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# Alternative Sources of Plant Protein in Himalayan states

BACHELOR'S THESIS

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# Declaration

I hereby declare that I have done this thesis entitled "Alternative sources of plant protein in Himalayan states" 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 15/5/2020

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Tereza Vachková

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## Abstract

This work focused on alternative source of proteins in Asian countries, where part of the territory occurs in the Himalayan mountains. The work aimed to summarize alternative sources of plant proteins and their occurrence in selected countries through the research of studies obtained from electronic and literary databases and sources. The Himalayan states were considered to be: the Kingdom of Bhutan, Pakistan, Nepal, the Tibetan Autonomous Region, and India. The introductory part of the work informed about the importance of plant proteins in the diet from the first beginnings of human evolution. It compared whether plant proteins could be considered a sufficient source of protein, in regards to the digestibility of the protein and the number of amino acids with which it is formed. The second part of the work presented life and agriculture in these countries, focusing on the most affected mountain areas—problems in individual countries, such as food shortages, high mortality, and poverty. The third part was devoted to a total of 54 neglected and underused plants that can be a valuable nutritional source of protein intake. The summary table describes the individual species of plants with their climatic requirements, nutritional values , and how to use their edible parts. From these plants, 11 plants, namely: *Nelumbo nucifera*, *Lagenaria siceraria*, *Guizotia abyssinica* (L.f.) Cass., *Hibiscus sabdariffa* L., *Limonia acidissima* L., *Lupinus albus* L., *Rumex vesicarius*, *Vigna aconitifolia* (Jacq.) Marechal, *Macrotyloma uniflorum*, *Phaseolus coccineus* L., *Moringa oleifera* were selected with a protein content exceeding 20 g / 100 g of edible portions. In which it was described in more detail: ecology, botanical description, nutritional values, method of use, amino acids.

**Key words**: protein, plant, neglected, underutilized, crops of the future, aminoacids, Himalayan, nutrition, Asian countries

## Abstract

Tato práce se zabývala alternativními zdroji bílkovin v asijských zemích, jichž část území se vyskytuje v himalájském pohoří. Záměrem práce bylo pomocí výzkumu odborných studií, získaných z elektronických a literárních databázích a zdrojů, shrnout alternativní zdroje rostlinných bílkovin a jejich výskyt ve vybraných zemích. Za himalájské státy byli považovány: Bhútánské království, Pákistán, Nepal, Tibetská autonomní oblast a Indie. Úvodní část práce hovořila o důležitosti rostlinných bílkovin v potravě již od prvních počátků lidské evoluce. Porovnávala, zda rostlinné bílkoviny mohou být považovány za dostatečný zdroj bílkovin. S ohledem na stravitelnost proteinu a počtem aminokyselin kterými je tvořen. Druhá část práce představovala život a zemědělství v těchto zemích, se zaměřením na nejpostiženější horské oblasti. Problémům v jednotlivých zemích, jako je nedostatek potravin, vysoká úmrtnost a chudoba. Třetí část byla věnována souhrnu 54 zanedbaných a nedostatečně využívaných druhů rostlin, které mohou představovat dobrý nutriční zdroj příjmu bílkovin. V souhrnné tabulce byly popsány jednotlivé druhy rostlin s jejich klimatickými požadavky, nutriční hodnoty a způsob využití jejich jedlých částí. Z těchto rostlin bylo vybráno 11 rostlin jmenovitě: *Nelumbo nucifera*, *Lagenaria siceraria*, *Guizotia abyssinica* (L.f.) Cass., *Hibiscus sabdariffa* L., *Limonia acidissima* L., *Lupinus albus* L., *Rumex vesicarius*, *Vigna aconitifolia* (Jacq.) Marechal, *Macrotyloma uniflorum*, *Phaseolus coccineus* L., *Moringa oleifera*, u kterých obsah proteinu přesahoval 20 g ve 100 g porci potravin, u nichž bylo podrobněji popsáno následující: ekologie, botanický popis, nutriční hodnoty, způsob využití a jejich zpracování, aminokyseliny.

Klíčová slova: bílkovina, rostlina, zanedbané, nedostatečně využívané, plodiny pro budoucnost, aminokyseliny, Himaláje, výživa, asijské státy

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## List of the abbreviations used in the thesis

FAO - Food and Agriculture Organization

WHO - World Health Organization

PDCASS - Protein digestibility-corrected amino acid score

DIAAS - Digestible indispensable amino acid score

NUS - Neglected and underutilized species

CFF - Crops of the future

PEM - Protein-energy malnutrition

# 1. Introduction

Ensuring adequate nutritionally rich food is the biggest challenge in the world today. The general concern in the world is caused by malnutrition in humans but also by protein malnutrition. Insufficient protein intake affects 500 million people worldwide. However, this problem is most common in developing countries. It is estimated that more than 10 % (820 million) of people worldwide now suffer from malnutrition (FAO 2019). Mild food insecurity, thus the lack of regular consumption of nutritionally valuable foods, occurs in 17.2 % of the world's population (1.3 billion people). Overall, food insecurity occurs in 26.4 % of the people, which is almost 2 billion people worldwide (Davis & White 2020). Sufficient nutritionally valuable food primarily affects the health of the individual and is essential for the proper function of the human body and its functioning throughout life (WHO/FAO/UNU 2007).

The worldwide calculation shows that every nine people are food insecure, of which in mountainous rural areas, food insecurity occurs every second. It is estimated that about 40% of the world's population lives in mountain areas in developing countries. This percentage shows that almost 300 million mountain residents suffer from food insecurity. In Asian mountain areas, there is a widespread shortage of nutritionally nutritious food, and there is a great deal of malnutrition. More than 192 million people in this area are food insecure. The Asian continent is characterized as the most affected locality with the most malnourished people in the world. It is estimated that more than 515 million (Romeo et al. 2015).

Supplementation, food fortification, or the inclusion of novel foods can lead to zero hunger and malnutrition. Compared to the first two variants, the addition of new, hitherto unused or little-used foods is the most demanding in the long run. However, from an economic, ecological, and sustainability point of view, this option works best. Therefore, the inclusion of novel foods that are underused is the best option to achieve these goals (Imathiu 2020).

# 2. Aims of the Thesis

The objective of this thesis was the investigation of available literature and electronic information sources to analyze the alternative sources of plant proteins and to analyze the traditionally used processing methods compared to a modern one with respect to sustainable development. The specific goal was a comprehensive evaluation of neglected and underutilized plant species as alternative sources of protein. Description of their occurrence and possible use as food.

# 3. Methodology

Data and information were obtained by searching in scientific databases such as Web of Science (www.webofknowledge.com), Taylor & Francis (www.taylorandfrancis.com), ScienceDirect (www.sciencedirect.com), Google Scholar (www.scholar.google.com), FAO (www.fao.org) and e-books ProQuest Ebook Central (www.ebookcentral.proquest.com). This work was focused on plants that had a protein content higher than 20 g / 100 g of edible portion. These plants were subsequently described: ecology, botanical description, nutritional values, method of use, amino acids.

The most used keywords for searching in the databases were: protein, plant, neglected, underutilized, crops of the future, aminoacids, Himalayan, nutrition

# 4. Literature Review

## 4.1. Proteins

Proteins are macromolecular compounds. Their macromolecules are constructed from amino acids that are linked together not only by peptide bonding but also by other species (disulfide, ester). The molecular structure of each protein is characterized by primary, secondary, tertiary, and complex proteins and tertiary structure (Webb 2012). They represent the building blocks of our body and participate in several specific functions. It serves as a building material for all tissues (skin, muscles, bones, nerves, and blood). As enzymes or hormones, they have catalytic, regulatory, and regulatory functions. It serves as an antibody to ensure the body's immunity and protection against pathogens. Other purposes could be for transport or muscle movement (Xu et al. 2011).

Proteins can be used as an energy source in extreme cases where the body cannot draw from other sources. Proteins can be divided into two primary groups according to their composition and structure (Bagchi et al. 2013).

### 4.1.1. Protein composition

Proteins can be divided into two basic groups according to their composition.

#### 4.1.1.1. Simple proteins

Simple proteins contain strings consisting of only amino acids (fibrillar and globular proteins).

**Fibrillar proteins**

They are insoluble in water and perform mainly structural functions. The individual peptide chains are interconnected by crosslinks to form parallel running strands. Examples of fibrillar proteins are collagen or keratin, occurring in hair, skin or nails (Holeček 2006).

**Globular proteins**

They are soluble in water because their chain has a spherical shape allowing the hydrophobic portions of the molecule to be wrapped inside. An example of globular proteins is eg. albumin (Holeček 2006).

#### 4.1.1.2. Compound proteins

Compound proteins contain other non-protein structure (glycoproteins, metalloproteins, chromoproteins, nucleoproteins, lipoproteins) (Holeček 2006).

### 4.1.2. Protein structure

The molecular structure of each protein is characterized by primary, secondary, tertiary and complex proteins and tertiary structure.

#### 4.1.2.1. Primary structure of proteins

It is the unique order or sequence of individual amino acids that are joined together in the polypeptide or proteins. Each protein has a unique primary structure. Different arrangements of amino acids yield different structures with different functions and activities. The primary structure might freely rotate into any shape (Kroschwitz 1990).

#### 4.1.2.2. Secondary structures of proteins

This is a regular arrangement or winding of protein chain segments based on linkages of disulfide, salt, and hydrogen bonds. Thus, it corresponds to the geometric configuration of the polypeptide chain. The individual parts of the protein may have the structure of the folded leaf (β-pleated sheet) or the right-hand helix (α-helix). The formation of these structures allows for hydrogen bonds acting between the functional groups C = O .. H-N (Kroschwitz 1990).

#### 4.1.2.3. Tertiary structure of proteins

The tertiary structure determines the arrangement of the entire macromolecule. It refers to the overall three-dimensional arrangement of its polypeptide chain in space (Engelking 2015). In this structure, we distinguish proteins into globular or fibrillar types. Fibrous proteins fulfil mainly structural functions. They are powerful and hydrophobic. Globular proteins have a spherical shape allowing the hydrophobic parts of the molecule to be wrapped in and therefore are hydrophilic. These shapes are not maintained only by hydrogen bridges but also by covalent bonds such as disulfide bridges, or ionic and hydrophobic interactions can also link them. Particularly noteworthy are disulfide bridges resulting from the oxidation of the -SH groups of cysteine. When we talk about hydrophobic interactions, we usually mean van der Waals force. The most durable bond is certainly disulfide bridges because they are covalent (Kroschwitz 1990).

#### 4.1.2.4. Quaternary structure of proteins

It is a combination of several protein chains or subunits that interact with each other and are arranged to form a more massive aggregate protein complex. The subunits must be specifically arranged to function to the entire protein properly. Any change in the structure of the subunit or the mode of its involvement causes significant changes in biological activity. The final shape of the protein complex is again stabilized by various interactions, including hydrogen bonds, disulfide bridges, and salt bridges. The particles involved in the quaternary structure are non-covalent (Murphy 2001).

### 4.1.3. Amino acids

Amino acids, as the basic building blocks of proteins, are essential for the synthesis of other proteins that are very important for the human body. Amino acids in the human body serve primarily for the development and construction of muscles, but they also play an essential role in the nervous, reproductive, immune, and digestive systems. Protein, along with other micro and macronutrients (e.g., carbohydrates, lipids, minerals) are a prerequisite for human health and well-being (Healthline Media & Red Ventures Company 2005).

Amino acids are organic compounds consisting of nitrogen, carbon, hydrogen, and oxygen with each amino acid having a variable side chain attached to it. This side-chain differs for each amino acid in size, charge, hydrogen bonding, reactivity, and affinity for water. Thus, the structure of the side chain determines the nature and properties of the amino acids. Therefore, the amino acids can be distinguished into three subgroups (acidic, basic, and neutral) (Xu et al. 2011). All amino acids found in natural proteins are L-amino acids since their amino group NH2 is located on the left (Agrawal 2009). In nature, up to 300 amino acids can be found, and even over 240 non-protein amino acids can be found in plants. However, these amino acids do not serve for protein synthesis because they do not have their specific tRNA or codon (Xu et al. 2011). However, only 20 are essential for human nutrition. These 20 amino acids are considered standard amino acids. They are not only used for protein synthesis but are also crucial for the production of hormones and neurotransmitters. All 20 different amino acids must be available to the body for synthesis (Webb 2012).

Essential amino acids, which are indeed essential, must be taken in the diet because our body cannot synthesize them by itself. They are phenylalanine, isoleucine, leucine, valine, lysine, methionine threonine, tryptophan. The most beneficial essential amino acids are animal proteins, most commonly used are meat and eggs. The remaining 12 amino acids are called non-essential. Non-essential amino acids make the body capable of doing so and partly cover their need for the body. These amino acids can be obtained by transamination from amino acids that remain in the body during protein degradation. However, substantial amounts of these free amino acids are metabolized and excreted from the body as CO2, ammonia, and urea (Wolfe et al. 2018). However, part of the amino acids can also be classified into the conditionally important group, are namely arginine and histidine. This is because these amino acids are essential for the human organism at the stage of illness or stress. For example, arginine deficiency in the body affects the proper functioning of cancer control processes (Xu et al. 2011).

#### 4.1.4. The importance of protein in the human body

In nutrition, it is vital that the food proteins provided can deliver the necessary protein the human body needs to survive (Waterlow 1998). The nutritional value of a protein is influenced not only by the nature of the protein but also by other aspects. Proteins are not always present in the same amount in the diet. Their content varies from source to source (Ferranti et al. 2018). The quality of the proteins depends on the amino acid content of the protein. If the intake of some amino acids is limited or deficient, the ability of protein synthesis is limited. This phenomenon occurs despite a sufficient intake of other amino acids because proteins cannot be synthesized without all the amino acids that are written in their constant genetic sequence (Webb 2012). Therefore, the state of the protein in the body is continuously monitored. If its content in the body does not reach the values that need to affect protein metabolism, energy, eating behaviour may also change. The motivation to eat increases, or only foods that are rich in protein are preferred. Alternatively, on the other hand, there may be an aversion to some foods (Tomé et al. 2019). Another factor is the digestibility of proteins, which determines the body's ability to digest proteins and use them for other necessary functions in the body (Ferranti et al. 2018).

Based on the need for dietary protein to ensure the maintenance and all special requirements for growth, reproduction, and breastfeeding, protein needs can be defined as the lowest level of protein intake in the diet that will compensate for body nitrogen loss and thus maintain lean body mass persons in energy balance with moderate levels of physical activity, and, in children or pregnant and nursing women, the needs associated with storing tissues or milk secretion in doses that are in accordance with good health (WHO/FAO/UNU 2007).

#### 4.1.4.1. Limiting amino acids

Plant and animal proteins are different in their differing numbers of essential amino acids. The most critical limiting plant essential amino acids that occur in the diet are lysine, sulfur amino acids, threonine, and tryptophan (Waterlow 1998). Plant proteins are a significant source of cysteine uptake and are also a contributor to glutamic acid (wheat 35 g/100 g). In contrast, animal proteins are a significant contributor to histidine, tyrosine, and leucine (Mariotti 2017).

**Lysine**

Mostly the predominantly amino acid lysine as it is a limiting amino acid mainly in cereals and also in wheat. The first irreplaceable function of lysine is to promote the use of calcium and fatty acids in the body. It is, therefore, closely related to the proper growth and development of bones, especially in children. However, in adulthood, it also regulates the amount of nitrogen in the body and reduces the level of triglycerides in the body. It is essential for the production of antibodies, enzymes, and healing processes in tissues where it helps the production of collagen. The recommended daily dose of this amino acid is estimated to be 30 mg/kg per day (WHO/FAO/UNU 2007).

**Threonine**

The importance of the threonine content in the human state is also crucial, although it is already present in relatively many crops, and its lack is, therefore, not very common. It is found in bones and connective tissue; it is mostly contained in elastin and collagen and especially in cardiac muscle. It is therefore believed to contribute to the strength and elasticity of the binders (ligaments, tissues, cartilage) and the nutrition of bones and teeth. Threonine is also used in the immune and nervous systems - it is involved in the production of neurotransmitters and is an essential component of antibodies (Kohlmeier 2015). Nevertheless, if it is not enough in our body can cause digestive problems and accumulation of fats in the liver, which leads to their failure. Threonine is essential for the synthesis of two non-essential amino acids - glycine and serine. It reaches low values, mainly in cereals (Waterlow 1998). The recommended daily dose should be about 10-20 mg/kg daily (WHO/FAO/UNU 2007).

**Phenylalanine and tyrosine**

Phenylalanine and tyrosine belong to aromatic amino acids. Phenylalanine is an essential amino acid for the body, while tyrosine is synthesized from it. Therefore, it is critical to provide enough phenylalanine to satisfy both amino acid consumption (Kohlmeier 2015). Phenylalanine is, therefore, a precursor of semi-essential tyrosine, which is used to produce neurotransmitters; dopamine, adrenaline and noradrenaline, and to develop thyroid hormones (Klomsiri et al. 2010). 25 mg/kg represents the requirement for daily intake of aromatic amino acids (WHO/FAO/UNU 2007).

### Methionine and cysteine

Methionine and cysteine are classified as sulfur amino acids. These amino acids contain a sulfhydryl group in the side chain. Cysteine can create the body itself, and the source of the sulfhydryl group is just methionine. This synthesis only takes place if sufficient methionine is provided by food. Methionine helps to dissolve fats and prevents their deposition in the liver. It is vital for the proper functioning of the immune and nervous systems. It contributes to the formation of neurotransmitters (adrenaline, noradrenaline, dopamine). The content of sulfur amino acids in pulses and fruits is only marginal, with a higher concentration in cereals and animal diets (Waterlow 1998).

Generally, there is more cysteine in plant proteins and more methionine in animal proteins (Mariotti 2017). The dietary methionine content should be around 10.4 mg/kg per day and 4.1 mg/kg cysteine. Thus, it shows that the total intake of sulfur amino acids should be at least 14 mg/kg daily (WHO/FAO/UNU 2007).

