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Alternative Sources of Plant Protein in Tropics and Subtropic: The Case Study of India

BACHELOR'S THESIS

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Declaration

I hereby declare that I have done this thesis entitled "Alternative Sources of Plant Protein in Tropics and Subtropic: The Case Study of India" independently, all texts in this thesis are original, and all the sources have been quoted and acknowledged by means of complete references and according to Citation rules of the FTA.

In Prague 15/4/2022

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Abstract

The thesis focused on collecting and examining data on protein-rich plants indigenous to India that have the potential to improve food security in the country. The concept of neglected and underutilised plant species was characterised and the need for further research on these species and their importance to Indian agriculture and food security was substantiated. The different processing methods used in these plants were characterized and described in terms of influence on sensory and nutritional properties. More attention was given to their effect on proteins. Plant species falling under specified categories were then arranged in a clear table giving basic information about the plant in terms of botanical systematics, the protein content of the different edible plant parts, the most commonly known processing and the way of consumption of these parts. The 60 plants listed in the table belong total of 26 different families: the most frequented were Fabaceae (28.3 %), Cucurbitaceae (11.7 %), Poaceae (6.7 %) and Solanaceae (6.7 %). Four species, namely *Moringa oleiflera* Lam., *Bauhinia purpurea* (L.), *Psophocarpus tetragonolobus* (L.), *Sesbania grandiflora* (L.) Poir. were selected on the basis of protein content (greater than 35 g/100 g in at least one of the edible parts) and their potential for further use. These species were then described in more detail. Additionally, information on processing was evaluated based on frequency: 48.4 % of the plants were consumed only after thermal processing, and 51.6 % of plants can be consumed in both forms, thermally processed or unprocessed. Thermal treatment of plants was mostly carried out by blanching, frying, drying and roasting.

Key words: plant-based protein, nutrition, neglected, underutilised, a crop of the future, Asian countries, India, food security

Abstrakt

Tato práce se zabývala sbíráním a zkoumáním dat o rostlinách původních v Indii bohatých na bílkoviny, jenž mají potenciál podpořit potravinovou bezpečnost v zemi. Byl charakterizován pojem opomíjených a nedostatečně využívaných druhů rostlin a byla odůvodněna potřeba dalšího výzkumu těchto druhů, stejně jako jejich význam pro indické zemědělství a potravinovou bezpečnost. Byly charakterizovány různé způsoby zpracování těchto rostlin a popsán jejich vliv na senzorické a nutriční vlastnosti. Větší pozornost byla věnována jejich vlivu na bílkoviny. Rostlinné druhy spadající do uvedených kategorií byly seřazeny do přehledné tabulky, v níž byly uvedeny základní informace o rostlině z hlediska botanické systematiky, obsahu bílkovin v jednotlivých jedlých částech rostliny, nejznámějšího zpracování a způsobu konzumace těchto částí. 60 rostlin uvedených v tabulce patří celkem do 26 různých čeledí, nejčastěji se jednalo o: *Fabaceae* (28,3 %), *Cucurbitaceae* (11,7 %), *Poaceae* (6,7 %) a *Solanaceae* (6,7 %). 4 druhy, a to *Moringa oleiflera* Lam., *Bauhinia purpurea* (L.), *Psophocarpus tetragonolobus* (L.), *Sesbania grandiflora* (L.) Poir. byly vybrány na základě obsahu bílkovin (více než 35 g/100 g alespoň v jedné z jedlých částí) a jejich potenciálu pro další využití. Tyto druhy byly následně podrobněji popsány. Dále byly vyhodnoceny informace o zpracování na základě četnosti: 48,4 % rostlin bylo konzumováno pouze po tepelném zpracování a 51,6 % rostlin lze konzumovat v tepelně zpracované i nezpracované formě. Tepelná úprava rostlin byla nejčastěji prováděna blanšírováním, smažením, sušením a pražením.

Klíčová slova: rostlinné bílkoviny, výživa, zanedbané, nedostatečně využívané, plodiny budoucnosti, Asijské státy, Indie, potravinová bezpečnost

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List of the abbreviations used in the thesis

AA	Amino acid
AAS	Amino acid score
BV	Biological value
DIAAS	Digestible indispensable amino acid score
EAAI	Essential amino acid index
FAO	Food and Agriculture Organisation of the United Nations
FSF	Future smart food
IAAO	Indicator amino acid oxidation
ICDS	Integrated Child Development Services
IFPRI	International Food Policy Institute
IMF	International Monetary Fund
IPGRI	International Plant Genetic Resources Institute
NFSA	National Food Security Act
NPU	Net protein utilisation
NUS	Neglected and underutilised species
PDCAAS	Protein digestibility-corrected amino acid score
PDS	Public Distribution System
PEM	Protein-energy malnutrition
RDA	Recommended dietary allowance
TPDS	Targeted Public Distribution System
UNO	United Nations Organisation
WFP	World Food Programme
WHO	World Health Organisation

1. Introduction

Population growth is described as one of the main current global problems. Most of the population is increasingly concentrated in the low or lower-middle-income countries, which raises the crucial question of how to ensure food security for a massive number of people while maintaining favourable environmental conditions as much as possible. The shortfall in resources for food security is already evident in the world we live in today. In 2020, 768 million people worldwide faced malnutrition, 418 million of whom live in Asia (FAO et al. 2021). The consumption and production of meat contribute significantly to adverse effects on human health and the environment (Steinfeld et al. 2006; Alain Mune Mune et al. 2016). One way to reduce the environmental impact of animal husbandry and reduce protein undernutrition is to replace meat with plant-based alternatives in the diet.

India is considered a country with one of the highest prevalence of undernutrition in the world (Bhutia 2014). Vast amounts of people do not have enough food to meet their daily requirements for protein, and in many cases, people are deficient in one or more micronutrients (Swaminathan et al. 2019). One of the plant-based sustainable alternatives with the potential to ensure food security are considered a neglected and underutilised crop species (NUS) containing a significant protein content, which is traditionally an essential part of the diet of many cultures worldwide (IPGRI 2002). Most rural communities in India are poor economically and depend on wild (non-cultivated or semi-cultivated) plant species to ensure their food needs during periods of food crisis (Rymbai et al. 2015). In addition, these traditional NUS species have often multipurpose use and are also high in nutritional value. Despite their extraordinary potential, they do not receive enough attention, are omitted in breeding programmes (Ashok et al. 2020) and are at risk of genetic erosion in the future (IPGRI 2002). Their impact on food security in India is considerable, but they cannot match commercial crops in yield and profit (Cheng et al. 2019).

2. Aims of the Thesis

This thesis investigates available literature and electronic information sources to analyse the alternative sources of plant proteins and their traditionally used processing methods.

3. Methodology

Individual information and analyses were performed based on professional, scientific literature (books and textbooks), scientific articles, and internet sources closely related to the issue of the chosen thesis. Data information were searched on scientific article databases; ScienceDirect, Google Scholar, PubMed and Web of Science. Internet data were obtained from verified sources (FAO, WHO, WFP, IFPRI, IPGRI, IMF). Primary search terms used in this thesis were: plant-based protein, nutrition, neglected, underutilised, a crop of the future, Asian countries, India and food security.

Underutilised or neglected plant species indigenous to India or cultivated for 200 or more years and are fully domesticated in this area were searched in this study. The collected data about the plants were arranged in a clear table that provides basic information about the plant (English, scientific and local name, family to which it belongs), nutritional values, mode of use, and processing of the individual edible part of plants. Based on the above possible processing methods listed in the table, a simple statistic was calculated using Microsoft Excel, determining the frequency of thermal and non-thermal processing method.

Examine plants were evaluated concerning the protein content and their processing method, and the potential for their further use. The plants with a protein content higher than 35 g/100 g in at least one of their edible parts and those with the tremendous potential for future use were described in geographical distribution, morphology, potential uses and nutritional and anti-nutritional values.

4. Literature Review

4.1. Food quality and processing

Food processing goes back as far as human history, as does its possible preservation. It is a set of several different processing steps through which we achieve the desired results without compromising the sensory or nutritional values (Fellows 2009). These steps ensure greater shelf life and food safety by securing microbial safety and stability of the raw materials' antinutritional substances (Janowicz & Lenart 2018). The biochemical composition is essential for understanding the sensory, physical properties and nutritional quality of the food; also, it plays a significant role in changes caused by processing (Fellows 2009).

4.1.1. Sensory characteristics

Sensory properties are one possible way we can characterise or define the quality of the food, specifically from the consumer's point of view. Sensory properties are individual indicators, including colour, flavour, texture, aroma and shape (Fellows 2009). There are ongoing efforts to develop new technologies in food processing to achieve desired sensory properties and reduce damage arising from food processing. From the sensory characteristics are by the processing the most affected taste, texture and colour.

Colour and appearance: Changes in colour and appearance appear naturally. Different pigmentation is caused by a pH change or by oxidation (Fellows 2009).

Flavour and aroma: Flavour and aroma can be changed or lost during processing when occurring changes in the biochemical components of carbohydrates, fats and proteins. On the other hand, we can achieve a completely new taste or aroma by processing. Major changes can be observed during fermentation when the sweet or acid taste changes (Fellows 2009).

Texture: Texture changes during food processing are caused by several aspects, such as changes in moisture content, fat ratio or hydrolysis of carbohydrates and proteins (Fellows 2009).

4.1.2. Processing methods

In addition to sensory properties, the processing methods also affect the nutritional value ratio, quality and digestibility of foods. With the right processing method, we can achieve the desired taste, increase the digestibility of certain nutrients or, on the contrary, reduce the amount of anti-nutrients. However, incorrect processing can lead to food degradation.

The methods described below in this thesis belong to the group of traditional (old) food processing methods. Many of them are used routine home processing and commercially, using modern technologies adapted to large-scale production. Large processing companies constantly monitor compliance with prescribed procedures, hygiene regulations and the required product quality (Fellows 2009). The processing itself is preceded by cleaning, primary processing, size reduction and sorting (based on shape, weight or sensory characteristics). After processing, food can be chilled or packaged in a protective atmosphere to guarantee shelf-life.

4.1.2.1. Thermal processing methods

Thermal processing is the most crucial method**.** With the help of heat treatment, we achieve the desired taste, getting rid of the adverse microorganisms, parasites, insects and antinutritional factors. This method has a wide range of applications, but it does result in significant changes in sensory properties and nutritional values. In the case of some nutrients (protein, starch and niacin), their availability and absorption in the human body are improved. However, a substantial part of the vitamins, aroma and pigments are lost (Fellows 2009).

It involves many processes, such as blanching, pasteurisation, heat sterilisation, evaporation, distillation, extrusion, dehydration, smoking, sun-drying, baking, roasting, frying, dielectric, ohmic and infrared heating. Some of these are described more in detail in this thesis.

4.1.2.1.1 Blanching

It includes two easy to implement, accessible and inexpensive methods; boiling and steam. There is a loss of nutrients (vitamins and micronutrients), a change in sensory values and, depending on the type of food, it may gain weight due to moisture absorption.

During methods, the water temperature ranges from 70 to 100 °C. One of the modern methods used mainly in Europe and Japan is microwave blanching, which should be a more economical option for large processing companies (Fellows 2009).

4.1.2.1.2 Extrusion

It is an effective method that aims to preserve as many nutrients as possible while reducing moisture, enzyme and microbiota activity. Food is exposed to a high temperature, but in a short period, extrusion cooking reaches temperatures above 100 °C (Fellows 2009).

