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# Functional Properties of Fruits of Common Medlar (*Mespilus germanica* L.) Extract

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**Abstract:** Common medlar (*Mespilus germanica* L.) is a long-lived plant with hard fruits, which are harvested in the fall and stored in cold and dark places. The aim of the work was to obtain the extract from freeze-dried fruits of medlar. Then, the samples were purified on a column with Amberlite XAD-16 ion exchange resin (two fractions were obtained and tested in further steps: methanol (MF) and water (WF)). A quantitative analysis of the polyphenolic compounds and selected elements was performed. In addition, in vitro tests of antidiabetic and antioxidant activity of the extracts were carried out. The applied methodology included the determination of antidiabetic activity by diffusion method, antioxidant activity by ABTS and FRAP methods, elemental analysisby atomic spectrometry, and quantitative and qualitative determination of phenolic composition by UPLC method. The highest antioxidant activity was observed in the MF of the medlar preparation, which was 245.31 µM Trolox/g (in ABTS test). Both fractions showed positive antidiabetic effects. For WF, even a small concentration of 1 mg/mL DMSO, the percentage of α-amylase inhibition was 35%. The WF dominated in terms of the total content of phenolic compounds (mainly gallic, procatechic, chlorogenic, and ferulic acids).

**Keywords:** medlar; *Mespilus germanica*; polyphenols; antioxidant activity



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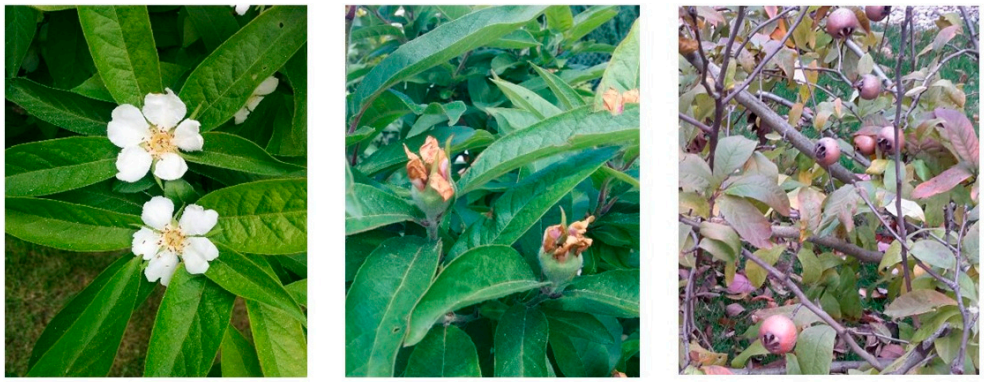
## 1. Introduction

Common medlar (*Mespilus germanica* L.) is a long-lived plant, belonging to the family Rosaceae. It occurs naturally in Central Asia, Lesser Asia, and the Caucasus. *Mespilus germanica* was cultivated as early as 3000 years ago in the Mediterranean countries. Subsequently, the plant also became acclimatized to France, Germany, and England. Nowadays, it is found in parks and gardens in southern and western Europe (Figure 1).

The fruits of medlar have brown-reddish color and they are 1.5–3 cm in diameter; the small ones have a weight of 10–80 g [1]. The hard fruits are harvested in the fall and stored in cold and dark places. Since ancient times, plants have been valued for their healing properties. Today, natural plant-based products with health-promoting effects are used as alternatives to synthetic and chemical medicines. Leaves, fruits, bark, and medlar wood have been used for therapeutic purposes [2]. Extract from the bark of the common medlar tree has found use as a diuretic and has also been used to treat colon infections, diarrhoea, and internal haemorrhage [3]. The leaves, bark, and unripe fruits contain high levels of tannins, which is why they have been used for tanning leather and clarifying wines. The wood is considered to be heavy, hard, and quite pliable, so it has been used to make fishing rods, knives, and tools. The researchers confirmed that the

