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Flavonols (kaempeferol, quercetin, myricetin) contents of selected fruits, vegetables and medicinal plants

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Abstract

The concentrations of flavonols (kaempeferol, quercetin, myricetin) were determined in 22 plant materials (9 vegetables, 5 fruits, and 8 medicinal plant organs). The materials were extracted with acidified methanol (methanol/HCl, 100:1, v/v) and analyzed by reverse phase high-performance liquid chromatographic (RP-HPLC) with UV detection. The total flavonols contents varied significantly ($P < 0.05$) among vegetables, fruits and medicinal plant organs ranged from 0 to 1720.5, 459.9 to 3575.4, and 2.42 to 6125.6 mg kg^{-1} of dry matter, respectively. Among vegetables, spinach and cauliflower exhibited the highest amounts of flavonols (1720.5 and 1603.9 mg kg^{-1}, respectively), however, no flavonols were detected in garlic. Within fruits, highest level of flavonols was observed in strawberry (3575.4 mg kg^{-1}), whereas, the lowest in apple fruit (459.9 mg kg^{-1}). Of the medicinal plant organs, moringa and aloe vera leaves contained the highest contents of flavonols (6125.6 and 1636.04 mg kg^{-1}), respectively, whereas, lowest was present in barks (2.42–274.07 mg kg^{-1}). Overall, leafy green vegetables, soft fruits and medicinal plant leaves exhibited higher levels of flavonols.

Keywords: Plant materials; Anti-oxidants; Extraction/hydrolysis; RP-HPLC; Flavonols

1. Introduction

Currently, the use of some natural anti-oxidants, particularly, the phenolic substances including flavonoids and phenolic acids in foods, as well as preventive and therapeutic medicine, is gaining much recognition because of their nutraceutical and health benefits (Fan, Ding, & Gu, 2007; Siddhuraju & Becker, 2007). Extensive epidemiological studies have indicated an inverse relationship between dietary flavonoids intake and the risk of coronary heart diseases, and certain cancers (Hung et al., 2004; Puupponen-Pimia et al., 2001; Tripoli, Guardia, Giammanco, Majo, & Giammanco, 2007).

Flavonoids are widely distributed in plant kingdom accounting for over half of the 8000 naturally occurring phenolic compounds (Harborne, Baxter, & Moss, 1999), however, their concentration varies from plant to plant or even in different organs of the same plant (Dinelli et al., 2006; Justesen & Knethsen, 2001). Many plants are considered to be excellent sources of flavonoids that could be used, not only to preserve foods, but also to contribute to a healthy diet (Justesen & Knethsen, 2001). Dietary flavonoids are considered to be even more powerful anti-oxidants than vitamins C and E (Sokol-Letowska, Osmianski, & Wojdylo, 2006).

Fruits and vegetables have been studied extensively for their flavonoid contents. Green leafy, yellow and red vegetables (e.g. onion, cabbage, cauliflower, broccoli), and dark coloured fruits (e.g. citrus species, berries, grapes, apple, plum) are rich in flavonoids (Dragovic-Uzelac, Levaj, Mrkic, Bursac, & Boras, 2007; Franke, Custer, Arakaki, & Murphy, 2004). Considerable research has been carried

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out to investigate flavonoids in cereals and other plant organs such as barks, fruits, peels, flowers and leaves, among others (Andreotti, Costa, & Treutter, 2006; Silva, Souza, Rogez, Rees, & Larondella, 2006).

Flavonoids represent a large family of low-molecular-weight phenolics and according to their molecular structures encompass several chemical classes such as flavones, flavanones, isoflavones, isoflavans, pterocarpans, coumestans, anthocyanins, flavanols (or catechins), and flavonols (Dinelli et al., 2006; Elizabeth et al., 2007). Food derived flavonoids, especially; flavonols (kaempeferol, quercetin, and myricetin) are widely occurring flavonoids and are reported to exhibit multiple biological functions such as anti-allergenic, anti-artherogenic, anti-inflammatory, anti-microbial, anti-thrombotic, anti-oxidant, cardioprotective and vasodilatory effects (Manach, Mazur, & Scalbert, 2005).

