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MEDICINAL PLANTS AND THEIR USES

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ABSTRACT: Medicinal plants, also called medicinal herbs, have been discovered and used in traditional medicine practices since prehistoric times. Plants synthesize hundreds of chemical compounds for various functions, including defense and protection against insects, fungi, diseases, and herbivorous mammals.^[2] The earliest historical records of herbs are found from the Sumerian civilization, where hundreds of medicinal plants including opium are listed on clay tablets, c. 3000 BC. The Ebers Papyrus from ancient Egypt, c. 1550 BC, describes over 850 plant medicines. The Greek physician Dioscorides, who worked in the Roman army, documented over 1000 recipes for medicines using over 600 medicinal plants in *De materia medica*, c. 60 AD; this formed the basis of pharmacopoeias for some 1500 years. Drug research sometimes makes use of ethnobotany to search for pharmacologically active substances, and this approach has yielded hundreds of useful compounds. These include the common drugs aspirin, digoxin, quinine, and opium. The compounds found in plants are diverse, with most in four biochemical classes: alkaloids, glycosides, polyphenols, and terpenes. Few of these are scientifically confirmed as medicines or used in conventional medicine.

KEYWORDS-medicinal plants, defense, herbalism, drugs, uses, medicines

I. INTRODUCTION

Medicinal plants are widely used as folk medicine in non-industrialized societies, mainly because they are readily available and cheaper than modern medicines. The annual global export value of the thousands of types of plants with medicinal properties was estimated to be US\$60 billion per year and growing at the rate of 6% per annum. In many countries, there is little regulation of traditional medicine, but the World Health Organization coordinates a network to encourage safe and rational use. The botanical herbal market has been criticized for being poorly regulated and containing placebo and pseudoscience products with no scientific research to support their medical claims.^[3] Medicinal plants face both general threats, such as climate change and habitat destruction, and the specific threat of over-collection to meet market demand.^[3]

Prehistoric times

Plants, including many now used as culinary herbs and spices, have been used as medicines, not necessarily effectively, from prehistoric times. Spices have been used partly to counter food spoilage bacteria, especially in hot climates,^{[5][6]} and especially in meat dishes that spoil more readily.^[7] Angiosperms (flowering plants) were the original source of most plant medicines.^[8] Human settlements are often surrounded by weeds used as herbal medicines, such as nettle, dandelion and chickweed.^{[9][10]} Humans were not alone in using herbs as medicines: some animals such as non-human primates, monarch butterflies and sheep ingest medicinal plants when they are ill.^[11] Plant samples from prehistoric burial sites are among the lines of evidence that Paleolithic peoples had knowledge of herbal medicine. For instance, a 60,000-year-old Neanderthal burial site, "Shanidar IV", in northern Iraq has yielded large amounts of pollen from eight plant species, seven of which are used now as herbal remedies.^[12] Also, a mushroom was found in the personal effects of *Ötzi the Iceman*, whose body was frozen in the Ötztal Alps for more than 5,000 years. The mushroom was probably used against whipworm.^[13]

Ancient times

In ancient Sumeria, hundreds of medicinal plants including myrrh and opium are listed on clay tablets from around 3000 BC. The ancient Egyptian Ebers Papyrus lists over 800 plant medicines such as aloe, cannabis, castor bean, garlic, juniper, and mandrake.^{[14][15]}

From ancient times to the present, Ayurvedic medicine as documented in the Atharva Veda, the Rig Veda and the Sushruta Samhita has used hundreds of herbs and spices, such as turmeric, which contains curcumin.^[16] The Chinese pharmacopoeia, the *Shennong Ben Cao Jing* records plant medicines such as chaulmoogra for leprosy, ephedra, and hemp.^[17] This was expanded in the Tang dynasty *Yaoxing Lun*.^[18] In the fourth century BC, Aristotle's pupil Theophrastus wrote the first systematic botany text, *Historia plantarum*.^[19] In

around 60 AD, the Greek physician Pedanius Dioscorides, working for the Roman army, documented over 1000 recipes for medicines using over 600 medicinal plants in *De materia medica*. The book remained the authoritative reference on herbalism for over 1500 years, into the seventeenth century.^[4]