fruit of medlar contains natural antioxidants that can prevent cancer [4]. Moreover, in comparison with other fruits, they have a lot of minerals, and they are low in sugars and high in vitamins. It is generally known that a diet rich in fresh fruit and vegetables is known to be beneficial to human health [5,6]. Berries, in particular, which are rich in polyphenolic compounds, are known to be a source of antioxidants that may reduce the risk of cardiovascular disease and some forms of cancer [7–9]. Underutilized fruits are consumed because of their flavor and their health benefits related to their bioactive compounds [10–12]. An example of this kind of fruit is the common medlar [4]. Due to the increasing demand for natural antioxidant compounds, research into new potential sources of these compounds is justified. Common medlar is a rich source of polyphenolic compounds, particularly phenolic acids [13]. They are valuable components that are widely found in daily foods such as fruits, vegetables, cereals, legumes and wine [14–16], and show strong antioxidant [17,18], anti-allergic [19], anti-inflammatory [20], antibacterial [21], antiviral [22] and immunizing properties [23]. In addition, they influence the sensory characteristics of food products, and their quantitative and qualitative composition also determines the sensory quality of fresh fruit and vegetables [24]. Polyphenols, especially flavonoids and phenolic acids, are capable of inhibiting α-glucosidase and α-amylase in the carbohydrate metabolism. They can be used to produce nutraceuticals and formulations, used during diabetes treatment [25]. Current antidiabetic therapies are based on synthetic drugs, which often cause side effects [26]. It is widely recognized that diet plays an important role in the management of diabetes [27–29].



(a) (b) (c)

**Figure 1.** Flowers of medlar (**a**), fruit buds (**b**), fruit ready for harvesting (**c**).

The medlar fruit (*Mespilus germanica* L.) has gained commercial importance in recent years, attracting research into its chemical composition. The objective of this study was to examine the antioxidant and antidiabetic activity (in vitro) of medlar fruit extract concentrated in the ion exchange resin.

## 2. Materials and Methods

### 2.1. Plant Materials

Medlar fruits were from a private farm in Down Silesia (Poland). The fruit was harvested in the second half of September 2020.

### 2.2. Extraction Procedure

Medlar fruits (1.0 kg) were fragmented and lyophilized for 24 h and ground in an electric mill. The resulting material was extracted with an 80% solution of ethanol in water, acidified with hydrochloric acid (10 mL HCl per 1 L solution). The extraction was carried out on a rotary shaker for 48 h at 25 °C. The material was then centrifuged, and the supernatant was evaporated on a rotary evaporator in a water bath at 40 °C to a volume of 10 mL. The obtained extract (MFE) was applied to a column packed with Amberlite

XAD-16 ion exchange resin (Rohm and Haas, Chauny Cedex, France). The diameter of the column was 10 cm, and the height of the resin layer was 50 cm. The column was washed with water to elute water-soluble compounds that were not adsorbed on the resin (organic acids, sugars, and other compounds). The column was then washed with 80% ethanol acidified with 1% acetic acid (10 mL acetic acid per liter of solution) to extract the bioactive compounds from the bed. The resulting solution was concentrated using a rotary evaporator, then lyophilized. Part of the preparation was dissolved in water and then lyophilized (WF), and the other part was dissolved in 80% methanol. The organic solvent was evaporated on a rotary evaporator and the residue was lyophilized (MF). Thus, the material for the study was the lyophilized plant preparation, the aqueous fraction of the preparation (WF), and the methanol fraction (MF) (Table 1).

**Table 1.** Sample codes.

| No | Sample | Sample Code |
|---|---|---|
| 1 | Extract of medlar fruit before purification at Amberlite XAD-16 | MFE |
| 2 | The aqueous fraction of the fruit preparation (after purification at Amberlite XAD-16) | MF |
| 3 | The methanol fraction of the fruit preparation (after purification at Amberlite XAD-16) | WF |
| 4 | The medlar concentrated extract (after purification at Amberlite XAD-16) | MFEC |

### 2.3. Analysis of Antioxidant Activity

The antioxidant activity was determined by the radical scavenging spectrophotometric assay (ABTS) method according to the modified procedure [30], and the ferric reducing antioxidant potential (FRAP) method [31]. The absorbance was measured using a UV Microplate Reader μQuant (Bio Tek, Winooski, VT, USA) at 734 nm for ABTS, and 563 nm for the FRAP method. All investigations were done in triplicate. The amount of antioxidant activity was expressed as μM of Trolox Equivalent per g of dry extract.

