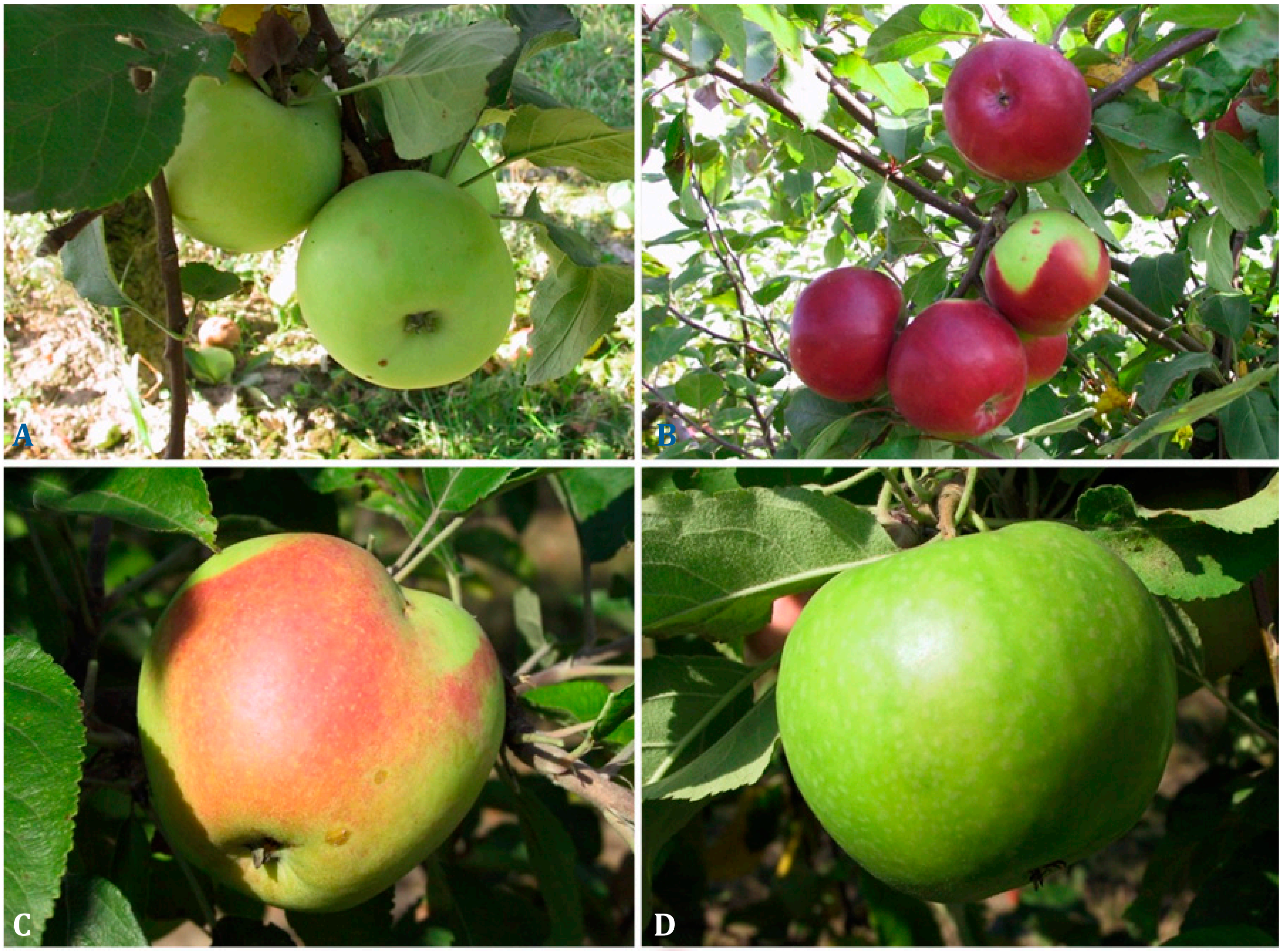

Figure 4a Cultivars of apples
A – Koronselska; B – Fameuse; C – Glockenapfel; D – Granny Smith