The primary sensory feature observed in this process is texture, which is influenced by the physicochemical properties of the raw materials. These changes affect the final appearance of the product (Ajita & Jha 2017). From another sensory characteristic, the changes are not particularly noticeable. When the temperatures are lower, this method increases the digestibility of the proteins, but at high temperatures, the proteins are denatured (Fellows 2009; Ajita & Jha 2017).

4.1.2.1.3 Dehydration

Dehydration or drying is an old method of processing that removes moisture from food, thereby preventing enzymatic reactions, inhibiting microorganisms' activity and extending the product's shelf-life (Fellows 2009; Janowicz & Lenart 2018). This process does not much alter nutritional values; minor changes can be observed in vitamins, lipids and proteins (Fellows 2009). Rather, drying changes the ratio of individual nutrients, decreasing moisture and increasing the nutrient content (Janowicz & Lenart 2018). Significant changes are observed in all sensory characteristics.

There are many ways to achieve the desired changes; freeze-drying by sublimation, using dry air, heated surfaces and sun or solar drying. Sun or solar drying is one of the most widely used methods worldwide. The most significant advantage is affordability, ease of implementation and efficiency, but it is challenging to control drying conditions, and external influences such as weather have to be considered (Fellows 2009).

4.1.2.1.4 Smoking

It is a traditional method of processing that, in the old concept, served more as a means of preserving the shelf-life of the food. However, nowadays the main aim of this process is to achieve the desired sensory properties such as colour, taste and aroma. It is mainly used to treat protein-rich foods, combining heat achieves a reduction of moisture, microorganisms and enzyme activity (Fellows 2009). Sometimes is a method combined with soaking in brine or rubbing with salt to add a preservative.

Due to the heat, lipids, proteins and vitamins are reduced. According to the degree of used temperature, we differentiate between cold (< 33 °C, food is not cooked), warm (25-40 °C) and hot (60-80 °C) smoking (Fellows 2009).

4.1.2.1.5 Baking and roasting

Baking and roasting are old methods of processing that are used extensively to this day. Both are very similar and work on the principle of hot air, which destroys microorganisms, removes moisture and changes sensory and nutritional properties.

The shelf-life of food processed by this method depends on factors such as storage, packing, moisture, pH, and food composition (Fellows 2009).

4.1.2.1.6 Frying

Frying is a unit process where the desired results are achieved by heating in oil. It is a method that reduces moisture, microorganisms and the desired specific sensory properties; aroma, texture, colour and flavour (Fellows 2009).

Shelf life depends on storage and the moisture content of the food. Most enzymes are deactivated, proteins are denatured, lipids are the least damaged, and temperature plays a significant role in vitamin loss (Fellows 2009). Some foods are coated before processing. Food partially absorbs oils during the process, so it is essential to choose the right type of oil (for sensory properties, but also from a consumer health point of view).

4.1.2.2. Non-thermal processing methods

Non-thermal processing methods are those where, without heat, food is modified and preserved without severe sensory or nutritional properties. It includes enzyme technology, irradiation, freeze-drying, high-pressure, ultrasound, cold plasma, and fermentation methods. In some publications, they can be found under the term "minimal processing".

4.1.2.2.1 High-pressure processing

High-pressure processing involves exposing food to high-pressure values of between 200 to 400 MPa, temperature below 50 °C, for a few seconds to a min (Zhang et al. 2019). It is used, for example, to pasteurise honey or dairy products and fruit juices and turn cocoa butter into stable crystals (Fellows 2009; Zhang et al. 2019).

The disadvantages are the cost of this method and the impossibility of applying it to dry raw materials or materials with entrapped air. With using high pressure, a slight increase in temperature is combined; the rate of increase depends on the type of material exposed, a temperature rise of 3 °C per 100 MPa is reported (Fellows 2009). The changes depend on the time of action. In some cases, physiochemical prosperities improve, pasteurisation occurs, and sensory and nutritional values change this process minimally; however, the weak bonds (electrostatic and hydrophobic) that we can find in some types of proteins and starches are disrupted (Allende et al. 2006; Fellows 2009).

4.1.2.2.2 Fermentation

Fermentation is a traditional processing method that is still one of the most widely used today. Specifically, in Asia, it is very popular. It is used in the production of alcohol, fruit, vegetables and cereals, and the manufacture of soya products, including those replacing meat products (Anal 2019).

The desired sensory properties and quality are achieved in different stages in the fermentation process using selected microorganisms, appropriate aeration, and moisture (Fellows 2009). These factors give the food its specific taste and aroma. Unwanted microorganisms and anti-nutritional substances are destroyed, and the food is also enriched with lipids, proteins and vitamins (Fellows 2009; Anal 2019). The method is easy to implement and affordable, often combined with other shelf-life preservation techniques (pasteurisation, chilling or packaging).

4.2. Proteins

Proteins are part of the macronutrients, biochemical compounds which humans consume in high quantities. In the human body, they generally provide energy and ensure proper growth, development and metabolism (Horák & Staszková 2011; Yada 2018). In addition to proteins, macronutrients include water, lipids, carbohydrates and fats.

From a biochemistry point of view, proteins are large biomolecules that comprises one or more amino acid chains (Fellows 2009). A significant component is nitrogen, they also contain hydrogen, carbon, oxygen, and, to a lesser extent, sulphur. The molecular structure of each protein is characterized by primary, secondary, tertiary and tertiary structures. The protein content is lower in plants (Horák & Staszková 2011).

4.2.1. Protein compositions

According to protein composition, we can divide them into two basic groups – a simple and globular protein that is then further subdivided according to their respective characteristics.

4.2.1.1. Simple proteins

Fibrillar proteins: Fibrillar proteins are also called scleroproteins. The molecules form elongated (fibrous) structures that become solid protein structures that are insoluble in water; they are flexible and chemically resistant (Horák & Staszková 2011). The best-known scleroproteins are collagen, keratin, and fibroin, a hair structure, horn, and cartilage component.

Globular proteins: Spherical or ellipsoidal, otherwise called spheroproteins. They are soluble in water, and their tertiary and secondary structure can be disrupted by boiling or changing the pH value - by the action of acids or lyes (Horák & Staszková 2011). Coagulation and denaturation occur. At the same time, they lose some of the biological properties of proteins, such as inducing muscle contractility or the ability of enzymes to break down food (Fellows 2009). Muscle tissue and enzymes are included.

4.2.1.2. Conjugated proteins

It consists of simple proteins combined in the body with other non-protein structures called the prosthetic groups (Horák & Staszková 2011). They are attached by weak interaction or covalent bonding. Amino acid without its prosthetic group is called holoprotein, and amino acid combined with its prosthetic group is called heteroprotein (Horák & Staszková 2011). Including metalloproteins, glycoproteins, chromoproteins, nucleoproteins, and lipoproteins.

4.2.2. Protein structure

We can usually distinguish primary, secondary, and tertiary protein structures. The quaternary structure of protein chains we can find in the case of some more complex proteins.

4.2.2.1. Primary structure

Primary protein structure is the unique sequence of amino acids in a polypeptide chain when the order of each amino acid determines protein (Horák & Staszková 2011). The primary structure indicates the protein's chemical properties and determines the higher structures. We distinguish by the number of amino acids dipeptide and tripeptide, consisting of 2 and 3 amino acids, then oligopeptide, which consists of less than 50 amino acids, and polypeptide with more than 50 amino acids (Horák & Staszková 2011). Making a bond between 2 functional groups is called a covalent (peptide) bond (Fellows 2009).

4.2.2.2. Secondary structure

It is a structure of polypeptides bounded by polypeptide chains or H-bonds. In secondary structure prevail two forms, α-helix, and β-pleated sheet structure, which play an important structural role in globular and fibrous proteins (Yada 2018). In α-helix, hydrogen bridges are formed between the individual layers of the helix. Bound forms C = O groups in one amino acid and N – H groups in another amino acid, which are four amino acids farther along the chain (Horák & Staszková 2011). In β-pleated are amino acids, stretches held in an almost fully extended conformation. This conformation has a "zig-zags" character due to the non-linear nature of single C-C and C-N covalent bonds (Fellows 2009).

4.2.2.3. Tertiary structure

It is an overall three-dimensional shape structure of the whole polypeptide chain; it is created when folding secondary structures elements together (Fellows 2009). It is formed by different domains linked by short polypeptide segments, often stabilized by disulphide bridges (Yada 2018). We distinguish fibrillar (myosin) and globular structure (albumin) according to their shape and properties.

4.2.2.4. Quaternary structure

The quaternary structure of proteins is the arrangement of subunits in protein agglomerates that collectively form a single functioning protein (Yada 2018). Subunits are compounds of separate polypeptide structures joined together by non-covalent interactions (H-bonds or hydrophobic effect). Only more complex protein complexes like DNA polymerase, collagen, or insulin show this arrangement (Horák & Staszková 2011). Because of weak interactions between the subunits, bonds can occur easily.

4.2.3. The importance of protein in the human body

Proteins are essential macronutrients of food that supply essential as well as nonessential amino acids for almost every task of a human's cellular life (Singh et al. 2017; Cheng et al. 2019). The human body needs protein for optimal growth and development and at least is created from 10,000 different proteins (Harvard T.H. Chan School of Public Health, 2022). Proteins are found in every part of the human body. They provide several essential functions like transport and storage (haemoglobin - CO_2, transferrin - Fe and lipoproteins), ensuring movement (actin and myosin), catalytic and regulatory (enzymes, hormones, and receptors), construction (biomembranes, cell organelles and tissues), protective and defensive (immunoglobulin, fibrin and fibrinogen) (Fellows 2009; Yada 2018). For the body, protein also has energy significance (Yada 2018). The body gains energy by digesting (by proteolysis) proteins. It is crucial in extreme cases when the body cannot gain sufficient energy from other sources.

The daily intake of proteins depends on several indicators such as gender, age, and physical activity. The daily protein requirement can be calculated, for example, by the method of Indicator Amino Acid Oxidation (IAAO). IAAO is a method based on available nitrogen balance, which can calculate protein requirement recommendations for all life stages (Courtney-Martin et al. 2016). According to a Daily recommended dietary allowance (RDA), a full-grown adult should get a minimum of 0.83 g, adolescents 1.0 g and children 1.5 g of protein for every kilogram of body weight per day (Delimaris 2013) A balanced diet provides about 10 % – 15 % of total energy (Singh et al. 2017). In addition, excess and deficiency in protein intake have an adverse effect on the body.

4.2.3.1. Protein deficiency

Millions of people in many African and Asian countries, especially young children, do not have the possibility to meet the RDA and do not get enough protein to fulfil their food insecurity. Underweight (low weight for age), stunting (low height for age), and wasting (low weight for height) can cause permanent impairment in later life (Bhutia 2014). Insufficient food intake due to poverty or unbalanced nutrient intake occurs as an imbalance between the supply of protein and energy. Because of this imbalance, the body's basic needs demanded to ensure optimal growth and function are not met (Harvard T.H. Chan School of Public Health, 2022).

Protein-energy malnutrition (PEM) affects particularly preschool children in the most crucial period of development time (Bhutia 2014). Protein deficiency and malnutrition have many symptoms; weakening respiratory system, growth failure, loss of muscle mass, heart muscle problems, and decreased immunity - increasing propensity to infections (Harvard T.H. Chan School of Public Health, 2022). Protein and calorie malnutrition have disastrous consequences for the child's body, and it occurs in two forms of diseases: marasmus and kwashiorkor (Alain Mune Mune et al. 2016). Severe protein malnutrition can cause fatal outcomes and lead to death (Cheng et al. 2019).

