Chapter 6
Nutraceutical and Bioactive Significance of Ferns with Emphasis on the Medicinal Fern *Diplazium*

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Abstract Being primitive vascular plants, pteridophytes (ferns) have wide geographic distribution in different climatic regimes by bridging the gap between lower and higher plants. Compared to the angiosperms, nutraceutical and bioactive potential of ferns attracted less attention. Many ferns are nutraceutically viable owing to their rich source of protein, fiber, minerals, vitamins, essential amino acids, and fatty acids. Besides bioherbicide potential, ferns are endowed with chemopreventive, hepatoprotective, cytotoxic, antihyperglycemic, leishmanicidal, trypanocidal, antimicrobial, antinociceptive, and immunomodulatory metabolites. Ferns are also valuable source of low-cost proteins, starch, and components of cosmeceutical significance. The genus *Diplazium* has pantropical distribution consisting of versatile nutraceutical and bioactive compounds. Future research should intensify toward exploitation of ferns as nutraceutical, healthcare, and industrial products to open up new avenues for food and pharmaceutical industries.

Keywords Bioactive compounds · Ethnic food · Leafy vegetable · Nutraceutical potential · Pteridophyte · Riparian fern

6.1 Introduction

Pteridophytes are the oldest primitive vascular plants constituting the second largest group of vascular plants contributing to the diversity of plant kingdom. Their global representation is more than 1200 species belonging to 204 genera. Pteridophytes are known to grow in varied climatic zones with different phytogeographical regimes depending on the microclimatic conditions. Being cosmopolitan, pteridophytes usually grow in the humid tropical, subtropical, temperate (Dryopteridaceae), alpine (Woodsiaceae), and arid (Cheilanthoideae and Pteridaceae) regions. Its sporophyte consists of roots, stem, leaves, and well-developed vascular strands. Although they prefer shady and moist habitats with moderate temperature regimes, they occupied

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a wide range of habitats including high altitude biomes. Medicinal and ethnobotanical uses of pteridophytes are less versatile compared to the angiosperms (Chowdury 1973; Vyas and Sharma 1998). Liu et al. (2012) documented about 52 species of ferns, which are edible in China. Caius (1935) documented several medicinal applications of ferns occurring in the Indian subcontinent. The in vitro propagation of pteridophytes is of great interest for the preservation of economically valued, medicinal, edible, and ornamental ferns (Bharti et al. 2013).

In the Indian subcontinent, the pteridophyte diversity is notable especially in the Himalayas, Western Ghats, and Eastern Ghats (Dixit 2000). They are more specifically distributed in temperate Himalayas and tropical ecoregions of Deccan Plateau (Shankar and Khare 1992; Vasudev 1999; Shrivastava 2007). Surveys in Kigga forests of the central Western Ghats revealed occurrence of 31 species of pteridophytes belonging to 20 families (Deepa et al. 2013). Surveys in Mudigere region of the Western Ghats resulted in documentation of 26 fern species belonging to 17 families with highest frequency of *Selaginella monospora* followed by *Adiantum philippense*, *Pteris biaurita*, *Adiantum concinnum*, and *Tectaria paradoxa* (Parashurama et al. 2016). Maridass and Raju (2010) documented up to 272 species of ferns and fern allies (95 genera belong to 34 families) from southern Western Ghats. Among them, 89 species were common, 33 species were rare, 26 were endemic species, 12 were near threatened, and 9 were very rare. Benjamin and Manickam (2007) described 61 medicinal pteridophytes (belong to 31 families) in the Western Ghats utilized by the native tribes to treat ailments like cold, cough, fever, stomach disorders, rheumatics, diabetes, and poisonous bites. The aim of the present chapter is to consolidate the usefulness of ferns especially nutraceutical value, bioactive potential, and functional attributes with emphasis on the values and relevance of different species of *Diplazium*.