Figure 4b Cultivars of apples
E – Kantówka Gdańska; F – Kardynalskie; J – Koksa Pomarańczowa; K – Królowa Renet; L – Krótkonóżka Królewska; N – Reneta Landsberska

trees, they are in danger of extinction. Poland undertook to protect old and local cultivars by ratifying the Rio de Janeiro Convention on Biological Diversity in 1992. The collection and preservation of these cultivars of apple trees is carried out by research centres and Botanical Gardens m.in in Warsaw, Poznań, Bolestraszyce (Żygala et al., 2011), Drawa National Park and its neighbouring lies in a plain called Drawska Plain, which is a fragment of the lake district South Pomeranian Lake District, in the north-western part of Poland (Oszmiański et al., 2018). In Lublin, in the experimental orchard of the University of Life Sciences in Lublin, in 2021, a quarter of about 70 old and local cultivars were planted, where the material consists of trees budding on the M9 rootstock, and the "slips eye" from scions from Bolestraszyce. Also, amateur growers are increasingly interested in planting trees of old cultivars, in home orchards and organic farms, and the amended regulations allow nurserymen to produce them.

Conclusions

As a result of centuries-old cultivation and breeding of apple trees, more than 10,000 cultivars were created, including in the common, conventional species *Malus* × *domestica* Borkh. The greatest diversity in the structure of cultivated cultivars was marked in the nineteenth century, due to the intensification of the intensity of breeding work and the cultivation of apple trees in many small areas. However, around the world, with the increase in the specialization of production, the number of cultivars of apple trees decreased to about twelve. This caused a huge risk of a decline in genetic diversity. In every region of the world where apple production has developed, there are many varieties of unknown origin, which are referred to as local cultivars. They are often characterized by unique nutritional values or features that enable them to survive. The preservation of these cultivars is justified due to the possibility of their use in the breeding of new cultivars, including those resistant to diseases. They can also be used in the food industry for the production of juices, cider and high-percentage distillates, as well as functional food. In addition, due to the higher content of some health-promoting ingredients, they are suitable for the production of anti-ageing cosmetics. In Poland, old and local cultivars are preserved in collection pomological gardens, e.g. in Bolestraszyce and Lublin, and by establishing organic orchards based on these cultivars.

References

Azari, M., Shojaee-Aliabadi, S., Hosseini, H., Mirmoghtadaie, L., & Hosseini, S.M. 2020. Optimization of physical properties of new gluten-free cake based on apple pomace powder using starch and xanthan gum. In *Food Science and Technology International*, *26*, 603–613. https://doi.org/10.1177/1082013220918709

Baric, S., Storti, A., Hofer, M., Guerra, W., & Dalla Via, J. 2020. Molecular genetic identification of apple cultivars based on microsatellite DNA Analysis. I. The database of 600 validated profiles. In *Erwerbs-Obstbau*, *62*, 117–154. https://doi.org/10.1007/s10341-020-00483-0

Barreira, J.C.M., Arraibi, A.A., & Ferreira, I.C.F.R. 2019. Bioactive and functional compounds in apple pomace from juice and manufacturing: Potential use in dermal formulations. In *Trends in Food Science & Technology*, *90*, 76–87. https://doi.org/10.1016/j.tifs.2019.05.014

Bonany, J., Brugger, C., Buehler, A., Carbó, J., Codarin, S., Donati, F., Echeverria, G., Egger, S., Guerra, W., Hilaire, C., Höller, I., Iglesias, I., Jesionkowska, K., Konopacka, D., Kruczyńska, D., Martinelli, A., Petiot, C., Sansavini, S., Stehr R., & Schoorl F. 2014. Preference mapping of apple varieties in Europe. In *Food Quality and Preference*, *32*, 317–32. https://doi.org/10.1016/j.foodqual.2013.09.0109

Božović, D., Jaćimović, V., & Lazović, B. 2013. Old apple varieties in central Montenegro. In *Agriculture & Forestry*, *59*(2), 217–223.

Broothaerts, W., & Van Nerum, I. 2003. Apple self-incompatibility genotypes: an overview. In *Acta Horticulturae*, *622*, 379–387.