### Tryptophan

The tryptophan content is not very high in the protein diet, but its occurrence is nutritionally essential. It is a precursor for metabolites such as serotonin and nicotinamide. Up to 50 % of niacin is converted daily by tryptophan synthesis. Niacin is converted to nicotinamide in the body. The content of cereals may be limiting, especially in maize, it is found to be very low and is therefore considered to be an amino acid limiting in some cases (Thornton, Whitley 2012). The average daily intake should be 4 mg/kg (WHO/FAO/UNU 2007).

Table 1. Amino acids requirements of infants, children and adolescents (WHO/FAO/UNU 2007)

| Age | Lysine | Threonine | Phenylalanine and Tyrosine | Methionine and Cysteine | Tryptophan |
|---|---|---|---|---|---|
| | mg/kg per day | | | | |
| 0.5 | 64 | 34 | 59 | 31 | 9.5 |
| 1 - 2 | 45 | 23 | 40 | 22 | 6.4 |
| 3 - 10 | 35 | 18 | 30 | 18 | 4.8 |
| 11 - 14 | 35 | 18 | 30 | 17 | 4.8 |
| 15 - 18 | 33 | 17 | 28 | 16 | 4.5 |
| > 18 | 30 | 15 | 25 | 15 | 4.0 |

### 4.1.5. Protein origin

#### 4.1.5.1. Plant protein

Plants constitute a primary resource of carbon, vitamins, minerals, protein, essential fatty acids for humans (Young and Pellett, 1994). Plant proteins differ from animal ones by usually being limited to one or more essential amino acids. This means that particular essential amino acid is not present at all, or its concentration is minimal. Typical limiting amino acids in cereals are lysine, while sulfuric amino acids (methionine and cysteine) are deficient in legumes. Tryptophan and threonine may occasionally be limiting in certain foods. Within plant proteins, the glycine, arginine, phenylalanine, and methionine content are also lower than the animal proteins. In human nutrition, coverage of histidine needs may be insufficient. This amino acid is essential in early childhood, while the adult can synthesize it in a small scale. Thus, in adulthood, histidine can be considered a semi-essential amino acid. Nowadays, it has been proven that proteins can be combined and complement each other (Kasper 2015).

A significant indicator of protein quality is its digestibility. There are antinutritional factors in plant proteins that can suppress protein digestion and thus reduce its efficiency in use. In most types of beans, there is a trypsin inhibitor, which reduces its inhibitory effect during heat treatment. This phenomenon leads to a structural change in the bonds. The frequent claim that the plant protein is not sufficient for the human body has been refuted in experiments when it has been found that for some plants, their purely utilized protein is comparable to some animal proteins (Mariotti 2017). The digestibility of these proteins is 80-90 %. Some plants do not reach these values, such as 75% rice. Meanwhile, several plants have a true digestibility, even several percents higher than wheat or soybean 96 %. Higher digestibility is often achieved with refined products (Siddique & Li, El Solh 2019). The results obtained with amaranth (*Amaranthus* spp.) showed a protein utilization of 89 % of egg protein or lupine (*Lupinus* spp. L.) with a protein utilization of 77 %. This value can be compared with the use of pure protein in beef of 78 % (Mariotti 2017).

In today's world, the most common sources of plant protein are, at the same time, widely consumed, proteins derived from cereals and legumes. Almost 50 % of cereal seed protein serves human needs and is the most important source of essential amino acids in the diet. For example, rice is the staple food for half the world's population and is the second most-produced cereal after corn. India, Indonesia, and Pakistan are the biggest producers (Siddique & Li, El Solh 2019). Thus, plant proteins are sufficient to provide nutrition to healthy adults, even without consuming animal proteins. However, an essential condition is a varied and high-quality diet. In developing countries, the plant diet is often not sufficiently diverse, and therefore in these parts of the body is inadequate protein supply. Since most plant proteins, in these countries, are taken from cereals that contain shallow lysine content (Siddique & Li, El Solh 2019).

#### 4.1.5.2. Animal protein

Wild animals served as a primary source of animal protein at the beginning of human development. With the growth of the human population, the animals were gradually domesticated. The first domesticated animals were probably goats and sheep, almost 9,000 years ago (McCormick 2003). All species of terrestrial, freshwater and marine animals can be classified as animal protein sources. Nearly 200 species of terrestrial animals can be used as a source of protein intake. However, up to 3,000 species can be used as a good source of macro-nutrients from marine wildlife (Nusantoro 2018). At this time, not all animal species in these categories are domesticated yet. Of the terrestrial species, it is only 44. A little more is domesticated in freshwater species, namely 180. The greatest success in the domestication of animals is achieved in marine species (250), as they are predisposed to perfect reproductive capacity. Therefore, their domestication is, in most cases, very successful (Hessel 2018). In foodstuffs of animal origin, their meat is most frequently used, and to a lesser extent, other parts, such as skin, blood, cartilage, or intestines, are also used for human food. However, these parts are rarely consumed (Nusantoro 2018).

The animal diet is a supplier of high quality and highly digestible protein, well absorbable micronutrients, and essential fatty acids (Neumann et al. 2014). At the same time, it is perceived as a source of excellent energy for the human body. The human body is unable to synthesize essential amino acids on its own. Therefore, these amino acids must be derived from food. Consequently, it obtains the necessary amino acids from food. Amino acids are an integral part of all structural and functional proteins involved in the construction of muscles, internal organs, and bones (Smil 2013). Compared to the plant diet, according to some studies, there are more high-quality proteins and related essential fatty acids, but mostly more vitamin A and D, iodine, zinc, and calcium (Adesogan et al. 2019). The animal diet also contains more iron and is the only one to provide vitamin B12 (Mariotti 2017). Vitamin B12 is an indispensable nutrient essential for DNA synthesis. Vitamin B12 deficiency secondarily affects the folate cycle, with the consequent impairment of purine and pyrimidine synthesis necessary for DNA and RNA production. It also plays a vital role in hematopoiesis, which is essential for the development of the central nervous system in childhood and is involved in the production of nucleic acids. Vitamin B12 deficiency in adults causes, for example, macrocytic anemia, affection of the posterior and lateral ropes of the spinal cord, peripheral nerves, and dementia or depression (Pawlak et al. 2013).

The advantage of obtaining animal protein is a perfect inclusion in conditions where it is not possible to grow plants, which in today's world represents 57 % of the earth's land. In 2016, 25 % of proteins came from animal sources. In recent years, however, livestock production has been facing environmental pollution problems, and the idea of reducing the need for meat products and replacing them with vegetable ones has been supported (Adesogan et al. 2019). This new type of diet is called a flexitarian diet. The menu consists mainly of vegetable dishes, but still consumes animal products. However, their consumption is limited to the recommended doses for a healthy diet, precisely because of the awareness of the link with the environmental impacts of animal production. Flexitarians have a much more flexible diet than people with vegetarian or vegan food (Raphaely & Marinova 2014).

The recommended daily protein intake is calculated according to the ideal protein, which contains equal values of all essential amino acids and is easily digestible. In most cases, protein is used as the protein in chicken eggs or cow's milk. Protein consumption in modern times should be from 101 g per day. If the body does not have a sufficient source of carbohydrates and fats, the energy begins to draw on the stored proteins. This condition is called protein malnutrition (Smil 2013). In developing countries, very high prices for animal products often cause the under-consumption of animal proteins. This makes animal protein inaccessible to a large number of people (Gomes Almeida Sá et al. 2020). This phenomenon very often occurs in low-income countries. Data from 2010 attributed malnutrition to approximately 13 % of the world's population, equivalent to approximately 925 million people (Smil 2013).

Insects could become a cheap and readily available alternative to animal protein in these countries. The use of insects as a good source of food is called Entomophagy, and in recent years this type of food has been given great importance. Insects have been used for consumption since the beginning of human development. In some, mostly more inferior parts of the world, this food component is still used to a lesser extent. It serves as a supplement to an unbalanced diet, which people are not able to secure in their conditions and mostly as an excellent source of protein (Patel et al. 2019). A considerable number of known edible insects are nutritionally comparable to commonly consumed animal foods such as chicken, pork, and beef or fish (Kasolo et al. 2018). The advantage of using insects as a protein is its perfect reproduction, the conversion of the food obtained, and also the use of less land than in livestock. In insects, the conversion values of food protein to processed body mass are reported to be about 53-73 %, while in livestock, it is 10-12 %. It is, therefore, mainly used for its excellent nutritional properties as a source of energy, proteins, minerals, and fats. It is considered a very nutritious meal. Edible insects provide in 100 g from 217 to 777 kcal, which can match the energy values of farm animals, which are 165 to 705 kcal/100 g (Kasolo et al. 2018).

Insects can be consumed at all possible stages. However, there is a noticeable difference in nutritional composition at different stages of development. The nutrient content is not only influenced by the developmental stage but also strongly depends on the type of insect and sex. It also depends on the diet, which is fed the insects. Or the final processing in the kitchen before human consumption. Variants for the treatment of edible insects are large quantities. Insects can be consumed as cooked, fried, baked, or extruded. In some countries, the hymns also do not heat and consume it raw. The protein content is, therefore, different for each insect species. Predominantly, edible insects have values between 35 % and 61 % of the protein content. Insects are considered to be a good source of protein mainly because of their excellent protein digestibility, which is around 67 % - 98 %. It can achieve these values due to the high percentage of essential amino acids (46% - 96 %) (Imathiu 2020).

In Central African countries, insects are widely used as a source of high protein intake. More than 50 % of the protein in their diet is obtained through the consumption of edible insects (Imathiu 2020). Today, trying to stop perceiving insects only as food for the poor, and try to integrate them as an alternative source of protein into the diet of the people of developed countries. So far, it is mainly about expanding knowledge about their nutritional benefits (Patel et al. 2019).

### 4.1.6. Proteins in human evolution

From the zoological perspective, all people living on our planet belong to Homo sapiens. This species has a subfamily of humans (Homininae), which, together with four other subfamilies, belong to the family Hominidae , superfamily Hominoidea, suborder higher primates (Anthropoidea) and order Primates (Bryl & Matyáštík 2000). The beginnings of evolutionary processes in human morphology and behaviour began to form during the Pleistocene period (2.5 million to 11,000 years ago). The origin of Homo sapiens dates back to 200,000 years since the period corresponds to fossil finds. Humans have been hunter-gatherers for a very long time of their kind. Until the development of agriculture in the early Holocene, 11,000 years ago (Veile 2018).

Nutrition was the most critical part of the health and development of the human race. The origins of the human diet are derived from the diet of higher primates. Predominantly, they preferred plant products as a source of food in their diet. Some species combined with plant food with insects or minimal amounts of animal meat. Fossil findings show that this type of diet persisted for early bipedal hominids, a period of 6 to 2 million years ago. In this period, an essential part of the diet was underground tubers, nuts, and seeds. The increase in animal meat values increased only in Homo habilis and Homo erectus, who were already able to hunt. However, a great deal of evidence confirms a significant, perhaps prevalent, dependence on the diet of plant products (Konner & Eaton 2010). The most likely reason that plants predominate in prehistoric men's diet is that they remain in place permanently, only changing their occurrence during different seasons (Lev et al. 2005). In most cases, they have no way to defend themselves against their consumption. Collecting and gathering are not nearly as dangerous or stressful as hunting with imperfect weapons (Mariotti 2017).

Most often, food was searched for contained the most needed nutrients and did not have to spend too much energy on it. This diet had to contain balanced nutrients providing sufficient energy and eight essential amino acids: valine, leucine, isoleucine, phenylalanine, tryptophan, lysine, methionine, and threonine (Armelagos 2014). Another important criterion was the method of processing and preparation of the food found. The raw materials were usually consumed within a few hours after collection. In most cases, they were not treated at all or very rarely and often were not heat-treated (Food and Nutrition Board, 1989). From wild plants, it became most comfortable to find various kinds of fruits, which were a common source of vitamin and sugar. Another prevalent diet was leaves, shoots, and seeds. From fruit trees, for example, *Pyrus syriaca*, *Pistacia palaestina*. Nuts are an excellent source of vegetable oils. Their numerous occurrences on-site proves that the direction of pistachio nuts (*Pistacia atlantica*) was frequent. In 100 grams of *Pistacia vera*, a very closely related species, approximately 19 g of protein is 54 g of fat. Their net calorific value is 594. Pickers must use a large number of fruits and vegetables to provide food. In one of many places, there were often more than 100 species (Lev et al. 2005).

Scientists have developed many methods for testing aspects of Homo Sapiens to show different ways of eating. It is mainly an analysis of biological adaptations (size, shape, and structure of teeth and biomechanics of jaws) and evidence related to the influence of food consumed based on the single individuals during their life (tooth wear and chemical composition of tissues). Based on these facts, possible models of food adaptations of the oldest representatives of our family have been developed. These models emphasize different dietary sources that they believe may have played a vital role in the development of food adaptations of the genus Homo (Ungar & Teaford 2002).

The most widespread hypothesis is that the diet was most fleshy. Proteins were mainly obtained from meat from large hunted animals. This theory suggests that meat accounted for at least 40 % of the diet at that time (Wrangham 2013). There are, however, several theories that attach importance to the consumption of plant foods in the early stages of human development. One of them deals with diet in connection with the evolution of the human brain. The brain of the hominids had to grow three times within two to three million years. During this, he was able to withstand conditions where much more energy had to be delivered to the body to enlarge the brain. At the same time, nutrients are vital for the brain of mammals, so nutritional nutrition has to be increased. In order to avoid energy constraints, increased energy was obtained from food. One source of this energy can be, above all, meat intake. Although meat has a higher energy density than plants, it does not provide the brain with the necessary energy. Because amino acids come from proteins, the brain cannot use it properly. One option is to convert the amino acid to glucose, but this reaction provides the brain with energy for only a short time. Increased meat intake is, therefore, not considered to be part of the brain tissue growth fuel (Cunnane & Crawfordb 2014). It is assumed that the diet consisted of 65 % of the plant diet and 35 % of the diet of animal origin. The daily energy intake is estimated at 3,000 kcal (12,558 kJ). With such high energy intake, our ancestors should receive most of the minerals and vitamins in much more significant amounts than currently recommended. Compared to today's vegetarians, they have an even higher income. Moreover, their consumption of vegetables, fruits, and berries is 2.6 times higher than the corresponding omnivores (Eaton et al. 1997).

Other paradigms deal with the issue of obtaining food from a coastal habitat. Here, the hominids found an accessible and extensive selection of foods that provided the brain with a supply of particular nutrients to develop the human brain. The food available on the coast contains a high source of iron, iodine, zinc, copper, selenium, vitamins A and D. There were also plenty of nutritious plants, crustaceans, molluscs, amphibians or bird eggs. The advantage of the coastal diet for hominids was the unnecessary high manual and cognitive skills. Therefore, it was not necessary to produce primitive weapons from stones or knowledge of fishing (Cunnane & Crawfordb 2014).

Another hypothesis claims that people are well adapted to receive high starch content in the diet. According to their estimates, up to 50 % or more of the calories from all over the world would come from starch. High starch foods such as tubers, rhizomes, seeds are widely used on all continents around the world. This theory is supported by duplication of the genes of amylase, an enzyme that cleaves starch. People are better equipped to take more starchy foods (Wrangham 2013).

Fifteen edible plants with edible underground organs were found around the Kebara cave in Israel. These include (*Asphodelus ramosus*) dandelion (*Taraxacum cyprium*), field eryngo (*Eryngium creticum*), bindweed (*Calystegia sepium*), belfry (*Campanula rapunculus*) and wild radish (*Raphanus raphanistrum*). Edible rhizomes or tubers found in the following plants were also consumed: *Cyperus rotundus*, *Glycyrrhiza glabra*, *Hordeum bulbous* (Lev et al. 2005). The highest concentration of plant residues was found near the grinding stone, which was probably used for processing plants for consumption. 78% of the burnt residues identified were predominantly in the legume family (Papilionaceae). Proteins are commonly found in this family, and therefore, most of the seeds found in this cave were from the Papilionaceae family, 83 %. For example, *Astragalus echinus, Cicer pinnatifidum, Hymenocarpos circinnatus, Lathyrus hierosolymitanus, Lens* sp.*, Pisum fulvum / Vicia palaestina, Scorpiurus muricatus, Trifolium* sp.. Pulses are believed to be the primary source of plant proteins, which accounted for 33-50 % of their daily food intake. Remarkably few grains discovered belonged to the family of cereals (Poaceae). Several seeds were found in caves in different places. For this reason, it is assumed that the food was stored and prepared at different locations that served these procedures. A large number of plant seeds of the following taxa have also been found in Ohalo, Israel: *Atriplex rosea / leucoclada, Avena barbata / sterilis, Bromus brachystachys, Galium tricornutum, Hordeum spontaneum, Malva aegyptia / parviflora / fruticose* and *Triticum dicoccoides* (Snir et al. 2015).

### 4.1.7. Quality of protein in the diet

Several indicators evaluate the quality of protein assessed. Among the basic ones are indicators based on the measurement of nitrogen values, whose proteins are the primary source. Examples include the Biological Value (BV), the Net Protein Utilization (NPU), and the nitrogen balance. Over time, the Amino Acid Score (AAS) and the Essential Amino Acid Index (EAAI) have proved to be more accurate, informing us about the representation of each amino acid. Moreover, the content and ratio of essential and non-essential amino acids are the basic parameters for evaluating the quality of proteins since protein synthesis requires their presence. Several methods used these properties to measure protein quality. However, more than 50 years ago, it was found that the biological value of a protein, which is the amount of protein absorbed from the diet used to synthesize human body proteins, can be determined by the appearance of an essential amino acid compared to human needs (Stuparič 2017).