6.2 Nutraceutical Importance

Bracken (*Pteridium*) fiddle heads are nutritionally rich sources in Korea, and they contain significant amounts of protein, fiber, vitamins, and minerals (Copeland 1942; Thakur et al. 1998). Table 6.1 provides proximal composition of different parts of 20 edible ferns. The range of proximal composition of ferns includes moisture, 25.6–91.1%; crude protein, 0.6–24.1%; total lipids, 0.2–21.5%; crude fiber, 0.5–62.2%; ash, 0.6–19.5%; and carbohydrates, 3.1–57.2%. The crude protein content in *Pteridium aquilinum* (leaves) is comparable to those of legume seeds (21.9–24.1%). The total lipids of stem and leaves of *Dicksonia antarctica* were higher than other ferns (21.5–15.5 vs. 0.2–6%). The crude fiber content was high in *Azolla microphylla* (leaves, 13.4%), *A. pinnata* (whole plant, 14.7%), and *Acrostichum aureum* (rhizome, 10.3%). The carbohydrate content was highest in roots of *Diksonia antarctica* (57.2%) followed by *A. aureum* (rhizome, 53.3%), *A. microphylla* (leaves, 37.7%), *A. pinnata* (whole plant, 33.8%), and *D. antarctica* (stem, 25.3%). The high ash content in leaves of *A. microphylla* (24.3%), whole plant of *A.*

Table 6.1 Proximal composition of 20 edible ferns (%)

	Parts used	Moisture	Crude protein	Total lipids	Crude fiber	Ash	Carbohydrates
Acrostichum aureum[14]	Rhizome	66.8	4.9	0.7	10.3	4.3	53.3
Athyrium filix-femina[2]	Fiddle heads	91.1	3.2	0.2	–	0.6	4.9
Azolla microphylla[7]	Leaves	80.5	24.1	3.3	13.4	19.5	37.7
Azolla pinnata[9]	Whole plant	75.7	23.5	3.7	14.7	24.3	33.8
Ceratopteris cornuta[5]	Sterile fronds	87.0	4.2	–	–	–	3.1
Ceratopteris cornuta[5]	Fertile fronds	91.0	5.3	–	–	–	7.4
Crepidomanes intramarginale[10]	Leaves	–	0.6	–	–	3.2	13.7
Dicksonia antarctica[13]	Leaves	55.7	9.2	21.5	–	9.0	4.6
Dicksonia antarctica[13]	Stem	53.1	3.1	15.5	–	3.0	25.3
Dicksonia antarctica[13]	Root	25.6	5.3	6.0	–	6.0	57.2
Matteuccia struthiopteris [1]	Fiddle heads	87.0	4.2	0.5	1.1	4.0	3.1
Nephrolepis biserrata[4]	Leaves	80.0	6.1	0.3	0.9	1.9	10.9
Nephrolepis cordifolia[3]	Leaves	78.4	1.6	–	–	11.0	11.4
Nephrolepis cordifolia[8]	Leaflets	65.4	10.8	–	–	1.3	21.5
Nephrolepis cordifolia[3]	Rachis	68.5	3.8	–	–	6.3	8.1
Nephrolepis cordifolia[3]	Rhizome	66.0	11.9	–	–	8.0	9.3
Nephrolepis exaltata[11]	Unipinnate leaflets	78.5	12.5	0.5	0.5	0.9	7.1
Nephrolepis exaltata[11]	Bipinnate leaflets	82.7	9.5	0.5	0.6	0.9	6.0
Nephrolepis furcans[6]	Leaves	85.0	0.9	0.2	3.3	2.1	8.5
Pteridium aquilinum[12]	Leaves	–	21.9	2.7	4.1	7.1	–

[1]Bushway et al. 1982; [2]Drury 1985; [3]Gauchan et al. 2008; [4]Oloyede et al. 2008; [5]Oloyede et al. 2010; [6]Oloyede et al. 2012; [7]Chatterji et al. 2013; [8]Oloyede et al. 2013; [9]Cherryl et al. 2014; [10]Greeshma and Murugan 2014; [11]Oloyede et al. 2014; [12]Awe and Amobi 2015; [13]Ekwealor et al. 2015; [14]Lobo and Gulimane 2015; – not determined

pinnata (19.5%), and leaves of *Nephrolepis cordifolia* (11%) reveals their rich mineral composition (Table 6.1).