### 2.4. Determination of Antidiabetic Activity

To determine the antidiabetic activity, the diffusion method was used [32,33]. 1, 5, 10, or 20 mg of the obtained material samples (MFE, MF, and WF) were dissolved in 1 mL dimethyl sulfoxide (DMSO). The powder was dissolved completely. Petri plates were filled with the prepared agar medium (3%) with starch (1%). The plates were stored at 4 °C. Before the analysis, cylindrical wells with a diameter of 0.5 cm were cut. The negative control ($T^-$) was a solution of 25 μL acarbose solution (50 mg/1 mL $H_2O$) compound contained in antidiabetic drugs and 25 μL of pork α-amylase solution (6 mg/10 mL $H_2O$). The positive control ($T^+$) was a solution of 25 μL of water and 25 μL of pork α-amylase solution (the same as erlier). The proper tests were: 25 μL of the tested medlar extract (MFE, MF, or WF) and 25 μL of pork α-amylase solution. All solutions were introduced into holes cut out of the agar. After 24 h inkubation at 35–37 °C the plates were dyed with iodine and the emergent clear zones were measured. The degree of inhibition was calculated. The hole with the positive control ($T^+$) was taken as the 100% clear zone. The tests were performed in three replications.

### 2.5. Determination of Phenolic Acids

The samples obtained in Section 2.2 were submitted to UPLC according to Kucharska et al. [34]. The analysis of polyphenolic compounds was determined using the UPLC Acquity system (Waters Corp., Milford, MA, USA) with a diode array detector (DAD). The separation was carried out on a chromatography column BEH Shield C18 (2.1 mm × 5 mm × 1.7 μm) at 30 °C, and the samples

were at 4 °C. Solvent A was a 4.5% formic acid solution and B was acetonitrile. The volume of the injected sample was 10 µL, and the flow rate of the eluents was 0.45 mL/min. Detection of phenolic acids was carried out at 320 nm. The concentration of the detected compounds was determined by a comparison of the peak areas in the chromatogram with the values of the calibration curve. The obtained results are shown in mg per 1 g of dry matter of extract. The determination was performed in triplicate.

### 2.6. Elemental Composition Analysis

Determination of the content of selected mineral elements in medlar fruit preparation of (MF + WF) was performed in the Food Research Laboratory (PCA accreditation No. AB1396) of the Wroclaw University of Environmental and Life Sciences. Mineralization of the samples was executed in a closed microwave system. A total of 5 mL of concentrated nitric acid (V) A.C.S. and 1 mL concentrated hydrogen peroxide A.C.S. were added to 0.5 g of a homogenous sample. Next, the samples were mineralized in the MARS 5 microwave sample preparation system, and then they were quantitatively transferred into 10 mL measuring vessels using redistilled water. Mineralization was carried out in accordance with the Polish Standard PN-EN 13805:2003 Food products—determination of trace elements—pressure mineralization [35]. Determination of mineral elements content was performed by atomic absorption spectrometry in an air–acetylene flame using the SpectraAA atomic absorption spectrometer with a V2 AA240FS flame attachment, using dedicated hollow cathode lamps [36]. The accuracy of the method was confirmed on the basis of the certified reference material NCS ZC 73012-Cabbage, and the measurement uncertainty was estimated at 5%.

### 2.7. Statistical Analysis

The data were analyzed using Statistica 13 software (Kraków, Poland). The Duncan test analyzed the differences between means ($p$-value < 0.05). The tables present the average standard deviations.

