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EXPERIMENTAL PAPER

Quince (*Cydonia oblonga* Mill.) as a useful source of antioxidants – antioxidant activity evaluation

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Summary

Introduction: Quince (*Cydonia oblonga* Mill.) is a plant of which both the fruits and the leaves are sources of compounds with antioxidant potential. Such activity could be helpful to prevent the development of so-called oxidative stress.

Objective: The aim of the study was to evaluate the antioxidant properties of ethanolic, methanolic and acetonic extracts of mature and immature quince fruits, as well as leaves.

Methods: The extracts were prepared using ultrasound-assisted extraction, for 15, 30 and 60 minutes. The antioxidant activity was assessed by DPPH, FRAP, ABTS and Folin-Ciocalteu (F-C) methods.

Results: Antioxidant activity of all of the evaluated extracts were observed. The highest potential determined with each method was found for leaf extracts. Moreover, higher activity of unripe fruit extracts compared to ripe fruit was observed. Taking into account the applied extractants, the highest antioxidant capacity was found for methanolic extracts, extracted for 60 and 30 minutes. By contrast, the lowest potential was observed mainly for ethanolic extracts (extraction time 15 minutes).

Conclusion: Quince extracts, particularly alcoholic extracts of leaves, seem to be a valuable source of antioxidants. Factors as extraction time, the type of solvent and degree of fruit maturity may influence the antioxidant activity of extracts.

Key words: ***quince, antioxidant activity, DPPH, FRAP, ABTS, Folin-Ciocalteu***

Słowa kluczowe: ***pigwa, aktywność antyoksydacyjna, DPPH, FRAP, ABTS, Folin-Ciocalteu***

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INTRODUCTION

Antioxidants, especially those of plant origin, are valuable compounds with health-promoting properties, mainly due to the possibility of preventing the development of so-called oxidative stress. This process can lead to the damage of proteins, lipids and nucleic acids, and to the development of many diseases, including neoplastic, metabolic, neurodegenerative or cardiovascular disorders [1–3]. One of the more important groups of antioxidants are phenolic compounds. Polyphenols, due to their antiradical properties, could exert anticancer, anti-inflammatory, antiaging, UV-protective, antibacterial as well as cardio- and neuroprotective action. However, in recent years some reports on potential polyphenol toxicity, not directly related to their concentration, but rather to exposure time and their mutual action have been published [4].

Quince (*Cydonia oblonga* Mill.), a member of *Rosaceae* family, is one of the plants containing the antioxidant compounds. Its fruits are often used in the food industry due to their aroma which is similar to that of orange and pineapple. Furthermore, quince is a valuable source of biologically active substances. These compounds could exert antioxidant, antibacterial, antiulcer, cardioprotective, anti-inflammatory, antidiabetic and antiallergic actions. The most health-promoting ingredients of quince, i.e. polyphenols with antioxidant potential, were found in the peel of the fruit as well as in the leaves and seeds [5–8].

The aim of the study was to compare the antioxidant properties of ethanolic, methanolic and acetonic extracts of the leaves as well as ripe and unripe fruits of *C. oblonga*. For this purpose, four spectrophotometric methods were applied. The effects of fruit maturity, solvent applied and the time of ultrasonic assisted extraction on the antioxidant capacity of the studied extracts were also evaluated.

MATERIAL AND METHODS

Chemicals

2,2-diphenyl-1-picrylhydrazyl (DPPH), 6-hydroxy-2,5,7,8-tetramethylchroman-2-carboxylic acid (trolox), 2,4,6-tripyridyl-S-triazine (TPTZ) and 2,2-azinobis(3-ethylbenzothiazoline-6-sulphonic acid) (ABTS) were purchased from Sigma-Aldrich, USA, whereas iron (III) chloride hexahydrate and the Folin-Ciocalteu reagent were bought from Merck, Darmstadt, Germany. Sodium carbonate anhydrous, 36% hydrochloric acid, sodium acetate anhydrous, potassium persulfate, methanol, acetone and 99.5% acetic acid, all of analytical grade, were from Chempur, Poland.

Plant material and extract preparation

The leaves, ripe and unripe fruits of the quince were obtained by our own cultivation (allotment garden) in Świnoujście (West Pomeranian region, Poland). Immature fruit was harvested in October 2015, mature in the next month, whereas leaves were collected in June 2015. Fresh material was extracted using ultrasound-assisted extraction at a frequency of 40 kHz, for 15, 30 and 60 minutes. For extraction, 70% and 96% (*v/v*) ethanol, 99.8% (*v/v*) methanol and acetone were used as solvents.

Antioxidant activity determination – DPPH, FRAP and ABTS assays

Antioxidant properties of the extracts were evaluated by four methods: DPPH, FRAP, ABTS and Folin-Ciocalteu (F-C), as described previously [9-11]. Briefly, to determine DPPH antioxidant activity, an 0.3 mM ethanolic solution of DPPH was prepared and diluted to an absorbance of 1.000±0.020 at 517 nm to form the test reagent. Then, 2,850 μl of this solution was added to 150 μl of the studied extract and incubated for 10 minutes at room temperature. After incubation the absorbance was measured using a UV-VIS spectrophotometer at 517 nm [9–11].