Several ferns are ideal source of major minerals (sodium, calcium, potassium, magnesium, and phosphorus) as well as trace elements (iron, copper, zinc, and manganese) (Oloyede et al. 2014). They possess remarkably high quantities of many essential amino acids (Deka et al. 2016; Zanariah et al. 1986; Sanginga and Hove 1989; Bhaskaran and Kannapan 2015). According to Delong et al. (2011), *Matteuccia struthiopteris* (ostrich fern) is known for higher quantity of rare fatty acids than green vegetable including ω-3 (arachidonic and eicosapentaenoic acids) and ω-6 fatty acids (γ-linolenic and dihomo-γ-linolenic acids). With ferns being nutritionally versatile, it is possible to preserve their fiddle heads (unfurled fronds) as source of food.

The process of preservation of fiddle heads is fairly simple, and cleaned fiddle heads should be steam boiled in hot water followed by sun drying or preserved in a salt layer, which could last long up to 2–3 years (Lee and Shin 2011). During requirement, the dried fiddle heads could be recooked (with mashed garlic, salt, sesame oil, and soybean sauces), while the salted fiddle heads should be rinsed with running water followed by cooking similar to dried ones. The fiddle heads are commonly boiled with butter followed by addition of cider or wine vinegar with a bit of pepper (Lee and Shin 2011).

Besides nutraceutical source to humans, some ferns such as *Dryopteris wallichiana*, *Nephrolepis biserrata*, and *Ophioglossum grande* are also useful as fodder in Nigeria (goat, sheep, and other ruminants) (Nwosu 2002; Oloyede et al. 2013). The aquatic fern *Azolla pinnata* is used as feed for broiler chicken, laying hens, goats, and calves of buffalo, while *Azolla filiculoides* serves as source of protein while rearing pigs (Becerra et al. 1990; Duran 1994; Samanta and Tamang 1995; Alalade et al. 2007; Balaji et al. 2009; Indira et al. 2009, Leterme et al. 2010; Cherryl et al. 2014).

6.3 Bioactive Potential

Although ferns bridge the gap between lower and higher plants, compared to angiosperms, ferns are underexplored as well as underutilized for their potency of phytochemicals (Cao et al. 2017). Ferns are also known to replace chemical herbicides owing to their inhibitory metabolites. Several studies documented therapeutic potential of ferns especially chemopreventive, hepatoprotective, cytotoxic, antihyperglycemic, leishmanicidal, trypanocidal, antimicrobial, antinociceptive, anti-inflammatory, and immunomodulatory properties (Wu et al. 2005; Wills and Asha 2006; Yonathan et al. 2006; Wills and Asha 2009; Radhika et al. 2010; Zheng et al. 2011a, b; Morais-Braga et al. 2013a, b; Socolsky et al. 2015; Cao et al. 2017). With expectation of a few (e.g., *Lycopodium*), ferns do not synthesize alkaloids. However, various phenolic compounds like acylphloroglucinols, nonprotein amino acids, cyanogenic glycosides, and flavonoids have been reported. Polyphenols are useful as

antioxidants, and it is generally recognized to reduce the risks of many chronic diseases. Screening of 37 ferns and fern allies (*Polystichum lepidocaulon* and *P. polyblepharum*) showed presence of 13% total polyphenols in dried fronds and rhizomes (Shin 2010; Shin and Lee 2010). In addition, the dried fronds of *Davallia mariesii* and rhizomes of *Athyrium niponicum*, *Cyrtomium fortunei*, *Dicranopteris pedata*, and *Dryopteris nipponensis* possess >10% of total polyphenols.