**Protein digestibility-corrected amino acid score (PDCASS)**

Food and Agriculture Organization (FAO) and the World Health Organization (WHO) have adopted this method as the preferred method for measuring the value of proteins in human nutrition. It is based on the observation of an essential amino acid, which occurs at the lowest concentration compared to human needs and is therefore considered to be a limiting amino acid. According to this, the chemical quality score of the protein can be calculated as a ratio of the amount in the test protein to the reference sample protein. This method compares the amino acid content of the test protein with a reference protein, such as an egg protein that has a high biological value (Bender 2012). This method evaluates the essential amino acid composition of a protein in the diet and its true faecal digestibility. The comparison spectrum of amino acids is derived from the requirements for essential amino acids of preschool children (Schaafsma 2000). The chemical score thus obtained is corrected by the actual digestibility of the test protein (in stool). If PDCAAS values are less than 100 %, this means that the protein is not able to provide sufficient amino acid supply that is necessary for body requirements. PDCAAS values greater than 100 % are rounded (reduced) to 100 %. Vegetable protein sources have not yet achieved results above 100 % in this method, except for soy proteins. The lowest value for these proteins was achieved for wheat gluten, for which PSCAAS was only 25 %. These results are probably due to a lower protein digestibility compared to animal sources. However, it also takes into account the inadequate occurrence of essential amino acids that are important to the needs of the human body (Berrazaga et al. 2019).

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**Digestible indispensable amino acid score (DIAAS)**

We consider it a new method for determining the quality of proteins in the human diet, published in 2013 by the FAO, since it replaced the old 1991 process called PDCAAS. DIAAS is determined based on true digestibility, which determines the relative digestible content of essential amino acids (IAA - Indispensable Amino Acid) and the specific requirements for them. Therefore, this method better reflects the real nutritional value of proteins for humans than the PDCAAS method itself. The DIAAS method also enables a more accurate evaluation of the resulting protein quality in a mixture composed of different protein sources (Berrazaga et al. 2019). Studies have also shown that DIAAS appears to be more accurate, particularly in the case of particular milk and plant protein sources, and provides more precise information concerning digestibility. Thus, the main factor in assessing the quality of food proteins is the amino acid composition, digestibility, and protein availability (Berrazaga et al. 2019).

Protein foods, which have a large amount of all essential amino acids, are said to be sources of high-quality proteins. These include food of animal origin as well as several plant foods, including soy, quinoa, and amaranth. Other plant protein sources usually have all essential amino acids, but the amount of one or two amino acids may be less (Marsh et al. 2009). From available studies, it was established in 1981 that a different balance of protein intake in males and females in adult subjects was not necessary. The recommended daily dose does not match all the publications. The best estimate of the average population requirement for healthy adults is estimated to be 0.66 g/kg per day of protein (WHO/FAO/UNU 2007).

In contrast, due to possible variability among human subjects, a safe protein level has been identified for the majority (97.5 %) of the healthy human population. This calculated dose corresponds to 0.83 g/kg per day (WHO/FAO/UNU 2007). This means that if a woman weighs 55 kilos, for example, she would have to take 46 g of protein per day in her diet (Smil 2013). In pregnant women, it is recommended to increase protein intake to 1.9 g per day during the first trimester. As pregnancy progresses, the recommended protein intake increases up to 31g in the third trimester (WHO/FAO/UNU 2007). In the lactation phase, the daily maintenance dose during the initial six months of lactation is 20 g of protein per day. After this phase, protein intake may drop to 12.5 g of protein per day (Elango & Ball 2016). The required safe level of protein intake in infants is 1.31 g/kg daily up to 6 months of age. In one year, the average protein intake of a child is 1.14 g per kilogram, which is then reduced to a daily intake of 0.9 g/kg, which is suitable for children under ten years (Smil 2013).

Vegetable proteins are very beneficial in recovering children from severe malnutrition if a properly balanced mix of vegetable proteins is supplied. Nutrition with plant proteins can provide the necessary nutrients to maintain the health and functionality of the body. However, it is essential to provide appropriate amounts and combinations of proteins. The lysine above is the most frequently limiting amino acid, therefore ensuring its necessary dose for the human organism is essential. To achieve the required dose and utilize protein efficacy, and thereby provide sufficient protein at the recommended daily dose, the diet could be composed, for example, of cereal proteins that account for 55 % of total protein intake. An additional 30 % would be divided between animal and pulse proteins. This ratio can be variable, 15 % of each can be used. Nevertheless, it is also permissible to use 40 % pulse protein and 6 % supply animal (Waterlow 1998).

#### 4.1.7.1. Protein deficiency

A constant problem in the world is high malnutrition, poor health, starvation, and hunger. Approximately 800 million people suffer from the insecurity of food and nutrition, a problem that affects the developing countries where the disadvantaged are located. Malnutrition of protein-energy is most often caused by the insufficient food supply, general poverty, but also by poor sanitary conditions (Heimburger et al. 2000). Poor nutrition is caused by the incorrect consumption of essential nutrients that are not consumed due to a lack of food. Additionally, by eating food that does not provide sufficient nutrient content, and it thus does not meet the daily nutritional requirements for them (Baldermann et al. 2016). The right balance between nutrient intake and nutrient needs is considered a healthy nutritional status. If there is an imbalance between them, malnutrition can occur. It manifests changes in metabolism, organ function, and body composition (Heimburger et al. 2000).

There may be a loss of growth, loss of muscle mass, or weakening of immunity. It is also the cause of anemia, iron or iodine deficiency, and blindness can occur. However, the consequences of inadequate nutrition can also lead to a weakening of the heart or respiratory system, and in very severe cases, death can occur (Harvard T.H. Chan School of Public Health 2020). Most of these symptoms are associated with diseases like kwashiorkor, marasmus, and dwarfism (Heimburger et al. 2000). Child malnutrition is different from malnutrition in adult individuals. In children, it affects their development and growth at their most crucial stage. Nutritional status can be observed by comparing the baby's weight to its height, revealing wasting syndrome. Wasting syndrome is a disease that causes loss of muscle and fat tissue. Another way to detect malnutrition is by comparing the height of the child to its age against the recommended standards. This disease is called stunning. The manifestation is underdeveloped by the brain, leading to future consequences in the child's life. It may lead to having reduced mental abilities, a lower predisposition to excellent learning, and the associated poor performance at school. It may also be at higher risk of obesity, diabetes, or hypertension in adult life (Heimburger et al. 2000). Protein-energy malnutrition (PEM) The problem of protein deficiency is prevalent in third world countries, where energy and protein resources are often limited.

The visual appearance of people with protein deficiencies is fragile as muscle mass is lost. Swelling may also occur (Marcus 2013).

The problem with the occurrence of illnesses associated with inadequate nutrition mainly concerns low- and middle-income countries. Animal feed is usually complicated to access in these countries (Baldermann et al. 2016). The animal diet contains nutrients that are essential for the human body. They are vitamin B12 and A, iron, zinc, and iodine. Failure to deliver them in the required quantities could result in poor neurological development that is associated with brain disorders, depression, dementia, and autism (Adesogan et al. 2019). Meat is globally considered to be a perfect nutritional diet that provides high protein values while increasing protein retention in the body. Unfortunately, for a large number of the population, it is unavailable because of its cost (Waterlow 1998).

There is a possibility of using neglected crops, which can bring an additional source of protein, micronutrients, and vitamins to a poor diet. Including such crops in the diet of residents who do not have sufficient access to animal proteins could contribute to improving nutrition in low-income areas. Most of the time, this problem occurs in the countryside where people are dependent on their crops. It serves not only as a source of financial income but also primarily as a source of food for their entire family (Baldermann et al. 2016).

#### 4.1.7.2. Excess protein intake in the diet

However, malnutrition can also be achieved by an excessive amount of protein in the diet, as proteins can displace other vital nutrients such as carbohydrates. At the same time, it gets a lot more calories, fats, and cholesterol into the body. Renal and hepatic impairment may begin. There is higher urinary excretion of calcium, which must then be replaced in the diet. If calcium is not given, calcium may be drained from the bones and blood. Also, more sodium can accumulate in the body as this mineral is part of a protein diet. A high amount of this element could be severe for disrupting the sodium and potassium balance in cells and blood (Marcus 2013).

In today's modern developed world, this is precisely the opposite problem. Instead of protein deficiency, many people are struggling to consume excessive amounts of protein, mainly animals. There is more meat consumption than safe levels. The intake of pure protein is about 3.0 g/kg and only from food. People also use dietary supplements that add about 1 g/kg. This exceeds the recommended daily dose of protein, which, according to experts, should not be more than twice the daily dose (WHO/FAO/UNU 2007). It is complicated to establish a link between food intake and disease risk. So far, it is only assumed that a diet with a higher intake of animal protein, primarily derived from meat, is associated with a higher risk of cardiovascular disease and cancer (Ortolá et al. 2020). Otherwise, it could be seen as a precursor of other conditions such as obesity, hypertension, diabetes, stroke, rheumatoid arthritis, multiple sclerosis, lupus, gallstones, atherosclerosis. , diverticulitis, foodborne diseases, osteoporosis, immune system disorders, allergies, and asthma (Mariotti 2017).

Recent research has addressed the diversity of plant and animal proteins in the diet and their impact on health outcomes. They concluded that different types of protein have different effects on results. They attribute beneficial effects on health promotion or disease prevention to plant proteins, while animal proteins predominantly showed poor clinical results (Ortolá et al. 2020). Their excessive consumption can cause various health problems, from metabolic to kidney damage (Cunnane & Crawfordb 2014). Animal protein, which is consumed at a high rate, leads to increased loss of calcium from the urine, which can cause osteoporosis. Consumption of red meat is also associated with coronary artery disease that leads to coronary artery disease. This is probably the most widespread, but at the same time, an uncertain risk to consumers (Heimburger et al. 2000).

Increased consumption also increases the risk of cancer, a typical example being colon cancer. According to World Cancer Research Fund and the American Institute for Cancer Research, the recommended dose of red meat is 500g per week or to maintain an average annual consumption per person of about 25 kg (Smil 2013). A diet high in meat usually contains a higher content of unsaturated fatty acids, which affect cholesterol elevation. Cholesterol is accumulated on the walls of the blood vessels, thereby impairing blood flow. This phenomenon contributes to a higher likelihood of heart attack by up to 40 %. It is precisely due to the high incidence of cholesterol, that excessive meat consumption is associated with coronary heart disease, as well as with the occurrence of fats, which are associated with the risk of colon cancer. In people with high cholesterol in the blood, it can be reduced by nearly 10 % by dietary changes if animal proteins are eliminated and replaced with plant proteins (University of Nottingham 2019). The plant diet contains less saturated fats and cholesterol, higher in fibre, magnesium, and potassium, vitamins C and E, folic acid, carotenoids, flavonoids, and other phytochemicals, all of which may contribute to reducing disease (Melina et al. 2009).

Excessive meat consumption is increasing worldwide, as many countries are becoming more abundant thanks to the emerging economy, such as India, Brazil, or China. Due to the global influence of Western countries, their inhabitants are trying to imitate the Western lifestyle. They are relieved of their typical diet, which consisted mainly of cereals, pulses, roots, and tubers, and passes to meat consumption. This leads to much higher adverse health and social outcome (Raphaely & Marinova 2014).

## 4.2. Mountains in developments regions

The mountains cover 22 % of the Earth's surface or 32 million $km^2$. They are an essential part of a quality of life to all the inhabitants of the country, as providers of 60-80 % freshwater on earth. Mountain areas serve as home to one-tenth of the world's population, accounting for approximately 915 million people living in the mountains, of which 90 % of the population live in developing countries (Romeo et al. 2015). Mountain resident people are mainly poor people who are marginalized, so hunger is a common and ordinary occurrence in these areas. Around 300 million people in mountain areas suffer from insufficient food intake, of which about half are affected by chronic hunger (Siddique & Li, El Solh 2019). It follows that 39 % of the population living in mountain areas suffers from vulnerability to food insecurity. A severe problem also shows that almost 45 % of rural people do not have sufficient access to food. It can, therefore, be assumed that every third inhabitant of mountain areas in developing countries is at risk of food insecurity and hunger (Romeo et al. 2015).

Worldwide, food insecurity in developing countries was attributed to 329 million (39%) inhabitants of mountain areas. These calculations were 30 % smaller (253 million) in 2000. These records are a significant indicator of deteriorating conditions in mountain areas, as the population in these areas increased by only 16 % between 2000 and 2012 (Romeo et al. 2015). Food vulnerability is taken as the likely inability of an individual or family to ensure food safety and adequate nutrition about external conditions. These include, for example, lack of access to markets due to poor infrastructure, low purchasing power, good food use, dietary diversity, poor sanitary conditions, lack of drinking water. Individuals who consume less than 1,370 calories and 14g of protein per capita in daily intake are at risk of food insecurity. A protein intake value, which is considered safe, is also established in these countries. It is determined that the intake of 58 g of protein per adult is sufficient for the healthy function of the organism (FAO Food Security Programme 2008).

The inhabitants of these countries are dependent on agriculture since it means for them both food and livelihood for them and their families. Agriculture in mountain areas is, in many ways, very restrictive for the people there. Initial cases are reduced availability, shorter time to crop because of a climate other than the lowlands, environmental conditions or considerable distance, and limited infrastructure for the transport of goods to the market. However, mountain farming has an excellent predisposition to growing large amounts of nutritious foods that are not sufficiently grown in the lowlands as a result of using this land for crop plants. There is a large number of neglected and underutilized species (NUS) in these areas that could be used as future intelligent foods. This becomes possible if we focus on their excellent nutritional values and perfect adaptation to the changing environmental and climatic conditions (Siddique & Li, El Solh 2019).

People living in the mountains make much more use of natural resources such as land, water, and biodiversity. This is very high in mountain areas. There is almost one-third of the plant species of the world. There are also 17 hotspots out of a total of 34 that are globally divided. This represents nearly 50 % of global biodiversity. Hotspots are areas with a high concentration of rare, endangered, and above all, relict and endemic species (Mittermeier & Rylands 2018).

### 4.2.1. Asia

In Asia, one-third of the planet's mountain cover occupies 35 % of the Asian mainland. The mountains of the Asian region are the most populated mountain areas. About 52 % of the world's mountainous population lives here. The Asian Mountains provide freshwater to nearly 2 billion people who live on the rivers of the most critical Asian rivers that originate in the Himalayas (World wildlife fund 2020). In the Asian mountains, there are great biodiversity hotspots. There are almost 5,000 species of vascular plants and other related wild crops, which is a quarter of the case that occurs only in this area (The critical ecosystem partnership fund 2017).

In 2012 more than 192 million mountain populations were vulnerable to food insecurity. These values have increased by 26 percent since 2000 (Siddique & Li, El Solh 2019). This shows an increase of 40 million people who do not have sufficient food intake. While the population of these countries has increased by only 8%, this increase in food insecurity was mainly reflected in Central, South, and West Asia, where it grew by almost 50 %. In the Himalayan countries, there is a regular lack of micronutrients; Insufficient intake of a balanced diet leads to increased infant mortality and also higher maternal mortality. Hunger and malnutrition in mountain areas are not seen as the first signs of upcoming poverty. Poverty is only sustained by these influences (Romeo et al. 2015).

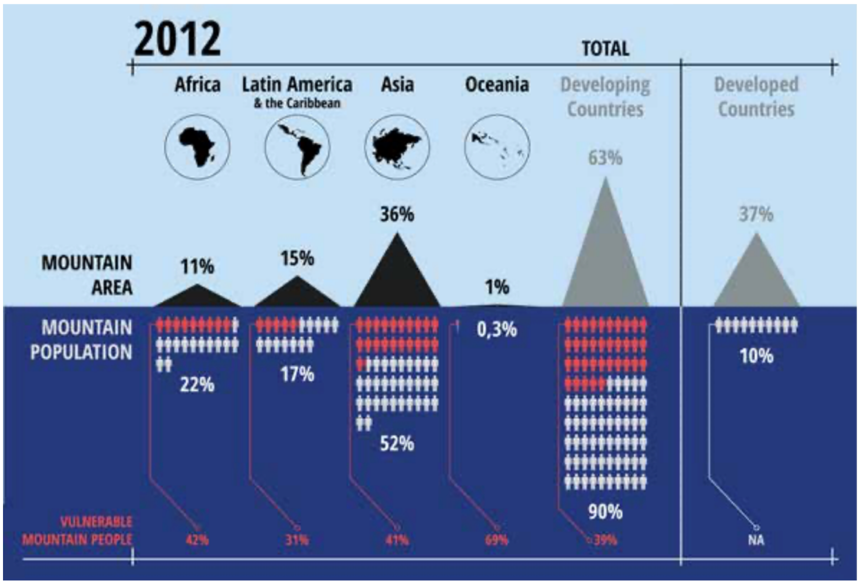


Figure 1. Mountain areas, population and vulnerability of food insecurity in 2012 (Romeo et al. 2015)

### 4.2.2. Himalaya mountains

The Himalayan mountain range is considered to be the youngest mountain range in the world. It originated 60 million years ago when the Asian and Indian lithospheric plates collided. However, the Himalayas have had the highest increase in height over the last two million years. Uninterrupted growth of this mountain range continues until today in the presence of frequent earthquakes. The oldest part of the Himalayan mountain range is located in the north, while in the south, there are younger parts of this mountain range (Zurick et al. 2006). The range extends to India, Nepal, China (Tibet), Bhutan, and Pakistan, with a length of 3,800 km and a width of up to 250 km. The area is complicated to determine, but it is around 650,000 $km^2$ (Ives 2004). The human population is present in more than 47 million people. Most of these inhabitants live in the middle zone of the mountains, which is located at an altitude of 1,500-4,500 meters (Zurick et al. 2006).

The Himalayan region can be divided into several respects. One possibility is based on the fact that the mountain range is naturally divided by the flows of large rivers; The first breakdown by the Indus rivers bounding the Himalayas from the west and the Brahmaputra (Yarlung-Tsangpo) in the east is now considered obsolete. Furthermore, the division by region does not correspond to the natural division of the mountains. The most frequently used division is nowadays considered geological division according to geological structure and relief. According to this geological division, the Himalayas are divided into four zones from north to south - the Tibetan zone (the outer edge of the Tibetan plateau), the large Himalaya (the highest, snow-capped peaks) of the small Himalayas (predominantly the middle zone) (Zurick et al. 2006).

The Himalayas are rich in diverse climates, terrain and are considered to be the most diverse region on Earth due to their vast size and geographical dimensions. The western part of the mountains is dry, and the temperatures are almost year-round low. In the preferred area, there is a subtropical climate, and there is an enormous amount of precipitation on Earth. There is colossal temperature, and precipitation jumps throughout the Himalayas. This is also due to different altitudes, which affect different climatic conditions and, thus, different vegetation zones across the surface of the mountains. The average temperature difference per kilometre of altitude is 6.4 ° C. Since altitude variations can reach up to 8,000 meters, temperature changes can be compared to temperatures that occur from tropical regions to the Arctic Circle (Zurick et al. 2006).

