Review

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Insects, Plants and Microorganisms from dry LANDS as Novel Sources of Proteins and Peptides for Human Consumption

Karen Nathiely Ramírez-Guzmán , Cristian Torres-León , David Ramiro Aguillón-Gutierrez , Jorge Alejandro Aguirre-Joya *

Posted Date: 3 October 2023

doi: 10.20944/preprints202310.0140.v1

Keywords: protein sources; insects; plants; microorganisms; dry lands

Review

Insects, Plants and Microorganisms from dry LANDS as Novel Sources of Proteins and Peptides for Human Consumption

Nathiely Ramírez-Guzmán [1], Cristian Torres-León [2] and David Aguillón-Gutierrez [2] & J.A. Aguirre-Joya [2]*

[1] Center for Interdisciplinary Studies and Research (CEII-UAdeC). Universidad Autónoma de Coahuila, Saltillo, 25280, México.
[2] Reaserch Center and Ethnobiological Garden (CIJE), Universidad Autónoma de Coahuila, 27480, Viesca, Coahuila, Mexico.
* Correspondence: jorge_aguirre@uadec.edu.mx

Abstract: Protein malnutrition is present in developing countries but also in developed ones, due by the actual eating habits with insufficient protein intake, in addition to this it is estimated by the Food and Agricultural Organization of the United Nations an increase of world population of 9.1 billion people in less those 30 years, posing the challenge of nourish the mankind. There are different strategies to afford this challenge, one of the most promising ones is to approach novel protein sources like plants, microorganisms, and insects from dry lands.

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Introduction:

According to the Food and Agriculture Organization of the United Nations (FAO) it is expected an increased word population of 9.1 billion people for 2050, and the food production needs to increase by 70 % to feed the word (FAO, 2009). In spite of the actual global production level of food, protein malnutrition still present in developing countries but also in developed ones due by the actual eating habits with insufficient protein levels in the diet (Grover & Ee, 2009).

Proteins are fundamental natural substances with bioactive activities, that are found in a wide range of species, in addition peptides are protein fragments that can purvey the nutrients needed for growth and development in humans. Typically, these peptides are conformed by 2 to 20 amino acids linked each other by peptide bonds (Bhandari et al., 2020).

Bioactive peptides are defined as those peptides that promotes beneficial health effects so food derived bioactive peptides are those who can be found naturally in food sources and have a beneficial health effects.

Main source of protein for human consumption is due by meat industry, nevertheless, the meat production is responsible for the 54 % of greenhouse gases generated by the agricultural activities, with a predictable increase to 59 % by 2030 (Villacís-Chiriboga et al., 2023). Another worrying aspect about the dependency of meat protein is the water print, to make a comparation about the water consumption.

Therefore, it is urgent to develop a new strategy to meet the huge demand of proteins for the growing worldwide population, but also considering sensory and nutritional need of the consumers as well as a lower negative environment impact.

Microorganisms isolated from arid areas of interest for the production of peptides and / or proteins for human consumption

The arid and semi-arid zones are described as geographic extensions characterized by having extreme and complicated climates, where extreme dryness predominates, these regions present prolonged periods of drought, sporadic rains with low averages and generally high temperatures in the day and low at night. (Alsharif et al., 2020; Guillen-Cruz et al., 2021) Which causes its vegetation to be reduced or almost absent, this affects the biodiversity of the areas since it influences the behavior and processes of the species that live there, due to they had an adaptation process to live in such conditions. (Guillen-Cruz et al., 2021). The arid and semi-arid zones of each region. Are of great importance for the conservation of biological diversity and the maintenance of the ecological processes that occur there. (Altieri, 2018)

Generally speaking of the flora and fauna since this is the visible part of the ecosystems, being an important factor added to the atmospheric conditions for their classification and naming of the different geographical areas that the planet earth. (Ashfaq et al., 2019) Has, however, another element present in each one of the ecosystems are the microorganisms since they participate in a vital way in the ecosystems and are in constant interaction with animals, plants and human beings. (Alsharif et al., 2020)