## 3. Results and Discussion

### 3.1. Extraction Procedure

Figure 2 shows the procedure used to extract medlar fruit, to obtain concentrated methanolic (MF) and water (WF) fractions of medlar fruit extract (MFE). As a result of the extraction and column concentration process, approximately 3 g of concentrated extract (MF and WF) was obtained from 1000 g of fresh fruit.

### 3.2. Antioxidant Activity

The comparison of antioxidant activity of the tested samples determined by ABTS and FRAP methods (Table 2) showed that the methanolic fraction of purified medlar preparation (MF) had the highest antioxidant activity, at 245.31 µm Trolox/g (ABTS) and 137.13 µm Trolox/g (FRAP). The aqueous fraction of purified medlar preparation (WF) showed slightly lower activity at 194.28 and 101.25 µm Trolox/g (for ABTS and FRAP methods, respectively). The concentration of the extract on the column increased the antioxidant activity. According to previous studies, an increase in the amount of phenolic compounds in the test material causes an increase in antioxidant activity [37]. As per research on the antioxidant activity of methanol and aqueous extracts of medlar fruit, stem bark and leaves (not purified Amberlite XAD-16), fruit extract (both aqueous and methanol) showed the best activity ($IC_{50}$ = 492 and $IC_{50}$ = 419 $\mu g \cdot mL^{-1}$ respectively), although the highest content of total phenolic compounds was found in extracts from bark [38].

### 3.3. Antidiabetic Activity

Diabetes mellitus has become a major public health threat across the globe. α-Amylase and α-glucosidase are the main enzymes involved in the breakdown of sugars in the human body [39]. Inhibitors of these enzymes are potential targets in the development

of lead compounds for the treatment of diabetes [40]. They help reduce postprandial hyperglycaemia and slow down carbohydrate digestion in people with diabetes [41].

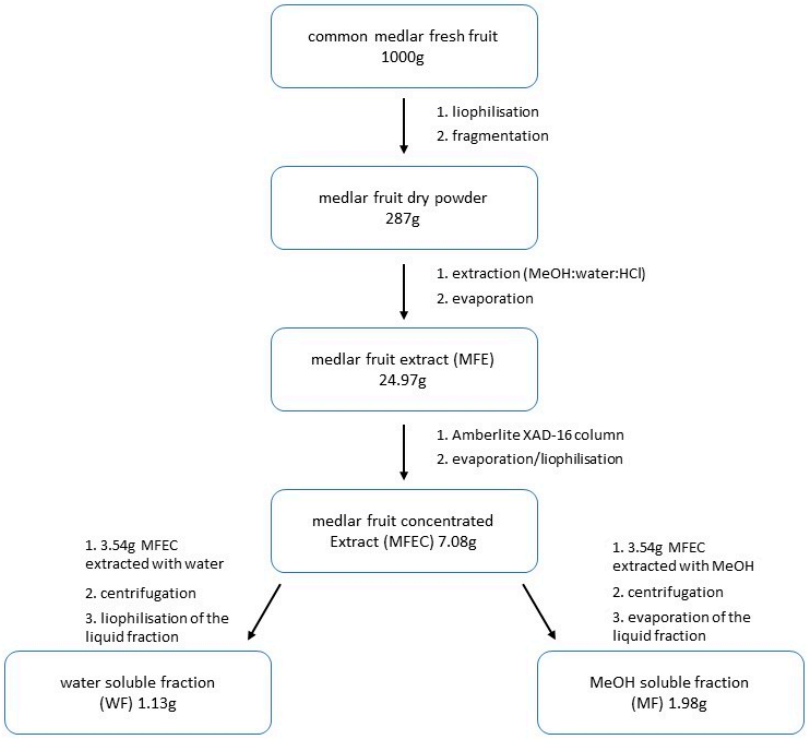



**Figure 2.** Extraction procedure to obtain concentrated methanolic (MF) and water (WF) fractions of medlar fruit extract (MFE).