The Himalayas were exposed to intense human activity nearly 7,000 years ago (Miehe et al. 2009). In the early beginnings of land cultivation, mountain populations began to grow barley (*Hordeum vulgare*) and buckwheat (*Fagopyrum esculentum*), followed by other crops such as wheat (*Triticum aestivum*), millet (*Panicum miliaceum*) and peas (*Pisum sativum*) (K. Pandit 2017).

### 4.2.3. Himalaya state

The Himalayan states include countries whose considerable part of the country made up of the Himalayan mountains. Countries like Bhutan or Nepal have Himalayan mountains in almost their entire territory. In India and Pakistan, mountain areas are located in the north of the country. The last land belonging to the Himalayan states is the autonomous region of Tibet, which lies almost entirely on the Tibetan plateau and is closed to the south by the Himalayas (Murton 2019).

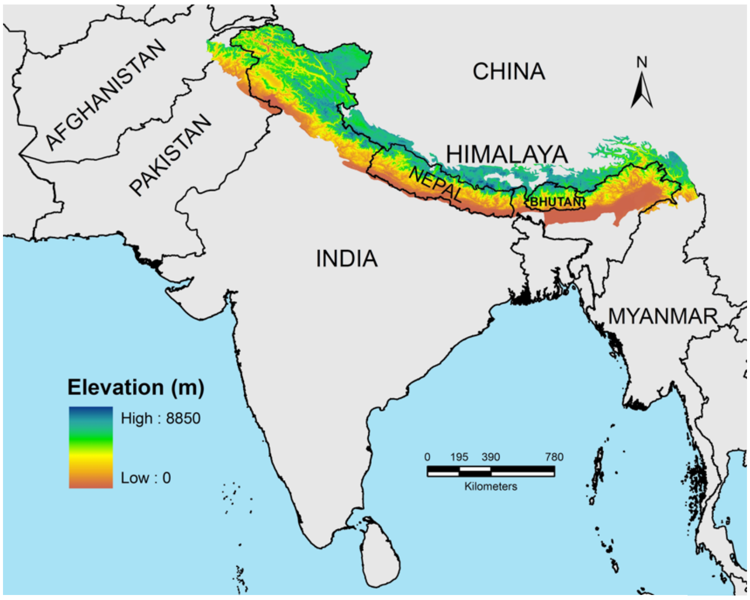


Figure 2. Himalayan states (Manish & Pandit 2018)

#### 4.2.3.1. Kingdom of Bhutan

Bhutan is a small landlocked country with an area of 38,394 square kilometres and a population of 754,394 in 2018 (The World bank group 2019). It is located in South Asia at the eastern end of the Himalayan mountains. From the north, it borders China (Tibet) and India on the rest of its borders (Hidano et al. 2016). Most of the country's territory, nearly 50 %, occurs at an altitude of over 3,000 meters. The elevation has a rising gradient from 100 meters above sea level, on the southern border with India, to over 7,500 meters in the north with China (Siddique & Li, El Solh 2019). The country has more climate zones thanks to this extreme altitude climb, which is only 170 km wide. There is a subtropical zone, which is typical of the lowlands in the south of the country. To the north, it becomes mild, with deciduous and coniferous forests. The last climatic zone is alpine, where alpine pastures and glacier peaks occur (Tempa et al. 2019).

The economy in Bhutan is considered one of the least developed in the world. It depends mainly on agriculture and forestry, which serves as the main livelihood of 80 % of the country's population. Agriculture is practised by individuals with small farms with an average size of 1.36 ha, who are dependent on natural resources such as forests, streams, and meadows. Usable arable land is only 112,549 ha across the country, which is only 3 % (Tshewang et al. 2017). The remaining area is covered by forest cover, spanning almost 73 % of the total land area. Alternatively, it is unsuitable for use in agriculture (Rahut et al. 2015).

The population density in Bhutan has a lower density than other countries in the western and central Himalayas. The most populated are valleys in the middle mountains, where enormous potential for land use for agriculture (Zurick et al. 2006). In 2015, the rural population represented 61 % of the total population. Of these, a third of them live below the poverty line (Herberholz & Phuntsho 2018).

Food insecurity and malnutrition are most often found in rural settlements. According to a study conducted in 2015, 21 % of children under the age of 5 had a reduced rate of growth in human development, and 4 % of children experienced wasting. The incidence of anemia was 48 % highest in children under five years, 34 % in pregnant women, and the lowest percentage in young people aged 10 - 19 years (Romeo et al. 2015).

Agriculture in this country is greatly influenced by different height ranges across the country. This is mainly due to the variety of microclimate affecting the crops being grown. The traditional low-input farming system is prevalent in Bhutan. Farmers own only a small amount of arable land, which very often is not very agriculturally beneficial. The most cultivated crops in Bhutan are rice (*Oryza sativa* L.), maize (*Zea mays* L.), and wheat (*Triticum aestivum* L.). Together, these crops represent 96 % of food grain production and represent the leading socio-economic security of agriculture for rural communities (Tshewang et al. 2016). The most widely grown crop is rice because if farmers have enough of it, this can mean important food intake for them. However, rice is more related to the culture of Bhutan than it is as a food safety crop. It has a vital role in traditions, in religion, and thus in the daily lives of local people. In 2017, rice was grown on an area of 21,471 ha (Bajgai et al. 2019). Wheat is considered to be one of the most important staple crops. However, its production is in Bhutan only three places after rice and corn. This is mainly since its yield in this country is not high due to worsened conditions such as poor soil fertility or insufficient external inputs. For this reason, wheat was grown only on an area of 1,505 ha. For example, the maize fields occupied an area of 22,909 ha (2017) (Tshewang et al. 2017). Mountain areas also serve for livestock breeding. They do not usually serve as a source of meat but use milk, wool, and manure. Indeed, the authorization for killing and running slaughterhouses must be authorized by the government in Bhutan because the believer part of the population must not defeat a living animal because of their faith. Therefore, there are not many slaughterhouses in Bhutan, and most, almost 90 % of the beef is imported from other countries (Hidano et al. 2016).

#### 4.2.3.2. Pakistan

Pakistan is an Asian country with an area of 79,610 $km^2$, located in South Asia. The population in 2018 was 212,215,030 million and ranked this country as the sixth most populous in the world (Ataullahjan et al. 2019). Almost 61% of Pakistan's area is mountain and mountainous, home to nearly 50 million people (Siddique & Li, El Solh 2019). The population in Pakistan is not evenly distributed across the country, but some parts of it are only very sparsely populated. Whereas some places here, reach the highest population density in the world, such as Karachi or Lahote (Weiss & Khattak 2013).

Differences in the climate are due to the different altitudes in this country, from sea level to 8,611 meters above sea level (Ali et al. 2020). In the northern Himalayas, temperatures reach -13 °C in winter, while they do not exceed 20 °C in summer (Khan et al. 2019). Forests in Pakistan are only 5 %, as more than 60 % of the Himalayan forests have been deforested in the past 30 years. If we compare the coverage of forests in other Asian countries, their common area is 30 % of their total area (Ali et al. 2020). This phenomenon was caused by high population growth and the use of wood as a fuel. The mountain population increases by 5 % every year, and they also use wood as a building material. Because of the cold climate in these conditions, this material is increasingly being used to build homes, and this leads to faster depletion of resources (Hussain et al. 2019).

More than 60 % of the country's population lives in rural areas. Poverty and illiteracy are widespread among these people, and their health is influenced by poorly available or poor-quality drinking water and related hygiene. Poverty is a significant problem for this country. Almost 23 % of the population is below the poverty line, and nearly two-thirds spend less than 2 $ per day (Weiss & Khattak 2013). Moreover, around 25 % of Pakistan's population has no access to electricity (Biresselioglu et al. 2019).

In 2014, according to the World Food Program, more than half of the population did not meet the recommended caloric intake of 2,100 kcal per person per day. Food insecurity and malnutrition occur in almost 47 % of the population (Kirby et al. 2017). Of these, malnutrition occurs in more than one-third of children under five. Stunning in children under the age of five was shown by 45 % in 2013 and wastage in 15 % (Syeda et al. 2020).

65 % of the population live in villages, and their primary source of income and subsistence is agriculture. This represents an improvement in living conditions for a large part of the population, as agriculture is the primary source of Pakistan's economy and development. The main crops are wheat, maize, sugar cane, and cotton (Ali et al. 2019). Rice and wheat account for 53 % of the recommended caloric intake, while traditional crops represent only 0.22 %. Millet, barley, and sorghum are considered traditional crops in Pakistan (Siddique & Li, El Solh 2019). Economic development in Pakistan is also very much linked to livestock production. However, the development of the livestock industry is not sufficient, as people here do not have adequate knowledge about animal diseases and coping with the illness. Therefore, there is a frequent incidence of disease in animals that they cannot prevent (Nasreen et al. 2020).

#### 4.2.3.3. Nepal

Nepal is a country located in South Asia, having borders in the north with China and the rest of the country sharing borders with India. Its area is 147,181 $km^2$, and the population according to the world bank in 2018 was 28,087,871 million. Most of the population, nearly 80 %, live in the country (Sürmeli et al. 2020). The relief of this landscape is very different, on the southern side of the country, the altitude is about 60 meters above sea level, while on Mount Everest the altitude it is 8,848 meters and is the highest peak in the world. The width between the southern and northern ends of the country is only 140 km. Therefore, there is a different climate in different parts of the country (Khanal et al. 2020). The southern part falls into the tropical climate, with temperatures around 22 - 27 °C in summer and around 10-15 in winter. In the north, the climate is the Arctic, where in summer, it is around 10-15 °C, but in winter, the temperature is below zero (Bhandari et al. 2020). Due to the high biodiversity in Nepal, there are almost 6,076 species of flowering plants, and many others are not yet discovered due to the lack of exploration of poorly accessible sites (Tiwari et al. 2019).

The landscape of Nepal can be divided into three areas: mountains covering 68 % of the land area, hills 15 %, and Terai (marshy lowland) 17 %. Terai is the most populated area, mostly due to quality soil, which is very fertile due to the loess deposits from the Himalayas. Almost half of the Nepalese population lives here. The area under cultivation is about 27 % of the land, and forests make up 40 % and pasture 17 % (Khanal et al. 2020).

A large proportion of the population lives in mountain areas but has declined over the years. Nevertheless, they produce 42 % of the total plant production in the country. Mountain areas are characterized by their approach to traditional agriculture, with 80 % of the population still using conventional farming practices (Adhikari et al. 2019).

Nearly 54 % of Nepal's population is in food insecurity, most of them living in mountainous areas. Where they regularly do not have enough food due to inadequate crop production, non-existent, or inferior infrastructure, poor drinking water supply, or poor hygiene (Khanal et al. 2020). In Nepal, various natural disasters often occur, from earthquakes to floods caused by monsoon rains. These disasters have an impact on the well-being of local people and impair the availability of food. The recommended daily caloric intake for the Nepalese population is 2,220 kcal per person (Adhikari et al. 2019). Remarkably, 37 % of children under five years of age suffer from malnutrition and stunning in this country (Sürmeli et al. 2020). Rice, wheat, and corn make up the central calorie intake in the daily recommended intake of almost 62 %. While NUS accounts for only 3.84 % of the daily calorie intake. The following are used as NUS: millets, barley, buckwheat, black gram, and horse gram (Siddique & Li, El Solh 2019).

Moreover, it is these crops that are the main crops that are grown in Nepal at higher altitudes (Siddique & Li, El Solh 2019). They are considered traditional and are used in traditional agriculture. The conventional farming system contributes to the maintenance of agrobiodiversity, helps good soil fertility, and serves nutritious and diverse food for the population. This maintains the development of agriculture, which serves to ensure sufficient food intake and alleviate poverty (Adhikari et al. 2019).

#### 4.2.3.4. Tibet autonomous region

Tibet, as a province of the People's Republic of China, is located mainly on the Tibetan Plateau, making Tibet the highest region in the world. The Tibetan Plateau is considered the largest in the world. Its area is about 2.5 million $km^2$, and the average altitude is about 4,000 meters above sea level (Wen et al. 2019). Some sources call it an Asian water tower, due to its glaciers and snow, which are covered by the main streams of Asian rivers such as the Yangtze, Yellow, Mekong, Salween, Brahmaputra, Indus, Sutlej. These rivers serve as a source of subsistence for more than 40 % of the world's population (Sun et al. 2019). The total area of Tibet is 1.2 million $km^2$, with an average altitude of about 3,000 m in the south of Tibet and about 4,500 m in the north (Zhao et al. 2008). It shares borders in the south and India, Nepal, Bhutan and the north with China. In 2017, Tibet's population was 3.4 million (Sun et al. 2019). Almost the majority of the population (64 %) in Tibet occurs in the four capitals of Lhasa, Shigatse, Nyingchi, and Naqu. The rest of the areas in Tibet are populated very sparsely (Wang et al. 2020).

On the plateau, temperature gradients occur over short distances, causing climatic conditions to be affected. Temperature, precipitation, and soil fertility are affected (Wang et al. 2019). The most typical for the Tibetan landscape is dry and semi-dry areas, which make up 70-80 % of the total area, as the whole area is in the rain shade.

Despite unfavorable climatic conditions, there are many plants (Fu et al. 2020). For example, the southeast region is very rich in biodiversity. There is one of the world's 34 hotspots (Yang et al. 2020).

The beginnings of settling the Tibetan plateau began approximately 2,100 years ago. The inhabitants lived on primitive agriculture and respected the landscape and its natural conditions. With population growth in recent years and urbanization, there has been a change in the landscape ecosystem (Sun et al. 2019). Agriculture serves as the main livelihood of 90 % of the country's population (Zhao et al. 2008). It provides the population with sufficient food and ensures the intake of critical nutritional values such as sufficient fibre. However, they also use agricultural residues as fuel (Brown & Waldron 2013).

As the living conditions are challenging in the Tibetan region, there is a high percentage of poverty, almost 24 % (Wang et al. 2019). Nutritional nutrition in this country is not proper. In 2001, over 51 % of children under seven were severely stunted. If we compare the situation with the whole of China, where the percentage of stunted children is only 17 %, this situation is dire. A study conducted in children under 36 months confirmed insufficient and inferior nutritional nutrition. Almost two-thirds of the children had rickets (Singh 2004).

Tibetan agriculture consists of two parts, namely plateau farming and lowland farming. The primary plants grown on the plateau are high mountain barley, wheat, peas, potatoes, buckwheat, and rapeseed. At the same time, lowland farming produces rice, maize, and all kinds of vegetables, especially in southeast Tibet. The most cultivated crops are, therefore, mainly spring barley and winter wheat, because they are well resistant to low temperatures in this area (Romeo et al. 2015). In 2010, cereals accounted for 71 % of the total sowing area. Oilseeds occupy 10 % of the sowing area. In recent years, the percentage of fodder crops has increased in the Tibetan crop rotation by almost four times. Most used are lucerne, maize, vetch, and oats. Fodder crops are most often grown on lower-yielding soils, while quality soils are used for cereals or other crops that serve food. Farmers usually use their cultivated products for their livelihoods or as feed for cattle. Alternatively, they exchange their products with other households or sell for profit (Brown & Waldron 2013). At the same time, farming is combined with livestock farming, which is grazed on vast plains. Between most the farmed animals include Yak, sheep, and Tibetan goats. It serves as a source of milk and meat. Meat from farm animals is mainly consumed in winter or at special celebrations. However, only some specialized households can defeat (Romeo et al. 2015).

#### 4.2.3.5. India

The area of India is 3,287,469 km$^2$ and is the seventh-largest country in the world. In the east, India borders on Bangladesh and Burma. It borders on China, Bhutan, and Nepal in the north and northeast. It borders Pakistan in the northwest. Its population of 1,353 billion makes it the second-most populous country in the world (The World Bank Group 2019). The Himalayan regions are located in 12 % of India (Tali et al. 2019). Moreover, they provide a home to 34 million people. They can be divided into the north-western Himalayas, which occupy 331,392 km$^2$ and northeast with an area of 262,179 km$^2$ (Siddique & Li, El Solh 2019). From the west, they reach Jammu and Kashmir, Himachal

Pradesh, Uttarkhand, Sikkim, and end in the east by Arunachal Pradesh (Worni et al. 2013).

There are six different climatic types in India. There are deserts in the western part, while the northern part is typical of the alpine climate, where we observe tundra and glaciers. In the southwestern part of India, there is a humid tropical climate with rainforests (Siddique & Li, El Solh 2019). At an altitude of about 2,500 m, the climate of temperate and subalpine forest occurs in the Indian Himalayan mountains. This altitude climate is typical of the western part of the mountains with the states of Himachal Pradesh, Uttarakhand and Jammu, and Kashmir (Chauhan et al. 2018). Temperatures in this area range from -4 to 20 °C in winter months and around 30 °C in summer (Ballesteros Cánovas et al. 2017). Land for agricultural purposes is located at 16 %, and approximately 69 % of the Himalayan area can be used for pastureland as it is desolate forests or meadows. The forests cover about 23,300 $km^2$ of the region of the Indian Himalayas. The remaining 15% are areas permanently covered with snow, providing enough water for lowland areas (Siddique & Li, El Solh 2019).

In the mountains of India live 80 % of the population of India, their primary source of income is agriculture, but above all, they serve to provide food for them. However, the majority of farmers in mountain areas manage only one hectare of land (Ali et al. 2020). The population living at lower altitudes is not exclusively dependent on agriculture, although it is still their primary source of income and livelihood. Their work commitments are associated with the authorities, or their hotels or are in the tourist industry (Murali et al. 2019).

A large number of the population living at higher altitudes suffer from food shortages due to deteriorating soil quality and thus reduced crop production. These shortcomings lead to the overall poverty of these people, as they do not have enough crops for their livelihood and cannot sell and profit from the surplus (Siddique & Li, El Solh 2019). In India, malnutrition is the leading cause of deaths among children under five years of age, under 68 % of all children under five years of age. Stunting was seen in 40 % of children and wasting in 16 % of children born (Swaminathan et al. 2019).