Although a number of studies on the flavonols contents of plant sources have been reported from different countries, the compositional data are still insufficient, which necessitates the need to investigate more and more materials for the search of credible and beneficial natural anti-oxidants. There is gap of information regarding the flavonols contents of Pakistani plants. The present study was, therefore, undertaken with the main objective to quantify the levels of less studied, but important, flavonols (kaempeferol, quercetin, myricetin) in selected vegetables such as peas, carrot, spinach, cabbage, cauliflower, turnip, onion, ginger and garlic and fruits such as apple, strawberry, mulberry, apricot, and plum and medicinal plants organs, namely barks of *Acacia nilotica*, *Terminalia arjuna*, *Eugenia jambolana* and *Azadirachta indica*, leaves of *Moringa oleifera* and *Aloe vera*, roots of *M.oleifera*, and fruit of *Ficus religiosa*, indigenous to Pakistan. To the best of our knowledge, almost all the strategic plant materials have not yet been investigated and quantified for the specific flavonols (kaempeferol, quercetin, myricetin), in particular, from sub-continental region. Furthermore, the plant materials such as *A. vera*, peepal fruit, barks of jaman, desi kiker, arjun, etc., have been the subject of our present study for the first time and not studied elsewhere. So, the present work would be informative and novel with regard to the quantification of specific flavonols and plant materials along with their native region. Such study is valuable for researchers in providing a base line data for future detailed characterization of other phenolics in these and related plants and thus a step towards their potential commercialization as nutraceuticals and anti-oxidant applications in the marketplace.

2. Materials and methods

2.1. Samples

A total of 22 plant materials were assayed. For convenience, the materials were categorized into three groups namely vegetables, fruits, and medicinal plant organs. The samples of vegetables (peas, carrot, spinach, cabbage, cauliflower, turnip, onion, ginger, and garlic) and fruits (apple, strawberry, mulberry, apricot, and plum) were purchased from the vegetable and fruit markets of Faisalabad, Pakistan. Medicinal plants organs (barks of *A. nilotica*, *T. arjuna, E. jambolana* and *A. indica*; leaves of *M. oleifera* and *A. vera*; roots of *M. oleifera*, and fruit of *F. religiosa*) were collected from the vicinity of University of Agriculture, Faisalabad, Pakistan. The specimens were further identified and authenticated by Professor Muhammad Ashraf, Department of Botany, University of Agriculture, Faisalabad, Pakistan. The scientific names of the species along with their families and other relevant information are presented in Table 1.

2.2. Reagents

The HPLC grade flavonol standards (kaempeferol, quercetin, myricetin) and *ter*-butylhydroquinone (TBHQ) were purchased from Sigma Chemicals Co. (St Louis, MO, USA). All other chemicals including acetonitrile, methanol, and hydrochloric acid used in this study were from Merck (Darmstadt, Germany), unless stated otherwise.

2.3. Sample preparation

Samples (1.0 kg) of each of the vegetables and fruits were washed with tap water after removing manually inedible parts with a sharp steel knife, cut into almost equal small pieces or slices (approx. 1×1 cm), and then mixed