**Table 2.** The antioxidant activity: Trolox equivalent antioxidant capacity defined as the concentration of Trolox (μm) with the same activity as 1 g of the tested dry extract (ABTS and FRAP method).

| Material | ABTS | FRAP |
|---|---|---|
| Fruit extract (MFE) | 187.56 ± 15.76 b,c | 82.35 ± 10.23 c |
| Methanolic fraction (MF) | 245.31 ± 50.42 a | 137.13 ± 9.87 a |
| Water fraction (WF) | 194.28 ± 55.85 b | 101.25 ± 8.14 b |

Mean values with different letters (a–c) within the same column were statistically different ($p < 0.05$), the same letters form one homogeneous group. Values expressed as mean ± standard deviation.

The results in Table 3 show that medlar extract (MFE), methanolic fraction (MF), and water fraction (WF), at a concentration of 20 mg/mL DMSO, inhibit α-amylase activity 100% with respect to acarbose. At a concentration of 10 mg/mL, MFE inhibits the enzyme 61%, while at a concentration of 5 mg/mL, it inhibits it by 47%. Even at low concentrations, MFE shows an inhibition of 15%. MF also shows an inhibitory effect on α-amylase. At a concentration of 1 mg/mL, it inhibits the enzyme by 26%, at a concentration of 5 mg/mL in 27%, and at 10 mg/mL by 31%. WF has the highest antidiabetic activity compared to the other fractions. At a concentration of 10 mg/mL, it inhibits the enzyme by 79%, at a concentration of 5 mg/mL in 52%, and at a concentration of 1 mg/mL by 35%.

In the treatment of diabetes, therapies are used to reduce postprandial hyperglycaemia. They work by inhibiting α-amylase and α-glucosidase, which are important enzymes involved in carbohydrate digestion. Plant foods that are rich in polyphenols have been shown to produce effects similar to drugs, which act as α-amylase and α-glucosidase inhibitors. Studies have shown that the bioactivity of polyphenols in plants is related to their antioxidant activity and, in addition, many of these plants also have hypoglycaemic properties [42]. A study by Elya et al. [43] showed that extracts from Indonesian plants, including *Camellia sinensis*, *Pometia pinnata*, *Persea Americana*, inhibit both α-amylase and

α-glucosidase better than acarbose. According to a study by Jung et al. [44], many types of natural products that contain terpenoids, alkaloids, flavonoids, and phenols have shown antidiabetic potential. In particular, the presence of compounds such as corosolic acid (Glucosol™), 4-(α-rhamnopyranosyl)ellagic acid, and 1,2,3,4,6-pentagalloylglucose showed significant antidiabetic activity. At present, many natural products and herbal medicines have been recommended for the treatment of type 2 diabetes. Delaying the digestion of complex sugars to simple sugars by inhibiting α-amylase and α-glucosidase is one therapeutic option for controlling postprandial hyperglycemia in prediabetes and diabetes [45,46]. The inhibition of postprandial hyperglycaemia delays micro- and macrovascular complications such as microangiopathy, cardiovascular, and cerebrovascular disease [47]. Natural preparations are available, for example, from white mulberry (*Morus alba*), common bean (*Phaseolus vulgarisoraz*) and ginkgo (*Ginkgo biloba*), and recommended to counteract type 2 diabetes. Alcohol extract from white mulberry leaf at 1 mg/mL had an inhibition of a-amylase of 70% [48]. The recommended dose of one of the commercially available preparations containing white mulberry leaf extract (Oleofarm Sp. z o.o., Wrocław, Poland) is 600 mg per day. Given the above data and study results, it can be surmised that a suitable daily dose for ME would be 1200 mg. However, without knowledge of pharmacokinetics and the in vivo studies performed, these are only simulations, which need to be confirmed by further research.