The free radical scavenging activity was also determined by the ABTS method. A 7 mM solution of ABTS was prepared by dissolving this compound in 2.45 mM aqueous $K_2S_2O_8$. This solution was allowed to stand in the dark at room temperature for 24 hours. Then, to the 2500 μl of solution, diluted previously to an absorbance of 0.700±0.005, 25 μl of extract was added. After the incubation time (6 min) the absorbance measurements were performed at 734 nm [9-11].

The ferric ion reducing power of quince extracts was evaluated by the FRAP method. The test reagent was prepared by mixing 1 volume of 10 mM TPTZ (in 40 mM HCl), 1 volume of 20 mM $FeCl_3$ and 10 volumes of acetate buffer (pH 3.6). 2,320 μl of such solution was mixed with 80 μl of extract. After 15 minutes of incubation at room temperature, the absorbance was taken at 593 nm.

Total polyphenol content determination

The total polyphenol content was evaluated by the F-C method. A 10% (*v/v*) aqueous solution of Folin-Ciocalteu reagent was prepared and allowed to stand in the dark at room temperature for 1 hour. A sample consisting of 2,700 μl of 5 mM Na_2CO_3 and 150 μl of extract was mixed with 150 μl of F-C reagent. Spectrophotometric measurements at 750 nm were taken after 15 minutes' incubation at room temperature.

In all methods, trolox was used as the reference. It is a known substance commonly used in such studies. Calibration curves were prepared using its different concentrations. Antioxidant capacity has been expressed as mg trolox/g raw material. Moreover, the free radical scavenging activities of the extracts, determined by the DPPH and ABTS methods, were expressed as RSA [%] (radical scavenging activity). All measurements were done in triplicate. Data are presented as arithmetical mean±standard deviation (SD).

Statistical analyses

The results were analysed by one-way analysis of variance and Tuckey's multiple range test (significance level of $p<0.05$) for comparison of means. Antioxidant activities of the extracts obtained with the different extraction methods were compared. Moreover, the Pearson correlation between the results obtained with the applied methods (ABTS, DPPH, FRAP and Folin-Ciocalteu) were calculated with Statistica 12 (Statsoft, Poland).

Ethical approval: The conducted research is not related to either human or animal use.

RESULTS

Antioxidant activities (RSA%), determined with the DPPH and ABTS methods, are provided in table 1. The obtained values for leaf and fruit extracts at both stages of maturity, extracted with the studied solvents, i.e. methanol, 70% and 96% (*v/v*) ethanol as well as acetone, were compared with regard to the different times of ultrasound-assisted extraction. Results are presented as means±standard deviations (SD).

Figure 1 presents the antioxidant activities of leaf, unripe and ripe fruit extracts determined by the DPPH method, expressed as trolox equivalents [mg trolox/g raw material], obtained using 70% and 96% (*v/v*) ethanol, methanol and acetone, and extraction times of 15, 30 and 60 minutes. All the extracts showed

Table 1.

Mean (±SD) radical scavenging activity [%] of leaves as well as unripe and ripe quince fruit extracts evaluated with the DPPH and ABTS methods.

Extraction solvent	Extraction time [min]	Radical scavenging activity – RSA [%]					
		DPPH			ABTS		
		raw material					
		Leaves	Unripe fruit	Ripe fruit	Leaves	Unripe fruit	Ripe fruit
70% (*v/v*) Ethanol	15	47.56±0.77	19.00±0.92	15.02±0.80	13.57±0.36	6.19±0.87	4.71±0.29
	30	54.06±0.98	24.52±0.66	12.15±0.35	12.52±0.64	6.52±0.46	6.43±0.29
	60	81.02±0.42	29.43±0.31	15.78±0.59	44.19±0.37	9.10±0.16	7.19±0.44
96% (*v/v*) Ethanol	15	80.22±1.45	15.78±0.15	9.91±0.60	46.43±0.36	4.86±0.25	7.24±0.72
	30	81.46±1.27	19.34±0.51	17.12±0.56	55.29±0.76	9.52±0.37	4.52±0.30
	60	87.33±0.12	19.11±0.35	13.61±0.70	76.00±0.52	4.86±0.25	7.52±0.30
Methanol	15	86.75±0.35	26.98±0.48	18.32±0.44	90.33±0.84	10.71±0.62	8.33±0.16
	30	86.55±0.27	32.66±0.66	24.26±0.83	45.19±0.75	9.19±0.81	10.24±0.30
	60	87.56±0.71	31.95±0.85	22.32±0.89	99.81±0.08	23.38±0.79	6.81±0.67
Acetone	15	66.70±0.69	15.67±0.78	16.75±0.42	55.38±0.24	4.19±0.33	6.76±0.70
	30	66.63±1.24	16.55±0.79	13.45±0.99	58.86±0.40	4.48±0.16	4.10±0.08
	60	73.41±1.07	17.89±0.21	14.58±0.84	78.71±0.58	4.10±0.08	4.57±0.52