Table 1
Scientific/traditional names and part used of the plant materials

Botanical name/variety	Common name	Part used
Vegetables		
Pisum sativum	Peas	Seed
Daucus carota	Carrot	Root
Brassica oleracea	Cabbage	Bud
Brassica oleracea	Cauliflower	Flower
Spinacia oleracea	Spinach	Leaves
Brassica rapa	Turnip	Root
Allium cepa	Onion	Bulb
Allium sativum	Garlic	Cloves
Zingiber cassumunar	Ginger	Rhizome
Fruits		
Malus pumila	Apple	Fruit
Prunus salicin	Plum	Fruit
Prunus armeniaca	Apricot	Fruit
Fragaria ananassa	Strawberry	Fruit
Morus alba	Mulberry	Fruit
Medicinal plant organs		
Eugenia jambolana Lam	Jaman	Bark
Acacia nilotica	Desi kiker	Bark
Azadirachta indica	Neem	Bark
Terminalia arjuna	Arjan	Bark
Moringa oleifera	Sohanjana	Leaves, root
Ficus religiosa	Peepal	Fruit
Aloe barbadensis	Aloevera	Leaves

well and homogenized. The samples of barks, leaves, roots were air-dried and ground into affine power, using a commercial blender (TSK-949, WestPoint, France). The material that passed through 80-mesh sieve was used for extraction purposes.

2.4. Sample extraction for HPLC

Extraction/hydrolysis of flavonols was carried out following the method of Tokusoglu, Unal, and Yildirum (2003) with slight modifications. Briefly acidified methanol (25 mL) containing 1% (v/v) HCl and 0.5 mg mL $^{-1}$ TBHQ was added to each plant material (5 g), however, the amount of *M. oleifera* leaves and spinach used was 1 g. HCl (1.2 M, 5 mL) was added and the mixture was stirred at 90 °C under reflux for 2 h to obtain aglycons of flavonol glycosides. The extract was cooled to room temperature and centrifuged at 1500*g* (5000 rpm) for 10 min. Upper layer was taken and sonicated for 5 min, to remove air. The final extract was filtered through a 0.45 μm (Millipore) filter, before injecting into HPLC.

2.5. Dry matter determination

Owing to varying water contents of different plant materials, all calculations were made on dry mass basis. For the determination of dry matter, 5–6 g of all samples (in triplicate) were dried in an electric vacuum drying oven (VOC-300 SD, EYELA, Tokyo, Japan) at 70 °C, for at least two days, until a constant weight was achieved.

2.6. HPLC separation

Flavonols (kaempeferol, quercetin, myricetin) analysis was performed using high-performance liquid chromatograph. An HPLC (model LC-10A, Shimadzu, Kyoto, Japan), equipped with two LC-10 AS pumps, SCL-10A system control unit, Rheodyne injector, CTO-10A column oven, SPD-10A UV–vis detector, and data acquisition class LC-10 software was used. A 20 μL volume of the filtered sample was injected into an analytical Supelco (Supelco Inc., Supelco Park, Bellefonte, PA, USA) ODS reverse phase (C18) column (250 × 4.6 mm; 5 μm particle size). Two solvent systems A: contained 3% trifluoroacetic acid and B: contained acetonitrile and methanol (80:20 v/v) were used. The chromatographic separation was performed by isocratic elution of the mobile phase (mixture of solvent A and B (50:50 v/v) that was filtered under vacuum through a 0.45 μm membrane before use) at a flow rate of 1.0 mL min^{-1} at 30 °C. Detection was performed at a wavelength of 360 nm.

Identification of flavonols (kaempeferol, quercetin, myricetin) was carried out by comparing their retention times with those of authentic standards (Sigma Chemicals Co., St Louis, MO, USA). Quantitative determination was carried using calibration curves of the standards. By analyzing dilution series of pure standards solutions ranged from 0.01 to 0.08 mg L^{-1}, minimum quantities were determined for the flavonols. The mean value of the signal-to-noise ration ($n = 8$) generated from the solution that just caused more than three times S/N ratio was used to calculate the detection limit (based on S/N = 3) of the corresponding flavonol. The detection limit for kaempeferol, quercetin and myricetin was 0.04, 0.05, 0.05 mg L^{-1}, respectively.

2.7. Statistical analysis

Three samples of each plant material were taken. Each sample was analyzed individually in triplicate and data are reported as mean ($n = 3 \times 3$) ± SD ($n = 3 \times 3$). Analysis of variance (ANOVA) was performed using Minitab 2000 Version 13.2 statistical software (Minitab Inc., PA. USA).