**Table 3.** Antidiabetic activity of the tested extracts expressed in % inhibition of α-amylase.

| Material | Percentage of Inhibition | | | |
|---|---|---|---|---|
| | Concentration [mg/mL DMSO] | | | |
| | 1 | 5 | 10 | 20 |
| Fruit extract (MFE) | 14.98 ± 0.07 c | 47.22 ± 0.07 b | 61.23 ± 0.19 b | 100 ± 0.00 a |
| Methanolic fraction (MF) | 25.79 ± 0.07 b | 27.14 ± 0.10 c | 30.74 ± 0.08 c | 100 ± 0.00 a |
| Water fraction (WF) | 34.96 ± 0.08 a | 52.11 ± 0.05 a | 79.29 ± 0.22 a | 100 ± 0.00 a |

Mean values with different letters (a–c) within the same column were statistically different ($p < 0.05$), the same letters form one homogeneous group. Values expressed as mean ± standard deviation.

### *3.4. Polyphenolic Compounds—Phenolic Acids*

In the profile of the phenolic compounds present in common medlar extracts, phenolic acids account for the largest proportion (Table 4). Moreover, the concentration of medlar fruit extract (Amberlite XAD-16) resulted in a doubling of phenolic compounds (MF and WF). The interest in phenolic acids stems from their potential protective role against oxidative damage. Furthermore, the antioxidant effect of plant products is mainly attributed to phenolic compounds such as phenolic acids [49]. Moreover, phenolic acids have been shown to increase glucose uptake and glycogen synthesis, improve glucose and lipid profiles in certain diseases (obesity, cardiovascular disease, melitius, and reduce its complications) [50–52]. Fruit tissues are able to synthesize phenolic compounds. Phenolic acids are widely found in daily foods such as fruits, vegetables, cereals, legumes, and wine [14]. Through the diet, we provide our body with beneficial phenolic acids through the consumption of fruit and vegetables. We can increase our intake of phenolic acids by making concentrated fruit extracts. The consumption of polyphenol-enriched foods is associated with a reduced risk of several diseases such as atherosclerosis [53,54], dyslipidemia [55], and diabetes [56]. From Table 4, it can be concluded that gallic acid has the highest proportion of the methanolic fraction (MF) and water fraction (WF) of common medlar extract (36.8 and 43.8 mg/g of extract, respectively). It is known for its antioxidant [57], anti-inflammatory [58], and antimicrobiological [59] properties. The second most abundant compound is protocatechuic acid: 11.66 and 7.00 mg/g of dry extract in MF and WF, respectively.

**Table 4.** Profile of phenolic compounds quantified [mg/1 g of dry extract] in the tested extracts.

| No | Rt [min] | Phenolic Acids | Extract (MFE) | Methanolic Fraction (MF) | Water Fraction (WF) |
|---|---|---|---|---|---|
| 1 | 3.08 | Gallic acid | 8.76 ± 1.23 b | 36.80 ± 0.3.11 a | 43.84 ± 3.27 a |
| 2 | 4.08 | ρ-Aminobenzoic acid | 1.17 ± 0.42 c | 2.90 ± 0.52 b | 4.55 ± 1.22 a |
| 3 | 4.25 | Protocatechuic acid | 0.61 ± 0.12 b | 11.66 ± 1.02 a | 7.00 ± 0.94 a |
| 4 | 4.75 | Catechin | 0.88 ± 0.05 b | 0.46 ± 0.07 c | 1.21 ± 0.25 a |
| 5 | 4.84 | (−)Epicatechin | 7.87 ± 0.98 a | 0.42 ± 0.07 c | 1.74 ± 0.32 b |
| 6 | 5.27 | Chlorogenic acid | 3.04 ± 1.01 b | 5.28 ± 0.92 a | 5.95 ± 1.02 a |
| 7 | 5.66 | Neochlorogenic acid | 5.27 ± 1.24 a | 1.82 ± 0.18 b | 1.86 ± 0.54 b |
| 8 | 6.06 | Procyanidin B2 | 3.52 ± 0.92 a | 3.51 ± 0.09 a | 2.93 ± 0.36 b |
| 9 | 6.85 | Caffeic acid | 0.36 ± 0.07 b | 0.33 ± 0.11 c | 0.39 ± 0.12 a |
| 10 | 8.04 | Ferulic acid | 0.98 ± 0.11 c | 0.48 ± 0.07 b | 5.46 ± 0.99 a |
| 11 | 8.12 | Sinapic acid | 0.09 ± 0.06 b | 0.35 ± 0.06 a | n.d. |
| 12 | | In total: | 32.05 | 64.01 | 74.93 |

Mean values with different letters (a–c) within the same row were statistically different ($p < 0.05$), the same letters form one homogeneous group. Values expressed as mean ± standard deviation. n.d. = not determined.