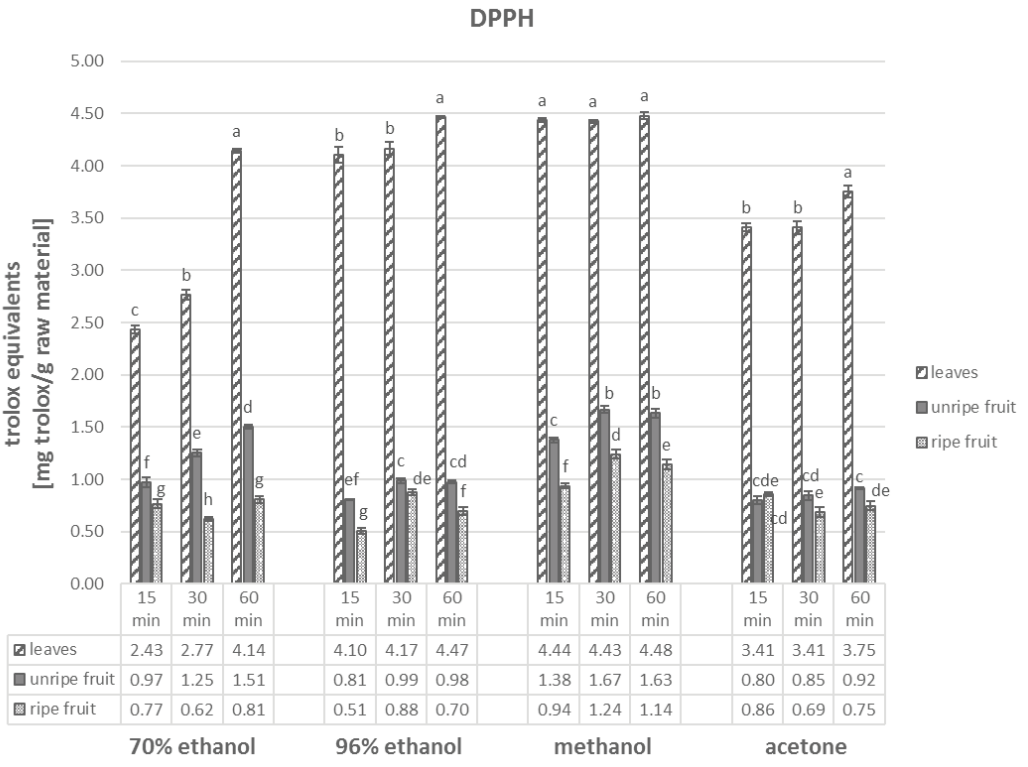

Figure 1.

Mean (±SD) antioxidant activities of leaves, unripe as well as ripe quince fruit extracts evaluated with the DPPH method, expressed as trolox equivalents [mg trolox/g raw material]. Vertical lines represent standard deviations. Bars marked with the same letters did not differ significantly taking the extraction solvent into account. Significance level $p<0.05$, n=30

antioxidant potential ranging from 0.51±0.03 to 4.48±0.04 mg trolox/g raw material. High activities were found for *C. oblonga* leaves and the highest for methanolic extracts treated with ultrasound for 60 minutes – 4.48±0.04 mg trolox/g raw material, with 4.43±0.01 and 4.44±0.02 mg of trolox/g raw material extracted for 30 and 15 minutes, respectively. These values corresponded to the antioxidant activity of 86.55±0.27 to 87.56±0.71% RSA. Comparable results were observed for ethanolic extracts of leaves – i.e. 4.47±0.01 mg of trolox/g raw material for the extracts in 96%(*v/v*) ethanol, *versus* 4.14±0.02 for 70% (*v/v*) ethanol. The antioxidant activity of ripe and unripe quince fruit extracts was markedly lower – from 0.51±0.03 to 1.67±0.03 mg trolox/g raw material. Taking into account all the raw material studied, the highest antioxidant activity was found for methanolic extracts. These results may suggest the usefulness of methanol as an extractant to obtain products with antioxidant potential. The lowest values were found for extracts of unripe fruit, especially for those prepared in 70% and 96% (*v/v*) ethanol. Their activity varied from 0.51±0.03 to 0.88±0.03 and from 0.62±0.02 to 0.81±0.03 mg trolox/g raw material, respectively. It should be added that the acetonic extracts of each material were characterised by medium antioxidant potential, as their activity was neither the lowest, nor the highest among all obtained in this study.

Antioxidant activities of leaves, ripe and unripe fruits of quince extracts, estimated by the ABTS method, expressed as trolox equivalents, depending on the applied solvent and the time of ultrasonic extraction, are shown in figure 2. Similarly to the DPPH method, the highest activities were found for methanolic extracts of quince leaves – 21.33±0.02 mg trolox/g raw material (corresponding to 99.81±0.08% RSA) for 60 minutes as well as for 15 minutes of extraction – 19.23±0.19 mg trolox/g raw material (corresponding to 90.33±0.84% RSA). The difference between the antioxidant capacity of leaf and fruit extracts is especially noticeable. The lowest values were obtained for acetonic extracts of ripe and unripe fruits – from 0.08±0.02 to 4.36±0.17 mg trolox/g raw material.