Ceci, A.T., Bassi, M., Guerra, W., Oberhuber, M., Robatscher, P., Mattivi, F., & Franceschi, P. 2021. Metabolomic characterization of commercial, old and red-fleshed apple varieties. In *Metabolites*, *11*(378), 1–18. https://doi.org/10.3390/metabo11060378

Coart, E., Van Glabeke, S., De Loose, M., Larsen, A.S., & Roldan-Ruiz, I. 2006. Chloroplast diversity in the genus *Malus*: new insights into the relationship between the European wild apple (*Malus sylvestris* (L.) Mill.) and the domesticated apple (696 Borkh.). In *Molecular Ecology*, *15*, 2171–2182. https://doi.org/10.1111/j.1365-294X.2006.02924.x

Crosby, J.A., Janick, J., Pecknold, P.C., Korban, S.S., O'connor, P.A., Ries, S.M., Goffreda, J., & Voordeckers, A. 1992. Breeding apples for scab resistance: 1945–1990. In *Fruit Varieties Journal*, *46*, 145–166.

Damyar, S., Hassani, D., Dastjerdi, R., Hajnajari, H., Zeinanloo, A.A., & Fallahi, E. 2007. Evaluation of Iranian native apple cultivars and genotypes. In *Journal of Food, Agriculture & Environmentaol*, *5*(3), 211–215.

De Souza, C.C., Oliveira, C.A., Pires, J.F., Pimentel, T.C., Raices, R.S.L., & Nogueira, L.C. 2020. Physicochemical characteristics and sensory acceptance of a mixed beverage based on organic apple juice and cardamom tea (*Elettaria cardamomum*) with allegation of functional properties. In *Food Science and Technology*, *40*, 669–676.

DeVore, M.L., & Pigg, K.B. 2007. A brief review of the fossil history of the family Rosaceae with a focus on the Eocene Okanogan Highlands of eastern Washington State, USA, and British Columbia, Canada. In *Plant Systematics and Evolution*, *266*, 45–57. https://doi.org/10.1007/s00606-007-0540-3

Donno, D., Beccar, G.L., Mellano, M.G., Marinoni, D.T., Cerutti, A.K., Canterino, S., & Biunous, G. 2012. Application of sensory, nutraceutical and genetic techniques to create a quality profile of ancient apple cultivars. In *Journal of Food Quality*, *35*, 169–181. https://doi.org/10.1111/j.1745-4557.2012.00442.x

Duralijo, B., Putnik P., Brdar, D., Markovinović, A. B., Zavadav S., Pateiro, M., Domĭnguez, R., Lorenzo, J.M., & Kovačević, B.B. 2021. The Perspective of croatian old apple cultivars in extensive farming for the production of functional foods. In *Foods*, *10*(708), 1–30. https://doi.org/10.3390/foods10040708

Dziubiak, M. 2006. Old apple cultivars and their origin. In *Rocznik Dendrologiczny*, *54*, 51–66.

Fatrcová Šramková, K., Brindza, J., Ivanišová, E., Juríková, T., Schwarzová, M., Horčinová Sedláčková, V., & Grygorieva, O. 2019. Morphological and antiradical characteristics of Rugosa rose (*Rosa rugosa* Thunb.) fruits canned in different kind of honeys and in beverages prepared from honey. In *Potravinarstvo Slovak Journal of Food Sciences*, *13*(1), 497–506. https://doi.org/10.5219/1065

Fowler, C., & Mooney, P. 1990. *Shattering. Food, politics, and the loss of genetic diversity*. Univ. Arizona Press, Tucson, AZ

Gayle, M.V., & Henk, D.A. 2016. Historic American Apple Cultivars: Identification and Availability. In *J. Amer. Soc. Hort. Sci.*, *141*(3), 292–301.