4.2.3.2. Protein excess

While malnutrition caused by inadequate protein intake is slowly receding, a new trend, excessive protein intake associated with obesity, is increasingly emerging worldwide. Short-time high protein consumption does not cause serious health problems, but long-term protein consumption exceeding the RDA of protein intake can be very harmful to the human body (Benjamin et al. 2018).

In general, excessive protein intake places severe pressure on the kidneys, bones and liver (Delimaris 2013). Increased protein intake affects the body's acidity, the kidneys and buffers' active resorption are fundamentally affected. The risk of kidney stones increases, especially with insufficient fluid intake. Also, the body is unable to absorb calcium resulting in hypercalciuria and excessive bone loss (Delimaris 2013). The extent and severity depend on the source of protein intake. The protein of plant origin is usually healthier, but along with the intake of high amounts of animal protein, the body also receives large amounts of saturated fat and cholesterol. A high intake of animal protein can then be the indirect cause of coronary heart disease or even colon cancer (Foyer et al. 2016; Cheng et al. 2019).

4.2.4. Protein origin

According to the source, protein can be found in animal and plant-based protein. Available evidence indicates that proteins are not always present in the same amount in the diet (Benjamin et al. 2018; Ferranti et al. 2018). Their contents differ according to the source (Benjamin et al. 2018). The main importance also has nutrients that come alongside it; fat, fiber, sodium, vitamins, and more (Harvard T.H. Chan School of Public Health, 2022).

Today the most important sources of protein are cereals and meat (Day 2013). Animals' proteins are more expensive, which can be crucial in developing countries with a high amount of rural poor population. It is estimated that the rich and middle classes tend to consume processed foods and more meat (Day 2013; Cheng et al. 2019). Due to the high population growth, there will be an increasing global demand for protein sources, especially animal-based protein sources, because of rapid economic growth and urbanization in developing countries (Foyer et al. 2016; Cheng et al. 2019).

4.2.4.1. Animal protein

Animal-based proteins are found in meat, eggs, and dairy products such as milk, cheese, or yoghurt. This protein used to be more popular because of the taste and well-balanced amino acid profiles; they provide all nine essential amino acids needed for human health. Also, it contains high levels of vitamin A, D, and B-12, iron (heme-iron), saturated fat, zinc, calcium, and cholesterol (Day 2013). From a nutritional point of view, animal-based proteins are higher-quality. However excessive consumption of animal protein increases the risk of diet-related chronic diseases, namely, type 2 diabetes and diseases of cardiovascular spectre (Alain Mune Mune et al. 2016).

It will be needed to reduce animal proteins in the future because of the strains that animal husbandry causes to the environment. Animal husbandry represents pressure on the environment. For example, the production of animal protein requires 100 times more water than the production of the same amount of plant-based protein (Pimentel & Pimentel 2003; Day 2013). High numbers of livestock cause water depletion and exacerbate climate change by producing greenhouse gases, disrupting the phosphorus and nitrogen cycle, and highly reducing biodiversity (Steinfeld et al. 2006; Michel et al. 2021). It is not surprising that there is a constant effort to search for unconventional or new protein sources.

In addition to plant proteins, traditional animal protein sources can be replaced by one of the non-traditional sources - insects. Edible insects have a great potential for human's food and nutritional security and the environment. Compared to conventional animal husbandry, it produces lower greenhouse gas emissions and requires less land and water. They have a rich nutritional profile and are a valuable source of fats, vitamins, minerals, and protein. The fat and protein content varies from one insect species to another, and the information on protein quality is currently limited. Nevertheless, protein content is higher in insect sources than in most plants (Bosch et al. 2014).

4.2.4.2. Plant protein

Plants are a source of dietary proteins and other essential nutrients. Most plant proteins are not complete, and they are missing at least one essential amino acid. On the other hand, plants contain high concentrations of specific phytonutrients, antioxidants, carbohydrates, minerals, vitamins, polysaccharides, and dietary fibre. From two forms of iron, plant-based food contains non-heme-iron, which is less readily absorbed. Even though plant-based proteins usually have lower nutritional quality, they can supply a sufficient amount of amino acids for human body requirements with the right combination (Day 2013). The amino acid compositions differ according to plant source. In legumes and oilseeds are methionine and cysteine in lower concentrations. Lysin is at a lower concentration in most plants, especially in cereals, compared with animal protein sources.

Protein from canola and soy is an exception which has a quite balanced composition of amino acids (Day 2013). It is proven that plant protein contributes to reduced risk of mortality via its benefits on risk factors for major chronic diseases like diabetes, gut cancer, cardiovascular disease, and also obesity (Foyer et al. 2016).

Plant protein used to be less digestible in its natural form than animal protein. However, consumption after a degree of processing enhances its acceptance. Concerning plant protein, the allergens they contain are discussed. Intolerance of gluten, which is part of a plant-based diet, can lead to coeliac disease. It is an inappropriate immune response, which symptoms include abdominal distension, chronic diarrhoea, and inability to absorb nutrients from the intestine. This can lead to losing weight and other problems caused by vitamins and minerals deficiency. The only treatment for coeliac disease is a strict diet or consumption of non-gluten cereals and legumes and products thereof (Day 2013).

Plant protein is generally cheaper, and thus, in countries where animal protein resources are scarce and considered expensive, this is an invaluable quality (Steinfeld et al. 2006). Replacing animals' protein with plant protein rich-food in the human diet could help not only in to prove environment but also in human health. Several studies have shown that a well-balanced diet rich in healthier plant proteins reduces the risk of many conditions caused by excessive meat consumption.

Extensive research of indigenous crop species has been conducted on several well-known legumes. Nowadays, probably the most economically worldwide important legume crop is soybean, which has undergone research through many studies, technological innovations, and breeding. This enabled soy use in a wide variety of foods products. However, for many lesser-known legumes with comparable nutritional properties, there are no technical and financial investments in their development (Cheng et al. 2019). Most of the plants with high protein content are not intended for direct human consumption but are used as feed for animals for conversion of plant protein into an animal to produce milk, eggs, or meat. This process is relatively inefficient because about 15 % of protein from feed plants is turned into animal protein, and the rest remains unused (Day 2013).

4.2.5. Quality of protein in the diet

In the case of proteins, their quality is more important than the quantity in the food intake. Protein quality depends on essential amino acids (AAs) content, digestibility, and bioavailability for the human organism (Singh et al. 2007). Digestibility and bioavailability can be partly influenced by the processing method but primarily depends on the initial amount and origin of the protein (Fellows 2009; FAO 2013).

Evaluations are calculated based on the capacity of the food and diets (protein source) to meet the essential-nitrogen requirements. Received protein intake has to satisfy the metabolic needs for nitrogen and AAs; provide average growth and normal function of metabolism in the individual needs for infants and children, pregnancy and lactation women (FAO 2013; Singh et al. 2017). Out of the 20 respective 21 (standard + selenocysteine) amino acids found in protein, humans are unable to synthesise nine of them (Horák & Staszková 2011). These nine AAs are called essential, and others are called non-essential. Essential amino acids must be taken from the diet, the non-essential amino acids are synthesised from the essential AAs in the body. According to the number of essential AAs contained in the source, sources are divided into complete protein, which contains all nine AAs, and non-complete protein, that are lacking in at least one of the nine essential AAs. The correct ratio of AAs ensures proper metabolism and functioning of the human body.

There are several indicators of protein quality. In particular, the amount and ratio between essential and non-essential AAs, and total nitrogen content - the nitrogen balance, are assessed. There are many fundamental quality indicators, namely Biological Value (BV), Net Protein Utilisation (NPU), Essential Amino Acid Index (EAAI), and Amino Acid Score (AAS). However, according to FAO, the most used and much more accurate are the Protein Digestibility-Corrected Amino Acid Score (PDCAAS) and Digestible Indispensable Amino Acid Score (DIAAS).

The use of the PDCAAS method was agreed upon at a consultation between FAO and WHO in 1989 and was widely adopted internationally. However, it later became criticised. The method is based on faecal AA digestibility, and it is calculated according to the limiting AAs in the sample. The method then compared the AA profile of the sample with the established standard AA profile. According to some studies, the method does not attribute extra nutritional value to high-quality proteins and does not consider the bioavailability of AAs. It also overestimates poorly digestible proteins and the protein quality of products containing antinutritional factors (FAO 2013).

After consultation in 2011 and considering the options, the FAO decided to promote a new method for measuring protein quality. The DIAAS method is based on the ileal digestibility score of individual essential AAs, thus becoming a much more accurate and comprehensive indicator of protein quality in the human diet. These qualities give more accurate qualitative results, especially for vegetable proteins concerning their digestibility (FAO 2013).

4.3. India

India is located on the Indian subcontinent in South Asia, with New Delhi as the capital. To the southeast of the Indian coast is the island state of Sri Lanka. It borders Bangladesh and Burma to the east, shares with Pakistan to the southeast, and China, Bhutan, and Nepal to the north and northeast. With 3,287,260 km^2 (FAOSTAT 2022) it is the seventh-largest county worldwide. India is the second most populated country globally; until 2021, there were about 1.39 billion people, which is about 17.7 % of the world's total population (IMP, 2022). In 2018, the rural population formed about 66 %, and the remaining 34 % fell into the urban population (FAOSTAT 2022). India was formerly a British colony but broke free from British colonial influence in 1947. Since then, India has progressed through development in many sectors and economic growth, which was in 1991 supported and accelerated by economic reforms (Kumar et al. 2020). At present, the Republic of India has the second-fastest growing economy in the world (IMP, 2022).

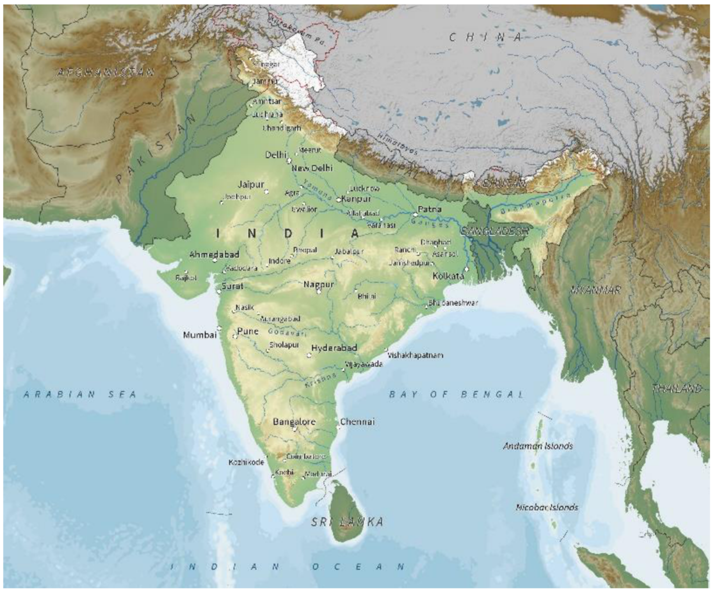

Figure 1. Physical Map of India (MAPSWIRE 2022)

India is a culturally, religiously and biologically diverse country. Republic is divided into 28 states with their own elected governments and eight union territories. There are 22 languages in active use and officially recognised by the government. The climate of the entire continent is influenced by the Indian Ocean, which is also the source of monsoon rains. According to Koppen's classification, there are several climatic zones, from tropical humid, temperate and arid to the mountains' climate located in the north of the Himalayan region. With its great topographic and climatic diversity, India has a rich and diverse flora and fauna. Generally, it is a biodiversity-rich region considered one of the biodiversity hot spots. Many plants native to India are useful to local people and are used in agriculture or medicine. Over 3,600 plant species are valuable in traditional preventive and curative treatments, for example, in Ayurveda (Dhyani & Gupta 2016).