Microorganisms are the most primitive and numerous organisms that exist on Earth, they colonize every environment: soil, water and air, it is estimated that there are about a nonillon of microbes, however, only 1% is known, one of the mainly reasons are that exists a wide unexplored areas with a huge diversity of microorganisms with interesting and unique characteristics. (Ramírez-Guzmán et al., 2018). Microbes are classified in many ways, one of them is by their ability to grow at different temperatures while mesophylls grow at moderate temperatures and this helps them to be cultivated and therefore be better known and studied, unlike the extremity of which they live in extreme conditions compared to those considered normal even where it might be thought that it is not possible for there to be life. (Alcalde et al., 1999; Verma et al., 2021).

A subtype of these are the thermophiles that endure extreme conditions of relatively high temperature above 45 °, which is why it is normal to find this type of microorganism in arid areas, each environmental condition in particular causes the organisms to acquire a variety of adaptation techniques, which makes them stable in a unique way in that specific environment, in this intervenes their metabolism and the ability to produce substances that allow them to survive, which are generally of high biotechnological and industrial interest such as the food industry. (Alsharif et al., 2020; A. Kumar et al., 2018; McDonald, 2017)

In recent years, interest in the study and development of functional and nutraceutical foods has increased greatly, given the great economic impact of the commercialization of this type of food and the products that contain them. (Dhritlahre et al., 2021). The constant changes in the eating habits of society in the constant search for a healthier life have focused on diets high in protein and bioactive peptides for their nutritional value and biological effector.(Megías et al., 2016; Ramírez-Guzmán et al., 2019; Torres-León et al., 2018). The most common sources of obtaining these molecules are from animal and plant sources, however, in recent years an important niche has been discovered in its production from or through microbial processes since there are two options: that the microorganism produces it or that it generates a compound such as the enzymes that are secreted from its metabolism, it helps to produce or synthesize some protein or peptide from another source. (Daliri et al., 2017; Mingyi et al., 2019)

To obtain bioactive peptides, they must be released from the parental protein in which they are encrypted and in an inactive form. There are several processes for obtaining bioactive peptides: Chemical synthesis, chemical hydrolysis, cooking, maturation, digestion, recombinant DNA technology, however, biotechnological methods such as microbial fermentation and enzymatic hydrolysis are the most used.(Cruz-Casas, et al 2021).

In general, microbial fermentations or enzymatic hydrolysis to obtain bioactive peptides and proteins are carried out from isolated strains of dairy products, with the predominance of bacillus species, especially lactic acid bacteria belonging to the genus *Lactobacillus*, which are prominent microbial groups. (Adams et al., 2020; Corrêa et al., 2014; Gammoh et al., 2020). The reason for the efficient production of peptides by this type of bacteria may be related to their amino acid auxotrophy. (Manzoor et al., 2021) Therefore, the number of works carried out with microorganisms isolated from other sources is reduced.

An example of obtaining bioactive peptides from microbial fermentation is the study of Gulyamova et al (2018) they detected bioactive peptides inhibitors of the angiotensin converting enzyme I with the potential to reduce blood pressure, they made a comparison of dochi a popular condiment in the Chinese gastronomy that consists of the fermentation of soybeans by *Aspergillus egypticus* in the study evaluated different times as well as a secondary fermentation. *Aspergillus egypticus* was first described in 1972 isolated and isolated from sandy soils in Egypt and used in other studies as well as it can inhibit pancreatic α-amylase activity. (Gulyamova et al., 2018; Zhang et al., 2006)

Obtaining new bioactive peptides from food proteins by enzymatic digestion in vitro, using proteolytic enzymes of microbial origin. Delgado-García et al (2019) They produced bioactive peptides from fish waste using proteases produced by halophilic microorganisms, they isolated from two localities classified as arid zones in America, the Uyuni desert, Bolivia and Cuatro Ciénegas Coahuila México, which are characterized by their little vegetation and climates. Dry, the microorganisms isolated in Uyuni, Bolivia were strains of the genus *Halobacterium sp.*While in the Cuatro Ciénegas region, the isolates were mainly bacteria of the *Bacillaceae* family, being the most abundant bacteria in natural environments, including the genera of *Alkalibacillus sp.*, *Marinococcus sp. and Halobacillus sp*, these genera were those that presented a greater capacity to produce hydrolytic enzymes, capable of degrading fish waste for the production of bioactive peptides of food interest.