The Fe^{3+} ions reducing power, expressed, as for the other methods, as trolox equivalents [mg trolox/g raw material] depending on solvent and extraction time is presented in figure 3. The activities were between 1.41±0.13 and 27.00±0.26 mg trolox/g raw material. The highest capacity was

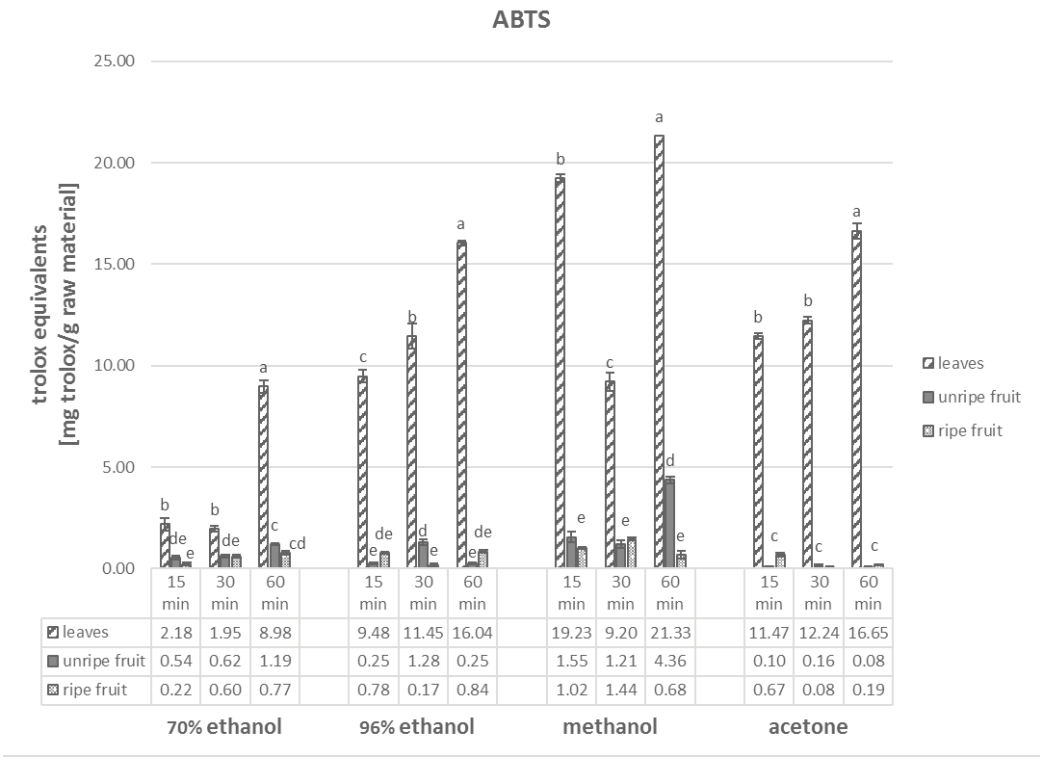

Figure 2.

Mean (±SD) antioxidant activities of leaves and unripe as well as ripe quince fruit extracts evaluated with the ABTS method, expressed as trolox equivalents [mg trolox/g raw material]. Vertical lines represent standard deviations. Bars marked with the same letters did not differ significantly taking the extraction solvent into account. Significance level $p<0.05$, n=3