4.3.1. Agriculture

Agriculture is one of the significant contributors to India's economy and a part of Indian culture. In the present day, occupying about 1,795,780 km^2 (FAOSTAT 2022). The major crops grown are cereals (wheat, sorghum, millet and rice), vegetables (tomatoes, melon), fruits (bananas, nectarines, peaches, papaya, citrus), sugar cane, tea, coffee, tobacco and spices (FAOSTAT 2022).

In 2019, 42.2 % of the population worked in this sector (WB 2022). Also, women play a vital role in the household and agricultural-allied activities. Farming changed fundamentally in the 1960s when the Green Revolution began. In addition to large-scale mechanisation, new varieties of staple crops began to be introduced into cropping practices. This created a gap between traditional farmers growing indigenous crops and conventional farmers aiming for maximum production (Swaminathan 2015).

Traditional local farmers tend to farm smaller areas, often combining livestock and crop production - agroforestry. Farmers keep the most cows, buffaloes, goats, sheep and fish. In cropping systems are usually cultivated and remained mainly confined to on a global scale less important, so-called underutilised crop species, which are natural wild, semi-wild or semi-domesticated indigenous species with multipurpose uses (Swaminathan 2015). Their biggest advantage for small farmers is high resistance to floods, drought, and the resistance of pests and diseases. However, their yields are not comparable to the main crops (Verma et al. 2012). The non-competitiveness and no possibility of saving seeds in a seed bank has caused the loss of varieties that farmers used to grow before the Green Revolution. Many governmental and non-governmental organisations are now concerned about saving traditionally grown crops. In addition to seed banks, conservation takes place through in-situ and on-farm methods. In the case of the on-farm method, the farmers serve as conservers, breeders, and also as cultivators (Swaminathan 2015). Seeds of the main bred varieties of crops have to farmers buy new every year from approved companies. This exposes poor farmers to some risk, as they may not even get back the purchase price in the case of a small harvest (Swaminathan 2015).

4.3.2. Food security in India

Food security ensures the physical and financial availability of food and water and its distribution to consumers in sufficient quantity and quality. Currently, food security is most challenged by population growth, land degradation, pollution and water scarcity, and the inability of economies and agriculture to respond to climate change (FAO et al. 2021). An effective means to overcome the protein crisis is to discover sustainable protein substitutes that are also healthy, accessible, and affordable for the poor rural population.

Both micronutrient and macronutrient malnutrition can be encountered in India. Micronutrient deficiency, commonly referred to as hidden hunger, often occurs in nutrients like zinc, iron, iodine, and vitamin A and B-12 (Swaminathan et al. 2019). Nevertheless, in India, protein malnutrition is a major public health problem, in 2017 affecting 68.2 % of children under five years of age. The prevalence of underweight and wasting in 2017 was 33.4 % and 18.3 % (WB 2022), and stunting was 39.3 % (Swaminathan et al. 2019) in 2017 and among five years old children in India.

PEM and related diseases burden the health system and affect India's economic growth. That's caused by a loss of adult productivity of 1.4 % of GDP (Bhutia 2014). The prevalence of undernutrition among children is mostly higher in rural than urban communities. Malnutrition is already present in newborns in India, and it is no exception that a malnourished mother gives birth to a low-birth-weight baby. The socio-cultural context also has an impact, as a family with many children is not able to devote enough time for care, education, and food for all children. As the number of members in the family increases, so do the chances of getting PEM.

In India, The Integrated Child Development Services (ICDS) organization plays a crucial role in the fight against malnutrition. The organization collects data, monitoring, and helps with supplementary nutrition of children aged 0-6 years and pregnant and lactating women. Even though the program has been operating since 1975, the problem of malnutrition persists (Sachdev & Dasgupta 2001).

Many governmental and non-governmental organizations work on food security in India. The crucial role plays a governmental controlled Public Distribution System (PDS), which is the largest food distribution network globally. India ensures the distribution of essential household supplies to people in need (WFP 2014). The PDS program is not intended to provide all food to households but instead serves as a support in times of adversity, such as a rise in the price of staples or poor yield. PDS works closely with the Targeted Public Distribution System (TPDS), which provides food distribution to up to 60 million households below the poverty line. In 2013, the law National Food Security Act (NFSA) was passed to strengthen PDS influence (WFP 2014). The NFSA has improved issues such as miss-targeting, under-coverage, and corruption problems (WFP 2014). However, the problem at the policy level persists.

According to FAO, the main drivers that threaten food security are conflicts, economic downturns, and climate extreme-related disasters in India. Although India has experienced rapid economic growth over the last two decades, the population almost has not benefited from it. The economic downturn can have major impact on the rural poor, who are already struggling to provide food security for their households (George & Mckay 2019). India is regularly plagued by crop-destroying locusts, resulting in exacerbating food insecurities and rising food prices, which are already unaffordable for many people.

Events of recent years are also reflected in food security. COVID 19 not only had a devastating influence on the economy but also on food security. Although the situation was slowly improving, there was a large increase in malnutrition between 2020 and 2021, when the COVID 19 pandemic was most severe. Thus, about 118 million more people were facing hunger in 2020 than in 2019 (FAO et al. 2021). On the other hand, the situation has provided an insight into the instability of the food system, which offers a unique opportunity for advancing and transforming the food system and making it more resilient to crises that might strike society in the future.

4.4. Neglected and underutilised species

Since the early 60´s the past century, when the Green revolution started in India, the most important thing in agriculture was increasing the productivity of the world's major staple crops like rice, maise, and wheat (Cheng et al. 2019). This foreshadowed today's situation, where more than half of humanity's needs for energy and protein are being met by these three crops (IPGRI 2002). New principles of agriculture stand on pillars made from productivity and economic profit. Due to using new agricultural practices, pesticides, chemical imputes, and new crops cultivars has improved productivity (Massawe et al. 2016). It has been estimated that humans have used between 40,000 to 100,000 plant species for different purposes during our history, including fibre, medical, food, fuel, forage, culture, etc. At the present day, we still use around 7,000 cultivated species all around the world. However, only 30 crop species become major crops in most of the world's agriculture (IPGRI 2002).

The determination of neglected and underutilised species (NUS) depends on researchers and their points of view on this issue. In addition to crops can be NUS as well aquatic animals, microorganisms, livestock, and insect species. NUS can be defined as an agricultural plant species of secondary priority, which have an enormous potential to contribute to food and human nutritional security, health, and culinary and dietary diversification. Can be cultivated and semi-domesticated crop species. Another essential condition is that NUS cannot be an exotic or introduced species (Cheng et al. 2019).

Their potential lies, among other things, in income generation and environmental services. According to the Food and Agriculture Organizations (FAO): NUS are plant species that for social, agronomic, or biological reasons have lost their importance over 500 years". Even though they are beneficial in many ways they are not included in the development, policy documents, and in any national research with no intention of commercial cultivation and investment from the public and private sector for research (Ashok et al. 2020).

Neglected and underutilised species are often called "minor crops" or by commercial companies as "new crops" or "future smart foods" (FSFs). That has given their inferior position in cropping systems in agriculture and because of poor scientific information and documentation. Another designation of NUS is 'crops of the future because of their wide use potential. The decline of these crops can lead to erosion of the genetic base (IPGRI 2002).

- Neglected crops (orphan crops) have regional importance – primarily grown in the place of their origin and are planted by local farmers. They have limited economic importance in the global market, but local people have countless significance at a regional level. Some species we can find are distributed worldwide, but this is more of an exception. Most are used as food or feed crop (IPGRI 2002). As underutilised crops, neglected crops also have potential in modern medicine.
- Underutilised crops have grown in the past more intensively, but for various genetic, agronomic, genetic, and cultural reasons, their use is gradually declining. They cannot keep up with the main crops - cannot compete with them in the same agricultural environment, and therefore, farmers and consumers are using these crops less (Ashok et al. 2020). Now we can find them filling ecological niches occupied by major crop plants.

There is an importance of a more diverse portfolio of agricultural crop species in the future (IPGRI 2002). Genetic erosion is also narrowing future development options for the rural poor. It would be a great loss from agroecology and genetic point of view due to their valuable traits used. One of the highlighted properties of the NUS is that they are generally adapted to marginal soil and resilient to regional climate conditions (Foyer et al. 2016).

In the future, we will probably use them for better adaptation and improvement of our current main crops. Extensive research could lead to increasing the value of these species and livelihood options for rural communities. Research and breeding can help make current NUS species more widely available in agriculture systems globally.

4.4.1. NUS crops of India

In India, rural societies depend on NUS, and thus, they play an empirical role in food security for the growing population. Different edible NUS plants are an essential commodity in the markets available to locals and an export commodity to urban people (Banerjee et al. 2013). There is still enormous agrobiodiversity to be found among them, which has a high potential to contribute to improving food security, human health and nutrition, incomes and offers one of the possible solutions to overcome crises related to climate change in the future (IPGRI 2002). Although some species are known in the pharmaceutical industry for their medical benefits, there are few studies on the local importance of these plants to indigenous farmers.

Independent organisations and the government of India have been trying for many years to find the right solution to the conservation of agrobiodiversity including NUS. In the case of conserving the genetic diversity of crops, the most successful method so far has been the on-farm method, where local farmers grow traditional crops to serve as a genetic bank of plants (Swaminathan 2015). In 2001, the government of India passed the Act "The Protection of Plant Varieties and Farmers", which resulted in the empowerment and inclusion of local communities (Sugam et al. 2016). Farmers can protect their crop varieties and register their innovations. Blending technology and innovations regarding agriculture with traditional practices of local people has become an effective method for increasing yields. Knowledge is then passed on between farmers, enriching each other's experience (Swaminathan 2015).

The following Table 1. lists the plant species considered NUS, originated or fully domesticated in India. Local tribes widely use them, often forming a significant part of their diet. There is a possibility to use these cultivars of plant species in nutritional programs to ensure food security and limit malnutrition in the rural population (Melo et al. 2013) .