The most significant percentage (76 %) of fertile land is used for grain production. The most used crop is wheat, corn, and rice. Other marginal areas are intended for planting vegetables, fruit, legumes, millet, buckwheat, amaranth, saffron, and oil crops.

Traditional crops are barley (*Hordeum vulgare*) and peas (*Pisum sativum*), which is mainly grown as feed for cattle (Murali et al. 2019). Since climates from subtropical to alpine are found in the mountain region, many varieties of fruit trees can be grown under these conditions. In India, there is a large variety of fruit, mainly varieties: mandarin, sweet orange, mango, guava, banana, lychee, apple, peach, plum, pecan, walnut, cherry, almond, strawberry, kiwi (Siddique & Li, El Solh 2019). Livestock is an integral part of alpine agriculture. Around 50 million farm animals are probably kept in India. The most common are cattle, goats, buffaloes, and sheep. The breeding of these animals serves as a source of dairy products, wool, manure for farmers. The use of livestock for the source of meat is not very common (Murali et al. 2019).

## 4.3. Neglected and underutilized crops

The first mention of neglected and underutilized species (NUS) appeared as early as 1999. In which described plants wild in nature, but within society was underutilized and undervalued. The term underutilized is mainly used to emphasize their untapped potential for better livelihoods in terms of excellent nutritional properties. Furthermore, these crops are also described as neglected, and this indicates low interest in research and improvement of their development over the community crops that are most commonly used in the modern world as a food source. Common synonyms that are used for these species may be crops of the future (CFF), foods of the future, traditional foods, under-used, under-exploited, under-developed, orphan, promising, lost, alternative, classical, niche crops (Kasolo et al. 2018). Underutilized crops are crops that can alter the potential of humanity to improve living conditions. Include more under-utilized crops in humankind´s diets and increase their cultivation could lead to improved nutritional needs. For example, improving the food supply for the poor in the world, food safety, and nutrition, reducing the occurrence of hidden hunger (Crops For the Future (CFF). A lack of vitamins and minerals causes that. The monotonous diet that causes this problem is not rich enough in the necessary micronutrients. The lack of these nutrients causes limited growth, development, health, and malnutrition (WHO 2014).

Beginning with the cultivation of crops around the world, it has gradually led to the domestication of most species of wild plants. Domestication occurred in all parts of the world, but at different times, by 25,000 BC, the diversity of both domesticated crops and animals was very high. With an increasing demand for food as a result of population growth, it has led to more significant investment in research and development, which has focused only on a minority of crops and animals (Kasolo et al. 2018). There are approximately 400,000 plant species in the world, of which nearly 30,000 are edible. Seven thousand species could potentially be used by humans, representing only 2 percent of all plant species. However, of this massive value, about 200 species are used for commercial purposes (Siddique & Li, El Solh 2019). Only 20 plants shield the worldwide supply of plant food. Of which maize, rice, wheat are three crops that humanity regularly uses to feed. They represent over 50 % of calories and 56 % of plant proteins used in human nutrition (Armelagos 2014). Also, all the attention and investment are transferred to these plants to focus on research and development (Notaro et al. 2017). Neglected and underutilized species are therefore very often unheeded, especially in terms of global production, as they are less critical for the market than other primary crops, which are also more interested (International Plant Genetic Resources Institute 2003). This shows the lack of attention and the use of tens of thousands of edible plant species that could contribute to improving living conditions (Notaro et al. 2017). They forget about their excellent nutritional properties, are underestimated, and their use is continuously decreasing. They experience genetic erosion and complete disappearance in some species, which could reduce their propagation and improve their properties (Ghane et al. 2010).

Current mountain farming consists of only a minimal number of plant species (Siddique & Li, El Solh 2019). Farmers prefer to replace traditional crops (buckwheat, millet, barley) with crops that are more profitable for them (mustard, cardamom, fruit, coffee) (Adhikari et al. 2019). The trend of growing these crops has led to a decrease in interest in traditional despite their excellent nutritional properties and adaptability. This has led to a reduction in diversity in diet and plant production and is due to increased malnutrition in mountain areas (Singh et al. 2019).

NUS are abundant crops that can be grown outside the season, can be used as a supply for year-round use. They can be planted among other crops or rotated with frequently grown plants. They are doing very well on marginal soils despite their low-profit potential, often poor nutrient soil or other undesirable properties. This is due to both natural and human choice, which puts them in an advantage over the main crops in these hostile conditions (Raneri et al. 2019). The advantage of traditional plants is the knowledge of their species by local people, easy accessibility, and use of their typical environment (Crops For the Future (CFF). Often their under-utilization is due to limited knowledge of cultivation by local farmers (Singh et al. 2019). Although the vast majority of crops are indigenous, semi-domesticated, or wild (Nguyen & Vu 2017) and therefore, there are no problems in growing under standard local climate (International Plant Genetic Resources Institute 2003). So far, these plants are grown very often in places where the soil is not very suitable for primary crops such as the maize, as mentioned earlier, wheat, and rice (Crops For the Future (CFF).

For NUS crops to be classified as future smart food, they need to meet both nutritional and climatic conditions. The most crucial criterion is sufficient nutrient content, which leads to improved nutrition. Plants must also be climate resistant or adaptable. Economical and easy to obtain in local conditions. Future smart food can bring many benefits to mountain areas because their content of both macronutrient and micronutrient is higher than in usually used crops in the mountains. Their adaptability and resistance to climatic conditions, such as drought, lower temperatures, high weather conditions, is perfect (Siddique & Li, El Solh 2019). They are also very tolerant of biotic stresses, which can be pests or diseases. They can adapt very well to stress conditions and thus be more resistant to production. This is ensured by low water and soil nutrient requirements. These properties are very beneficial for poor farmers. As they do not have to use pesticides, they cannot afford it when growing NUS (Kasolo et al. 2018). Thanks to their excellent nutritional value, FSF can serve to improve the livelihood of local people and become an essential source of protein, micronutrients, energy, and fibre (Siddique & Li, El Solh 2019). The reintroduction of these species into the crop rotation could help to overcome the problems of nutritional insufficiency, ensure nutritious food and improve the overall economy of rural people (Ghane et al. 2010).

NUS is often mistaken for the food of the poor and forget their extraordinary benefits (Singh et al. 2019). The aim is to show the potential of traditional plants, raising awareness of them for all customers and thus increasing demand. In Nepal, for example, conventional crops are promoted in supermarkets where millet cakes or buckwheat flour can be purchased (Siddique & Li, El Solh 2019).

### 4.3.1. Plants as source of protein

In this work, it was analyzed 54 kinds of plants which are found in Himalayan states. Most of the plants, 31 species, can be grown above 1,500 m.a.s.l., and are therefore suitable for areas with higher altitudes. The most numerous representative in this analysis was the Fabaceae family with twelve plant species. The second most represented group of plants was the family Cucurbitaceae. Seeds, leaves, and tubers were characterized as parts of the plants with the highest protein content. Fruits, pods, nuts are less nutritionally rich parts, but they can also be suitable for human nutrition. More detailed data on all plants are shown in Table 2.

Table 2. Selected plants

| | English name | Scientific name | Local name | Family | Part of crops | Protein g/100g | Temperature (°C) | Rainfall (mm) | Altitude (m.a.s.l.) | Edible parts / Mode of use | Countries | Reference |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1) | Drumstick | *Moringa oleifera* | Sahinjan - Nepal<br>Sohanjan - Pakistan<br>Si-Gru - Tibetian<br>Mungna - Hindi | Moringaceae | pods<br>leaves - fresh/dry<br>seeds | 2.0<br>6.7 / 27.1<br>46.6 | -1 - 48 | 250 -3,000 | 0 - 2,000 | Fruits– young eat as a vegetable, older added to sauces, made a paste by crushing and fried<br>Seeds – fried, make oil | India, Nepal, Pakistan, Bhutan, Tibet | 1., 2., 3., 4., 5., 6. |
| 2) | Finger millet | *Eleusine coracana* | Ragi - India<br>Koddo - Nepal | Poaceae | grains | 7.4 | 11 - 27 | 500 - 1,000 | 2, 500 - 3,000 | Grains – food cereal, flour for the preparation of porridge, "cakes",raw cakes can be stored for several days | India, Nepal, Bhutan | 7., 8. |
| 3) | Faba bean | *Vicia faba* L. | Bakulla - Nepal<br>Hawaii-amubi - India<br>Jangli mattar - Pakistan | Fabaceae | seeds - raw | 4.8 | 13 – 30 | 650 – 1,000 | 0 - 3,000 | Seeds – dry, mature, raw immature or pods, boiled, eaten as a vegetable | India, Pakistan, Nepal | 9., 10., 11., 12., 7., 6. |
| 4) | Foxtail millet | *Setaria italic* | Kaguno - Nepal<br>Kangni - Pakistan | Poaceae | grains | 11.0 | 5 - 35 | 300 - 400 | 0 - 2,000 | Grains – husked, cooked, eaten like rice, ground into a flour and made bread porridges and puddings, sprouted seed eat as a vegetable | Pakistan, Nepal, Bhutan, India, Tibet | 13., 14., 7. |
| 5) | Barnyard millet | *Echinochloa frumentacea* | Sanwa - Hindi | Poaceae | grains | 11.0 | 10 - 35 | 450 - 1,000 | 0 - 2,000 | Seeds - cooked, ground into a flour, eaten as a porridge | India, Nepal, Pakistan, Tibet, Bhutan | 15., 16., 17., 18. |
| 6) | Job's tears | *Coix lacryma-jobi* | Adlay- India<br>Baru - Hindi<br>Bhirkoulo - Nepal | Poaceae | grains | 14.1 | 10 – 28 | 600 - 4,300 | 1,600 - 2,100 | Grains – husking, roasted, boiled, eat alone or mixed with rice, ground into a flour and used to make porridge, cakes, soups | India, Bhutan, Nepal, Tibet, Pakistan | 7., 19., 20., 21. |
| 7) | Sword bean | *Canavalia gladiata* (Jacq.) DC. | Tabare simi - Nepal<br>Lalkududumpal - Hindi | Fabaceae | pods | 2.7 | 15 – 30 | 700 – 4,200 | 0 - 900 | Flowers, young leaves, green pods, and seed – edible after cooking<br>Young pods – raw, cooked | India, Nepal | 6., 15., 22. |
| 8) | Scarlet bean | *Phaseolus coccineus* L. | Lobia - Pakistan | Fabaceae | seeds - dry | 20.3 | 15 - 22 | 1,500 | 1,500 – 2,000 | Pods - green and young are boiled, steamed sauteed Flowers - used in salads Leaves - potherbs Seeds - dry, green, boiled | India, Nepal, Pakistan | 7., 23., 24. |
| 9) | Sacred lotus | *Nelumbo nucifera* | Kamala - India<br>Kanwal - Hindi | Nymphaeaceae | seeds<br>roots | 16.6 - 24.2<br>1.5 | 6 - 36 | 700 - 4,000 | 0 - 1,400 | Roots – raw, cooked, stews or fried, ground to flour, sliced pieces – candied or pickled | Pakistan, India, Bhutan, Nepal, Tibet | 25., 26., 27., 28., 29. |

(continued)

Table 2. Selected plants (continued)

| English name | Scientific name | Local name | Family | Part of crops | Protein g/100g | Temperature (°C) | Rainfall (mm) | Altitude (m.a.s.l.) | Edible parts / Mode of use | Countries | Reference |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 10) Tamarind | *Tamarindus indica* | Imli - Nepal<br>Ambliki - India | Fabaceae | seeds | 2.8 | 12 - 45 | 1,500 | 0 - 1,500 | Fruit pulps – fresh, raw, condiment, spice<br>Young greens tamarind – pickled<br>Seeds – roasted, boiled, fried, ground to a flour | India, Nepal, Pakistan | 6., 15., 30. |
| 11) Elephant foot yam | *Amorphophallus paeoniifolius* | Ol - Nepal<br>Ol kachu - Indie | Araceae | tubers | 1.2 | 20 - 35 | 1,000 - 1,500 | 0 - 750 | Leaves, young shoots – cooked as a vegetable, potherb<br>Tubers – baked, boiled, fried, pickles | India, Nepal | 15., 31., 32. |
| 12) Swamp taro | *Cyrtosperma chamissonis* | Akhi - Hindi | Araceae | tubers | 0.9 | 15.5 – 38 | 2,500 | 0 - 600 | Tubers – boiled, steamed, roasted, fried, for longer storage scald and dry in the sun, ground to a flour Leaves, young and flowers – cooked as a vegetable | India, Pakistan | 32., 33. |
| 13) Chayote squash | *Sechium edule* (Jacq.) Sw. | Iskush - Nepal<br>Chow chow - India | Cucurbitaceae | fruits<br>leaves<br>seeds<br>tubers | 0.8<br>2.6 – 4.8<br>5.50<br>2.0 – 10.4 | 13 - 21 | 1,500– 2,000 | 300 – 2,000 | Tubers – eat as a vegetable, boiled, raw, steamed, baked, fried, pickled<br>Fruits – eat as a vegetable, raw or boiled, fried<br>Seeds – fried of roasted<br>Young leaves – boiled, steamed | Nepal, India, Bhutan | 5., 6., 34. |
| 14) Greater yam | *Dioscorea alata* L. | Ratalu - India<br>Tarul - Nepal | Dioscoreaceae | tubers | 5.2 | 26 - 34 | 1,000 - 1,500 | 0 - 2,700 | Tubers - boiled, baked, fried, dried, roasted can be processed into flakes or flour | India, Bhutan, Nepal | 35., 36., 37., 38., 39. |
| 15) Rice bean | *Vigna umbellata* | Marsyam - Nepal<br>Rawaan - Pakistan<br>Bejiamah - Inda | Fabaceae | seeds | 19.3 | 10 - 40 | 700 - 1,700 | 200 - 2,000 | Seeds – mature, dried, eat as a pulse, boiled, the dried germinating seeds are made into flour<br>Leaves, young pods, sprouted seeds – boiled and eaten as a vegetable, young pods can be eaten raw | Bhutan, Nepal , India, Pakistan | 40., 41.,42. |
| 16) Indian gooseberry | *Phyllanthus emblica* L. | Amala- Nepali, Hindi<br>Kyou-rhoo-rah - Tibet | Euphorbiaceae | fruits | 0.5 | 10 - 40 | 630 - 800 | 800 - 1,500 | Fruits – fresh, cooked, dried, pickled<br>Seed pods - cooked | India, Nepal, Tibet, Pakistan | 15., 43., 44., 45. |
| 17) Rosella | *Hibiscus sabdariffa* | Laalchandan - Nepal<br>Lal ambari - India | Malvaceae | seeds<br>leaves | 33.5<br>3.3 | 12.5 - 27.5 | 130 – 250 | 0 - 600 | Young leaves, stems - raw, cooked, added to the salad, boiled, used as a condiment, potherb, spices<br>Seeds - roasted, ground into a powder, oil Blossoms - raw, cooked, roasted, used as a flavor | India, Pakistan, Nepal | 5., 46., 47. |
| 18) Snake gourd | *Trichosanthes cucumerina* L. | Chichinda- Hindi<br>Cicindo - Nepal<br>Jangli Chachinda - Pakistan | Cucurbitaceae | fruits | 0.6 | 30 - 34 | 700 - 4,200 | 0 - 1,500 | Fruits – young is cooked and eaten as a vegetable<br>Leaves – cooked and eaten as greens<br>Seeds - ground to flour, seed oil | India, Nepal, Pakistan | 6., 48., 49., 50. |

(continued)

Table 1. Selected plants (continued)

| English name | Scientific name | Local name | Family | Part of crops | Protein g/100g | Temperature (°C) | Rainfall (mm) | Altitude (m.a.s.l.) | Edible parts / Mode of use | Countries | Reference |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 19) Wood apple | *Aegle marmelos* (L.) *Correa* | Bael - Nepal | Rutaceae | fruit | 2.1 | 0 - 48 | 570 - 2,000 | 0 - 1,200 | Pulps – used as fruit or vegetable, fresh, pickled, preserved<br>Young leaves and shoots – raw as vegetables, condiment | Nepal, India, Pakistan | 43., 51., 52. |
| 20) Elephant apple | *Limonia acidissima* L. | Bela - Hindi | Rutaceae | pulps<br>seeds | 7.1 - 8.0<br>26.1 | 20 - 29 | 800 - 1,200 | 0 - 450 | Fruits - raw, dried and ground into powder<br>Young leaves - raw used in salads | India, Pakistan | 53., 54. |
| 21) Perilla | *Perilla frutescens* (L.) Britton | Silam - Nepal<br>Bhangjira - India | Lamiaceae | seeds | 18.0 | 8 - 35 | 1,200 - 5,000 | 350 - 3,300 | Seeds - raw, spices, preserved in salt, ground into powder, oil Fresh plant - spicy vegetables, flavor for fish<br>Leaves - raw, cooked, used as a vegetable, dried for later use, spice<br>Seedlings - added to salat | India, Nepal | 55., 56., 57., 58. |
| 22) Bitter gourd | *Momordica charantia* | Teeta karela - Nepal<br>Karela - Hindi | Cucurbitaceae | fruits | 1.0 | 24 - 27 | 1,000 - 4,000 | 0 - 1,500 | Fruits - mature, unripe<br>Leaves and young fruits - steamed or roasted and eaten as a vegetable<br>Young shoots and leaves - eaten as greens | India, Nepal | 6., 59., 60. |
| 23) Jamun | *Syzygium cumini* | Jomuna - Hindi<br>Ber - Pakistan, India<br>Dza Mbu - Tibet<br>Jaambu - Nepal | Myrtaceae | fruits | 0.7 | 12 - 48 | 900 - 1,000 | 0 - 1,200 | Fruits - raw, unripe used for vinegar, rubbing or soaking in saltwater used for more mediocre fruit<br>Young leaves - eaten as a vegetable | India, Nepal, Pakistan, Tibet, Bhutan | 61., 62., 63., 64., 65. |
| 24) Indian jujube | *Ziziphus mauritiana* | Bindin - India | Myrtaceae | fruits | 0.8 | 10 - 42 | 400 - 1,500 | 0 - 1,000 | Fruits - raw, cooked, pickled, boiled, stew, baked, dried and ground into a powder Leaves - cooked as a vegetable Seeds - raw | India, Pakistan, Nepal, Bhutan | 66. |
| 25) Kokum butter tree | *Garcinia indica* | Ramboostan - Hindi | Clusiaceae | fruits | 4.7 | 20 - 36 | 2,500 - 4,000 | 0 - 800 | Fruits - raw, cooked, dried, spices, processed into a drink Seeds - oil, butter | India | 67., 68. 69. |
| 26) Rambhutan | *Nephelium lappaceum* | Sitaaphal - Nepal | Sapindaceae | pulps | 0.8 | 20 - 32 | 2,000 – 3,000 | 0 -1,600 | Fruits - fresh, stewed, cooked, pickled Seeds - roasted, oil | India, Nepal | 70., 71., 72., 73. |
| 27) Custard apple | *Annona squamosa* L. | Hindi sharifa - Pakistan<br>Ghar Tarul - Nepal | Annonaceae | pulps | 1.2 – 2.4 | 10 - 30 | 500 - 1,000 | 0 - 1,000 | Pulps - fresh, pulp used in dessert, fermented to prepare beverages | Nepal, India,Bhutan, Pakistan | 74., 75., 76. |
| 28) Dioscorea | *Dioscorea deltoidea* | Gun - Hindi<br>Kanis - Pakistan<br>Kause simi- Nepal | Dioscoreaceae | tubers | 1.6 | 10 - 34 | 1,200 -2,000 | 450 - 3,100 | Tubers - cooked, eaten as a vegetable | Nepal, Pakistan, India, Tibet, Bhutan | 77., 78., 79. |
| 29) Seabuckthorn | *Hippophae rhamnoides* | Chiraunji - Hindi | Elaeagnaceae | leaves | 17.1 | -40 - 40 | 250 - 800 | 1,200 - 5,500 | Seeds - oil Fruits - fresh, cooked, making fruit juice Leaves - green powder used for baking, smoothie | Tibet, India, Nepal, Bhutan, Pakistan | 80., 81., 82., 83. |