Goncharovska, I. & Levon, V. 2021 Content of anthocyanins in the bark of fruit and berry plants due to adaption to low temperatures. In *Khimiya Rastitel'nogo Syr'ya*, *1*, 233–239. https://doi.org/10.14258/jcprm.2021017747

Goncharovska, I., Kyznetsov, V., Antonyuk, G., Dan, C., & Sestras A.F. 2022. Flower and fruit morphological characteristics of different crabapple genotypes of ornamental value. In *Notulae Scientia Biologicae*, *14*(1), 162–171. https://doi.org/10.15835/nsb14110684

Grygorieva, O., Klymenko, S., Brindza, J., Schubertová, Z., Nikolaieva, N., & Šimková, J. 2017a. Morphometric characteristics of sweet chestnut (*Castanea sativa* Mill.) fruits. In *Potravinarstvo Slovak Journal of Food Sciences*, *11*(1), 288–295. https://doi.org/10.5219/684

Grygorieva, O., Klymenko, S., Ilinska, A., & Brindza, J. 2018a. Variation of fruits morphometric parameters of *Elaeagnus multiflora* Thunb. germplasm collection. In *Potravinarstvo Slovak Journal of Food Sciences*, *12*(1), 527–532. https://doi.org/10.5219/922

Grygorieva, O., Klymenko, S., Vergun, O., Hudz, N., Nikolaieva, N., Schubertová, Z., Palamarchuk, O., & Brindza, J. 2017b. Morphological characteristics and determination of volatile organic compounds of *Diospyros virginiana* L. genotypes fruits. In *Potravinarstvo Slovak Journal of Food Sciences*, *11*(1), 612–622. https://doi.org/10.5219/808

Grygorieva, O., Klymenko, S., Vinogradova, Y., Vergun, O., & Brindza, J. 2018b. Variation in morphometric traits of fruits of *Mespilus germanica* L. In *Potravinarstvo Slovak Journal of Food Sciences*, *12*(1), 782–788. https://doi.org/10.5219/999

Guilford, P., Prakash, S., Zhu, J.M., Rikkerink, E., Gardiner, S., Bassett, H., & Forster, R. 1997. Microsatellites in *Malus* × *domestica* (apple): abundance, polymorphism and cultivar identification. In *Theor. Appl. Genet.*, *94*, 249–254.

Halász, J., Hegedüs, A., György, Z., Pállinger, E., & Tóth, M. 2011. S-genotyping of old apple cultivars from the Carpatian basin: methodological, breeding and evolutionary aspects. In *Tree Genetics Genomes*, *7*, 1135–1145.

Hartmann, W. 2015. *Farbatlas Alte Obstsorten*. 5th ed., Ulmer Verlag, Stuttgart.

Hecke, K., Herbinger, K., Veberič, R., Trobec, M., Toplak, H., Štampar, F., Keppel, H., & Grill, D. 2006. Sugar-, acid- and phenol contents in apple cultivars from organic and integrated fruit cultivation. In *Eur J Clin Nutr*, *60*, 1136–1140.

Hokanson, S.C., Szewc-Mcfadden, A.K., Lamboy, W.F., & Mcferson, J.R. 1998. Microsatellite (SSR) markers reveal genetic identities, genetic diversity and relationships in a *Malus* × *domestica* Borkh. core subset collection. In *Theor. Appl. Genet.*, *97*, 671–683.

Horčinová Sedláčková, V., Hulin, M., & Brindza, J. 2020. Comparison of old and landraces varieties of the apple tree (*Malus domestica* Borkh) in the variability of some morphological characters of leaves and flowers. In *Agrobiodiversity for Improving Nutrition, Health and Life Quality*, *4*(1), 112–123. https://doi.org/10.15414/agrobiodiversity.2020.2585-8246

Horčinová Sedláčková, V., Hulin, M., Vinogradova, Y., Goncharovska, I., & Brindza, J. 2021. Comparison of old and local apple varieties and seedlings (*Malus domestica* Borkh.) in the variability of some morphological characters of fruits and seeds. In *Agrobiodiversity for Improving Nutrition, Health and Life Quality*, *5*(1), 55–71. https://doi.org/10.15414/ainhlq.2021.0007

Iaccarino N., Varming C., Petersen M.A., Viereck N., Schütz B., Toldam-Andersen T.B., Randazzo, A., & Enlelsem, S.B. 2019. Ancient Danish apple cultivars – a comprehensive metabolite and sensory profiling of apple juices. *Metabolites*, *11*(9), 139. https://doi.org/10.3390/metabo9070139