Table 1. Overview of NUS plant species in India

	Scientific name	English name	Local name	Family	Edible part	Protein g/100 g	Type of processing	Mode of use	Reference
1.	*Aegle marmelos* (L.) Correa	Bengal Quince Bael Golden apple Stone apple	Belgiri Maredu, Bilva Bel Kham Shivaphala Belo Vilva marun	Rutaceae	fruit seeds leaves	1.6 – 3.6 9.7 1.0	raw/ fermented/ dried pressed raw	sherbet, syrup, marmalade, nectar, juice, powder, slab, wine, tea oil - used in the bakery used as leafy seasonal vegetable	8, 12, 23, 25, 26, 27, 28
2.	*Alocasia macrorrhiza/ Alocasia indica*	Giant taro leaves Colocassia Taro	Shriew khmat blang Man Kachu Charakanda	Araceae	tubers	2.0 - 3.9	boiled	used as a vegetable, usually eaten with pulses (soups, stews)	1, 6, 12
3.	*Amaranthus hybridus*	Green pigweed	Dantu koora	Amaranthaceae	seeds leaves	17.9 34.8	raw/ dry/ roasted/ boiled / baking boiled/ cooked	used similarly as oat or rice, flour used as a vegetable, salads	82, 83
4.	*Baccaurea ramiflora* Lour.	Burmese grape	Sohramdieng Sohmyndong	Phyllanthaceae	fruit leaves	5.6 -	raw/ fermented raw, boiled, cooked	used for making wine, squash, RTS, jam, dye chocolate colour, juices used as a vegetable or flavouring agent (curries)	42, 44
5.	*Bauhinia purpurea* (L.)	Orchid tree Pink butterfly tree Camel´s foot tree	Koilar Kurial Kaniar Mantharai Devakanchan Kachnar	Fabaceae	flowers leaves (dry) seeds	3.7 – 4.5 (%) 15.2 43.7	cooked cooked – boiled roasted/ pressed	eaten as vegetables, curries used as vegetables, cooking with rice oil, used as pulses	12, 15, 23, 35, 36, 37
6.	*Canavalia ensiformis* (L.) *DC.*	Jack bean	Abai Barma	Fabaceae	seeds leaves	23.4 – 35.3 -	cooked/ dry steamed	used as beans or flour, powder (drinks - coffee supplement) used as a vegetable	55, 56, 58, 59
7.	*Canavalia gladiata* (Jacq.) DC.	Sword bean	Thammakaya Adavi thamma Kozhi avarai	Fabaceae	seeds pods leaves flowers	26.8 – 35.0 2.7 - -	cooked raw/ cooked steamed/ boiled steamed	eaten as pulses used in green salads used as a vegetable, flavouring agents flavouring agents, decorating the meal	8, 12, 56, 59
8.	*Castanopsis indica*	Chinquapin Indian chestnut	Soh ot Hingori	Fagaceae	seeds	3.04 – 4.9	raw/ cooked		1, 46
9.	*Chenopodium album* (L.)	Lamb´s quarter	Bathua sag Paloi Chandan betu Papukkura	Amaranthaceae	leaves shoots seeds	3.7 - 4.3 29.2 - 32.2 -	raw/ cooked cooked boiled	salads, used as a vegetable used as a vegetable flour (bread and pancakes)	8, 12, 79, 80, 81

(continued)

Table1. Selected plant species (continued)

	Scientific name	English name	Local name	Family	Edible part	Protein g/100 g	Type of processing	Mode of use	Reference
10.	*Citrullus colocynthis* (L.) Schrader	Bitter Apple	Hanjal Idrayan Anedri Rakhal Pcitummatti	Cucurbitaceae	fruit seeds	0.7 13.9 – 27.6	raw/ boiled roasted/ dried	mature is eaten raw or used in fresh juices, ripen is usually used in curries eaten mostly with salt	8, 15, 16, 17, 18
11.	*Coccinia grandis* (L.) Voigt/ *Coccinia indica* Wight & Arnott	Small gound Scarlet gourd Ivy gourd	Telakucha	Cucurbitaceae	seeds fruit leaves	19.5 1.0 – 2.0 3.3 – 4.9	dry/ roasted raw/ comfited/ cooked/ pickled/ dried/ fermented cooked/ fried	powder (flavouring agent), eaten with salt or spicy unripe is used as a vegetable, used in soups and curries, ripe fruit is eaten raw, chips used as leafy vegetables, salads	8, 12, 17, 24
12.	*Coix lacryma-jobi*	Job´s tears	Baru Gurlu Samkru	Poaceae	grains	13.7	boiled/ roasted/ dried	used as rice, flour	12, 70
13.	*Cucumis prophetarum* (L.)		Andanga	Cucurbitaceae	seeds fruit leaves	26.9 - -	dried/ roasted raw/ cooked raw/ cooked	powder (flavouring agent), roasted are eaten with salt or spicy sauces, stews used as vegetables, salads	17
14.	*Cyphomandra betacea* (Cav.) Sendtn.	Tree tomato Tamarillo	Soh baingon dieng	Solanaceae	seeds fruit	22.6 1.6 – 1.8	boiled/ steamed/ pressed cooked, raw	oil (cooking, pharmaceutic) unripe – sour and sweet dishes, jam, chutney, sambal, curry mature – stews, soups, stuffing, salads	1, 3, 4, 8, 12
15.	*Dioscorea bulbifera* (L.)	Aerial Yam	Kolkant Ratalu Genthi Varahi	Dioscoreaceae	tubers	3.1	boiled/baked/ fried	needed to be processed, contain toxic alkaloids	11, 53, 43
16.	*Docynia indica* (Wall.) Decne.	Assam apple	Sohphoh Sohptet	Rosaceae	fruit	0.4 – 3.8	raw/ boiled/ sundried/ pickled	eaten fresh when ripen only, half ripen are eaten with salt or boiled with sugar, preparation jelly, wines, syrup	45, 47
17.	*Dolichos lablab* (L.)	Hyacinth bean	Avarai Chikkudu	Fabaceae	seeds	22.4 – 31.3	boiled/ roasted	needed to be processed before eating	12, 57
18.	*Echinochloa frumentacea*	Indian barnyard millet	Sanwa Jhangora Shamul Shyama Kodisama	Poaceae	grains	10.1	dried	flour (bakery, noodles and pasta), used as cereals	83

(continued)

Table1. Selected plant species (continued)

	Scientific name	English name	Local name	Family	Edible part	Protein g/100 g	Type of processing	Mode of use	Reference
19.	*Eleusine coracana* (L.)/ *Eleusine Indica* (L.)	Finger millet	Burada chollu Garuvu chodi	Poaceae	grains	5.0 – 8.7	dried	preparation of traditional meals (porridge, dumpling, bread, pancake,..)	8, 12, 66, 67
20.	*Eryngium foetidum* (L.)	False coriander	Dhania Khasi Bhandhania	Apiaceae	leaves	2.2 – 2.9	raw/ cooked	seasoning, flavouring agent, soups, curries, salad, marinade	1, 2, 8
21.	*Flemingia vestita*	Flemingia root	Soh phlang	Fabaceae	tubers (raw) (dry)	2.2 – 7.2 6.1 - 7.2 2.2	dried/ cooked	eaten with perilla	1, 5
22.	*Garcinia indica* (L.)	Kokum butter tree	Ramboostan	Clusiaceae	fruit seeds	2.0 – 4.7 -	raw/ cooked/ sundried pressed/ dried	used in chutney, curries, soups, stews, squash, juices, syrup oil, flour, butter	8, 75
23.	*Gynocardia odorata*	Chaulmoogra	Sohliang Salmogra Lemtem Deshi	Achariaceae	seeds	6.3	boiled/ fried	should have been cooked before eaten, oil *fruit – is poisonous	1, 41, 42
24.	*Hibiscus sabdariffa* (L.)	*Rosella* *Indian sorrel*	Lal Ambari Patwa Manipuri Tenga-Mora	Malvaceae	shoots leaves flowers seeds	3.3 3.5 2.0 – 6.6 28.9	raw/ cooked raw/ cooked raw/ dried/ cooked/ frizzed dried/ pressed	leaves and shoots are used as a vegetable (with tamarind pulp or chutney) beverages (syrup, wine, tea), added to fruit salads, jams, jellies, chutney, oil	8, 11, 12, 32, 34
25.	*Hippophae rhamnoides* (L.)	Seabuckthorn Grain chenopod	Chiraunji	Eleagnaceae	seed	17.1	dried/ pressed	oil	76, 78
26.	*Houttuynia cordata*	Chameleon plant Saurusus	Jamyrdoh	Saururaceae	tubers leaves	3.2 -	raw/ cooked dried/ cooked	stews, soups, salads, used mainly as a flavouring agent used as flavouring agents in meals	1, 49
27.	*Lablab purpureus* (L.) Sweet	Hyacint beans (red) (curve, green) (green)	 (Ri Saw) (Ri Kdor) (Ri Jyrngam)	Fabaceae	seeds (immature) (mature) leaves pods	4.5 – 24.0 4.5 – 5.4 23.0 -24.0 4.5 21.0 – 29	boiled/ roasted boiled boiled	used as common beans, curries used as a vegetable used as vegetables	1, 8
28.	*Lagenaria siceraria* (Mol.) Standl/ *Cucurbita Lagenaria* (L.)	Bottle gourd	Anamkap kaya Ekathari kaya Suraikkai	Cucurbitaceae	fruit seed	0.5 19.5 – 35.0	raw/ boiled/ fried/ pickled dried/ baked/ pressed	used as a vegetable (stews, making pickles) flour, oil	8, 12, 23, 38, 39
29.	*Limonia acidissima/* *Feronia limonia* (L.) Swingle	Elephant apple Wood apple	Kaith Velaga Vilanga Kawath	Rutaceae	fruit (pulp) seeds leaves	3.2 - 8.0 26.0 -	dried/ raw/ cooked dried pickled	eaten ripe (with or without seeds), sherbet, treacle, candy, powder powder used to make pickles	8, 12, 31

(continued)

Table1. Selected plant species (continued)

	Scientific name	English name	Local name	Family	Edible part	Protein g/100 g	Type of processing	Mode of use	Reference
30.	*Luffa acutangular* (L.) Roxburgh/ *Cucumis actutangulus* (L.)	Angled loofah Ringed gourd Chinese okra	Beera Donda beera Jnni Peerkai	Cucurbitaceae	fruit leaves flowers	0.6 – 1.2 5.1 -	cooked/ fried cooked cooked/ raw	immature used as a vegetable, used for soups or curries used as a vegetable used as a vegetable, salads	8, 12
31.	*Luffa cylindrica* (L.)/ *Luffa aegyptiaca* P. Miller, Gard.	Smooth loofah Sponge gourd	Dhudul Neti beera Mezhuku peerkai	Cucurbitaceae	fruit leaves flowers seeds	0.6 – 1.2 5.1 - 27.2	cooked/ fried cooked cooked pressed	immature is edible only, used as a vegetable, used in soups, stews, curries, in green salads used as a vegetable oil	8, 12
32.	*Moringa oleiflera* Lam.	*Drumstick* *West Indian Ben* *Behen tree*	Mugna Munaga Marungai Munakaya Shobanjama Sohjan	Moringaceae	leaves (fresh) (powder) (dry) pods (raw) seeds flowers	6.7 – 29.4 6.7 – 11.9 27.1 27.2 – 29.4 12.4 32.2 - 36.0 17.9 – 24.5	dried/ cooked/ raw raw/ boiled/ canned dried/ pressed/ fried cooked/ dried	salad, sauces, soups, and crushed into a powder added to sauces (curry, sambar, korm) oil (cooking), added to meals (sauces) used as a vegetable, sauces, tea, soups	9, 10, 12, 20, 21, 23, 85
33.	*Morrus australis*	Mulberry tree	Soh langdkhur	Moraceae	fruit	3.6	raw/ cooked	juice, jam, wine, dye	1, 8
34.	*Mucuma puriens* (L.) DC.	Velvet bean	Gonca Kavach Konch	Fabaceae	seeds	26.0 – 33.0	dried/ cooked	eaten as a pulse	8, 56, 58, 61
35.	*Murraya koenigii* (L.) Sprengel	Curry leaves	Barsuga Bhrusanga patra Karepaku Kariveppilai	Rutaceae	fruit leaves (fresh) (dry)	2.0 6.0 – 12.0 6.0 12.0	raw/ cooked raw/ cooked/ fried/ dried	ripe are eaten raw, curries used as flavouring agent fresh (leafy vegetable used in salads), used in curries and soups, powder	12, 15, 24, 29, 30
36.	*Nelumbo nucifera* Gaertn.	Sacred lotus Indian lotus	Kamal, Pavan	Nymphaeaceae	tubers seeds leaves	2.0 – 3.0 18.0 -	raw/ cooked/ dried/ conned/ pickled raw/ boiled/ roasted raw/ boiled	flour, sweetmeats unripe are eaten like nuts used as a vegetable, young eaten raw	8, 12, 13, 14, 23
37.	*Nigella sativa* (L.)/ *Nigella vretica* Mill.	Black cumin	Ajaji Kalaunji Kunchika	Ranunculaceae	seeds	16.0	cooked	spices - chutney, pickles, vegetable dishes, dye	15
38.	*Parkia roxburghii* G. Don	Tree bean	Kharial Manipuri seem Aoelgap	Fabaceae	seeds pods leaves	6.0 – 27.5 12.01 - 18.8 -	raw/ boiled/ fried roasted/ dried cooked/ raw	side dish with rice used as a vegetable salads (not too common)	8, 12, 62, 63