(continued)

Table 1. Selected plants (continued)

| English name | Scientific name | Local name | Family | Part of crops | Protein g/100g | Temperature (°C) | Rainfall (mm) | Altitude (m.a.s.l.) | Edible parts / Mode of use | Countries | Reference |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 30) Almondett seed | *Buchanania lanzan* | Chiple ningro - India | Anacardiaceae | seeds | 19.0 | 23 - 25 | 700 - 4,000 | 0 - 1,300 | Fruits - pulp, raw, dried fruit can be mixed with seeds and used to make bread, drying prolongs storage<br>Seed - raw, roasted, cooked, oil | India, Nepal | 64., 84., 85., 86. |
| 31) Vegetable Fern | *Diplazium esculentum (Retz)* Sw | Paloi - Hindi<br>Pani niuro - Nepal | Athyriaceae | leaves | 8.7 | 15 - 30 | 250 -3,000 | 0 - 2,300 | Young leaves - cooked as a vegetable<br>Tubers - boiled, steamed, raw | India, Nepal | 5., 87., 88. |
| 32) Lamb's quarter | *Chenopodium album* L. | Bathua sag - Hindi<br>Bathwra - Pakistan<br>Snergod - Tibet<br>Adavi dumpa- India<br>Bethe - Nepal | Chenopodiaceae | leaves<br>seeds | 4.3<br>16.0 | 5 - 30 | 300 - 400 | 0 - 3,600 | Young shoots and leaves - used as a vegetable, boiled, dried for later use | India, Nepal, Bhutan, Pakistan, Tibet | 5., 89. |
| 33) Aerial yam | *Dioscorea bulbifera* | Githa - Nepal<br>Su ka ri - Tibet | Dioscoreaceae | tubers | 3.1 | 12 - 38 | 1,000 - 4,000 | 0 - 2,300 | Tubers - cooked, baked, boiled, fried, produce starch, and flour<br>Inflorescences - raw<br>Bulbils - boiled | India, Bhutan, Tibet, Nepal, Pakistan | 39., 90., 91. |
| 34) Green pigweed | *Amaranthus hybridus* | Barella - Nepal<br>Dantu koora - India | Amaranthaceae | leaves<br>seeds | 2.4 - 3.7<br>14.0 | 8 - 35 | 200 - 1,200 | 0 - 1,400 | Leaves, young seedlings -raw, steamed, fried, cooked as a leafy vegetable, potherb, ash can be used as vegetable salt<br>Seeds - raw, cooked, roasted, cereal substitute, ground into a flour and used to prepare porridge or bread | India, Nepal, Bhutan, Pakistan, Tibet | 5., 90. |
| 35) Balsam apple | *Momordica balsamina* L. | Kareliya - Hindi<br>Wal - India | Cucurbitaleae | fruits<br>leaves | 2.0<br>3.0 | 15 - 25 | 300 - 700 | 0 - 2,000 | Leaves - cooked as a leafy vegetable Fruits - ripe, unripe, cooked as a vegetable, pickled | India, Nepal | 5., 92. |
| 36) White lupin | *Lupinus albus* L. | Loki - Pakistan | Fabaceae | seeds - raw | 36.2 | 18 - 24 | 400 - 1,000 | 1,500 - 3,000 | Seeds - cooked, pickled, roasted, ground to flour | Pakistan | 6., 7. |
| 37) Bottle gourd | *Lagenaria siceraria* | Sorakaya - India<br>Altumba - Hindi<br>Laukaa - Nepal<br>Ku Ba - Tibet<br>Jangli badam - Pakistan | Cucurbitaceae | fruits<br>leaves<br>seeds | 0.6<br>4.4<br>28.2 | 20 – 35 | 600 – 1,500 | 0 - 2,500 | Fruits - boiled, pickled, used as a vegetable<br>Pods - steamed, fried<br>Leaves - eaten as a vegetable<br>Seeds - roasted, boiled, pounded and mixed with other grains | India, Pakistan, Nepal, Tibet, Bhutan | 6., 63. |
| 38) Coastal almond | *Terminalia catappa* L. | Baangla Baadaam - India<br>Hijli Badam - Hindi<br>Kaathe Badaam - Nepal<br>Bajra - Pakistan, Hindi | Combretaceae | nut - dry | 15.0 | 7 – 28 | 750 - 3,000 | 300 – 800 | Seeds – fresh, cooked, roasted, sundried, preserved by smoking, oil | Pakistan, India, Nepal | 6., 67., 93. |

(continued)

Table 1. Selected plants (continued)

| English name | Scientific name | Local name | Family | Part of crops | Protein g/100g | Temperature (°C) | Rainfall (mm) | Altitude (m.a.s.l.) | Edible parts / Mode of use | Countries | Reference |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 39) Spiny Bitter Gourd | *Momordica cochinchinensis* Spreng. | Chatel - Nepal<br>Bhat-Karela - Hindi | Cucurbitaceae | leaves | 5.6 | 20 – 35 | 1,500– 2,500 | 400 - 1,100 | Fruits - young and immature, cooked, fried, raw used as a vegetable, dried, source of oil<br>Young leaves - raw as a vegetable, fried | Nepal, India, Tibet | 6., 94. |
| 40) Chebulic myrobolan | *Terminalia chebula* Retz. | Harro - Nepal Harra - Hindi | Combretaceae | fruits | 4.0 | 0 - 17 | 1,000 -1,500 | 0 - 2,000 | Fruits - ripe and dried, consumed in a salad, pickled, fried, spice<br>Seeds - raw, oil | India, Nepal, Bhutan, Pakistan, Tibet | 95., 96. |
| 41) Niger | *Guizotia abyssinica* (L.f.) Cass. | Jhuse til - nepal | Asteraceae | seeds | 23.5 | 13 - 28 | 1,000 - 1,300 | 1,700 – 2,200 | Seeds - fried, dried, milled into flour, pressed, oil, spices | Indie, Nepal, Bhutan, Pakistan | 97., 98., 99. |
| 42) Jungle rice | *Echinochloa colona* L. | Sama - Nepal<br>Kayada- India | Poaceae | seeds | 3.0 | 16 - 36 | 400 - 1,200 | 0 - 2,000 | Seeds - raw, cooked, used as a replacement for rice, ground into a flour and used as porridge or mush<br>Young shoots and plants - cooked, raw, used as vegetable | India, Nepal, Pakistan | 91., 100. |
| 43) Sessile joyweed | *Alternanthera sessilis* (L.) DC | Saranchi Saag - Nepal<br>Gudrisag - Hindi | Amaranthaceae | leaves | 4.7 | 10 - 20 | 100 - 700 | 0 - 1,800 | Leaves - cooked as a vegetable, raw as a salad | India, Nepal, Pakistan | 5., 101. |
| 44) Bladder dock | *Rumex vesicarius* | Bhote paalungo - Nepal<br>Chukra - Hindi | Polygonaceae | leaves | 20.1 | 23 - 25 | 100 - 500 | 0 - 1,150 | Leaves - boiled , fersh, used as a vegetable<br>Young shoots and stems - raw, eaten as a vegetable | Nepal, India, Pakistan | 5., 102., 103. |
| 45) Garlic Chives | *Allium tuberosum Rottler ex Spreng* | Dundu saag - Nepal | Amaryllidaceae | leaves | 2.6 | 10 - 20 | 500 - 700 | 0 - 1,800 | Leaves - raw, cooked - added to salad<br>Flowers, flowers buds - raw, cooked<br>Root - raw, cooked | India, Nepal, Pakistan, Bhutan, Tibet | 104., 105 |
| 46) Asian spinach | *Basella alba* L. | Poi sag - Nepal<br>Poi - Hindi | Basellaceae | shoots - fresh | 1.8 | 20 - 35 | 700 - 4,200 | 0 - 1,500 | Young shoots - raw, boiled, fried, used as a vegetable, potherb<br>Seed - oil | India, Nepal | 5., 106. |
| 47) Ivy gourd | *Coccinia grandis* (L.) Voigt | Kundruk - Nepal<br>Kanduri - Pakistan<br>Kunduru - Hindi | Cucurbitaceae | fruits | 1.2 | 25 - 35 | 1,500 - 2,500 | 0 - 2,300 | Fruits - ripe, raw, steamed, unripe green fruits - boiled and added in soups<br>Shoots - fried, boiled<br>Leaves - raw, boiled, used as a vegetable | India, Nepal, Pakistan, Bhutan | 5., 107. |
| 48) Pigweed | *Amaranthus lividus* L. | Lude Saag - Nepal<br>Bhaji - Hindi | Amaranthaceae | leaves | 3.5 | 15 - 25 | 200 - 2,700 | 0 - 2,000 | Leaves - raw, cooked as a leafy vegetable, preserve by drying, potherb<br>Seeds - cooked, ground into flour | India, Nepal | 5., 91., 108. |
| 49) Water chesnut | *Trapa bispinosa Roxb* | Singada - Nepal<br>Simghada - Hindu | Lythraceae | seeds - dry | 10.0 | 10 - 35 | 300 - 1,600 | 0 - 2,700 | Seeds - raw, boiled, roasted, dried and then ground into flour | Nepal, India, Pakistan | 5., 109., 110. |

(continued)

Table 1. Selected plants (continued)

| English name | Scientific name | Local name | Family | Part of crops | Protein g/100g | Temperature (°C) | Rainfall (mm) | Altitude (m.a.s.l.) | Edible parts / Mode of use | Countries | Reference |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 50) Water spinach | *Ipomoea aquatica Forssk.* | Sind - Pakistan<br>Kalmaisaaga - Hindi<br>Kalmi sag - Nepal | Convolvulaceae | leaves | 2.6 | 20 - 30 | 700 - 4,200 | 0 - 1,500 | Young shoots and leaves - raw, fried, steamed, boiled, used as a leafy vegetable, potherb | India, Nepal, Pakistan | 5., 109., 110. |
| 51) False amaranth | *Digera muricata* | Tandla - Pakistan<br>Lathmahuria - India | Amaranthaceae | leaves | 4.3 | 20 - 30 | 300 - 600 | 0 - 1,500 | Leaves, young shoots - boiled, eaten as a vegetable, potherb | Pakistan, India, Nepal | 5., 63. |
| 52) Bitter apple | *Solanum incanum* L. | Adavi vanaya - Inda | Solanaceae | fruits | 4.2 | 10 - 30 | 250 - 2,000 | 0 - 2,500 | Fruits, leaves - green, unripe, raw, cooked, used as a vegetable | Bhutan, India, Phakistan | 111., 112., 113. |
| 53) Horse gram | *Macrotyloma uniflorum* | Gahat - Nepal<br>Kulath - India<br>Kulthi - Pakistan | Fabaceae | seeds | 21.7 | 20 – 30 | 300 – 600 | 0 - 1,800 | Seeds – whole or ground, poached, boiled, fried, mature, sprouted | India, Bhutan, Pakistan, Nepal | 7., 114., 115. |
| 54) Moth Bean | *Vigna aconitifolia* (Jacq.) Marechal | Bhringga - Hindi<br>Moth - Pakistan | Fabaceae | seeds - raw | 22.9 | 24 - 32 | 200 - 750 | 0 - 2,500 | Seeds - ripe, cooked, fried, sprouted, ground into flour<br>Immature pods - boiled, eaten as a vegetable | Pakistan, Nepal, India | 7., 116. |

1. - (Liu et al. 2018) 2. - (Wadhwa et al. 2013) 3. - (Dhakar et al. 2011) 4. - (Roloff et al. 2009) 5. - (Grubben 2004) 6. - (Lim 2012) 7. - (Bring & Belay 2006) 8. - (Chandra et al. 2016) 9. - (Venkidasamy et al. 2019) 10. - (Jensen et al. 2010) 11. - (Singh et al. 2013) 12. - (Singh et al. 2014) 13. - (Mal et al. 2010) 14. - (Hariprasanna 2016) 15. - (Arora 2014) 16. - (Sood et al. 2015) 17. - (Lim 2013) 18. - (Sood et al. 2015) 19. - (Rajesha et al. 2017) 20. - (Duncan et al. 2019) 21. - (Shrestha et al. 2018) 22. - (Adebowale et al. 2006) 23. - (Singh et al. 2016) 24. - (Normah et al. 2013) 25. - (Sheikh 2014) 26. - (Mukherjee et al. 2009) 27. - (Lim 2016) 28. - (Das 2013) 29. - (Dhanarasu & Al-Hazimi 2013) 30. - (Azad 2018) 31. - (Ravi et al. 2009) 32. – (Lim 2014) 33. – (Manner 2011) 34. - (Vieira et al. 2019) 35. - (Rosida et al. 2015) 36. - (Larief et al. 2018) 37. - (Jyothy et al. 2017) 38. – (Saranraj et al. 2019) 39. – (Kumar et al. 2017) 40. – (Majumdar 2011) 41. – (Siddique & Li, El Solh 2019) 42 - (Dahipahle et al. 2017) 43. – (Lim 2012) 44. - (Kuttan & Harikumar 2011) 45. – (Ekanayake et al. 2018) 46. – (Da-Costa-Rocha et al. 2014) 47. - (Guardiola & Mach 2014) 48. - (Singh et al. 2017) 49. – (Bharathi et al. 2013) 50. – (Idowu et al. 2019) 51. – (Anurag et al. 2014) 52. - (Singh 2019) 53. – (Kumar & Deen 2017) 54. - (Rodrigues et al. 2018) 55. – (Yu et al. 2017) 56. – (Dhyani et al. 2019) 57. – (Gwari et al. 2004) 58- (Pandey & Bhatt 2008) 59. – (Ahmad et al. 2016) 60. - (Behera et al. 2007) 61.– (Tewari & Gomathinayagam 2014) 62. – (Nair 2017) 63. – (Malik & Qureshi 2015) 64. – (Aeri et al. 2020) 65. – (Ayyanar & Subash-Babu 2012) 66. – (ICUC 2002) 67. – (Janick & Paull 2008) 68. - (Ramachandran 2014) 69. - (Braganza et al. 2012) 70. - (Hernández-Hernández et al. 2019) 71. - (Mahmood et al. 2018) 72. – (Li et al. 2018) 73. – (Lim 2013) 74. – (Jagtap & Bapat 2018) 75. – (Martínez-Maldonado et al. 2013) 76. – (Ray 2002) 77. – (Gautam et al. 2004) 78. – (Bibi et al. 2016) 79. – (Khare 2008) 80. - (Kauppinen 2017) 81. – (Li & Beveridge 2003) 82. – (Ciesarová et al. 2020) 83. – (Shi et al. 2010) 84. – (Pal et al. 2019) 85. – (Rai et al. 2015) 86. – (Duke 2000) 87. – (Zihad et al. 2019) 88. – (Das et al. 2013) 89. – (Chandra Deka et al. 2019) 90. – (Lim 2016) 91. – (Quattrocchi 2016) 92. – (Singh Thakur et al. 2009) 93. – (Li & Siddique 2018) 94. – (Do et al. 2019) 95. - (Jansen et al. 2005) 96. – (Subramoniam 2016) 97. – (Ramadan 2012) 98. – (Syume & S. Chandravanshi 2015) 99. - (Zimmer et al. 2019) 100. – (Sayani & Annalakshm 2017) 101. - (Joshi et al. 2020) 102. – (Alfawaz 2006) 103. – (Kambhar 2014) 104. - (Shah 2014) 105. - (Jannat et al. 2019) 106. – (Adesina & Adeyeye 2013) 107. – (Saikia & Phookan 2018) 108. – (Nehal et al. 2016) 109. – (Kaur et al. 2016) 110. – (Austin 2008) 111. – (Patel et al. 2018) 112. – (Schmelzer & Gurib-Fakim 2008) 113. – (Quattrocchi 2012) 114. – (Aditya et al. 2019) 115. – (Sreerama et al. 2008) 116. – (Tyagi et al. 2017)

From 54 species of neglected and underutilized crops, 11 plants were selected with the highest protein value. These plants were described as follows.