6.3.1 Antioxidant Properties

In many countries, brackens are considered as poisoning plants owing to their carcinogenic and anti-thiamin properties (Somvanshi and Ravishankar 2004). However, the hot water extracts of dried bracken fiddle heads yielded acidic polysaccharides, which exhibits anticomplementary activities (Byeong et al. 1994). Antioxidant activities (DPPH radical and ABTS radical-scavenging) have been studied from the frond and rhizome extracts of several fern genera (*Adiantum*, *Athyrium*, *Coniogramme*, *Cytominum*, *Davallia*, *Dicranopteris*, *Dryopteris*, *Hypolepis*, *Lycopodium*, *Lygodium*, *Matteuccia*, *Onoclea*, *Osmunda*, *Pteridium*, *Polypodium*, *Polystichum*, *Pteris*, *Pyrrosia*, *Selaginella*, *Thelypteris*, and *Woodsia*) (Shin 2010). Many of them showed different antioxidant activities by scavenging DPPH and ABTS radicals. More specifically, fern families like Dryopteridaceae, Osmundaceae, and Woodsiaceae exhibited powerful antioxidant activities. The fiddle heads of *Athyrium acutipinulum* also showed strong antioxidant effects (Lee et al. 2005). Crude extracts of some ferns showed higher antioxidant activity than vitamin C (Soare et al. 2012). Thus, it is expected that analyzing antioxidant activities in ferns would result in the development of several healthcare products to combat aging as well as chronic diseases (Soare et al. 2012).

6.3.2 Antimicrobial Activities

Ferns are known for their efficient antimicrobial agents against several harmful microbes. They are also useful in developing antibiotic sprays, packing material, toothpaste, and handwash products and to protect human body from undesired microbes. The extracts obtained from ferns serve as effective antimicrobial agents against Gram-positive bacteria (e.g., *Bacillus subtilis* and *Staphylococcus aureus*), Gram-negative bacteria (e.g., *Escherichia coli*, *Pseudomonas aeruginosa*, and *Salmonella typhi*), and fungi (Banerjee and Sen 1980; Vincent and Kanna 2007; Lee et al. 2009). The genus *Dryopteris* exhibited vigorous antibiotic activities. *Dryopteris crassirhizoma* and *D. filix-mas* could be used to control methicillin-resistant *Staphylococcus aureus* (MRSA) (Lee et al. 2009), while *D. cochleata* serve against Gram-positive bacteria, Gram-negative bacteria, and fungi (Banerjee and Sen 1980). Because of high activity of *D. crassirhizoma* against *Streptococcus*, its anti-tooth

decay substance has been patented in Korea. However, according to Shin (2010), fronds of *Athyrium niponicum* and *Hypolepis punctata* are more efficient than *D. crassirhizoma* against *Streptococcus mutans* and *S. sobrinus*.

6.3.3 Cosmeceutical Qualities

Ferns are also useful as cosmetic ingredients. For example, *Dryopteris* spp. possess strong inhibitory activities against acne causing *Propionibacterium acnes* on the skin (Yoon et al. 2006). Many fern extracts containing high phenolic compounds are currently used as ingredients of body and facial cosmetics (e.g., cleanser, toner, moisturizer, shampoo, and conditioner). Extracts of some ferns are useful and effective natural cosmetic ingredients. Furthermore, the phenolic compounds of ferns are beneficial in skin care owing to prevention of UV-induced skin damages, anti-wrinkle, and skin-whitening properties (Svobodová et al. 2003; Tanaka et al. 2004; An et al. 2005; Parvez et al. 2006). A number of ferns possess phytoecdysteroids (e.g., ecdysone) (which is not present in most of the angiosperms) helpful in promoting cell regeneration, refining skin texture, and strengthening skin barrier (Lin and Lin 1989; Meybeck et al. 1997). Since fern spores are not causing hay fever, cosmetics consisting of fern spores are patented in Korea, and such products are used as facial scrub (Moran 2004).

6.4 Functional Attributes

Physicochemical characteristics of proteins play a prominent role in quality control of food stuffs. The low-cost protein derived from green vegetables will meet the demand of food proteins in many industries. The food processing industries emphasize on leaf protein isolates owing to low lipid and fiber content (Rana et al. 2015). Green leaves possess protein up to 40–70% along with carotenoids, vitamin E, and minerals (Badar and Kulkarni 2011). Isolation of high quality of green leaf protein is simple, affordable, and favorable for commercial applications (Moure et al. 2002). However, the functional properties of fern proteins are less studied, and only countable research articles are available.