(continued)

Table1. Selected plant species (continued)

	Scientific name	English name	Local name	Family	Edible part	Protein g/100 g	Type of processing	Mode of use	Reference
39.	*Perilla frutescens* (L.)	Perilla	Bhangjira Bhanjira Bhangra jhutela Nei lieh	Lamiaceae	seeds (raw) (roasted) leaves	14.7 - 23.9 14.7 - 23.9 14.9 - 15.3 -	raw/ cooked/ roasted/ pressed dried/ cooked	oil, powder, adding to the chutney (flavouring purpose), oil cake locally called pinna flavouring (mixed with chyura), vegetable, food colourants	1, 5, 22
40.	*Persicaria decipiens* (R. Br) K. L. Wilson	Willow weed Snake root	-	Polygonaceae	leaves roots	3.6 -	raw/ cooked/ boiled cooked	used as a vegetable, salad, served with rice eaten as vegetable or salad	9, 12
41.	*Phaseolus coccineus* (L.)	Scarlet bean Scarlet runner bean	Bangda Katthiri Namalakaya	Fabaceae	seeds	9.6 – 20.3	dried/ boiled	used as pulses	8, 12, 71
42.	*Polygonum plebeium* R. Br.	Small knotweed	Chemti sag Sarpakshee	Polygonaceae	leaves roots	17.0 -	boiled cooked	Leaves – used as a vegetable, boiled Roots – cooked with potatoes or rice	9, 12
43.	*Portulaca oleracea* (L.)	Pigweed Purslane	Nona sak	Portulaceae	leaves stems seeds	1.3 – 3.0 0.8 - 1.4 -	cooked/ roasted cooked dried/ backed	used as a vegetable, green salad, vegetable juice used as a vegetable flour, powder (blended in with cereals, hotcakes, gruels, or bread)	9, 12, 24, 51
44.	*Potentilla polyphylla* Wall. ex Lehm.	Cinquefoil roots	Lynniang Langsniang	Rosaceae	tubers	3.2	boiled/ backed	used as a vegetable	1, 48
45.	*Psophocarpus tetragonolobus* (L.)	Winged bean Goa bean	Morusu Avarai	Fabaceae	leaves seeds tubers pod flowers	5.0 – 5.9 29.7 – 39.0 3.0 – 15.0 1.9 – 4.3 2.8 – 5.6	cooked/ steamed cooked/ dried/ roasted/ fermented/ pressed steamed/ roasted/ boiled raw/ pickled/ fried/ steamed steamed/ raw	young used in salad, used as a vegetable mature are used as pulse (for flour, oil, milk, fermented products), eaten as peanuts, unripe are used in curries and soups used as a vegetable immature are eaten as a vegetable used for colour (decorating of the meal)	9, 12, 19
46.	*Pyrus pashia Hamilton* ex D. Don	Himalayan pear	Sohjhur Sohait-syiar Chalthei Shegal	Rosaceae	fruit	3.7	raw/ sundried	eaten raw, chips	12, 42

(continued)

Table1. Selected plant species (continued)

	Scientific name	English name	Local name	Family	Edible part	Protein g/100 g	Type of processing	Mode of use	Reference
47.	*Rhus chinensis* Mill./ *Rhus javanica* (L.)		Sohmluh, Sohsama	Anacardiaceae	fruit	9.3 – 11.6	raw	eaten raw when ripe	42, 45
48.	*Sechium edule (Jacq.) Sw.*	Chayote	Chow chow	Cucurbitaceae	fruits seeds leaves tubers	0.8 – 1.7 5.5 2.7 – 4.9 2.0 – 10.0	raw/ cooked/ candied/ roasted dried/ roasted cooked/ roasted/ fried/ boiled cooked	eaten raw when fully ripe, curries, chutney taste like nut, roasted, powder used as a vegetable, salads, used as a vegetable (stews and soups)	8, 74
49.	*Senna (Cassia) obtusifolia* (L.)	Low senna	Chakunda Chirauta chokad	Fabaceae	leaves seeds	5.6 -	dried/ cooked roasted	used as a vegetable, tea substitute for coffee	8, 9
50.	*Sesbania grandiflora (L.) Poir.*	Agathi sesbania West-Indian pea	Dhaincha Bok phul	Fabaceae	leaves flowers pods seeds	4.5 – 8.4 14.5 – 24.7 35.0 30.0 – 40.0 %	dried/ boiled/ steamed steamed/ boiled cooked/ dried pressed	eaten as a vegetable, salad eaten as a vegetable, added to soups and sauces) eaten as beans oil	8, 24, 40, 86, 52, 50,
51.	*Setaria italica* (L.)	Foxtail millet Italian millet	Chinna kora Erra kora Perunthinai	Poaceae	grains	9.2 – 11.2	dried	bread, used as rice, puddings, flour	8, 12, 67, 68, 69
52.	*Solanum ferox (L.)*	Hairy-Fruited Eggplant	Soh ngang rit, Ram Begun	Solanaceae	fruit	2.0 - 4.0	cooked	added to meals (sour flavour of the kari)	1, 12, 54
53.	*Solanum gilo*	Bitter tomato	Soh-ngang, Bitter brinjal	Solanaceae	fruit	4.2	cooked/ pickled/ fried	stews, pickles, and fries	1, 7
54.	*Solanum torvum* Swartz.	Eegpland, Cherry eggplant	Tit Begun	Solanaceae	fruit leaves	2.4 -	cooked/ dried/ roasted cooked	used as a vegetable, soups and sauces (bitter taste) cooked with salt and chilly	9, 12
55.	*Tamarindus indica* (L.)	Tamarind	Tetuli, Ambliki Imli Koya Chinta	Fabaceae	seeds pulp leaves flowers	13.3 – 28.1 2.0 - 9.1 4.0 – 5.8 2.8	dried raw/ dried/ cooked cooked cooked	powder raw, juices, powder, curries, chutneys, sauces, ice cream, sherbet used as a vegetable, curries, sauces, stews, soups, salads used as vegetables, soups, stews, and salads	12, 72, 73, 52

(continued)

Table1. Selected plant species (continued)

	Scientific name	English name	Local name	Family	Edible part	Protein g/100 g	Type of processing	Mode of use	Reference
56.	*Trapa bispinosa* Roxb.	Water chesnut	Simghara	Trapaceae	fruit	4.4 - 10.0	raw/ boiled	eaten raw when ripe	8, 23, 84
57.	*Vicia faba* (L.)	Faba bean Broad bean	Hawai-amubi	Fabaceae	seeds	26.0	cooked	used as beans	8, 12
58.	*Vigna aconitifolia* (Jacq.)	Moth bean	Tuluka payir Kuncumapesalu	Fabaceae	seeds	24.3	cooked/ roasted/ dried	flour	12, 23, 75, 77
59.	*Vigna trilobata* (L.) Verdc./ *Dochilos trilobatus* (L.)	Jungle mat bean	Mgani Mugawana Mungani Bin-me	Fabaceae	seeds	22.1	cooked	eaten as pulses, only by the poorest people	8, 64, 65
60.	*Vigna umbellata* (Thunb.) Ohwi & Ohashi	Rice bean	Thattam payiru	Fabaceae	seeds leaves	19.2 – 20.4 -	raw/ dried/ boiled cooked	used as a vegetable, salads used as a vegetable	12, 60

1. (Chyne et al. 2019), **2.** (Paul et al. 2011), **3.** (Ramakrishnan et al. 2013), **4.** (Abdul Mutalib et al. 2017), **5.** (Standal et al. 1985), **6.** (Mollejon & Tibe Chapter 2019), **7.** (Angami & Chhetri 2018), **8.** (PROSEA 2022), **9.** (Grubben & Denton 2004), **10.** (Lakshmana et al. 2019), **11.** (Khare 2007), **12.** (Pullaiah et al. 2016), **13.** (Kay & Gooding 1987), **14.** (Mohan Maruga Raja et al. 2010), **15.** (Singh & Fernandes 2018), **16.** (Hussain et al. 2014), **17.** (Sadou et al. 2007), **18.** (Akansha et al. 2018), **19.** (Lepcha et al. 2017a), **20.** (Gopalakrishnan et al. 2016), **21.** (Madane et al. 2019), **22**. (Pandey & Bhatt 2007), **23.** (Lokhande 2020), **24.** (Banerjee et al. 2013), **25.** (Dar et al. 2015), **26.** (Maskey et al. 2018), **27.** (Sarkar et al. 2020), **28.** (Sharma et al. 2007), **29.** (Chauhan et al. 2017), **30.** (Singh et al. 2014), **31.** (Hemalatha & Parameshwari 2019), **32.** (Jabeur et al. 2017), **33.** (Kaur & Sharma 2020), **34.** (Gbadura Adanlawo et al. 2006), **35.** (Sarfraz et al. 2010), **36.** (Dhyani & Gupta 2016), **37.** (Verma et al. 2012), **38.** (Hassan et al. 2008), **39.** (Patel et al. 2019), **40.** (Karmakar et al. 2016), **41.** (Kalita & Devi 2019), **42.** (Rymbai et al. 2015), **43.** (Uthirapathy et al. 2013), **44.** (Raghavan & Ramjan 2018), **45.** (Cun-wu et al. 2010), **46.** (Agrahar-Murugkar & Subbulakshmi 2005), **47** (Thu N T 2014)., **48.** (Seal 2011), **49.** (Jyoti Sharma et al. 2016), **50.** (Bunma & Balslev 2019), **51.** (Petropoulos et al. 2019), **52.** (Maisuthisakul et al. 2008), **53.** (Bhandari et al. 2003), **54.** (Lim 2013), **55.** (Akpapunam & Sefa-Dedeh 1997), **56.** (Doss et al. 2011), **57.** (Deka & Sarkar 1990), **58.** (Agbede & Aletor 2005), **59.** (Sridhar & Seena 2006), **60.** (Kaur et al. 2013), **61.** (Josephine & Janardhanan 1992), **62.** (Kamisah et al. 2013), **63.** (Singha et al. 2021), **64.** (Kalidass et al. 2012), **65.** (Zaheer et al. 2021), **66.** (Rao 1994), **67.** (Devi et al. 2011), **68.** (Kumar & Parvathy Parameswaran 1998), **69.** (Monteiro et al. 1988), **70.** (Ding et al. 2021), **71.** (Aquino-Bolaños et al. 2021), **72.** (Singh Bhadoriya et al. 2010), **73.** (Martin 2007), **74.** (Vieira et al. 2019), **75.** (Jagtap et al. 2015), **76.** (Li & Schroeder 1996), **77.** (Adsule 1996), **78.** (Khan et al. 2021), **79.** (Gqaza et al. 2013), **80.** (Poonia & Upadhayay 2015), **81.** (Saini et al. 2020), **82.** (Adeyeye & Omolayo 2011), **83.** (Akubugwo et al. 2007), **84.** (Adkar et al. 2014), **85.** (Melo et al. 2013), **86.** (Lim 2014).