#### *4.3.1.1. Nelumbo nucifera*

Scientific name: *Nelumbo nucifera*

English name: Sacred lotus

Family: Nymphaeaceae

**Ecology:** The sacred lotus is a large, perennial, an aquatic plant that must have constant access to water. Therefore, its most common occurrence is in the mud at the bottom of shallow ponds, lakes, lagoons, marshes, and flooded fields. It can be found from shallow habitats up to a depth of 2.5 meters. It prefers a warm and temperate tropical climate. It thrives very well in a sunny environment (Singh 2014).

**Botany:** Most often, the plant grows to a height of 1.5 meters and can spread to an area of up to 3 meters. The plant has two types of leaves: aerial and floating, with a diameter of 20 to 90 cm. The flowers can be white, pink, or pinkish-white and have a diameter of up to 20 cm (Mukherjee et al. 2009). Seeds up to 3 cm in size are disordered in hard fruits that are black. There are about 10 - 30 seeds in one fruit (Hajela et al. 2018).

**Nutritional value:** Lotus seeds have a low-fat content, a high protein content (10.6 – 14.8 %) with proper amounts of essential amino acids. They also provide plenty of starch, polysaccharides, and oligosaccharides. The seeds also serve as a source of vitamins (B, C, E), calcium, iron, zinc, phosphorus (Zhang et al. 2015).

**Mode of use:** Seeds with a protein content of 16.6 g to 24.2 g per 100 g represent a promising potential source of alternative proteins (Arora 2014). The green embryos found in lotus seeds have a bitter taste and are therefore traditionally removed after harvest. The seeds are most often boiled or dried. Then they are usually ground into a powder or paste. These are then added to traditional dishes or bread (Chen et al. 2018). The seeds can also be roasted to get a meal similar to popcorn, which serves as a quick snack. Fresh rhizomes can also serve as a good source of protein, eaten raw, fried, or cooked and used as vegetables in soups. For longer shelf life, rhizomes can be pickled (Goel et al. 2001).

Table 3. Amino acid composition of *Nelumbo nucife*ra seeds (Zhang et al. 2015)

| | Arginine | Histidine | Leucine | Lysine | Methionine | Phenylalanine | Threonine | Tryptophan | Valine | Isoleucin |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | mg/100 g | | | | |
| ***Nelumbo nucifera*** | - | 502.4 | 151.6 | 974.3 | 1647.4 | 863.4 | 458.94 | - | 1101.9 | 991.8 |

### *4.3.1.2. Lagenaria siceraria*

Scientific name: *Lagenaria siceraria*

English name: Bottle gourd

Family: Cucurbitaceae

**Ecology:** Bottle gourd is an annual, climbing herb that thrives very well in tropical and subtropical climates. It can adapt very well to semi-dry conditions. Nevertheless, it thrives best along lakes and rivers, in mild sunlight. It can tolerate even lower temperatures, but if the temperature drops below 10 degrees, fruits and flowers are destroyed (Lim 2012).

**Botany:** It grows to 9 meters and is its alternating leaves, reaching a size of up to 30 cm. The fruit is a berry. The size and shape of the fruit are often different for individuals. It can have a globular, bottle-shaped or club-shaped, cylindrical, or elongated form. And they grow to a length of up to one meter. The seeds have a white or brownish colour, an elongated shape, and their size is about 2 cm (Lim 2012).

**Nutritional value:** Dehulled seeds serve as a food source, accounting for almost 35 % of protein and 50 % of oil. The seeds also contain ethical values of mineral elements such as K, Na, Mg, P, Fe, and others. The seeds achieve excellent results with the essential amino acids leucine, lysine, cysteine, and threonine. Low values are reported for isoleucine, methionine, and phenylalanine (Hassan et al. 2008).

**Mode of use:** Due to the excellent representation of amino acids in the seeds of Bottle gourd could help to improve the nutritional value in the diet. The seeds are roasted before consumption, or they can be ground and added to other types of cereal flour. The seeds also form a good source of edible oil, which can be obtained by extracting from the seeds. It is then used as a standard cooking oil (Grubben 2004). Leaves can also be a good alternative source of protein. They are consumed raw as vegetables or can be added to other plants. Fresh leaves are added to various porridges, but most often to corn. The leaves can be dried for longer shelf life (Chimonyo & Modi 2013).

Table 4. Amino acid composition of *Lagenaria siceraria* seeds (Lim 2012)

| | Arginine | Histidine | Leucine | Lysine | Methionine | Phenylalanine g/100 g | Threonine | Tryptophan | Valine | Isoleucin |
|---|---|---|---|---|---|---|---|---|---|---|
| *Lagenaria siceraria* | 4.77 | 0.72 | 1.80 | 0.87 | 0.70 | 1.72 | 0.85 | - | 1.33 | 0.99 |

#### *4.3.1.3.* *Guizotia abyssinica* (L.f.) Cass.

Scientific name: *Guizotia abyssinica* (L.f.) Cass.

English name: Niger

Family: Asteraceae

**Ecology:** Niger thrives in both colder and warmer tropical and subtropical regions. It tolerates flooded areas with a lack of oxygen very well. It is very often grown on sandy, poor soil (Adarsh et al. 2014).

**Botany:** Niger is an annual herb growing to a height of up to 2 meters. The leaves are arranged opposite each other and have a length of up to 20 cm. The leaves are coloured dark green, but their underside is coloured yellow. The flowers of this plant have a size of 15 to 50 mm. Their colour is initially yellow and with gradual maturation changes to gold. In one bulb, there are approximately 50 seeds, glossy black with a length of up to 6 mm (Sumeet & Seema 2012).

**Nutritional value:** Niger seeds contain 483 calories, 17 – 30 % protein 483 calories, and 30 – 50 % oil. The oil contains a high concentration of vitamin K1 and also β-carotene. The amino acid tryptophan reaches low values (Ramadan 2012). Seeds are a good source of phosphorus and also micro-minerals such as iron or manganese (Deme et al. 2017).

**Mode of use:** The seeds can most often be roasted before consumption and then crushed and added to other crushed pulses or cereals. The seeds are also used as spices (most often flavored fried vegetables), or are used to make porridge or are mixed with other legumes (Getinet & Sharma 1996). The dry seeds are ground into flour, which is then used in baking, it is also possible to mix the ground seeds with honey and use them in cakes. It is also possible to obtain edible oil from the seeds, which is very nutritionally rich (Ramadan 2012). The traditional extraction of oil takes place by first heating the seeds, then grinding and mixing with hot water. This is then removed from the surface. The oil traditionally obtained in this way has a worse shelf life, but it is possible to extend it by heating and storing in airtight containers. More modern oil extraction is performed on manual or electronic mills (Bulcha & van der Vossen, Mkamilo 2007).

Table 5. Amino acid composition of *Guizotia abyssinica* (L.f.) Cass. seeds (Getinet & Sharma 1996)

| | Arginine | Histidine | Leucine | Lysine | Methionine | Phenylalanine | Threonine | Tryptophan | Valine | Isoleucin |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | mg/100 g | | | | |
| ***Guizotia abyssinica* (L.f.) Cass.** | 621 | 162 | 388 | 294 | 109 | 327 | 237 | 54 | 362 | 307 |

### *4.3.1.4.* ***Hibuscus sabdariffa* L.**

Scientific name: *Hibiscus sabdariffa* L.

English name: Rosella

Family: Malvaceae

**Ecology:** The best conditions for the growth of this plant are dry, subtropical, and tropical mountain climates (Guardiola & Mach 2014). It can tolerate warmer and wetter climates but is prone to frost damage. It is suitable to grow it in both light sandy and heavy clay soils. It tolerates poor soil. Better conditions for growth are in moist but well-drained soil. It can withstand drought, thanks to its deep roots. The plant cannot grow in a dreamy environment (Da-Costa-Rocha et al. 2014).

**Botany:** Rosella is an annual herb that grows to a height of 2.4 m. Its stems are red; the leaves are alternating with a length of up to 12.5 cm. Large flowers with short stems most often have red petals with a dark centre. The fruit is a capsule that can be up to 2.5 cm long. The seeds of the plant have a dark brown colour and a size of 7 mm (Da-Costa-Rocha et al. 2014).

**Nutrition value:** The seeds contain a perfect amount of protein, fibre, and minerals (phosphorus, magnesium, and calcium). The protein content in the seeds is 23.0 %, fiber is 15.3 %, they also contain 119-128 mg Ca, 596-672 mg P, 4.0 mg Zn, 3.1 mg Cu, 393-396 mg Mg. The leaves of this plant also provide an excellent nutritional composition; they contain 43 calories, 3.3 g of protein, 1.6 g of fibre, 214 mg of P, 4.8 mg of Fe, 0.17 mg of thiamine, 0.45 mg of riboflavin, 0.5 mg of niacin and 54 mg of ascorbic acid per 100 g (Ismail et al. 2008)

**Mode of use:** The seeds of this crop can serve as a good source of plant protein in undeveloped and developing countries. The seeds are eaten baked, roasted, or ground and added to other food (sauces or soups) (Mohamed et al. 2012). Heat treatment of these seeds (cooking or baking) improves the availability of some nutrients; on the other hand, the nutritional value of amino acids or vitamins may decrease. Seeds after fermentation can also be used as a spice. The seeds can also provide edible oil (17%), which can be used for cooking (Aminul Islam et al. 2016). The oil is extracted from the seeds by grinding the seeds, which are then soaked in water made alkaline with ashes, then pounded (Grubben 2004). Leaves can also serve as a good source of protein (3.30 g / 100 g). They are eaten raw, cooked, or stewed; they are also used as spices. The leaves are also used to prepare soup, to which other ingredients are then added or added to legume soups. It is also possible to make pesto from the leaves, which is supplemented by other spices (Aminul Islam et al. 2016). For longer shelf life, the leaves tend to be dried (Mohamed et al. 2012).

Table 6. Amino acid composition of *Hibiscus sabdariffa* L. seeds (Hainida et al. 2008)

| | Arginine | Histidine | Leucine | Lysine | Methionine | Phenylalanine | Threonine | Tryptophan | Valine | Isoleucin |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | mg/100 g | | | | |
| *Hibiscus sabdariffa* L. | - | 7.04 | 15.44 | 13.77 | 2.50 | 11.11 | 8.50 | - | 9.85 | 7.17 |

#### *4.3.1.5. Limonia acidissima* L.

Scientific name: *Limonia acidissima* L.

English name: Elephant apple

Family: Rutaceae

**Ecology:** Elephant apple most often occurs on dry plains, in areas with monsoon climates. Or as a stray plant that occurs along roadsides, field boundaries, and river banks. It resists drought well and thrives most on light soils. However, it can also be grown on saline and neglected land, where it is not possible to grow other fruit trees (Kumar & Deen 2017).

**Botany:** This plant is a slow-growing, small to medium-sized tree that grows to a height of up to 9m. The alternating leaves have a dark green colour; they are often slightly toothed or serrated at the edges. The fruit is a berry with a size of 5 - 12.5 cm, it can be oval or round. The fruit is covered with a woody, hard shell, which is up to 6 mm thick. The pulp is brown and contains white seeds (Vijayvargia & Vijayvargia 2014).

**Nutrition value:** The fruit is provided per 100 g of 140 kcal. It contains excellent values of beta-carotene, vitamin B and C, and thiamine. It can also serve as a source of carbohydrates, proteins, and minerals (mostly high in phosphorus and calcium). Mature pulp contains 10.00 % protein, 1.45 % fat, 7.45 % carbohydrates, 0.17 % calcium, 0.08 % phosphorus, 0.07 % iron per 100 g of edible portion (Kerkar et al. 2020). The crushed seeds contain 49.51 % protein, 23.16 % carbohydrates. They are also excellent sources of minerals; in 100 g of edible portion, there is 8.49 iron, 5.76 mg of zinc, 1.66 mg of manganese, 703.78 mg of magnesium, 9.55 mg of sodium, 494.3 mg of potassium, 1227, 6 mg of phosphorus and 7.18 mg of copper (Sonawane et al. 2016). The seeds contain outstanding values of the essential amino acids lysine, arginine, leucine and phenylalanine (Hainida et al. 2008).

**Mode of use:** Elephant apple fruit is an excellent source of plant protein in 100g of the edible portion located 7.1 - 8.0g of protein (Arora 2014). As the fruit is covered with a tough shell, it is most often opened with a hammer, and the pulp is then carved out by hand using a spoon. The fruit is consumed raw or mixed into drinks and desserts; it can also be used to make jam. This method of processing allows the fruit to be consumed even after several months. The pulp can also be dried for more extended durability. The fruit can be used for food products such as fruit bar, chutney, sherbet, or pulp powder. The seeds contain the most significant percentage of protein from parts of this plant. They can be ground into flour, which is then added to other dishes. Edible oil is also obtained from the seeds. (Rodrigues et al. 2018).

Table 7. Amino acid composition of *Limonia acidissima* L. seeds (Sonawane et al. 2016)

| | Arginine | Histidine | Leucine | Lysine | Methionine | Phenylalanine<br>mg/g | Threonine | Tryptophan | Valine | Isoleucin |
|---|---|---|---|---|---|---|---|---|---|---|
| ***Limonia acidissima* L.** | 4.59 | 1.24 | 5.19 | 1.61 | 0.69 | 2.87 | 1.61 | - | 1.09 | 2.44 |

### *4.3.1.6.* ***Lupinus albus* L.**

Scientific name: *Lupinus albus* L.

English name: White lupin

Family: Fabaceae

**Ecology:** White lupine is a crop that thrives at lower temperatures. It can tolerate frost, but at temperatures below -8 C, the flower is damaged, or seed germination is interrupted. If the temperatures exceed the optimal values, flowering slows down, and fruit production is lower. In the wild, it is located in habitats with poor soil, meadows or pastures. It thrives better in drained soils at higher altitudes. It is resistant to drought, thanks to deep roots (Malik & Qureshi 2015).

**Botany:** It is a long day, an annual herb that grows to a size of 1.2 meters. Oblong or obovate, alternating leaves up to 6 cm in format. White flowers grow in clusters. The fruit is pods that are 60 – 100 mm long. There are 3 - 6 seeds in the pod. The seeds are most often white, rectangular, or square in size with a size of 6 - 12 mm. Other colour variants can be brown, black, olive, or they can be mottled (Lim 2012).

**Nutritional value:** From 32.9 % to 36.0 % of proteins occur in seeds. Compared to other legumes, it has excellent amino acid values: arginine, lysine, leucine, phenylalanine. The seeds provide 1,552 kJ of energy, 9.7 g fat and 40.4 g carbohydrate per 100 g. They are also an excellent source of crude fibre (94.4 - 142.0 g/kg). And contain increased amounts of manganese or iron (Janusz 2017)

**Mode of use:** The seeds can be ground into flour and used in the preparation of bread or pasta. They can increase the nutritional value of these foods due to their good protein values (36.2 g / 100 g). They can also be roasted and then immediately consumed as a small snack. Boiled seeds are the most commonly used (Lim 2012). In some households, the seeds are picked for longer shelf life. Other processing techniques used are germination or fermentation. Edible oil can also be obtained from seeds (Janusz 2017). The seeds can be stored for a very long time (4 to 10 years) if they dry properly and are stored in dry conditions (Azeze et al. 2016).

Table 8. Amino acid composition of *Lupinus albus* L. seeds (Janusz 2017)

| | Arginine | Histidine | Leucine | Lysine | Methionine | Phenylalanine g/100 g | Threonine | Tryptophan | Valine | Isoleucin |
|---|---|---|---|---|---|---|---|---|---|---|
| *Lupinus albus* L. | 11.4 | 3.3 | 7.8 | 4.9 | 2.05 | 5.6 | 3.5 | 0.6 | 4.1 | 4.3 |

### *4.3.1.7. Rumex vesicarius*

Scientific name: *Rumex vesicarius*

English name: Bladder dock

Family: Polygonaceae

**Ecology:** It is located in arid areas of warm temperate or tropical zones. It grows between stones or on grassy and gravel slopes. It tolerates even wetter habitats. It prefers sunny places; it does not succeed in the shade (IUCN 2005).

**Botany:** Bladder dock is an annual or perennial, semi-succulent herb. It has a shrubby shape, and the stems grow branched from the base. It grows to a height of up to 50 cm (Kambhar 2014). Simple, alternating leaves have a triangular shape and a length of up to 7 cm. The fruit is walnut with a size of 3 - 5 mm (Grubben 2004).

**Nutritional value:** It contains relatively high nutritional values. It is a suitable source of vitamin (mostly vitamin C), minerals, proteins, and fibres. It is also an excellent source of carbohydrates, as its content meets 40 % of daily needs. It contains a good source of minerals (K, Na, Ca, Mg, Fe, Mn, and Cu) (Ahmad et al. 2019).

**Mode of use:** Leaves with their protein content (20.1 g / 100 g) can be a good source of protein. The leaves can be eaten fresh but are most often cooked together with legumes. The heat-treated leaves are thus mixed with the porridge, or chutney is made from them, or they can be pickled for longer shelf life. Fresh leaves are also used in soups (Kambhar 2014). They are prepared in the same way as other vegetables. Due to their more acidic taste, they can be used in salads as aromas (Grubben 2004).

Table 9. Amino acid composition of *Rumex vesicaurius* leaves (El-Tantawy 2002)

| | Arginine | Histidine | Leucine | Lysine | Methionine | Phenylalanine | Threonine | Tryptophan | Valine | Isoleucin |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | mg/100 mg | | | | |
| ***Rumex vesicarius*** | 4.39 | 2.48 | 2.56 | 4.67 | 4.08 | 13.01 | - | - | 5.17 | 7.05 |

#### *4.3.1.8. Vigna acinitifolia (Jacq.) Marechal*

Scientific name: *Vigna aconitifolia (Jacq.) Marechal*

English name: Moth Bean

Family: Fabaceae

**Ecology:** Moth beans are very drought resistant, suitable for growing in mountainous, arid, or semi-arid areas (Kaleem et al. 2020). It is a short-lived plant, but there are also daily neutral species. This plant does not thrive in wet soils (Bring & Belay 2006).