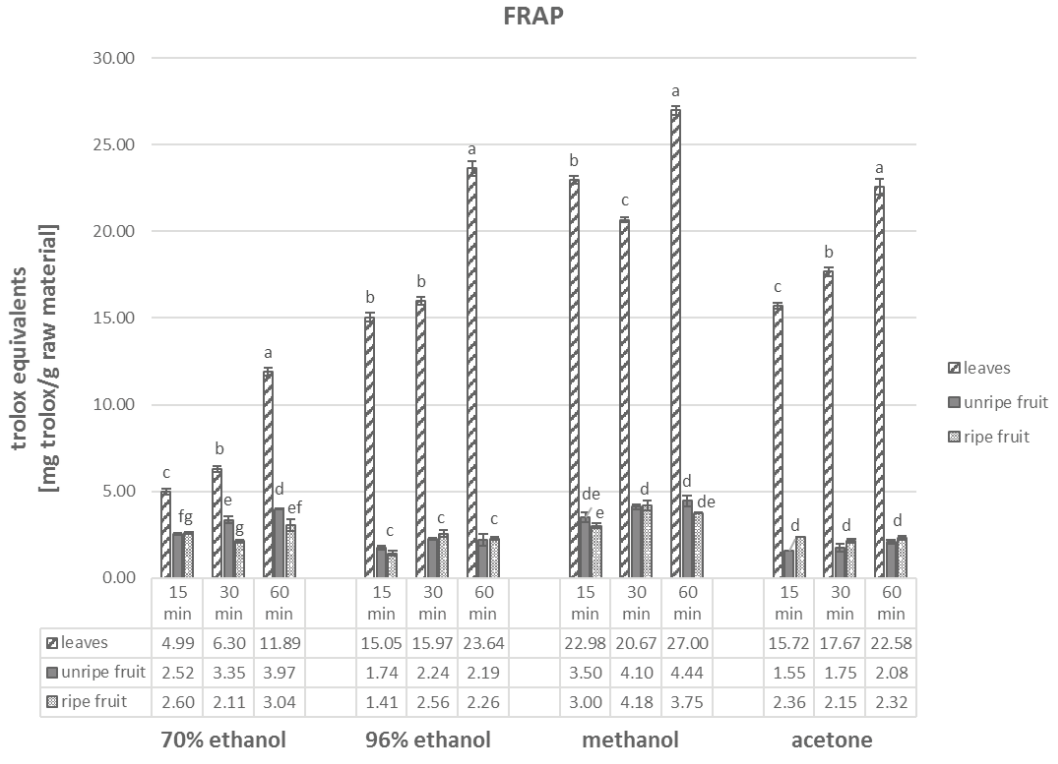

Figure 3.

Mean (±SD) antioxidant activities of leaves and unripe as well as ripe quince fruit extracts evaluated with the FRAP method, expressed as trolox equivalents [mg trolox/g raw material]. Vertical lines represent standard deviations. Bars marked with the same letters did not differ significantly taking the extraction solvent into account. Significance level $p<0.05$, n=3

obtained for methanolic leaf extract (extraction time 60 min), whereas the lowest – for quince ripe fruit extract in 96% (*v/v*) ethanol, extraction time – 15 min. As previously, low values were observed for unripe fruit samples extracted with acetone for 15 min – 1.55±0.01 mg trolox/g raw material. Moreover, it should be added that activities of all of the fruit extracts were significantly lower compared to those of leaves and ranged from 1.41±0.13 to 4.44±0.29 mg trolox/g raw material. In contrary, the activities of the leaf extracts varied from 4.99±0.16 to 27.00±0.26 mg trolox/g raw material.

Total polyphenols contents, determined by the Folin-Ciocalteu method, depending on extraction time and solvent used, are presented in figure 4. Obtained values ranged from 0.81±0.03 to 20.93±0.28 mg trolox/g raw material. Similarly to other activities, the highest concentrations were obtained for the quince leaf extracts, while the lowest – for fruits extracts. The highest polyphenols content was found in methanolic extracts of leaves, after 60 minutes' extraction – 20.93±0.28 and slightly lower for 15 min extraction – 17.76±0.18 mg trolox/g raw material, as well as acetonic extract obtained during 60 minutes (18.67±0.14 mg trolox/g raw material). The concentration of total polyphenols in mature and immature fruits extracts was lower, ranged from 0.81±0.03 to 3.36±0.18 mg trolox/g raw material. These values differ significantly from the leaf extract results.

Linear regression and correlation coefficients, between activities of the same extracts, evaluated with different methods are presented in figure 5. The highest correlations (r>0.900) for quince leaf extracts were found between the results obtained by FRAP *vs.* F-C (r=0.933, p<0.0001) as well as F-C *vs.* ABTS methods (r=0.916, p<0.0001). Taking into account the activity of extracts from unripe fruit, the highest correlation coefficient was observed between the activities evaluated by DPPH *vs.* FRAP (r=0.987, p<0.0001), DPPH *vs.* F-C (r=0.979, p<0.0001) as well as FRAP *vs.* FC (r=0.974; p<0.0001). In ripe fruit extracts, a high correlation coefficient was found for the FRAP *vs.* F-C (r=0.981, p<0.0001), DPPH *vs.* FRAP (r=0.958, p<0.0001) as well as DPPH *vs.* F-C methods (r=0.935, p<0.0001).

Based on the results of this study, it can be observed that methanolic extracts show the highest antioxidant properties, regardless of the raw material in the extracts. In the group of leaf extracts, one-hour extraction proved to be the most effective, in contrast to both ripe and unripe fruits – the optimal extraction time was 30 and 60 minutes. The