In total, data on 60 different plants were collected in Table 1. The vast majority (28.3 %) belongs to the Fabaceae family, followed by plants from Cucurbitaceae (11.7 %), Poaceae (6.7 %) and Solanaceae (6.7 %) families.

Of the 60 plants, 48.4 % of the plants were consumed only after thermal processing (cooking), and 51.6 % of plants can be consumed in both forms, thermally processed or unprocessed. The most common types of heat treatment were blanching, drying, frying and roasting. In the case of non-thermal, fermentation was the most commonly found. Most of the seeds were dried, roasted, powdered into flour or pressed into oil. The fruits are eaten raw, mostly without thermal treatment or processed into jams, juices, squashes or fermented for beverages preparation. The leaves, pods and tubers are mainly used as a vegetable, the leaves are a common part of green salads.

Protein content was collected for as many edible parts as possible; if data for protein content per 100 g could not be found, the content was omitted or given as an approximate percentage. The highest protein content was recorded in seeds, then in leaves and pods. Flowers, fruits, shoots and stems generally contained less protein. For 15 species, the protein content, at least in one of the edible parts, was found to be greater than 20 g/100 g, for 11 species it was found to be greater than 30 g/100 g. The plants with the highest protein content and the greatest potential in terms of utilization were described further in the text.

It is necessary to consider whether studies have measured their protein proportion in dried or fresh form, because some parts contain a large amount of moisture, sometimes more than 80-90 g/100g, which affects the fractions of individual nutrients.

4.4.2. Selected plant species

Four species, namely *Moringa oleiflera* Lam.*, Bauhinia purpurea* (L.)*, Psophocarpus tetragonolobus* (L.)*, Sesbania grandiflora* (L.) Poir.were selected on the basis of protein content (greater than 35 g/100 g in at least one of the edible parts) and their potential for further use. These species are described in followed chapters in terms of geographical distribution, morphology, potential use and nutritional and anti-nutritional values.

4.4.2.1. Moringa oleiflera Lam.

Moringa oleiflera is a perennial softwood tree belonging to the Moringaceae family. In India is commonly known as Mugna, Munaga, Marungai, Munakaya, or Shobanjama. In English is known as Drumstick, West Indian Ben, Behen tree or Horseradish tree (Pandey et al. 2019). In the western world, there is little known even though researchers consider Moringa one of the most beneficial tree species worldwide (Pandey et al. 2019). There are no reports about commercial plantings, which are mostly found in traditional local markets (Ramachandran et al. 1980).

Origin and geographical distribution: The Moringa tree is indigenous to the North-West sub-Himalayan region of India. In this region it has been commonly distributed and cultivated for a long time and still can be found there wild cultivars. From India, the tree was introduced to America in the nineteenth centuryelázquez-Zavala et al. 2016) and in the twentieth century to Africa (Pandey et al. 2019). Nowadays is naturalized in many places worldwide; in India, Afghanistan, Arabia, Bangladesh, China, Pakistan, Sudan, Ethiopia, Central America, Pacific, and Caribbean Islands (PROSEA 2022)**.**

Ecology and botany: The Moringa is a deciduous, rapidly growing tree with drooping leaves. Grows in subtropical and tropical areas, at elevations of up to 1,000 m above sea level. The best performs reported on dry sandy soil with soil pH ranges of 4.5 to 8. Tolerate annual temperatures of 18.7 to 28.5 °C and annual precipitation of 760 to 2,250 mm (Palada 1996).

Tree height ranges between 5–10 m, and the trunk is slender and much-branched (Pandey et al. 2019). The leaves are feathery and compound, length ranges between 30 – 60 cm, with 3 to 9 leaflets on the ultimate pinnules. Terminal leaves are obovate and slightly larger than lateral leaves (Palada 1996). Fragrant flowers are bisexual, creamy-white, and form compound inflorescence (Kalappurayil & Joseph 2017). In India, flowering occurs maximally from January to February (Palada 1996). The pods are pendulous, triangular, brown, about 30-120 cm long and 1.8 cm wide. Into pods can be found about 20 seeds of dark brown colour. Seeds have three papery wings (Palada 1996).

Propagation: There are two main ways of *M. oleiflera* propagation, planting stem cuttings or by seed. In India is preferred vegetative propagation method. According to some studies, the fruit produced by plants raised from seeds is of inferior quality (Ramachandran et al. 1980; Palada 1996).

Mode of use: Moringa tree is considered one of the multipurpose trees due to the potential use of each part of the plant. Its versatile use includes therapeutic, cosmetic, and medical ornamental purposes (Sánchez-Machado et al. 2010; Melo et al. 2013).

Almost every part of the *M. oleiflera* is edible. Leaves, flowers, pods, and seeds tree produces throughout the year (Ramachandran et al. 1980), and are commonly used in various vegetable dishes in several countries (Ashok et al. 2020). Leaves are eaten fresh green as a salad or are cooked, mostly used in curries, soups, sauces, pickles, and seasoning (Alain Mune Mune et al. 2016; Ashok et al. 2020). They can also be dried and crushed into powder, used in food supplements. Flowers are also cooked as a vegetable or added to sauces and are also used to prepare tee and soups (Sánchez-Machado et al. 2010). Immature young pods are cooked or boiled as a vegetable or used fresh in salads. Traditionally are added to sauces like curry, sambar, or korm, also can be preserved by canning (Sánchez-Machado et al. 2010). Because of the high content of fat, seeds are used for oil, which can be used as vegetable cooking oil or as a cosmetic oil. Seeds are further fried or added to sauces (Sánchez-Machado et al. 2010; Sharma et al. 2019).

Moringa has a large scale of medicinal properties; almost every part of the tree has medicinal values. Contain two unique alkaloids cause this - moringine and moringinine, flavanols and phenolic acid. Leaf powder can be used for patients with anaemia (Siddhuraju & Becker 2003), children with malnutrition (supplement), or pregnant and lactating woman (Pandey et al. 2019). Moringa tree is used for the treatment amount of acute or chronic conditions. For example, as treatment of liver fibrosis, obesity, diabetes, muscle diseases, tumours, diarrhoea (Razis et al. 2014), anxiety, asthma, blackheads, blood impurities, bronchitis (Mahmood et al. 2010), and is part of antidote (spider, centipede, scorpion), tonics for body or lungs (Ramachandran et al. 1980) and stimulants.

The wood yields serve as a blue dye. In India, the moringa tree is sometimes used in agroforestry, where it serves as a support for climbing crops (beans or black pepper). Trees are used as field borders or hedgerows, also serving as windbreaks and living fences (Ramachandran et al. 1980). Of course, the tree can be used for firewood when fuel is scarce or as fodder for livestock (Pradheep et al. 2003). The tree is considered a soil improver, and extracts are used for water purification (Velázquez-Zavala et al. 2016). Because of its high flowering, the tree is also good for honey production (Ramachandran et al. 1980).

Nutritional value: In India is commonly used in many traditional dishes, but the nutritional value of these dishes cannot be provided due to a lack of information. The macronutrient composition of edible parts might vary which is caused mainly by the maturity of the edible parts and their post-processing. Also, biotic and abiotic conditions of the environment where the tree grows may affect (Melo et al. 2013).

All parts of the Moringa tree are high in nutrients. Contains essential amino acids, vitamins A, B (1,2,3,6,7), C, D, E, K and minerals (Mahmood et al. 2010), beta-carotene, omega 3 and fatty acids, and more than 40 natural antioxidants (Mahmood et al. 2010; Razis et al. 2014). Concretely leaves contain antioxidant prosperities, are high in Ca, Fe (Ramachandran et al. 1980), and are a good source of P, and vitamins A and C - one cup of leaves provide more than the recommended daily allowance (Razis et al. 2014).

Figure 2. Flower of *Moringa oleiflera* (Issadeen 2009)**.**

Figure 3. Pods of *Moringa oleiflera* (Wikimedia 2016).

4.4.2.2. ***Bauhinia purpurea*** **(L.)**

Bauhinia purpurea (L.) belongs to the Fabaceae family. Locally in India is known as Koilar, Kurial, Kaniar, Mantharai, and Devakanchan, in English as an Orchid tree, Pink butterfly tree, or Camel´s foot tree. Plant gained the attention of researchers and pharmacological institutions mainly due to its phytochemical compositions, which could be a source of medical agents (Ramadan et al. 2006; Sarfraz et al. 2010). Unfortunately, there is not much information available on this species from a nutritional point of view. In addition, it is also a nutritionally valuable food, which needs to be exploited up to its full potential.

Origin and geographical distribution: The natural habitat of the Bauhinia tree ranges from Burma to North-East Indian sub-mountainous tract, and it is domesticated today on many continents. Species of the genus Bauhinia are generally cultivated (mainly as a medicinal plant) in Asia, Africa, South America and Central America (Sarfraz et al. 2010)

Propagation: Propagation is possible in several ways; grafting, layering, or seed (PROSEA 2022).

Ecology and botany: Bauhinia is small to a moderate-sized, evergreen, deciduous tree growing across India at altitudes ranging between 2,000-3,000 m altitude (PROSEA 2022). It grows well in sunny locations, and the soil conditions are not demanding.

Flowers are bisexual, from pinkish to purple colour, and flowering appears early in spring from February to April, and the inflorescence is partially opened (PROSEA 2022). The colour of the flowers distinguishes it from other Bauhinia species at first sight (Dhyani & Gupta 2016). The leaves are glabrous, rigid, shallowly cordate, and subcoriaceous (PROSEA 2022).

Mode of use: It is a multipurpose plant species**.** Mostly is known as an ornamental tree due to its colourful flowers (PROSEA 2022).

Pods, flowers, buds and seeds are edible and traditionally used as vegetables. Young pods, same as the mature seeds, are eaten cooked (Rajaram & Janardhanan 1991; Ramadan et al. 2006)**.** Buds and flowers are used in pickles, curries and broths, leaves are eaten as a vegetable with rice or are used as flavouring agents for meat and fish dish (Sarfraz et al. 2010). The greatest potential in terms of nutrition lies in the seeds, which could be used in the future to produce oil - both for cooking and industrial (Ramadan et al. 2006).

Buds, flowers, bark and leaves are well known for their therapeutic and medicinal properties, mainly used in traditional Indian Ayurvedic medicine (Ramadan et al. 2006). It was reported that Bauhinia contains polyphenolics Nowadays is a plant primarily used to cure cough (Ramadan et al. 2006), diarrhoea, pain, rheumatism, delirium and wounds (Rajaram & Janardhanan 1991). Leaves extracts have effects as an analgesic or are used as antifungal, antimicrobial activity, antitumor activity, antipyretic and anti-inflammatory remedy (Sarfraz et al. 2010).

Nutritional value: Leaves are rich in content of rich in iron, calcium, vitamin C, carbohydrates, protein and energy (Dhyani & Gupta 2016). However, they contain polyphenolics, which are considered antinutritional due to their affinity for protein (Dhyani & Gupta 2016). Buds and flowers are good sources of crude fats, fibre, protein, carbohydrates and total energy. In addition, they also contain phenols and dietary antioxidants (Ramadan et al. 2006). Seeds contain a high amount of potassium (Rajaram & Janardhanan 1991), essential fatty acids, specifically linoleic and oleic acid (Sarfraz et al. 2010), and lipid-soluble bioactives (Ramadan et al. 2006). Seeds contain free phenols and tannins (Rajaram & Janardhanan 1991).