3. Results and discussion

3.1. Flavonols in vegetables

Mean concentration of individual flavonols (myricetin, quercetin, kaempeferol) in different plant materials is shown in Table 2. Results showed that *M. oleifera* leaves (Sohanjana) contained highest amount of total flavonols (myricetin, quercetin, kampeferol). Strawberry, spinach, *A. vera* leaves, cauliflower, and *Ficus religiosa* fruit also exhibited good levels of flavonols. On the other hand, barks of *E. jambolana*, *A. indica, T. arjuna*, cabbage, and ginger were found to be the poor sources of flavonols.

Among vegetables, kaempeferol was the dominant flavonol. The kaempeferol levels in the investigated vegetables ranged from 0.3 to 795.9 mg kg^{-1} of dry matter. Significantly ($P < 0.05$) higher levels were observed in spinach (59.6), followed by cabbage (23.9), cauliflower (17.9), peas (15.5), ginger ≈ turnip (14.9–14.7), and onion (0.3). Conversely, kaempeferol was not detected in carrot and garlic.

The kaempeferol contents of spinach (*Spinacia oleracea*) was found to be comparable with the results (49–9 mg kg^{-1}) of Franke et al. (2004), however, lower than those reported by Nuttila, Kammiovirta, and Oksman-Caldentey (2002) (3039–3667 mg kg^{-1}). Highest kampeferol levels in spinach among the 9 vegetables analyzed in the present study are in good agreement with the proclamation that leafy vegetables are a good source of kampeferol (Goldbohm, Hertog, Brants, Vanpoppel, & Venden Brandt, 1998; Nuttila et al., 2002). Franke et al. (2004), also investigated that green onion (*Allium cepa*) contained higher levels of kampeferol (18–26 mg kg^{-1}) than red onion (*A. cepa*) (3–6 mg kg^{-1}). Lower kampeferol contents (0.27 mg kg^{-1}) of onion (*A. cepa*) in the present study investigation may be justified by the fact that red onion (edible part) has been investigated. However, colour of the species should not be considered as the limiting factor for the extent of phytochemicals, as it has been reported earlier that red, violet, pink and yellow onions (*A. cepa*)

Table 2
Flavonols contents (mg kg^{-1} dry matter) of different vegetables, fruits, and medicinal plant organs