Other studies carried out by Delgado-García, et al., (2014) isolated bacteria from the same region of the Coahuilense semi-desert in four different locations including Cuatro Ciénegas, reported the metabolic capacity of eight strains *Salinicoccus roseus* (EC-01), *Halobacillus sp*. (AS-04), *Oceanobacillus sp*. (ES1-03), *Halobacillus trueperi* (CT2-03), *Bacillus pumilus* (CP-01), *Bacillus subtilis* (AS-09), *Bacillus atrophaeus* (PN-01), *Bacillus atrophaeus* (SY-01) to produce enzymes for degradation of starch, pectin, cellulose and xylan. The production of enzymes such as amylases, pectinases and xylanases are of interest in the human food industry since they intervene in the process of making food products such as in the fruit processing industry for clarification of juices and wines, in baking to improve the quality of the bread and decrease the viscosity of pasta, brewing industry among others.(Gómez-garcía et al., 2016; Izarra et al., 2010; Torres-León et al., 2018, 2021)

The use of different enzymes such as: hydrolases, proteases in the food industry is also important since these enzymes have been reported for various purposes such as production of dairy products, bakery and clarification of xanthan gum (Adams et al., 2020; Corrêa et al., 2014; D. Kumar & Gong, 2018; Seviour et al., 2013) in Table 1 you can see a list of microorganisms with the metabolic capacity necessary for the production of these enzymes and the different arid zones around the planet from which they were obtained.

Table 1. Microorganisms isolated from arid zones with the capacity to produce protein compounds.

Molecule	Source of obtaining	Area	Reference
Protease	*Streptomyces sp.*	Saurashtra region, Gujarat India	(Mehta et al., 2006)
Protease	*Aspergillus flavus* and *Aspergillus niger*	Thiruvarur District Tamilnadu	(Soil et al., 2015)
Hydrolase	*Diploschistes diacapsis, and Lepraria crassissima*	Tabernas Desert Spain	(Miralles et al., 2012)
Hydrolase	*Glomus sp, Acaulospora sp* and *Scutellospora sp*	Baja California and Baja California Sur, México.	(Chávez, 2018)

In extreme environments such as arid zones, we can find organisms, distinguishable by their unique biochemistry and extraordinary physiological capacities, the result of adaptations to special environmental conditions. Their adaptations and particular characteristics can be useful for their

 doi:10.20944/preprints202310.0140.v1

application in numerous fields such as food due to their production of peptides and proteins, which indicates that they have great potential, but that unfortunately they have not been as studied as they should be. (Muro Urista et al., 2011; Saadi et al., 2015; Sawant & Nagendran, 2014)

Plants from arid zones as a source of protein for human consumption

Proteins are essential macronutrients in human nutrition. Plant proteins are made up of twenty-two essential amino acids (Dunlop et al., 2015). Integrating proteins from diverse plant sources can supply an adequate amount of essential amino acids to fulfill human nutritional needs (M. Kumar et al., 2022).

The search for new protein sources is a global priority, and plants grown in arid areas are a sustainable alternative. The great biological diversity of arid zones is a potential source of natural resources. Plants that grow in arid regions have some advantages; these plants are adapted to adverse growing conditions, require less water, and allow the use of infertile land (Ventura-Sobrevilla et al., 2022). Additionally, these resources can be used in a sustainable way to improve the quality of life of rural populations (Ventura-Sobrevilla et al., 2022). The use of plant proteins will be essential when animal-derived proteins fail to satisfy the requirements of the global population (M. Kumar et al., 2022). It is increasingly important to find new crop plants or genotypes of crops that have adaptation strategies to water loss in extremely arid conditions (Ahmed et al., 2020). The range vegetation in arid regions consists of shrub species, abundant cacti, and grasses (H. M. Andrade-Montemayor et al., 2011).