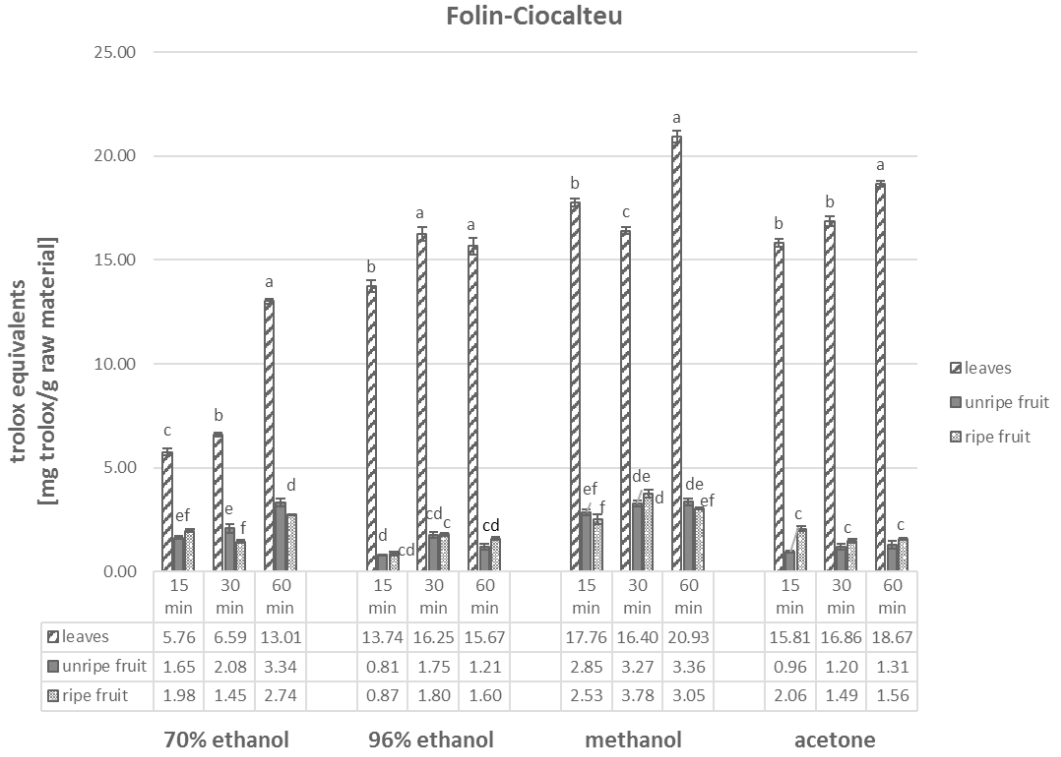

Figure 4.

Mean (±SD) total polyphenols contents in leaves and unripe as well as ripe quince fruit extracts evaluated with the Folin-Ciocalteu method, expressed as trolox equivalents [mg trolox/g raw material]. Vertical lines represent standard deviations. Bars marked with the same letters did not differ significantly taking the extraction solvent into account. Significance level p<0.05, n=3