	Myricetin	Quercetin	Kampeferol	Total flavonols
Vegetables				
Peas	$_{A}146.2^{k} \pm 4.4$	$_{B}36.4^{g} \pm 1.1$	$_{C}15.5^{h} \pm 0.6$	$198.1^{k} \pm 6.8$
Carrot	$_{A}525.3^{g} \pm 10.5$	ND	ND	$525.3^{h} \pm 16.4$
Cabbage	ND	ND	$_{A}23.9^{g} \pm 0.7$	$23.9^{m} \pm 2.1$
Cauliflower	$_{A}1586.9^{d} \pm 33.7$	ND	$_{B}17.9^{h} \pm 0.4$	$1603.9^{d} \pm 46.9$
Spinach	$^{A}1660.9^{c} \pm 30.2$	ND	$_{B}59.6^{e} \pm 1.8$	$1720.5^{c} \pm 37.6$
Turnip	$_{A}457.0^{h} \pm 18.3$	ND	$_{B}14.7^{h} \pm 0.6$	$471.7^{i} \pm 4.5$
Onion	ND	$_{A}104.5^{e} \pm 4.2$	$_{B}0.3^{j} \pm 0.1$	$104.8^{l} \pm 4.6$
Garlic	ND	ND	ND	ND
Ginger	ND	ND	$_{A}14.9^{h} \pm 0.4$	$14.9^{n} \pm 0.6$
Fruits				
Apple	$_{A}308.9^{j} \pm 12.4$	$_{B}119.5^{e} \pm 4.8$	$_{C}31.4^{f} \pm 1.3$	$459.9^{i} \pm 15.4$
Plum	$_{A}564.1^{g} \pm 11.3$	ND	$_{B}0.7^{j} \pm 0.2$	$564.8^{h} \pm 14.3$
Apricot	$_{A}406.9^{i} \pm 16.3$	$_{B}322.1^{b} \pm 6.4$	$_{C}5.8^{i} \pm 0.2$	$784.8^{g} \pm 32.6$
Strawberry	$_{A}3382.9^{b} \pm 101.5$	ND	$_{B}192.6^{c} \pm 5.8$	$3575.4^{b} \pm 73.5$
Mulberry	ND	$_{A}359.4^{a} \pm 7.2$	$_{B}284.3^{a} \pm 5.7$	$643.7^{f} \pm 21.4$
Medicinal plant organs				
Jaman (bark)	ND	$_{A}1.2^{i} \pm 0.3$	$_{A}1.3^{j} \pm 0.2$	$2.4^{o} \pm 0.3$
Desi kiker (bark)	$_{A}188.9^{k} \pm 3.8$	$_{B}63.4^{f} \pm 1.9$	$_{C}21.7^{g} \pm 0.6$	$274.1^{j} \pm 5.6$
Neem (bark)	ND	$_{A}31.9^{g} \pm 1.3$	$_{B}0.5^{j} \pm 0.1$	$32.4^{m} \pm 1.7$
Arjan (bark)	ND	$_{B}7.7 \pm 0.3$	$_{A}8.9^{i} \pm 0.3$	$16.6^{n} \pm 0.7$
Sohanjana (leaves)	$_{A}5804.4^{a} \pm 116.1$	$_{B}281.0^{e} \pm 5.6$	$_{B}40.2^{f} \pm 0.8$	$6125.6^{a} \pm 120.9$
Sohanjana (root)	$_{A}170.2^{k} \pm 6.8$	ND	$_{B}13.9^{h} \pm 0.4$	$184.1^{k} \pm 8.1$
Aloe vera (leaves)	$_{A}1283.5^{e} \pm 38.5$	$_{C}94.8^{e} \pm 2.8$	$_{B}257.7^{b} \pm 5.2$	$1636.0^{d} \pm 32.7$
Peepal (fruit)	$_{A}694.0^{f} \pm 13.9$	$_{B}256.3^{d} \pm 2.6$	$_{C}160.8^{d} \pm 4.8$	$1111.1^{e} \pm 33.3$

Values are means ± SD, for three samples of each plant material, analyzed individually in triplicate ($n = 3 \times 3$) ± SD ($n = 3 \times 3$).
Small letters in superscript indicate significant differences ($P < 0.05$) among different species.
Capital letters in subscript indicate significant differences ($P < 0.05$) among contents of flavonols.
ND; not detected.
The detection limit for kaempeferol, quercetin and myricetin was 0.04, 0.05, 0.05 mg L^{-1}, respectively.

have higher amounts of flavonols (quercetin, kaempeferol, etc.) than white and green (Patil, Pike, & Yoo, 1995; Prakash, Singh, & Upadhyay, 2007).

Myricetin was the second most abundant flavonol detected in the plant species investigated in the present study. The range of myricetin content was 146.2–1660.9 mg kg^{-1} of dry matter. The ranking of vegetables on the basis of myricetin contents in decreasing order is spinach (1660.9 mg kg^{-1}) > cauliflower (1586.9 mg kg^{-1}) > carrot (525.3 mg kg^{-1}) > turnip (457.0 mg kg^{-1}) > peas (146.2 mg kg^{-1}). However, myricetin was not detected in cabbage, onion, and garlic. Less informations are available regarding the contents of myricetin in vegetables used in the present work. Huang, Wang, Evas, Shikany, and Pace (2007) also reported no detection of myricetin in the investigations of phenolic compounds of 12 vegetables including peas (*Vigna unguiculata*) hull and onion (*Allium fistulosum*) using HPLC.