Middle Ages

In the Early Middle Ages, Benedictine monasteries preserved medical knowledge in Europe, translating and copying classical texts and maintaining herb gardens.^{[20][21]} Hildegard of Bingen wrote *Causae et Curae* ("Causes and Cures") on medicine.^[22] In the Islamic Golden Age, scholars translated many classical Greek texts including Dioscorides into Arabic, adding their own commentaries.^[23] Herbalism flourished in the Islamic world, particularly in Baghdad and in Al-Andalus. Among many works on medicinal plants, Abulcasis (936–1013) of Cordoba wrote *The Book of Simples*, and Ibn al-Baitar (1197–1248) recorded hundreds of medicinal herbs such as *Aconitum*, *nux vomica*, and tamarind in his *Corpus of Simples*.^[24] Avicenna included many plants in his 1025 *The Canon of Medicine*.^[25] Abu-Rayhan Biruni,^[26] Ibn Zuhr,^[27] Peter of Spain, and John of St Amand wrote further pharmacopoeias.^[28]

Early Modern

The Early Modern period saw the flourishing of illustrated herbals across Europe, starting with the 1526 *Grete Herball*. John Gerard wrote his famous *The Herball or General History of Plants* in 1597, based on Rembert Dodoens, and Nicholas Culpeper published his *The English Physician Enlarged*.^[29] Many new plant medicines arrived in Europe as products of Early Modern exploration and the resulting Columbian Exchange, in which livestock, crops and technologies were transferred between the Old World and the Americas in the 15th and 16th centuries. Medicinal herbs arriving in the Americas included garlic, ginger, and turmeric; coffee, tobacco and coca travelled in the other direction.^{[30][31]} In Mexico, the sixteenth century *Badianus Manuscript* described medicinal plants available in Central America.^[32]

19th and 20th centuries

The place of plants in medicine was radically altered in the 19th century by the application of chemical analysis. Alkaloids were isolated from a succession of medicinal plants, starting with morphine from the poppy in 1806, and soon followed by ipecacuanha and strychnos in 1817, quinine from the cinchona tree, and then many others. As chemistry progressed, additional classes of potentially active substances were discovered in plants. Commercial extraction of purified alkaloids including morphine began at Merck in 1826. Synthesis of a substance first discovered in a medicinal plant began with salicylic acid in 1853. Around the end of the 19th century, the mood of pharmacy turned against medicinal plants, as enzymes often modified the active ingredients when whole plants were dried, and alkaloids and glycosides purified from plant material started to be preferred. Drug discovery from plants continued to be important through the 20th century and into the 21st, with important anti-cancer drugs from yew and Madagascar periwinkle.^{[33][34][35]}

Medicinal plants are used with the intention of maintaining health, to be administered for a specific condition, or both, whether in modern medicine or in traditional medicine.^{[31][36]} The Food and Agriculture Organization estimated in 2002 that over 50,000 medicinal plants are used across the world.^[37] The Royal Botanic Gardens, Kew more conservatively estimated in 2016 that 17,810 plant species have a medicinal use, out of some 30,000 plants for which a use of any kind is documented.^[38]

In modern medicine, around a quarter^[a] of the drugs prescribed to patients are derived from medicinal plants, and they are rigorously tested.^{[36][39]} In other systems of medicine, medicinal plants may constitute the majority of what are often informal attempted treatments, not tested scientifically.^[40] The World Health Organization estimates, without reliable data, that some 80 percent of the world's population depends mainly on traditional medicine (including but not limited to plants); perhaps some two billion people are largely reliant on medicinal plants.^{[36][39]} The use of plant-based materials including herbal or natural health products with supposed health benefits, is increasing in developed countries.^[41] This brings attendant risks of toxicity and other effects on human health, despite the safe image of herbal remedies.^[41] Herbal medicines have been in use since long before modern medicine existed; there was and often still is little or no knowledge of the pharmacological basis of their actions, if any, or of their safety. The World Health Organization formulated a policy on traditional medicine in 1991, and since then has published guidelines for them, with a series of monographs on widely used herbal medicines.^{[42][43]}