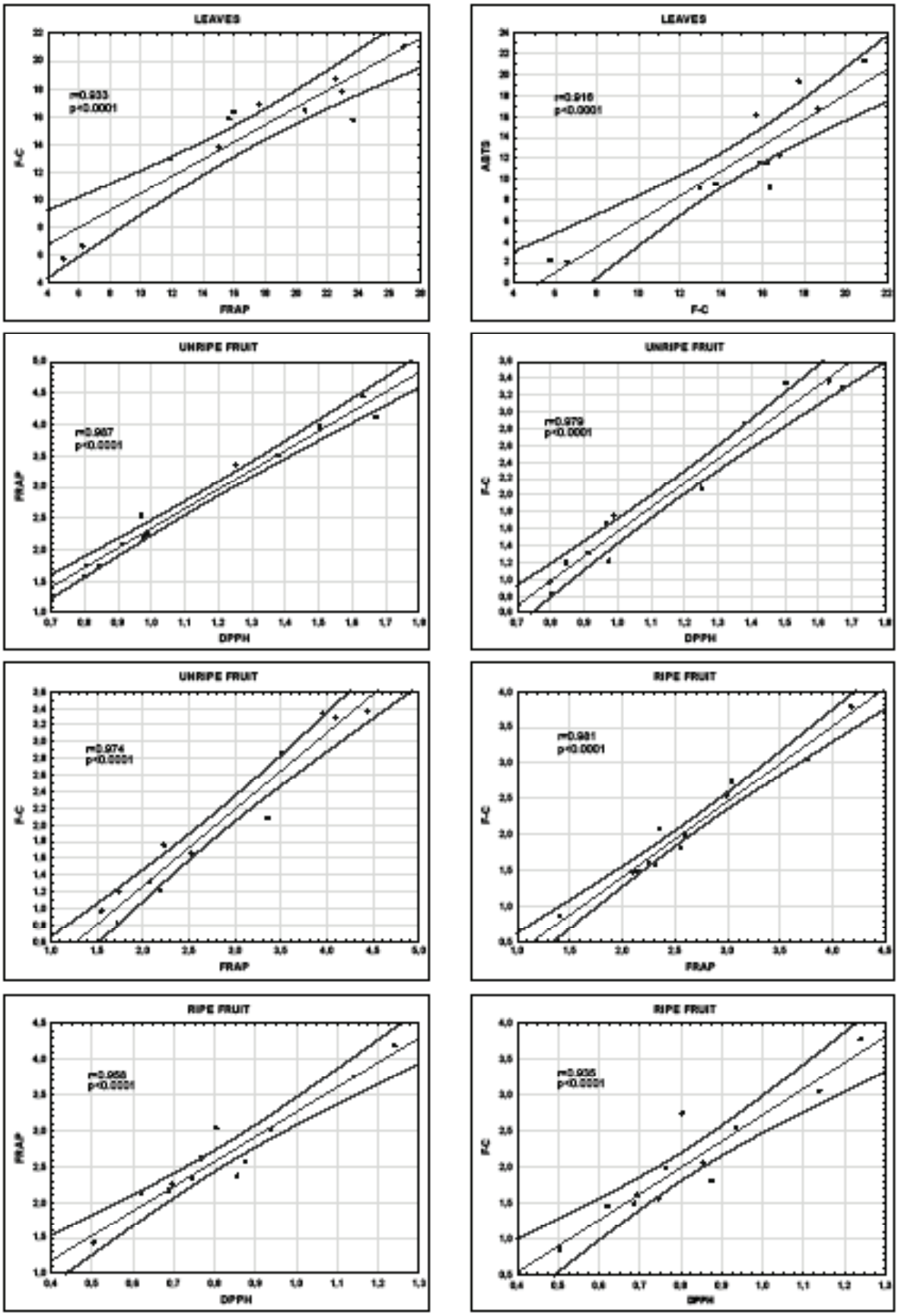

Figure 5.

Correlations between antioxidant capacities of leaf and fruit extracts of *Cydonia oblonga* Mill. [mg trolox/g raw material] obtained using different analytical methods

lowest efficiency for all raw materials (except for the acetonic unripe fruit extract assessed by the ABTS method) was observed for 15 minutes' extraction. Comparing the antioxidant activity of ripe versus unripe fruit extracts, it was found that, in most cases, the higher potential was observed for the unripe fruit of *C. oblonga* extracts.

DISCUSSION

As previously mentioned, a great number of so-called civilisation disorders can be developed by reactive oxygen species (ROS). To protect an organism against ROS, a lot of plant extracts rich in substances with antioxidant potential are used. One such plant seems to be *C. oblonga.*

In this study, the antioxidant activity of methanolic, ethanolic and acetonic extracts of different parts of quince was evaluated. The results obtained using all of the four applied methods (DPPH, FRAP, F-C and ABTS) showed the highest antioxidant potential for methanolic extracts of quince leaves treated with ultrasound for 60 minutes. The valuable properties of this part of the quince have been reported by Costa *et al.* [12]. They evaluated the antiradical and antihemolithic abilities of methanolic extracts from *C. oblonga* compared to green tea. They showed that leaves seemed to be a better source of antioxidants than fruit.

This finding was confirmed in our study. Additionally, Costa *et al.* stated that the studied parameters were comparable to those of green tea, however, in some cases they presented even higher antiradical activity than *Camelia sinensis* extracts. Similar conclusions were made by Oliveira *et al.* [8]. They claimed that quince leaves contained more phenolic compounds compared to the fruit. They identified several compounds in the leaves like 3-O-, 4-O- and 5-O-caffeoylquinic acids, quercetin-3-O-galactoside, kaempferol-3-O-glycoside, 3,5-O-dicaffeoylquinic acid, quercetin-3-O-rutinoside, and kaempferol-3-O-rutinoside, but their content differed depending on the geographical origin of the raw material and the month of its harvest. Teleszko and Wojdyło [13] compared the antioxidant properties of leaf and fruit extracts of various plants, including, among others, quince, and found that its leaf extracts showed significantly higher activity than fruit. In the case of the ABTS method, extracts of quince fruit had shown almost 15 times lower activity (expressed in mmol trolox equivalent/100g of dry matter) than leaves of this plant, whereas in the FRAP method it was 11 times lower. Moreover, the assessed total polyphenol content, was over four times higher in leaf extracts compared to those of fruit [13].

Zielonka-Brzezicka *et al.* [10] analysed the antioxidant potential of raspberries and blackberries belonging to the same *Rosaceae* family. They also found high antioxidant properties of these plant leaves. The highest DPPH and FRAP activities of the examined extracts, obtained with an ultrasound-assisted process, were observed for raspberry as well as blackberry leaves – up to 97.60% RSA for the DPPH and 7.16 mmol Fe^{2+}/l using the FRAP technique. It should be added that similar results were observed in our other studies, performed to evaluate the antioxidant activity of rowan leaf, fruit and flower extracts. Based on the obtained results, it can be concluded that the antioxidant potential of leaf extracts is higher compared to fruit extracts [9].

The antioxidant activities of the studied extracts differed depending on the applied methods, however, the major tendency was observed in all cases, and could be confirmed by high correlation coefficients between the results obtained using different techniques (fig. 5). As previously mentioned, the antioxidant capacities of leaf extracts were higher compared to the fruit samples, irrespectively of the applied technique. Using the DPPH method, in most cases, the activity of unripe fruit extracts was higher than for the ripe ones. However, similar conclusions cannot be drawn for other methods, because using ABTS, FRAP as well as the F-C assays, this trend has not been confirmed. In addition, it should be noted that the highest values of trolox equivalents were obtained for the FRAP method, whereas the lowest were with the DPPH technique. Matysiak *et al.* [14] suggested that the DPPH method has lower sensitivity compared to the other techniques often used for *in vitro* evaluation of antioxidative activity such as the ABTS test. Apak *et al.* [15] recommended applying at least two methods, based on different mechanisms of action, to evaluate these properties because none of the commonly used tests is able to accurately evaluate potential antioxidant activities.