The rhizome starch fern is commonly employed in the food industry for preparation of vermicelli, cakes, and concentrated soups marketed in East Asian countries (Zhang et al. 2011). The fern starch is also useful in preparation of liquor and soft drinks in China (Liu et al. 2012). The starchy paste obtained from *Marsilea drummondii* is edible in Australia (Mannan et al. 2008). The starch purified from fern is significantly tough with suitable elastic properties (Cao et al. 2007). The starch granules from the rhizome of *Acrostichum aureum* possess high solubility (35%) as well as swelling power (12.3%) (Lobo and Gulimane 2015). The protein solubility is also remarkable in ferns, for example, high solubility is known in leaf protein

concentrate of *Nephrolepis biserrata* (55.9%, pH 8), *Arthropteris orientalis* (45%, pH 10), and *Diplazium esculentum* (28.52%, pH 12) (Essuman et al. 2014; Rana et al. 2015). Ferns such as *Nephrolepis biserrata* and *Arthropteris orientalis* possess pH-dependent foam capacity and attain maximum foam capacity at pH 14. An epiphytic fern *Metapolypodium memeiense* is also used as a taste enhancer during cooking vegetables, and many ferns are available in local markets of China as dried fronds, salted fronds, packed fronds, fern starch, fern starch noodles, fern starch cakes, and fern leaf tea (Liu et al. 2012). Different parts of about 144 species of ferns are edible and utilized to replenish nutrition in China.

6.5 *Diplazium*: A Versatile Fern

Diplazium is a diverse genus belonging to the lady fern family (Athyriaceae). This fern has pantropical distribution and is separated from *Allantodia* based on the characteristic non-imparipinnate fronds and grooves from rachis to costa (Ching 1964). It is a terrestrial fern with erect to suberect rhizome forming caudex and strong roots. The fronds are large and pinnately compound with herbaceous lamina.

6.5.1 Diversity

The genus *Diplazium* consists of 400 species distributed in different pantropical regimes (e.g., Malesia, Neotropics, Afro-Madagascar region, and cold temperate regions of Eurasia) (Tryon and Tryon 1982; Wu and Ching 1991; Chu and He 1999; Pacheco and Moran 1999; Mickel and Smith 2004; Roux 2009). The rare and endangered endemic fern *Diplazium molokaiense* was reported in East Maui, Hawaii (Wood 2006). *Diplazium fimbriatum* has been reported as a new species from Brazil (Mynssen and Matos 2012). Several *Diplazium* spp. are known from Thailand (*D. bantamense*, *D.cordifolium*, *D. crenatoseratum*, *D. esculentum*, *D. polypodioides*, *D. riparium*, *D. silvaticum*, *D. simplicivenium*, *D. sorzogonense*, and *D. tomentosum*) (Boonkerd et al. 2008). Indonesia also possesses many *Diplazium* spp. (*D. asperum*, *D. cordifolium*, *D. esculentum*, *D. lomariaceum*, *D. pallidum*, *D. simplicivenium*, *D. sorzogonense*, and *D. tomentosum*) (Slik et al. 2006). Kholia (2011) has documented nearly 40 species of *Diplazium* in India, and up to 17 species have been reported in Sikkim alone. The common *Diplazium* in India include *D. bellum*, *D. dilatatum*, *D. doederleinii*, *D. esculentum*, *D. forrestii*, *D. kawakamii*, *D. latifolium*, *D. laxifrons*, *D. longifolium*, *D. maximum*, *D. medogense*, *D. polypodioides*, *D. sikkimense*, *D. spectabile*, *D. squamigerum*, and *D. stoliczkae*. The *Diplazium* species are also reported from the Western Ghats regions of Maharashtra, Karnataka, Kerala, and Tamil Nadu (Dudani et al. 2012, 2014; Das et al. 2013; Kavitha et al. 2015; Patil et al. 2016; Sathish and Vijayakanth 2016). It is possible to conserve *Diplazium* spp. by spore explant (initiation, multiplication, and

differentiation), which is economical as well as rapid method of propagation (Nair et al. 2014).