Ivanišová, E., Grygorieva, O., Abrahamová, V., Schubertova, Z., Terentjeva, M., & Brindza, J. 2017. Characterization of morphological parameters and biological activity of jujube fruit (*Ziziphus jujuba* Mill.). In *Journal of Berry Research*, *7*(4), 249–260. https://doi.org/10.3233/JBR-170162

Jakobek, L., Ištuk, J., Buljeta, I., Voća, S., Žlabur, J., Skendović, Š., & Babojelić M. 2020. Traditional, indigenous apple varieties, a fruit with potential for beneficial effects: their quality traits and bioactive polyphenol contents. In *Foods*, *9*(52), 1–18. http://dx.doi.org/10.3390/foods9010052

Jakobek, L., & Barron, A.R. 2016. Ancient apple varieties from Croatia as a source of bioactive polyphenolic compounds. In *J. Food Compos. Anal.*, *45,* 9–15.

Jankowski, E. 1923. *Dzieje ogrodnictwa w Polsce w zarysie* [The history of gardening in Poland in outline]. Bank dla Handlu i Przemysłu, Warszawa. [In Poland]

Jemrić, T., Babojelić, M.S., Fruk, G., & Šindrak, Z. 2013. Fruit quality of nine old apple cultivars. In *Not. Bot. Horti. Agrobo.*, *41*(2) 504–509.

Juniper, B.E., & Mabberley, D.J. 2006. *The Story of the Apple*. Portland, OR: Timber Press.

Király, I., Kovács, G., Molnár, K., & Florkowski, W.J. 2020. Evaluation of fruit quality of apple land varieties. In *Gradus*, *7*(3), 44–50.

Kobori, M., Masumoto, S., Akimoto, Y., & Oike, H. 2012. Phloridzin reduces blood glucose levels and alters hepatic gene expression in normal BALB/c mice. In *Food Chem. Toxicol.*, *50*, 2547–2553.

Kschonsek, J., Wolfram, T., Stöckl, A., & Böhm V. 2018. Polyphenolic compounds analysis of old and new apple cultivars and contribution of polyphenolic profile to the *in vitro* antioxidant capacity. In *Antioxidants*, *7*, 20.

Kschonsek, J., Wiegand, C., Hipler, U.C., & Böhm, V. 2019. Influence of polyphenolic content on the *in vitro* allergenicity of old and new apple cultivars: A pilot study. In *Nutrition*, *58*, 30–35.

Lucas, E., & Medicus, F. 1878. *Sadownictwo zasadzające się na prostych prawach. Poradnik podręczny dla wykładu uprawy owocowej, oraz własnego nauczenia się takowej* [Orcharding based on simple laws. Handbook for the lecture of fruit cultivation, and your own learning of such]. G. Sennewald, Warszawa. [In Poland]

Mcclure, K.A., Gong, Y., Song, J., Vinqvist-Tymchuk, M., Palmer, L.C., Fan, L., Burgher-Maclellan, K., Zhang, Z., Celton, J.-M., Forney, C.F., Migicovsky, Z., & Myles, S. 2019. *Genome*-wide association studies in apple reveal loci of large effect controlling apple polyphenols. In *Hortic. Res.*, *6,* 1–12 https://doi.org/10.1038/s41438-019-0190-y

Mei, X., Zhang, X., Wang, Z., Gao, Z., Liu, G., Hu, H., Zou, L., & Li, X. 2016. Insulin sensitivity-enhancing activity of phloridzin is associated with lipopolysaccharides decrease and gut microbiota changes in obese and type 2 diabetes (db/db) mice. In *J. Agric. Food Chem.*, *64*, 7502–7511.

Migicovsky, Z., Gardner, K.M., Money, D., Sawler, J., Bloom, J.S., Moffett, P., Chao, C.T., Schwaninger, H., Fazio, G., Zhong, G.Y., & Myles, S. 2016. Genome to phenome mapping in appl using historical data. In *Plant Genome*, *9*(2) 1–15. http://dx.doi.org/10.3835/plantgenome2015.11.0113

Militaru, M., Butac, M., Sumedrea, M., Călinescu, M., & Marin, F.C. 2015. Evaluation of resistance to pests and diseases of some old apple varieties. In *Fruit Growing Research*, *31*, 34–37.