### 3.5. Elemental Composition Analysis

In Table 5, the results of the elemental composition of a purified preparation of the pulp of medlar (MF + WF) are presented. The highest amount of sodium was identified (1186.03 mg/kg dry weight of purified preparation). In the human body, sodium is involved in the water–electrolyte balance, acid–base balance, and the functioning of the nervous system and muscular system. Deficiency of this element may manifest through headaches, nausea, lack of appetite, and disorders of orientation. The main source of sodium in the human diet is table salt and processed products containing sodium chloride, e.g., bread, cold cuts, and cheese. For adults, the normal intake is 1500 mg/day. According to a study carried out on medlar fruit, the sodium content ranged from 115 to 124 mg/kg [60]. Purification/concentration of the extract in our study resulted in an approximately 10-fold increase in its contents. The purified preparation of the medlar fruit was characterized by high contents of potassium and calcium (585.29 and 463.3 mg/kg dry weight, respectively). The content of other elements, essential for our diet, that were determined in the studied plant material, was comparable to their amount in popular fruit and vegetables.

**Table 5.** Elemental composition of a purified preparation of the pulp of medlar (MF + WF) [mg/kg] and daily requirements for adults [mg/day].

| No | Element | [mg/kg] | [mg/Day] [61] |
|---|---|---|---|
| 1 | Copper | 2.68 ± 0.41 | 0.9 |
| 2 | Zinc | 6.05 ± 0.91 | 10–15 |
| 3 | Sodium | 1186.03 ± 127.43 | 1500 |
| 4 | Iron | 14.28 ± 0.85 | 6–8 |
| 5 | Magnesium | 76.3 ± 4.06 | 250–350 |
| 6 | Potassium | 585.29 ± 37.21 | 4700 |
| 7 | Calcium | 463.05 ± 21.17 | 1000–1200 |
| 8 | Manganese | 3.74 ± 0.68 | 1.8–2.3 |

## 4. Conclusions

Our study provides valuable information on the antioxidant and antidiabetic capacity (in vitro) of medlar fruit extract and concentrated fractions at ion exchange resin. The use of a method to concentrate medlar fruit extract on an ion exchange resin resulted in a preparation with higher polyphenol concentration, antioxidant and antidiabetic activity in in vitro tests. Natural extracts of plant origin could be exploited as nutraceuticals, and cost-effective food additives for human and animal health. The biological properties of plant extracts usually cannot be attributed to the activities of single constituents. However, phenolic compounds are known to be responsible for antioxidant or antidiabetic activity, among

other things. It is, therefore, worth using different extraction methods and procedures to increase the concentration of these compounds in the extracts (e.g., ion exchange resin purification), to achieve the best possible health-promoting effect from the obtained biological material. A concentrated medlar fruit extract with both antidiabetic and antioxidant activity may find application in the development of less expensive complementary strategies for type 2 diabetes, in combination with other nutritional and pharmacological strategies. Furthermore, consuming inhibitors of α-amylase derived from natural dietary components could be an effective therapy for managing postprandial hyperglycemia with minimal side effects, as opposed to traditional treatment with drugs such as acarbose. However, it is essential to know the exact chemical composition and mechanisms of action of individual substances, in order to be able to use this plant material in therapeutic applications.

This study and the obtained results provide a basis for further in vivo studies and clinical studies.

**Author Contributions:** A.K.Ż.: conceptualization, methodology, writing—original draft preparation, writing—review and editing, supervision; M.S. and S.C.: formal analysis; M.O.: software, statistical analysis. All authors have read and agreed to the published version of the manuscript.

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