Table 2 shows the main plants of arid regions that have been investigated as a source of protein with functional properties. Legumes are among the main plants with the potential for use for protein production. According to Singh and Abhilash (2019), legumes are important crops for food and nutritional security, and legumes are second to cereals as a source of human nutrition. Underutilized legumes contain adequate quantities of essential amino acids compared to other crops (Naeem et al., 2020).

Table 2. Plants from arid zones as a source of protein with functional properties.

Common name/Part used	Scientific name	Country	Protein (%)	Molecules	Functional properties	Source
Kashrangeeg	*Lablab purpureus* (L.)	Egypt	15	-	-	(Ahmed et al., 2020)
Hyacinth bean	*Lablab purpureus* (L.)	India	28	Glycosides viz. aloe-emodin, emodin, chrysophenol, rhein	Cytostatic potential and anticancer activities	(Naeem et al., 2020).
Hyacinth bean	*Lablab purpureus* (L.)	South Africa	87.8	Arginine and lysine	Digestibility	(Mohan & Mellem, 2020)
Cacti pads	*Opuntia ficus-indica*	Mexico	7.7			(H. M. Andrade-Montemayor et al., 2011)
Cladodes	*Opuntia ficus-indica*	Mexico	13.8			(Ramírez-Moreno et al., 2013)
Prickly pear	*Opuntia ficus-indica*	Iran		Opuntin B	ribonuclease activity	(Rasoulpour et al., 2020)

 doi:10.20944/preprints202310.0140.v1

Mesquite	*Prosopis pallida*	Peru	9.5		(Gonzales-Barron et al., 2020)
Mesquite pods	*Prosopis laevigata*	Mexico	11.7		(H. Andrade-Montemayor et al., 2009)
Sangri pods	*Prosopis cineraria*	India	31	Antioxidant activity	(Garg et al., 2020)
pods	*Prosopis cineraria*	India	24.9	Antifungal activity	(Solanki et al., 2018)
Algarrobo	*Prosopis alba*	Argentina	85.5	Antiinflammatory and antioxidant activities	(Cattaneo et al., 2014)
Flowers	*Calligonum azel*	Tunisia	17.8		(Bannour et al., 2016)

Lablab purpureus (L.) Sweet in the Fabaceae family is named locally as kashrangeeg in Nubia, Egypt (Ahmed et al., 2020). The plant is used as a forage for grazing cattle, sheep, goats, and pigs. This plant is a legume of indeterminate growth, annual or biennial, as determined by environmental conditions. Despite having so many benefits, this plant has been underutilized. Currently, there are only reports of cultivation in sub-tropical areas of Africa, Central and South America, the West Indies, Southeast Asia, and Indonesia (The crop can be used in rotation with cereals to add fixed N to the soil) (Naeem et al., 2020). According to Table 2, the protein content is between 15 and 85%. Ahmed et al. (2020) showed that *L. purpureus* is a good source for proteins seeds and pods and can be used in many forms such as the unripe pods and mature green seeds with the haulm, leaves, dry basis, and straw used as livestock feeds (Mohan & Mellem, 2020). Additionally, this plant contains marvelous features to tolerate stress generated by drought and salinity (Naeem et al., 2020). It can be used as food and feed legumes as herds readily consume them in their desert environment (Ahmed et al., 2020). *L. purpureus* has a wide spectrum of therapeutic potentials, such as Cytostatic potential and anticancer activities (Naeem et al., 2020). This plant has other techno-functional properties such as foaming, emulsification, and gelation. The performance of this crop under drought stress offers comparatively cost-effective nutrition (Naeem et al., 2020).

In the American continent, two species of plants from arid zones have been studied as a source of protein. *Opuntia* spp. and *Prosopis* spp. have a low water requirement and excellent adaptation to semiarid regions (H. M. Andrade-Montemayor et al., 2011).