Quercetin was only detected in peas (*Pisum sativum*) and onion (*A. cepa*). The concentration in onion (104.5 mg kg^{-1} of dry matter) was significantly ($P < 0.05$) higher than that in peas (36.4 mg kg^{-1} of dry matter). The quercetin levels of peas (seed) in our study were found to be lower than that in peas hull (*V. uniguiculata*) (55.0 mg kg^{-1}) reported by Huang et al. (2007). This discrepancy in the results could be explained by the fact that peel tissues or outer covering of the seeds usually contain larger amount of phenolics, anthocyanins and flavonols (Li et al., 2006).

Generally quercetin levels are higher in outer layers of the onion than in the inner ones. Nuttila, Puupponen-Pimia, Aarni, and Oksman-Caldentey (2003) reported that concentration of quercetin in onion (*A. cepa*) varied from 7 mg to 83,477 mg kg^{-1}, depending on the part of the plant and variety. The quercetin content of onion (*A. cepa*) in the present study was found to be lower than those in red or yellow spring (*A. cepa*) onion (113 and 1274 mg kg^{-1}, respectively), however, greater than that found in giant onion (*A. cepa*) (85 mg kg^{-1}) as investigated by Nuttila et al. (2003).

Among 9 different vegetables analyzed in the present study, garlic (*Allium sativum*) is the only one that contained none of the flavonols (myricetin, quercetin, kaempeferol). Nuttila et al. (2003) also reported that garlic (*A. sativum*) did not contain quercetin or kampeferol in detectable amounts, except for the organic leaves of garlic.

Data for flavonol contents of different fruits, showed the presence of kaempeferol in all investigated fruits; however, its level varied widely ranging from highest in mulberry (284.3 mg kg^{-1}) to lowest in plum (0.7 mg kg^{-1}).

Strawberry also contained reasonable level (192.6 mg kg^{-1}), nonetheless, its concentration was quite low for apple (31.4 mg kg^{-1}) and apricot (5.8 mg kg^{-1}).

The kaempeferol content of the fruits strawberry (*Fragaria ananassa)*, plum (*Prunus salicin*), and apple (*Malus pumila*) in the present investigation was found to be higher than those reported by Franke et al. (2004). According to their findings kaempeferol contents of strawberry (*Fragaria* spp.) ranged from 6 to 13 mg kg^{-1}, while those of plum (*Prunus domestica*), and apple (*Malus sylvestris*) were below the detection limits (<0.1 mg kg^{-1}). However, kaempeferol content i.e. 192.6 mg kg^{-1} of strawberry (*F. ananassa)* in our present study fell in the range of (108–437 mg kg^{-1}) reported by Olsson et al. (2004).

Quercetin was the second most abundant flavonol detected in the fruits analyzed in the present work. Highest level was detected in mulberry (359.4 mg kg^{-1}), followed by apricot (322.1 mg kg^{-1}), and apple (119.5 mg kg^{-1}). Greater level of quercetin in apricot than apple is in agreement with the results of Dragovic-Uzelac, Pospisil, Levaj, and Delonga (2005), who investigated that quercetin 3-rutinoside level in apricot (*Prunus armeniaca*) (26.36 mg kg^{-1}) is higher than those of apple (4.6 mg kg^{-1}). Van Der Sluis, Dekker, Skrede, and Jongen (2004) reported that quercetin glycosides are the main flavonol of apple. Franke et al. (2004) reported that quercetin content of apple (*M. sylvestris*) with and without skin ranged from 7 to 76 mg kg^{-1}, which is quit lower than those investigated in our study. On the other hand quercetin was not detected in plum and strawberry. This is in disagreement with the results of the investigation of Franke et al. (2004), although quercetin content reported in their study was quite low i.e. 9–11 mg kg^{-1} (strawberry) (*Fragaria* spp.) and 8–12 mg kg^{-1} (plum) (*P. domestica*). Literature reports higher levels of quercetin in strawberry (Olsson et al., 2004) and plum (Kim, Jeong, & Lee, 2003).