**Botany:** It is an annual herb that grows to a height of 40 cm. Its stems are square and hairy. The alternating leaves have a length of 5 to 10 cm. The fruit is pods that have a cylindrical shape, and their length is from 2.5 to 5 cm. There are 4 - 9 seeds in the pod. The seeds have a rectangular to a cylindrical shape; their colour is most often whitish green, yellow, or brown. Some may be covered with black spots (Bring & Belay 2006).

**Nutrition value:** Moth bean seeds are considered an excellent source of protein; they contain 22 – 24 % protein. They are also nutritionally rich in minerals (Ca, Mg, Fe, Zn, and Mn) and lipids. 1.435 kJ of energy, 1.6 g of fat, 61.5 g of carbohydrate can be obtained from a 100 g edible portion of seeds. The limiting amino acid in this crop is cysteine, methionine, and sulfur amino acids. While threonine, phenylalanine, and tyrosine occur to a greater extent than recommended (Singh & Ansari 2018).

**Mode of use:** Ripe seeds are eaten boiled or fried. They can be prepared either as whole seeds or also divided. They can also be germinated and then added to other types of legumes. By grinding the seeds, flour is obtained, which is then mixed with other types of flour to make bread. Another edible part of this plant is immature green pods, which are consumed as vegetables (Bring & Belay 2006).

Table 10. Amino acid composition of *Vigna aconitifolia* seeds (Kaleem et al. 2020)

| | Arginine | Histidine | Leucine | Lysine | Methionine | Phenylalanine | Threonine | Tryptophan | Valine | Isoleucin |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | g/100 g | | | | |
| *Vigna aconitifolia (Jacq.) Marechal* | 6.14 | 2.76 | 7.42 | 6.34 | 1.62 | 5.48 | 3.96 | 1.24 | 5.16 | 4.1 |

#### *4.3.1.9. Macrotyloma uniflorum*

Scientific name: *Macrotyloma uniflorum*

English name: Horse gram

Family: Fabaceae

**Ecology:** The typical climate for growth is sub-humid to semi-arid in tropical and subtropical regions. This plant is very tolerant of water shortages and is also resistant to heat stress. It does not tolerate frost and wet soil and can be grown on poor soils (Sreerama et al. 2008).

**Botany:** It is an annual, climbing herb that grows to a height of 60 cm— with alternating, ovate, diamond-shaped leaves. The leaves and stem are covered with whitish hairs. The fruits are pods which have an elongated shape and a length of 3 to 8 cm. The seeds have a trapezoidal or elongated shape, and there are 5 - 10 of them in one pod. They can be coloured reddish-brown. A possible variant is also mottled coverage (Bring & Belay 2006).

**Nutrition value:** 100 g of the edible portion of Horse graham seed contains 1394 kJ of energy, 1 g of fat, 60 g of carbohydrate, and 4.7 g of fibre. The seed contains excellent nutritional values of protein (24.24%), calcium (0.34%), and iron (72%) and molybdenum. Deficient amino acids are methionine and tryptophan (Ranasinghe & Ediriweera 2017).

**Mode of use:** The seeds are used as a pulse for their good protein content of 21.7 g / 100 g edible portion. The most common method of preparation is boiling in water, but they can also be consumed fried. Dried seeds can also be ground into flour and used in the production of various food products. The seeds can also be germinated or fermented in a similar way to soybeans before consumption (Aditya et al. 2019). Dried seeds can be stored for a very long time without pests. Because they are not as attractive to pests as others (Kumar 2006).

Table 11. Amino acid composition of *Macrotyloma uniflorum* seeds (Venkidasamy et al. 2019)

| | Arginine | Histidine | Leucine | Lysine | Methionine | Phenylalanine | Threonine | Tryptophan | Valine | Isoleucin |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | mg/100 g | | | | |
| *Macrotyloma uniflorum* | 8.8 | 3.15 | 8.96 | 0.52 | 1.16 | 6.31 | 3.82 | 1.16 | 6.47 | 6.14 |

### *4.3.1.10. Phaseolus coccineus* L.

Scientific name: *Phaseolus coccineus* L.

English name: Scarlet bean

Family: Fabaceae

**Ecology:** It thrives most in a warmer climate, on permanently moist, organically well-supplied soils. However, they must be well-drained. In tropical areas, it can be grown very well at higher altitudes. This plant thrives best in full sun. At lower temperatures, the plant dies. The seeds are susceptible to frost (Labuda 2010).

**Botany:** Climbing, a perennial plant that grows to a height of 3 meters. The stems are round and glabrous, the leaves trifoliate, coarsely hairy. The alternating leaves have a triangular shape with a diameter of 10 cm (Bring & Belay 2006). The fruit is a slightly curved pod, immature with a rough surface; ripe has a smooth surface, grey-green to beige. The pods reach a length of 30 cm. The shape of the seeds is oval. They are coloured either in one colour - white, black, in shades of brown or grey. There are often otherwise coloured spots on these substrates (Labuda 2010).

**Nutritional value:** *Phaseolus coccineus* beans contain decent amounts of proteins, carbohydrates, fibre, and minerals. It provides an energy of 1,419 kJ per 100 g, is a good source of vitamin C (7 mg), and also iron (9 mg). The most concentrated essential amino acid in these seeds is leucine, with non-essential amino acids, the highest content being glutamic acid. The limiting amino acids, as with most legume species, are sulfur amino acids (Alvarado-López et al. 2019).

**Mode of use:** The edible parts of the plants are considered to be immature seeds in immature pods and dry seeds. They are used for the preparation of salads and stews, whether they are added to soups or eaten only as vegetables (Sinkovič et al. 2019). Beans are most often cooked before use, but it is also possible to consume them raw. The seeds are dried in the sun for longer shelf life, then stored in bags for further use (O. Aremu et al. 2017). They can also be ground into flour and used to prepare bread (Zia-Ul-Haq et al. 2014). The seeds are left to dry for a few more days after harvest (Bring & Belay 2006).

Table 12. Amino acid composition of *Phaseolus coccineus* L. seeds (O. Aremu et al. 2017)

| | Arginine | Histidine | Leucine | Lysine | Methionine | Phenylalanine | Threonine | Tryptophan | Valine | Isoleucin |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | g/100 g | | | | |
| *Phaseolus coccineus* L. | 3.85 | 2.0 | 6.63 | 3.10 | 1.91 | 4.00 | 3.23 | - | 3.26 | 3.78 |

### *4.3.1.11. Moringa oleifera*

Scientific name: *Moringa oleifera*

English name: Drumstick

Family: Moringaceae

**Ecology:** Tropical and subtropical plant growing well at lower altitudes. It can be grown in drier areas as it is well resistant to water shortages. Unsuitable conditions are wet soil and also low temperatures. It can also be raised on marginal soils bud prefers well-fertile, sandy-loamy soils (Malik & Qureshi 2015).

**Botany:** A small, deciduous tree or shrub, growing to a height of 10 meters. The oval, alternating leaves are 30 to 60 cm long. The fruit is an elongated, suspended capsule. The length of this capsule is from 30 to 100 cm. Inside there are seeds with a diameter of 1 - 1.5 cm, triangular with three wings (Lim 2012).

**Nutrition value:** *Moringa oleifera* is a very nutritious source of protein, minerals, vitamins, calcium, iron, and phosphorus. Essential amino acids, including sulfur-containing amino acids, occur in higher concentrations than recommended. It contains a large number of minerals. The leaves contain 261 mg, calcium 444 mg of potassium, 3mg of iron per 100 g of an edible portion (Gopalakrishnan et al. 2016). The leaves also contain about 30 mg of zinc; this value represents the daily intake of zinc needed in the diet. The plant also has excellent content of vitamins (A, B, C, D, and E, folic acid, nicotinic acid). For mature seeds, crude protein values of 332.5 g, crude fat 412 g were measured, and carbohydrates were represented in 211.2 g (Lim 2012).

**Model of use:** This plant can provide good alternative sources of plant protein in more of its edible parts. Leaves and unripe pods are most often eaten as vegetables. The leaves are eaten fresh or dried and then ground to a powder. This powder is used for children who are malnourished or for pregnant and breastfeeding women (Pandey et al. 2019). The pods are harvested immature and then eaten fresh or can be cooked. They are added to soups and curries or can be preserved for longer shelf life. The seeds are prepared by cooking, roasting, or frying or ground into a powder. Processed in this way, they resemble peanuts in their taste. Immature seeds can be eaten fresh like peas. Edible oil can also be obtained from seeds (Lim 2012). Harvested pods are most often dried for one or two days. They must be well ventilated and laid in the shade. The leaves are tied together in larger bundles to maintain freshness (Palada et al. 2019).

Table 13. Amino acid composition of *Moringa oleifera* parts (Brilhante et al. 2017)

| | | Arginine | Histidine | Leucine | Lysine | Methionine | Phenylalanine | Threonine | Tryptophan | Valine | Isoleucin |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | g/100 g | | | | |
| | leaves | 0.4–1.8 | 0.1–0.7 | 0.4–2.2 | 0.3–1.4 | 0.1–0.5 | 0.3–1.6 | 0.1–1.3 | 0.1–5.2 | 0.4–1.4 | - |
| *Moringa oleifera* | pods | 0.36 | 0.11 | 0.65 | 0.15 | 0.15 | 0.43 | 0.39 | - | 0.54 | - |
| | seeds | 4.5 | 2.3 | 6.7 | 1.5 | 2.4 | 4.0 | 3.1 | 1.6 | 4.3 | - |

# 5. Conclusions

This work dealt with the use of neglected and underused species, as they are not given enough attention today, and many of these species are slowly ceasing to grow. With the overall improving economy in some developing countries, there is also a shift away from traditional foods, and people tend to prefer imported crops. NUS crops are very often despised even by indigenous villagers. They prefer commercial plants because they predominate in the market and are more affordable.

In this work, 54 species of plants occurring in the Himalayan states were investigated. Thanks to their nutritional composition, they could become a potentially useful source of protein for local people. From these plants, 11 species were selected, which showed the most significant potential with their protein content, as an alternative source of protein. Specifically, they were: *Nelumbo nucifera*, *Lagenaria siceraria*, *Guizotia abyssinica* (L.f.) Cass., *Hibiscus sabdariffa* L., *Limonia acidissima* L., *Lupinus albus* L., *Rumex vesicarius*, *Vigna aconitifolia* (Jacq.) Marechal, *Macrotyloma uniflorum*, *Phaseolus coccineus* L., *Moringa oleifera*.

Seeds, leaves, and tubers were characterized as parts of the plants with the highest protein content. Fruits, pods, nuts are less nutritionally rich parts, but they can also be a beneficial dietary supplement for people in developing countries. The most common ways of preparing these crops were cooking or frying ripe but also immature parts of plants. Most edible parts can also be eaten raw and prepared similarly to vegetables. The dried seeds are ground into flour, which can be added to other types of flour or used to make bread, porridge, or other traditional dishes. Edible oil is also obtained from the seeds by pressing, which is then used for cooking. The most common way to maintain the longer shelf life of these crops was by drying or pickling; some fruits are used to make jams or chutney.

In developing countries, the availability of animal protein is deficient. As its price is very high, the consumption of meat is an occasional issue for most people. Cultural and religious influences also influence the use of animal products in these countries. The inclusion of these plants in a regular diet could help supplement the necessary proteins and essential amino acids. They can also serve as a supplement to essential vitamins and minerals that are missing in some animal sources. These crops are very resistant to climate change, and their cultivation is possible even in degraded conditions, where most commercial plants fail. A potential increase in the production of these crops will not only ensure nutritional security. Still, it may also boost the economies of the regions concerned, as funding for the import of other foods will be reduced. For the future use of NUS as nutritious food, however, there must primarily be a change in the perception of these foods. For the greater promotion of their good economic and nutritional value. Thus, to achieve more abundant cultivation of neglected and underused crop species by local farmers as they represent an outstanding contribution to reducing poverty, hunger, and malnutrition.

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# Appendices

## List of the Appendices:

# Appendix 1: Pictures of selected plants

Figure 3. Dried lotus seed of *Nelumbo nucifera* (Nháy 2014)

Figure 4. Roots of *Nelumbo nucifera* (Fotoos 2014)

Figure 5. Fruits of *Lagenaria siceraria* (Magu et al. 2017)

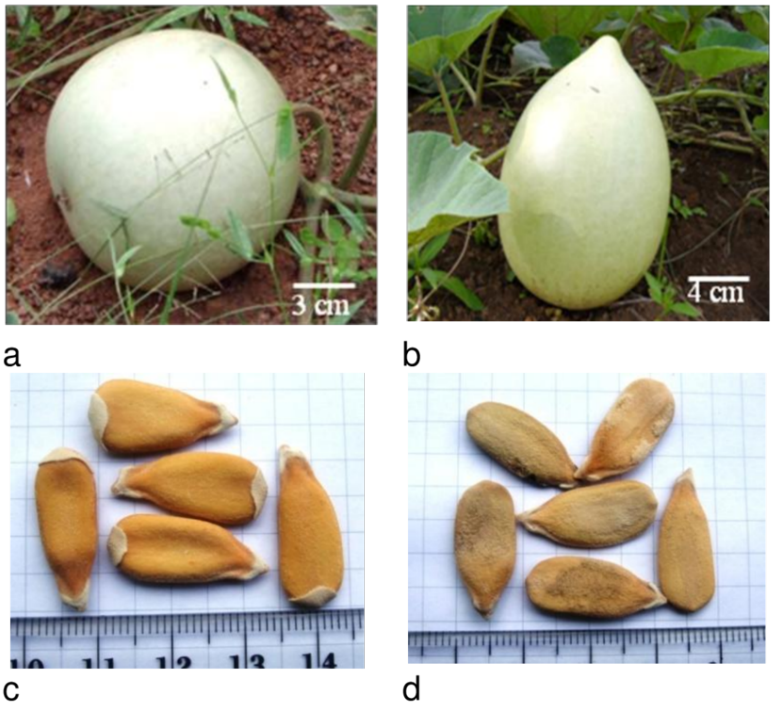


Figure 6. Fruit and seeds of *Lagenaria siceraria* (Yao et al. 2013)

Figure 7. *Guizotia abyssinica* (L.f.) Cass. (Hunter 2012)


Figure 8. Seeds of *Guizotia abyssinica* (L.f.) Cass (Slotta 2012)

Figure 9. Leaves and developing seed pod of *Hibiscus sabdariffa* L. (Mokkie 2014)

Figure 10. Fruits of Hibiscus sabdariffa (Zarif 2014)

Figure 11. Fruit cut open to reveal flesh and seeds of *Limonia acidissima* L. (Sylveno 2014)

Figure 12. Fruits of *Limonia acidissima* L. (Garg 2014)

Figure 13. *Limonia acidissima* L. (Antan 2014)

Figure 14. *Lupinus albus* L. (Echardour 2012)

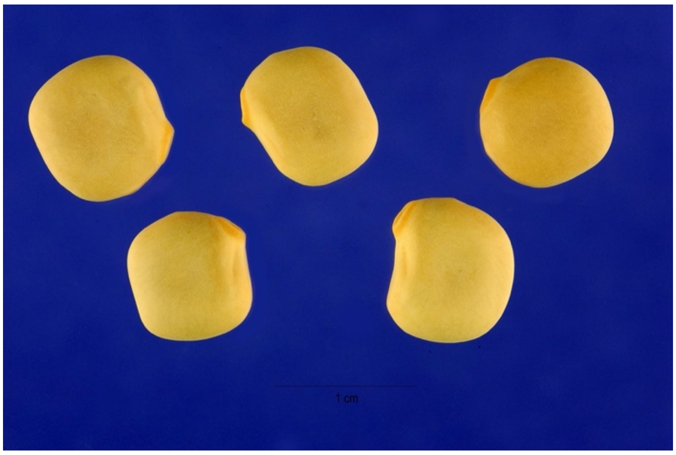


Figure 15. Seeds of *Lupinus albus* L. (Hurst 2012)

Figure 16. *Rumex vesicarius* L. (Browicz 2001)

Figure 17. *Vigna aconitifolia* (Jacq.) Marachal seeds (Kaleem et al. 2020)


Figure 18. *Vigna acinitifolia* (Jacq.) Marechal (Azmat 2014)

Figure 19. Seed of *Macrotyloma uniflorum* (Ramesh 2014)

Figure 20. Seedspods of *Macrotyloma uniflorum* (Australian National Botanic Gardens 2014)

Figure 21. *Phaseolus coccineus* L. (Zell 2014)

Figure 22. Seeds of *Phaseolus coccineus* L. (Hugowolf 2014)

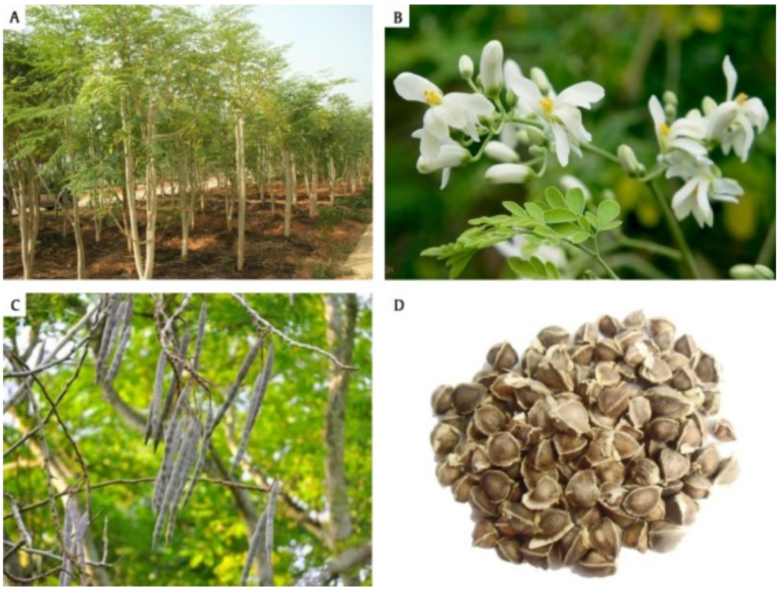


Figure 23. Whole plant, flowers, mature pods, and dried fruits of *Magnifera oleifera* (Liu et al. 2018)