6.5.2 Nutraceutical Value

Fiddle heads and tender pinna of *Diplazium esculentum* are commonly edible in the Western Ghats region, which is common along the rivers and swampy areas in the Western Ghats of India (Copeland 1942; Akter et al. 2014; Greeshma and Sridhar 2016; Sridhar and Karun 2017; Greeshma et al. 2018). It is one of the most commonly consumed fern in hilly tribes in Northeastern India and the Philippines (Copeland and Collado 1936). Fiddle heads of three *Diplazium* species reported from different regions are known to possess a wide range of crude protein (0.2–31.2%), total lipid (0.1–8.3%), crude fiber (0.4–12.7%), ash (1.4–17.6%), and carbohydrates (0.02–68.6%) (Table 6.2). The qualitative test showed presence of reducing sugars especially anthraquinones and anthranol glycosides (Tongco et al. 2014).

Fern shoots are excellent source of minerals and electrolytes (e.g., potassium, iron, manganese, and copper) (Seal 2012). Fresh shoots contain up to 7% of daily required quantities of potassium, which combats blood pressure as well as regulate heart contractions. *Diplazium* spp. are also composed of major minerals (calcium, sodium, potassium, magnesium, and phosphorus) and trace elements (iron, copper, zinc, and manganese) (Table 6.3). The mineral composition of *Diplazium* is dependent on the species as well as different segments used for analysis. Potassium and calcium are the most abundant minerals present in *Diplazium* spp. Different parts of *Diplazium esculentum* and *D. sammatti* fulfil the range of NRC-NAS (1989) standards for major minerals and trace elements required for infants, children, and adults. Besides, these ferns also meet the desired Na/K (<1) and Ca/P (>1) ratios; such ratios are known to combat the blood pressure and prevent the loss of calcium in urine to restore calcium in bones, respectively (Shills and Young 1988; Yusuf et al. 2007).

Leaves and fiddle heads of *Diplazium esculentum* are also known for several indispensable and dispensable amino acids (Table 6.4). The fiddle heads possess higher amount of amino acids compared to leaves with exception of sulfur amino acids. Interestingly, sulfur amino acids were substantially higher in leaves than fiddle heads (methionine, 2.1 vs. 1.4 g/110 g protein; cystine, 4.2 vs. 0.5 g/100 g protein). The leaves fulfil the FAO-WHO (1991) stipulated standard for sulfur amino acids (6.3 vs. 2.5 g/100 protein). This offers nutraceutical advantage of use of fiddle heads along with desired quantity of leaves to gain sulfur amino acids. The fiddle heads also fulfil FAO-WHO (1991) standard for indispensable amino acids like histidine, isoleucine, leucine, lysine, threonine, and valine. Among the dispensable amino acids, glutamic acid was highest in leaves, while the glycine was highest fiddle heads followed by glutamic acid, alanine, proline, aspartic acid, serine, and arginine.

Table 6.2 The proximal composition of three *Diplazium* species (%)

	Parts used	Habitat	Moisture	Crude protein	Total lipids	Crude fiber	Ash	Carbohydrates
Diplazium esculentum[5]	Fiddle heads	India (Sikkim)	92.4	31.2	8.3	4.6	16.2	44.3
Diplazium esculentum[8]	Fiddle heads	India (Karnataka)	–	16.1	7.5	2.3	12.1	19.3
Diplazium esculentum[2]	Leaves	India (Meghalaya)	87.6	14.4	0.1	3.9	12.2	8.4
Diplazium esculentum[6]	Leaves	India (Assam)	71.7	18.3	0.3	4.45	14.4	5.5
Diplazium esculentum[3]	Leaves	India (Arunachal Pradesh)	–	17.4	5.6	12.7	17.6	37.7
Diplazium esculentum[7]	Leaves	India (Himachal Pradesh)	–	0.2	–	–	–	0.02
Diplazium esculentum[4]	Leaves	Philippines	91.8	0.9	0.3	0.7	1.4	–
Diplazium esculentum[4]	Leaves	Philippines	–	10.7	3.4	9.1	17.4	–
Diplazium maximum[7]	Leaves	India (Himachal Pradesh)	–	0.2	–	–	–	0.02
Diplazium sammatii[1]	Young pinna and crozier	Nigeria	85.3	10.2	14.1	0.4	10	62.3
Diplazium sammatii[1]	Mature pinna	Nigeria	80.0	10.3	9.5	0.4	11.2	68.6