Medicinal plants may provide three main kinds of benefit: health benefits to the people who consume them as medicines; financial benefits to people who harvest, process, and distribute them for sale; and society-wide benefits, such as job opportunities, taxation income, and a healthier labour force.^[36] However, development of plants or extracts

having potential medicinal uses is blunted by weak scientific evidence, poor practices in the process of drug development, and insufficient financing.^[3]

Phytochemical basis

All plants produce chemical compounds which give them an evolutionary advantage, such as defending against herbivores or, in the example of salicylic acid, as a hormone in plant defenses.^{[44][45]} These phytochemicals have potential for use as drugs, and the content and known pharmacological activity of these substances in medicinal plants is the scientific basis for their use in modern medicine, if scientifically confirmed.^[3] For instance, daffodils (*Narcissus*) contain nine groups of alkaloids including galantamine, licensed for use against Alzheimer's disease. The alkaloids are bitter-tasting and toxic, and concentrated in the parts of the plant such as the stem most likely to be eaten by herbivores; they may also protect against parasites.^{[46][47][48]}

Modern knowledge of medicinal plants is being systematised in the Medicinal Plant Transcriptomics Database, which by 2011 provided a sequence reference for the transcriptome of some thirty species.^[49] Major classes of plant phytochemicals are described below, with examples of plants that contain them.^{[8][43][50][51][52]}

Alkaloids

Alkaloids are bitter-tasting chemicals, very widespread in nature, and often toxic, found in many medicinal plants.^[53] There are several classes with different modes of action as drugs, both recreational and pharmaceutical. Medicines of different classes include atropine, scopolamine, and hyoscyamine (all from nightshade),^[54] the traditional medicine berberine (from plants such as *Berberis* and *Mahonia*),^[b] caffeine (*Coffea*), cocaine (*Coca*), ephedrine (*Ephedra*), morphine (opium poppy), nicotine (tobacco),^[c] reserpine (*Rauvolfia serpentina*), quinidine and quinine (*Cinchona*), vincamine (*Vinca minor*), and vincristine (*Catharanthus roseus*).^{[52][57]}

Glycosides

Anthraquinone glycosides are found in medicinal plants such as rhubarb, cascara, and Alexandrian senna.^{[59][60]} Plant-based laxatives made from such plants include senna,^[61] rhubarb^[62] and *Aloe*.^[52]

The cardiac glycosides are powerful drugs from medicinal plants including foxglove and lily of the valley. They include digoxin and digitoxin which support the beating of the heart, and act as diuretics.^[44]

Polyphenols

Polyphenols of several classes are widespread in plants, having diverse roles in defenses against plant diseases and predators.^[44] They include hormone-mimicking phytoestrogens and astringent tannins.^{[52][64]} Plants containing phytoestrogens have been administered for centuries for gynecological disorders, such as fertility, menstrual, and menopausal problems.^[65] Among these plants are *Pueraria mirifica*,^[66] kudzu,^[67] angelica,^[68] fennel, and anise.^[69]

Many polyphenolic extracts, such as from grape seeds, olives or maritime pine bark, are sold as dietary supplements and cosmetics without proof or legal health claims for medicinal effects.^[70] In Ayurveda, the astringent rind of the pomegranate, containing polyphenols called punicalagins, is used as a medicine, with no scientific proof of efficacy.^{[70][71]}

Terpenes

Terpenes and terpenoids of many kinds are found in a variety of medicinal plants,^[73] and in resinous plants such as the conifers. They are strongly aromatic and serve to repel herbivores. Their scent makes them useful in essential oils, whether for perfumes such as rose and lavender, or for aromatherapy.^{[52][74][75]} Some have medicinal uses: for example, thymol is an antiseptic and was once used as a vermifuge (anti-worm medicine).^[76]

In practice

Cultivation

Medicinal plants demand intensive management. Different species each require their own distinct conditions of cultivation. The World Health Organization recommends the use of rotation to minimise problems with pests and plant diseases. Cultivation may be traditional or may make use of conservation agriculture practices to maintain organic matter in the soil and to conserve water, for example with no-till farming systems.^[77] In many medicinal and aromatic plants, plant characteristics vary widely with soil type and cropping strategy, so care is required to obtain satisfactory yields.^[78]