Wojdyło *et al.* [16] also estimated the properties of quince fruit using the DPPH, ABTS and FRAP methods. They evaluated samples obtained from frozen and dried raw material of 13 different plant varieties. The antioxidant activity depended on the plant and ranged between 0.9 and 2.4 μmol trolox/g dry matter for ABTS, 0.9 and 2.5 for DPPH as well as 0.4 and 1.5 for the FRAP method.

Using the Folin-Ciocalteu method, the highest total polyphenol concentrations, expressed as trolox

equivalents [mg trolox/g raw material], were found for methanolic and acetonic leaf extracts. Slightly lower values were observed for leaf extracts in 96% (*v/v*) ethanol. Similar to the previously described methods, all the extracts from quince fruit showed a significantly lower antioxidant potential compared to leaves. Hamauzu *et al.* [17] evaluated the antioxidant properties of quince, apple and Chinese quince fruits using various methods, including F-C. They found a high content of phenolic compounds in *C. oblonga* fruit – 302.7 mg/100 g of fresh weight, which is an almost five times higher level than that of apple extracts, but at the same time fourfold less than Chinese quince extracts (1,280 mg/100 g of fresh weight). Silva *et al.* [18] examined pulp, peel, seed and two kinds of quince jam for the content of phenolic substances. They showed the presence of kaempferol, quercetin, coumaric and caffeoylquinic acids, among others. In addition, they came to the conclusion that phenolic compounds were the main group of antioxidants in quince extracts. Their results suggested that, similar to our findings, the leaves, due to their valuable properties and composition, could be considered as a potential rich source of antioxidant substances [18].

As already mentioned, in the present study, the highest antiradical properties have been observed in the methanolic extracts from individual parts of the plant. The application of methanol as a favourable extractant was also confirmed by others. Boonkaew *et al.* [19] and Sati *et al.* [20], analysing *Ginkgo biloba* leaves extracts, found that, compared to other solvents, methanolic extracts showed higher antioxidant activity. Do *et al.* [21] in their study on *Limnophila aromatica* also analysed the effect of the solvent and its composition on the antiradical capacity of the obtained extracts. They used ethanol, methanol and acetone at concentrations of 100%, 75% and 50%. The highest results of the total polyphenol content were obtained in extracts prepared in the most concentrated ethanol. High concentration also proved to be the most effective observed for acetonic samples, while in methanolic extracts, the highest activity was found with 75% solvent. In our study, the higher antioxidant properties were found for extracts prepared in 70% (*v/v*) ethanol compared to those obtained by applying 96% (*v/v*) ethyl alcohol as the extraction solvent. Our study, as well as those of other authors, confirmed the effectiveness of both methanol and ethanol to obtain extracts with high antioxidant potential, however, the concentration of each aqueous-alcoholic solution should be individually adjusted to the particular plant material.

The influence of extraction time on the antioxidant properties of the samples should also be taken into account. The highest activities were found for samples extracted for 60 and 30 minutes. Ghitescu *et al.* [22] reported the results of their studies on polyphenols in spruce wood extracts. They found that a one hour-long ultrasound-assisted extraction was the most effective. However, different results were obtained by Muzykiewicz *et al.* [9]. They found that *Sorbus aucuparia* leaf extracts with the highest activity were obtained by ultrasound-assisted extraction for 15 minutes, while for fruits 60 min extraction seemed to be the most favourable. Bimakr *et al.* [23] also confirmed that ultrasound-assisted extraction seemed to be a valuable method to obtain plant extracts with a high content of antioxidants. Tiwari [24] noted that extracts prepared by this method could be influenced, among others, by such factors as solvent properties, frequency of ultrasound used and extraction time. The author pointed out that extending the extraction time of the raw material could favourably affect the content of active substances in the extracts. On the other hand, it can lead to undesirable changes in the substances obtained in the extraction process. Azwanida [25] postulates that every process should be properly optimised depending on the purpose for acquiring an individual extract.

CONCLUSIONS

All of the studied quince extracts showed antioxidant activity. The highest potential was found for methanolic extracts of leaves. It should be added that all activities of extracts obtained from leaves were significantly higher than those of the quince fruit extracts. Moreover, the higher activities were found for methanolic extracts compared to other solvents. Ultrasound-assisted extraction seems to be a valuable green technology to obtain extracts with high antioxidant activity. Moreover, extending the extraction time can enhance such activity. The capacities of unripe and ripe quince fruit extracts were comparable, but slightly higher values were obtained for unripe fruit.

Conflict of interest: Authors declare no conflict of interest

The article is partly based on a PhD thesis entitled "The selected Polish plants as a valuable source of natural antioxidants", at the Faculty of Health Sciences, Pomeranian University in Szczecin in 2018. Author: Anna Muzykiewicz. Supervisor: Prof. Adam Klimowicz, PharD DSc.

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