[1]Bassey et al. 2001; [2]Seal 2012; [3]Tag et al. 2014; [4]Tongco et al. 2014; [5]Pradhan et al. 2015; [6]Deka et al. 2016; [7]Wali et al. 2016; [8]Greeshma et al. 2018; – not determined

6.5.3 Bioactive Potential

It is believed by the native tribes in India that *D. esculentum* is useful to counteract constipation and serve as an appetizer (Kala 2005; Das et al. 2008). Concoction of this fern is used to cure hemoptysis and cough, while the rhizomes serve as insecticides (Kaushik et al. 2011, 2012). Studies on *D. esculentum* also showed its usefulness as anaphylactic shock and mast cell stabilizer (Das et al. 2012). The fiddle heads contain only 34 calories of energy per 100 g, and nonetheless their high-quality nutraceutical profile is composed of health promoting antioxidants, vitamins, and essential fatty acids (ω-3 and ω-6).

Fresh fronds possess very high quantities of antioxidant vitamin A and carotenes. Fiddle heads weighing 100 g contain 3617 IU (or 120%) of recommended daily requirements of vitamin A. Further, they also endowed with small to moderate quantities of many B vitamins (e.g., niacin, riboflavin, and thiamine). Besides vitamins

Table 6.3 Mineral composition of different parts of two *Diplazium* species (mg/100 g)

	Diplazium species and parts used for analysis								
	Diplazium esculentum[7] (fiddle heads)	*Diplaziumesculentum*[6] (fiddle heads)	*Diplazium esculentum*[4] (fiddle heads)	*Diplazium esculentum*[3] (leaves)	*Diplazium esculentum*[5] (leaves)	*Diplazium esculentum*[2] (fronds)	*Diplazium sammatti*[1] (young pinna)	*Diplazium sammatti*[1] (mature pinna)	NRC-NAS standards[8]
Na	145	29.0	360.0	118.0	9.5	79.0	520.0	560.0	120–500
K	3351	74.5	1120.0	4373.0	914.4	2370.0	1600.0	1600.0	500–2000
Ca	436	52.7	1290.0	873.0	192.7	1020.0	190.0	190.0	600–800
Mg	481	15.3	–	–	0.4	505.0	–	–	60–350
P	1050	–	80.0	–	–	500.0	6.8	7.2	500–800
Mn	123	21.1	–	5.1	–	–	–	–	
Fe	52	38.2	–	25.7	11.2	560.0	4.3	6.7	10–15
Zn	194	4.3	–	16.7	2.7	58.0	3.6	4.5	12–15
Cu	509	1.7	–	2.6	0.3	4.0	3.5	2.5	0.6–3
Na/K ratio	0.04	0.39	0.32	0.03	0.01	0.03	0.33	0.35	
Ca/P ratio	0.41	–	16.1	–	–	2.04	27.9	26.4	

[1]Bassey et al. 2001; [2]Sundriyal and Sundriyal 2001; [3]Seal 2012; [4]Tag et al. 2014; [5]Pradhan et al. 2015; [6]Deka et al. 2016; [7]Greeshma et al. 2018; [8]NRC-NAS 1989 range for infants, children and adults; – not determined

Table 6.4 Amino acid composition of *Diplazium esculentum* in comparison with FAO-WHO standard (g/100 g protein)