Miller, S. 2014. Wyoming apple project attempts to save Wyoming's diverse apple cultivars. In *Winter*, *5*, 8.

Mitre, I., Mitre, V., Ardelean, M., Sesters, R., & Sesters, A. 2009. Evaluation of old apple cultivars grown in Central Transylvania, Romania. In *Not. Bot. Hort. Agrobot. Cluj.*, *37*(1), 235–237. http://dx.doi.org/10.15835/nbha3713127

Morresi, C., Cianfruglia, L., Armeni, T., Moncini, F., Tenore, G.C., D'urso, E., Micheletti, A., Ferretti, G., & Bacchetti, T. 2018. Polyphenolic compounds and nutraceutical properties of old and new apple cultivars. In *J. Food Biochem.*, *42*(e12641), 1–11. http://dx.doi.org/10.1111/jfbc.12641

Mudge, K., Janick, J., Scofield, S., & Goldschmidt, E.E. 2009. A history of grafting. In *Hortic. Rev.*, *35*, 437–493. https://doi.org/10.1002/9780470593776.CH9

Noiton, D., & Alspach, P.A. 1996. Founding clones, inbreeding, coancestry, and status number of modern apple cultivars. In *Journal of the American Society for Horticultural Science*, *121*, 773–782.

Noiton, D., & Shelbourne, C.G.A. 1992. Quantitative genetics in an apple breeding strategy. In *Euphytica*, *60*, 213–219.

Nosecka, B. & Bugała, A. 2019. Rynek jabłek w Polsce [Apple market in Poland]. In *Agroindustry*. www.agroindustry.pl/index.php/2019/04/29/rynek-jablek-w-polsce [In Poland]

Ordidge, M., Kirdwichai, P., Fazil Baksh, M., Venison, E.P., Gibbings, J.G., & Dunwell, J.M. 2018. Genetic analysis of a major international collection of cultivated apple varieties reveals previously unknown historic heteroploid and inbred relationships. In *Plos one*, 1–26 https://doi.org/10.1371/journal.pone.0202405

Oszmiański, J., Lachowicz, S., Gławdeł, E., Cebulak, T., & Ochmian, I. 2018. Determination of phytochemical composition and antioxidant capacity of 22 old apple cultivars grown in Poland. In *Eur. Food Res. Technol.*, *244*, 647–662. https://doi.org/10.1007/s00217-017-2989-9

Papp, D., Király I., & Tóth, M. 2015. Suitability of old apple varieties in organic farming, based on their resistance against apple scab and powdery mildew. In *Org. Agr.* http://dx.doi.org/10.1007/s13165-015-0126-2

Passafiume, R., Tinebra, I., Sortino, G., Palazzolo, E., & Farina V. 2021. New clones and old varieties quality of Sicilian hillside apple cultivation. In *Agriculture Journal*, *15*, 66–74. http://dx.doi.org/10.2174/1874331502115010066

Patzak, J., Paprštein, F., Henychová, A., & Sedlák, J. 2012. Comparison of genetic diversity structure analyses of SSR molecular marker data within apple (*Malus* × *domestica*) genetic resources. In *Genome*, *55*, 1–19. http://dx.doi.org/10.1139/g2012-054

Petkovsek, M.M., Slantar, A., Stampar, F., & Veberic, R. 2010. The influence of organic/integrated production on the content of phenolic compounds in apple leaves and fruits in four different varieties over a 2-year period. In *J. Sci. Food Agric.*, *90*, 2366–2378. http://dx.doi.org/10.1002/jsfa.4093

Pollegioni, P., Woeste, K.E., Chiocchini, F., Del Lungo, S., Olimpieri, I., Tortolano, V., Clarc, J., Hemery, G.S., Mapelli, S., & Malvolti, M.E. 2017. Ancient humans influenced the current spatial genetic structure of common walnut populations in Asia. In *PLoS One, 10*(e0135980). https://doi.org/10.1371/journal.pone.0135980

Putnik, P., Lorenzo, J., Barba, F., Roohinejad, S., Režek Jambrak, A., Granato, D., Montesano, D., & Kovačević, B.D. 2018. Novel food processing and extraction technologies of high-added value compounds from plant materials. In *Foods*, *7*, 106.