Myricetin was detected only in plum and strawberry. However, myricetin content of strawberry (3382.9 mg kg^{-1}) was found to be significantly ($P < 0.05$) higher than those of plum (564.1 mg kg^{-1}). Absence of myricetin in apple and apricot in our analysis is in accordance with the results of Franke et al. (2004) and Dragovic-Uzelac et al. (2005).

Data for flavonol (myricetin, quercetin, kaempeferol) contents of different medicinal plant organs also indicated that kaempeferol is the most abundant flavonol, detected in all sources; however, its concentration varied widely, ranging from 0.5 to 257.7 mg kg^{-1}. Highest kaempeferol level was observed for *A. vera* leaves (257.7 mg kg^{-1}), followed by *F. religiosa* fruit (160.8 mg kg^{-1}), *M. oleifera* leaves (40.2 mg kg^{-1}), *A. nilotica* bark (21.7 mg kg^{-1}), *M. oleifera* root (13.9 mg kg^{-1}), *T. arjuna* bark (8.9 mg kg^{-1}), *E. jambolana* bark (1.3 mg kg^{-1}), and *A. indica* bark (0.5 mg kg^{-1}).

Quercetin was also detected in all samples, except, *M. oleifera* root to varying levels (1.2–281.0 mg kg^{-1}). Highest levels were found in *M. oleifera* (281.0 mg kg^{-1}), followed by *Ficus religiosa* fruit (256.3 mg kg^{-1}), *A. vera* leaves (94.8 mg kg^{-1}), *A. nilotica* bark (63.4 mg kg^{-1}), *A. indica* bark (31.9 mg kg^{-1}), *T. arjuna* bark (7.7 mg kg^{-1}), and *E. jambolana* bark (1.2 mg kg^{-1}).

Less frequently occurring flavonol was the myricetin; however, its level was significantly ($P < 0.05$) higher than quercetin and kaempeferol. Highest level of myricetin was detected in *M. oleifera* leaves (5804.4 mg kg^{-1}), followed by *A. vera* leaves (1283.52 mg kg^{-1}), *F. religiosa* fruit (694.0 mg kg^{-1}), *A. nilotica* bark (188.9 mg kg^{-1}), and *M. oleifera* root (170.2 mg kg^{-1}). Conversely, myricetin was not detected in the barks of *E. jambolana*, *A. indica,* and *T. arjuna*.

Little is known about the flavonol (myricetin, quercetin, kampeferol) contents of these plant materials. In our study the investigated flavonol levels (myricetin, quercetin, kaempeferol) were found to be higher in leaves and fruits, which is in good agreement with the previous reports (Shahidi, 1997). Siddhuraju and Becker (2003) reported that quercetin and kampeferol levels of *M. oleifera* leaves (Sohanjana) ranged from 6340 to 27,490 mg kg^{-1} and 647 to 1050 mg kg^{-1}, respectively. Silva et al. (2006) reported that photosynthesis reaction taking place in leaves results in the greater concentration of the phytochemicals (like flavonoids, phenolic acids).

4. Conclusion

Leaves of *M. oleifera* exhibited commendably higher levels of flavonols (myricetin, quercetin, kampeferol). Cauliflower, spinach, leaves of *A. vera*, fruit of *F. religiosa* and strawberry also revealed the presence of considerable amounts of flavonols. The anti-oxidant effects and health benefits of flavonols are fascinating. Thus the results of the present study support the anti-oxidant and nutraceutical potential of these plant species indigenous to Pakistan. However, further investigations involving more detailed in vitro and in vivo studies are required to ascertain inclusive phenolics anti-oxidant system of these plant materials and develop their application for particular food or nutraceutical purposes.

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