	D. esculentum[1] (leaves)	*D. esculentum*[2] (fiddle heads)	FAO-WHO standard[3]
Indispensable amino acids			
Histidine	0.2	2.3	1.9
Isoleucine	0.6	5.3	2.8
Leucine	0.7	8.1	6.6
Lysine	0.3	8.4	5.8
Methionine	2.1	1.4	[a]2.5
Cystine	4.2	0.5	
Phenylalanine	0.8	6.2	[b]6.3
Tyrosine	0.6	3.3	
Threonine	0.6	4.3	3.4
Tryptophan	–	–	1.1
Valine	0.2	6.3	3.5
Dispensable amino acids			
Alanine	0.4	7.7	
Arginine	0.2	5.2	
Aspartic acid	0.3	6.3	
Glutamic acid	4.6	8.0	
Glycine	0.1	10.5	
Proline	[c]	6.8	
Serine	[c]	5.5	

[1]Deka et al. 2016; [2]Greeshma et al. 2018; [3]FAO-WHO 1991
[a]Methionine + Cystine
[b]Phenylalanine + Tyrosine
[c]Not detectable

(essential for vision), fiddle heads also serve as powerful natural antioxidants required by the human body for maintaining the integrity of the skin and mucus membranes. Studies also suggested that natural foods rich in vitamin A help in protecting the body against lung and oral cancers. They are also excellent source of many natural polyphenolic flavonoids (α-carotene and β-carotene), and they will be converted into vitamin A in vitro. The fresh fiddle heads of 100 g contain 26.6 mg (44%) of daily required vitamin C content. Vitamin C is a moderately potential water-soluble antioxidant with flavonoid compound like carotenes, which helps scavenging harmful free radicals, offering protection from cancers, inflammation, viral cough, and cold. Unique sweet taste of fiddle heads comes from their richness in vitamin C.

Ethanolic extract of shade-dried fronds possesses high quantities of phenolics, flavonoids, and saponins than aqueous extract (Das et al. 2013). Further, the chromatogram of HPTLC revealed presence of different types of polyphenols as well as steroidal saponins. Aqueous and ethanolic extracts of the *D. esculentum* showed inhibitory effect against growth of many human as well as plant pathogenic bacteria. The positive results are comparable with tetracycline as standard antibiotic. It was found that mixing fern extract with antibiotic in equal proportions will be more effective against pathogenic bacteria than antibiotic alone (Amit et al. 2011).

6.6 Concluding Remarks

Pteridophytes distributed in a wide range of habitats prefer shady moist conditions with moderate temperature regimes. They are also versatile like angiosperms in ethnobotanical and medicinal properties. Fiddle heads of several ferns are nutritionally rich especially proteins, fiber, minerals, and vitamins. They are also known for remarkably high quantities of many essential amino acids and endowed with essential fatty acids. Starch from fern rhizomes is suitable for preparation of several foodstuffs and industrial products. In addition to the leaf protein and rhizome starch, ferns possess many valuable functional attributes useful in production of food as well as medicinal products. Many ferns are known for antimicrobial, cytotoxic, hepatoprotective, antihyperglycemic, antiprotozoal, antinociceptive, immunomodulatory, and chemopreventive properties. Ferns have the capability to serve as bioherbicide to replace chemical herbicides.

Diplazium is one of the versatile ferns distributed in pantropical regions. In India, this fern is widely distributed in the Western Ghats and Sikkim. The fiddle heads of *Diplazium* possess good proximal components and minerals. *Diplazium* shows high antioxidant activities due to presence of vitamin A and carotenoids. They possess many therapeutic potential like protection of mucus membranes, prevention of cancers, and protection against inflammation.

Pteridophytes have potential nutraceutical and bioactive components useful in human diet and therapeutics. Many ferns could be cultivated in different locations besides their native habitats like kitchen gardens, botanical gardens, and arboretum similar to those of orchids. Although *Diplazium esculentum* occurs naturally as riparian fern in the Western Ghats, it could be cultivated in lateritic soils of Southwest India without major efforts. Morphologically distinct 3–4 varieties (or landraces) of *D. esculentum* are known from the Western Ghats based on ethnic knowledge of locals and tribes. Serious efforts are warranted toward utilization of ferns in the direction of nutraceuticals, and health protective attributes would open up new avenues for food and pharmaceutical industries.

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