Reim, S., Proft, A., Heinz, S., Lochschmidt, F., Höfer, M., Tröber, U., & Wolf, H. 2015. Pollen movement in a *Malus sylvestris* population and conclusions for conservation measures. In *Plant Genetic Resources*, *15*, 194. https://doi.org/10.1017/S1479262115000465

Reiss, R., Johnston, J., Tucker, K., Desesso, J.M., & Keen, C.L. 2012. Estimation of cancer risks and benefits associated with a potential increased consumption of fruits and vegetables. In *Food and Chemical Toxicology*, *50*, 4421–4427.

Rejman, A. 2004. *Pomologia* [Pomology]. Wyd. PWRiL Warszawa. [In Poland]

Rubauskis, E., & Borisova, I. 2021. Traditionally grown old apple varieties in intensive type orchard. *Zinātniski praktiskā konference "Līdzsvarota Lauksaimniecība",* 25.–26.02.2021., LLU, Jelgava, Latvij, 94–98.

Spaho, N., Gaši, F., Leitner, E., Blesić, M., Akagić, A., Žuljerić, S.O., Kurtović, M., Ratković, D.D., Murtić, M.S., Akšić, M.F., & Meland, M. 2021. Characterization of volatile compounds and flavor in spirits of old apple and pear cultivars from the Balkan Region. In *Foods*, *10*, 1258. https://doi.org/10.3390/foods10061258

Splenger, R.N. 2019. Origin of the apple: the role of megafaunal mutualism in the domestication of *Malus* and Rosaceous trees. In *Frontiers in the Plant Science*, *10*(617), 1–18. https://doi.org/10.3389/fpls.2019.00617

Stanivuković, S., Žujić, M., Žabić, M., Mićić, N., Bosančić, B., & Đurić, G. 2017. Characterization of old apple cultivars from Bosnia and Herzegovina by means of pomological and biochemical analysis. In *Natulae botanicae horti Agrobotanici Cluj-Napoca*, *45*(1). https://doi.org/10.15835/nbha45110537

Smardzewski, W. 1917–1932. *Atlas owoców* [Fruit Atlas]. Rkps, Ogród Botaniczny PAN, Warszawa-Powsin.

Vergun, O., Rakhmetov, D., Rakhmetova, S., Fishchenko, V., & Shymanska, O. 2020. Content of nutrients in different parts of *Ipomoea batatas* L. (Lam.). In *Agrobiodiversity for Improving Nutrition, Health and Life Quality*, *4*, 101–111. http://dx.doi.org/10.15414/agrobiodiversity.2020.2585-8246.101-111

Way, R.D., Aldwinckle, H.S., Lam, R.C., Rejman, A., Sansavini, S., Shen, T., Watkins, R., Westwood, M.N., & Yoshida, Y. 1990. Apples (*Malus*). In *Acta Hortic.*, *290*, 1–62.

Wojdyło A., Oszmiański J., & Laskowski P. 2008. Polyphenolic compounds and antioxidant activity of new and old apple varieties. In *Agricultural and Food Chemistry*, *56*, 6520–6530

Xiang, Y., Huang, C.-H., Hu,Y., Wen, J., Li, S., Yi, T., Chen, H., & Xiang, J.M H. 2016. Evolution of Rosaceae fruit types based on nuclear phylogeny in the context of geological times and genome duplication. In *Mol. Biol.*, *34*, 262–281. https://doi.org/10.1093/molbev/msw242

Yue, C., & Tong, C. 2011. Consumer preferences and willingness to pay for existing and new apple varieties: Evidence from apple tasting choice experiments. In *HortTechnology*, *21*, 376–383.

Żygala, E., Antoniewska, E., Lib, D., & Piorecki, N. 2011. *Inwentaryzacja i zachowanie starych odmian drzew owocowych w Dawnej Galicji Wschodniej* [Inventory and conservation of old varieties of fruit trees in the ancient Eastern Galicia]. In: Dolatowski J., Piorecki A. (eds) Stare odmiany jabloni w dawnej Galicji Wschodniej. Bolestraszyce, 7–82. [In Poland]