Opuntia spp. contains between 7.7 and 13.8% protein (Table 2). *Opuntia ficus-indica* (Prickly pears, nopal) belong to the *Cactaceae* family and grow in arid parts of the world (García-Cayuela et al., 2019). Nopal is used in food and as forage. Nopal has traditionally been used in Mexico since pre-Columbian times by the Aztecs in culinary preparations (de Albuquerque et al., 2019). The young stems of *Opuntia* spp., known as cladodes are widely consumed in Mexico (Ramírez-Moreno et al., 2013).

Prosopis species are considered multipurpose trees and shrubs by FAO, and their fruit constitutes a food source for humans and animals (Cattaneo et al., 2014). The flour obtained by grinding the pods of *Prosopis spp* is rich in protein. This species has a protein content between 9.5 to 85.5% (Table 2), with valine as the only limiting amino acid (Díaz-Batalla et al., 2018). Cattaneo et al. (2014) suggest that *Prosopis spp.* flour protein isolate could be a new alternative in the formulation of foods for humans. Bigne et al. (2018) mixed mesquite flour (150–350 g / kg) with wheat flour (850-650 g / kg) to obtain composite sweetbreads. Sensory analysis revealed a remarkable degree of acceptability for these mixed pieces of bread, particularly at the 250 g/kg replacement level.

The *Calligonum* genus (North African Sahara) is known for feeding purposes (Bewal et al., 2008). Bannour et al. (2016) reported that *Calligonum azel* Maire flowers are high protein (Table 2). The authors conclude that this plant can be used as a food ingredient.

The main disadvantage of arid zone plants is the presence of antinutritional factors such as non-protein amino acids (Huang et al., 2011) and tannins, phytate (18.9 mg/g), and trypsin inhibitors 0.15 TIU/mg (Naeem et al., 2020; Subagio, 2006). Plants such as legumes and tree seeds such as the genera *proposis* spp contain antinutritional factors that inhibit the activity of proteases in the gastrointestinal tract (H. M. Andrade-Montemayor et al., 2011). Although specific tannins like galotanins can be functional, they generally have adverse effects when bound to proteins (Torres-León et al., 2017). Before using the seeds as food, some treatments are needed to reduce their antinutritional factors (trypsin inhibitor and phytate) (Subagio, 2006). These antinutritional factors can be eliminated using cooking methods. Torres et al. (2016) reported the extraction of tannins with cooking and soaking in the mango seed (By-product with a high content of tannins 0.19-0.44%). These methods are commonly used in flour production and can be an alternative to eliminate antinutritional factors in plants in arid zones (Torres-León et al., 2018). Antinutritional compounds of Mesquite pods can also be removed by roasting the pod at 150 °C for 45 minutes (H. M. Andrade-Montemayor et al., 2011). The series of treatments or steps during protein isolation reduces the antinutritional factors to an undetectable level (Khattab & Arntfield, 2009). Garg et al. (2020) reported that protein isolation from *Prosopis cineraria* (Evaluating extraction factors using the response surface methodology) generates a 95% reduction in tannins. Mohan and Mellem (2020) recently reported high digestibility values with protein efficiency ratios for isolates greater than 2 (2.61–6.66). According to the authors, high digestibility results may suggest lower contents of antinutritional factors.

Environmental factors affect plant development. Although antinutritional factors can be negative, the molecules generated in these climatic conditions also produce interesting functional properties in plant molecules. In these plants, heat stress decreases the leaf area and accumulates reactive oxygen species (ROS); this makes the plants have to develop bioactive molecules that reduce the damaging effects of ROS. Table 2 shows the main functional properties reported in the plant protein of arid zones. Due to the importance of desert plants and their important role in sustainable development, further research is needed to investigate the potential of other plants in arid zones as a source of protein. Functional properties must also be investigated.

Insects from arid areas of interest as consumption or obtaining of proteins and peptides of human consumption

Insects are a food source for many cultures around the world. These can be consumed at different stages of their development and be prepared in different ways, thus forming an important part of gastronomy in various places. Although there are cosmopolitan insects, the species of edible insects will largely depend on the type of ecosystem in which a human population is found and the season of the year.