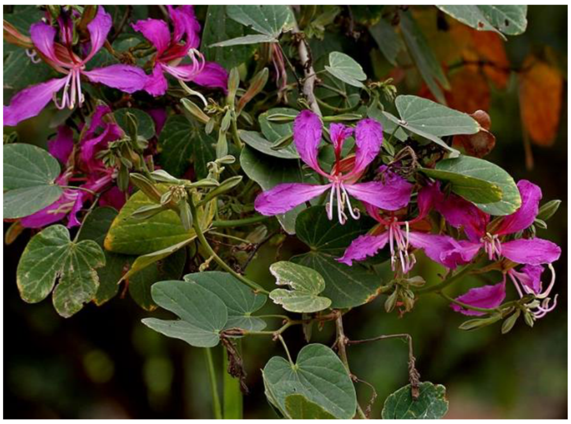

Figure 4. Flowers of *Bauhinia purpurea* (Garg 2008).

Figure 5. Pods and seeds of *Bauhinia purpurea* (Worthington 2016).

4.4.2.3. Psophocarpus tetragonolobus **(L.)**

Psophocarpus tetragonolobus is a tropical legume from the Fabaceae family, commonly called Winged bean, Asparagus pea or Goa bean in English. In India is known as Morusu Avari or Charkoni-sem (Hymowitz & Boyd 1977). It is a minor crop cultivated along with rice or is grown wildly alongside the fields, fences or hedges (Lepcha et al. 2017). In recent years, the plant has received more attention, mainly due to its nutritional qualities .

Origin and geographical distribution: Its origin has been speculated for many years. According to some authors of publications and botanists, it is a plant native to Asia, according to others, it has roots in Africa (Hymowitz & Boyd 1977; Lepcha et al. 2017; PROSEA 2022).

Nowadays, it can be found in many tropical and subtropical countries worldwide, but it is widely distributed in Asia (PROSEA 2022). Psophocarpus is widespread in Indonesia, Malaysia, Thailand, Philippines, India, Bangladesh, Myanmar, Madagascar, Papua New Guinea and Sri Lanka (Lepcha et al. 2017).

Botany and ecology: It thrives best in humid and warm equatorial climates (PROSEA 2022). Typically, *P. tetragonolobus* is a perennial, self-pollinating herb growing 3-4 m tall. The flowers are usually borne singly, blue, purple or blue-white. Pods can reach 30-40 cm in length and contain between 5-21 seeds. The roots are tuberous (Lepcha et al. 2017).

Propagation: The most common and easiest method of propagation is from seed. The first pods fully ripen after 4-5 months but can be harvested and eaten earlier (PROSEA 2022).

Mode of use: Most parts of the plant are edible at all stages of the life cycle (Lepcha et al. 2017). Green immature pods are eaten as vegetables, raw or processed. Tubers are also eaten, but mostly in Burma. Seeds used in soups, curries or the mature are roasted and eaten as peanuts (Hymowitz & Boyd 1977). Seeds are also used to prepare flour, milk, tofu, tempeh, miso or oil (PROSEA 2022).

Like many plants, *P. tetragonolobus* contains a significant amount of substances that are used in medicine. According to studies, the extracts have antimicrobial and antioxidant properties, specifically in the seeds are recorded contents of bioactive peptides and angiotensin-converting enzyme inhibitors (Lepcha et al. 2017). The roots are used to treat vertigo, with pods used to treat ulcers or sores, and the leaves are used to treat smallpox (Lepcha et al. 2017).

It is used as a cover crop (Hymowitz & Boyd 1977). Thanks to its symbiosis with nodes bacteria, it accumulates and fixes nitrogen, thus improving soil fertility (Lepcha et al. 2017b). It is also used as valuable green fodder for livestock (PROSEA 2022).

Nutritional value: It is comparable in terms of protein content, for example, to soybeans. It contains large amounts of minerals P, K, S, Mg, Ca, Na, Fe, Mn, Zn, B, Cu and Cr and vitamins A, B (1, 2, 3, 6) and 9, C and E (Lepcha et al. 2017).

After protein (33 g/100 g), seeds contain a significant amount of carbohydrates (32 g/100 g), fat (16 g/100 g) and fibre (5 g/100 g) (Lepcha et al. 2017; PROSEA 2022). Most of the fatty fats are contained in the seeds stigmasterol and β-sitosterol. However, amino acids containing sulphur are limiting (Lepcha et al. 2017).

Antinutritional contains free phenolics, tannins, phytic acid, saponins, trypsin inhibitors, phytate (antioxidant), chymotrypsin inhibitors and hemagglutinins (Kortt 1984; Lepcha et al. 2017). Specifically, tannins and phenolic compounds are important to consider because reducing the quality of the proteins in food (Lepcha et al. 2017).

Figure 6. Pod and seeds of *Psophocarpus tetragonolobus* (AumsWow. 2018).

Figure 7. Plant of *Psophocarpus tetragonolobus* with pods (Eagleton 2020).

4.4.2.4. *Sesbania grandiflora* (L.) Poir.

Sesbania grandiflora is a tropical and subtropical tree belonging to the Fabaceae family. In English it is called Agathi sesbania, West-Indian pea or August flower, in India it is known by the names Dhainca, Bok phul, Agasti, Bak, Basma, Basna, Agusta, Bagphal, Bake, Kacang Turi and Petai belalang. Agathi is not a commercial crop and is most commonly found in paddy fields, roadsides, household gardens and mixed crop plots (Karmakar et al. 2016).

Origin and geographical distribution: The origin of the plant is not entirely clear. It is thought to have originated in tropical South or Southeast Asia. About 200 years ago reached Africa and Central and North America, where it quickly became domesticated (PROSEA 2022). However, in some countries on these continents, it is considered an exotic species or weed (Karmakar et al. 2016).

Botany and ecology: *S. grandiflora* grows best in hot and humid environments. It is a lowland species, growing at maximum altitudes of 800-1,000 m (Karmakar et al. 2016; PROSEA 2022), and is not tolerant of low temperatures (below 10 °C) and is not very wind resistant. On the other hand, it tolerates waterlogging and prolonged dry periods, making it ideal for seasonally flooded environments (Karmakar et al. 2016).

Small or medium-sized rapidly growing tree, loosely branching, reaching heights between 8-15 m (Karmakar et al. 2016; PROSEA 2022). The trunk is unarmed, roots of the tree have nodules and can also develop floating roots. Leaves are compound, alternate, and pinnate, about 15-30 cm long. On the terminal end of the branches are about 3-4 cm long leaves. The inflorescences have 2-5 large flowers, 5-10 cm long and curved. The flowers are usually yellow, white or pink to red and are pollinated by birds. Pods are 30-50 cm long, narrow and drooping downwards, containing 15-40 seeds (Karmakar et al. 2016).

Propagation: Mostly propagated from seeds or by stem or branch cuttings. Seeds are produced from a young age, germinate very well and no dormancy is needed (PROSEA 2022).

Mode of use: Pods, flowers, seeds and leaves are edible. Flowers are the most used part of the Sesbania, specifically the ones with red colour. Flowers' bitterness can be reduced by removing the stamen and calyxes (Karmakar et al. 2016). They are eaten raw or cooked (pressure, fried, boiled or stamen), used mostly in salads or soups. Leaves are eaten when young, usually chopped and cooked (steamed, boiled or fried), because of their bitter taste, they are served with coconut milk or some sweet additives (Karmakar et al. 2016).

Traditionally used in Ayurvedic medicine. The leaves are diuretic and laxative containing chemical compositions that cleanse the body and are antiparasitic, anticancer and antidiabetic (Wagh et al. 2009; Karmakar et al. 2016). They are also used to reduce fever and treat respiratory diseases. The flowers are used to treat gloom, headaches and coughs (Wagh et al. 2009).

Because of its beautiful flowers, it can be found in parks or household and botanical gardens as an ornamental tree, or hedge. Sometimes it is planted other climber crops as pepper or vanilla (Karmakar et al. 2016). Due to its protein, mineral and vitamin content, it is considered a suitable fodder, serving as green fodder for livestock (leaves and pods), especially for goats and cattle in dry seasons (Karmakar et al. 2016; Bunma & Balslev 2019). In crises, the wood from the tree can be used as fuel, but this is extremely uneconomical as the wood burns quickly and produces large amounts of smoke when burnt (Bunma & Balslev 2019).

Like *P. tetragonolobus*, it is valued as a soil improvement, mulch or green manure crop due to the symbiosis of the roots with nodal bacteria (Karmakar et al. 2016). It is also used as a fibre crop for cellulose production, after appropriate processing, the material is made into paper (Bunma & Balslev 2019). The tree bark and seed endosperm are used for gum production, as a substitute for gum Arabic (Karmakar et al. 2016; PROSEA 2022).

Nutritional value: Sesbania is a good source of nutrients. For an edible portion of 100 g of flowers, protein values range from 14.5-24.7 g. The leaves and flowers are a good source of calcium, iron and vitamins, especially vitamin B (Wagh et al. 2009; Karmakar et al. 2016).

All the edible parts are high in sterols, saponins and tannins. Substances such as leucocyanidin, cyanidin, sesbaminide, oleanolic acid and its methyl ester can be found in the seeds (Wagh et al. 2009; Bunma & Balslev 2019). The bark contains tannins and resin

(Wagh et al. 2009). Of the antinutritional compounds, it contains a higher amount of phytate, oxalate and tannic (Bunma & Balslev 2019).

Figure 8. Flowers of *Sesbania grandiflora* (Sutradhar & Choudhury 1970).

Figure 9. Branches with pods of *Sesbania grandiflora* (Flora of Bangladesh. 2019).

5. Conclusions

This work has focused primarily on plants NUS containing a high amount of protein. India is the centre of origin of many NUS and serves as a reservoir for plant species used in various ways. Their importance on a regional scale is very often underestimated, but they are providing food security to the majority of the population living outside large urban metropolises and who depend on agricultural produce. These crops are not only part of their diet but also have an irreplaceable value in their rituals and food culture.

A total of 60 plant species from 26 different families were collected in this survey. The vast majority belong to the Fabaceae family (28.3 %), followed by plants from Cucurbitaceae family (11.7 %), Poaceae (6.7 %) and Solanaceae (6.7 %) families. Processing was evaluated based on frequency; 48.4 % of the plants were consumed only after the thermally processed form, and 51.6 % of plants can be aeaten in both forms, thermally processed or unprocessed. When edible parts were thermally processed, it was mainly drying, baking, blanching and frying. In the case of non-thermal, fermentation was the most commonly found.

For 15 species, the protein content, at least in one of the edible parts, was found to be greater than 20 g/100 g, for 11 species it was found to be greater than 30 g/100 g. Based on the collected data, 4 plants with the highest protein content and the greatest potential in terms of utilization were selected and described in detail, namely; *Moringa oleiflera* Lam.*, Bauhinia purpurea* (L.)*, Psophocarpus tetragonolobus* (L.)*, Sesbania grandiflora* (L.) Poir.

NUS plants have a great potential in terms of nutritional, medicinal and environmental properties, however, the nutritional value and quality of these species need to be more examined. By breeding and proving their potential it can become a possible measure to overcome the malnutrition problem for the still-growing population not only in India.

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