Generally, edible insects are those easy to identify and capture, that exist in great numbers and that are present for a good part of the year. There are more than 2000 species of edible insects around the world. In addition to providing an important source of protein, they need in proportion less food and space than livestock to generate 1 kg of protein and minimize the contamination generated by food production in traditional livestock (Van Huis, 2016)

Edible insects are part of the traditional eating habits of Mexico and the world, their preparation and consumption have remained practically the same for centuries, so they are an important part for the development of some peoples and can generate economic income (Baigts-Allende et al., 2021).

In addition, Mexico is the most entomophagous country on the planet with 549 species of edible insects (Ambrosio-Arzate et al., 2010; Esparza-Frausto et al., 2008). Although the consumption of insects and other arthropods in Mexico is more widespread towards the central and southern areas, this practice also occurs in the north, for example, in the state of Durango scorpions are consumed, even as a gourmet dish.

The production of edible insects in arid areas can largely solve the problem of food security, offering a highly nutritious and relatively inexpensive option, especially in those areas where water resources are scarce and consequently livestock and agriculture are no longer extensively viable (Melo-Ruíz et al., 2017).

Other productive alternatives in the arid and semi-arid zones of Mexico are made up of some species of edible insects such as wild bees and the honey ant, which are used mainly for self-consumption. There are other species of insects that have great economic potential, because their consumption is very popular in the central area of the country; these species are the red and white maguey worm, and escamoles, since they have a delicate flavor and high nutritional quality (40% protein) (Tarango Arambula, 2005).

It is well known that the nutritional value of insects is high, for example, the protein content of edible insects ranges from 28 to 81%, expressed on a dry basis. Most species have 55 to 65% of good quality protein, that is, half to almost three-quarters of their body is made up of proteins, whose digestibility, that is, their use, ranges from 75 to 98%, which implies that almost all of it is used.

There are chemical ratings that reach 96% (quality of the protein) in insects, only surpassed by those of the egg and those of the milk. The most edible insect orders are Hymenoptera, Orthoptera, Hemiptera and Coleoptera, which have a protein content that ranges from 9.45 to 77.13% (Ramos-Elorduy et al., 1998). It is also known that in insects the protein content is lower than that of fat, on average, there is twice as much protein as fat, although in some cases the protein can be up to 7 times more. The insects that contain the highest amount of protein belong to the Orthoptera order (65.96%), on the contrary, it is those of the Coleoptera order that contain the least (44.03%), therefore, in most insects, on average the half of the dry weight is protein (Lizhang et al., 2008). Some edible insect larvae in Mexico have a protein content that ranges from 45.25 to 60.75%, and all of them contain eight essential amino acids (Melo-Ruíz et al., 2017). In conclusion, edible insects could alleviate poverty and malnutrition in arid and semi-arid areas of the planet, offering an economic, environmental and sociocultural viable alternative.

Conclusion

Despite the fact that studies and research are carried out on a daily basis, everything that nature can offer has not yet been discovered, so it is important and necessary to continue exploring all that it can contribute. There are natural sources of compounds of nutritional value such as plants, and animals such as insects and microorganisms that are generally studied by the natives of ecosystems that we consider more diverse such as those of tropical or temperate climates, we still have to explore the arid areas that in recent years have generated interest since, due to their extreme characteristics, they force their inhabitants to adapt and carry out complex metabolic processes that originate compounds of interest such as proteins and bioactive peptides for human consumption, which most of them are extracted from conventional sources such as meat and dairy products, adding to this the expected changes in average lifestyles on a global scale will demand a greater amount of consumption of animal products.

This will further increase the demand for food-grade protein, however, the disadvantages that this type of industry causes is known, since its intensive production of dairy and slaughter cattle causing damage to the environment due to its greenhouse gas emissions. and the excessive use of water, for which the implementation of the production of these compounds through non-conventional sources such as insects, plants, and microbial is of utmost importance for society and the environment, being an interesting option since the population worldwide is growing and in more and more places malnutrition and human health is a problem, the 2030 agenda of the United Nations lists the objectives of sustainable development, which includes the fight against climate change and zero hunger.

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