Preparation

Medicinal plants are often tough and fibrous, requiring some form of preparation to make them convenient to administer. According to the Institute for Traditional Medicine, common methods for the preparation of herbal medicines include decoction, powdering, and extraction with alcohol, in each case yielding a mixture of substances. Decoction involves crushing and then boiling the plant material in water to produce a liquid extract that can be taken orally or applied topically.^[79] Powdering involves drying the plant material and then crushing it to yield a powder that can be compressed into tablets. Alcohol extraction involves soaking the plant material in cold wine or distilled spirit to form a tincture.^[80]

Traditional poultices were made by boiling medicinal plants, wrapping them in a cloth, and applying the resulting parcel externally to the affected part of the body.^[81]

When modern medicine has identified a drug in a medicinal plant, commercial quantities of the drug may either be synthesised or extracted from plant material, yielding a pure chemical.^[33] Extraction can be practical when the compound in question is complex.^[82]

Usage

Plant medicines are in wide use around the world.^[83] In most of the developing world, especially in rural areas, local traditional medicine, including herbalism, is the only source of health care for people, while in the developed world, alternative medicine including use of dietary supplements is marketed aggressively using the claims of traditional medicine. As of 2015, most products made from medicinal plants had not been tested for their safety and efficacy, and products that were marketed in developed economies and provided in the undeveloped world by traditional healers were of uneven quality, sometimes containing dangerous contaminants.^[84] Traditional Chinese medicine makes use of a wide variety of plants, among other materials and techniques.^[85] Researchers from Kew Gardens found 104 species used for diabetes in Central America, of which seven had been identified in at least three separate studies.^{[86][87]} The Yanomami of the Brazilian Amazon, assisted by researchers, have described 101 plant species used for traditional medicines.^{[88][89]}

Drugs derived from plants including opiates, cocaine and cannabis have both medical and recreational uses. Different countries have at various times made use of illegal drugs, partly on the basis of the risks involved in taking psychoactive drugs.^[90]

Effectiveness

Plant medicines have often not been tested systematically, but have come into use informally over the centuries. By 2007, clinical trials had demonstrated potentially useful activity in nearly 16% of herbal extracts; there was limited in vitro or in vivo evidence for roughly half the extracts; there was only phytochemical evidence for around 20%; 0.5% were allergenic or toxic; and some 12% had basically never been studied scientifically.^[43] Cancer Research UK caution that there is no reliable evidence for the effectiveness of herbal remedies for cancer.^[91]

A 2012 phylogenetic study built a family tree down to genus level using 20,000 species to compare the medicinal plants of three regions, Nepal, New Zealand and the Cape of South Africa. It discovered that the species used traditionally to treat the same types of condition belonged to the same groups of plants in all three regions, giving a "strong phylogenetic signal".^[92] Since many plants that yield pharmaceutical drugs belong to just these groups, and the groups were independently used in three different world regions, the results were taken to mean 1) that these plant groups do have potential for medicinal efficacy, 2) that undefined pharmacological activity is associated with use in traditional medicine, and 3) that the use of a phylogenetic groups for possible plant medicines in one region may predict their use in the other regions.^[92]

Regulation

The World Health Organization (WHO) has been coordinating a network called the International Regulatory Cooperation for Herbal Medicines to try to improve the quality of medical products made from medicinal plants and the claims made for them.^[93] In 2015, only around 20% of countries had well-functioning regulatory agencies, while 30% had none, and around half had limited regulatory capacity.^[84] In India, where Ayurveda has been practised for centuries, herbal remedies are the responsibility of a government department, AYUSH, under the Ministry of Health & Family Welfare.^[94]

WHO has set out a strategy for traditional medicines^[95] with four objectives: to integrate them as policy into national healthcare systems; to provide knowledge and guidance on their safety, efficacy, and quality; to increase their availability and affordability; and to promote their rational, therapeutically sound usage.^[95] WHO notes in the strategy that countries are experiencing seven challenges to such implementation, namely in developing and enforcing policy; in integration; in safety and quality, especially in assessment of products and qualification of practitioners; in controlling advertising; in research and development; in education and training; and in the sharing of information.^[95]

II. DISCUSSION

The pharmaceutical industry has roots in the apothecary shops of Europe in the 1800s, where pharmacists provided local traditional medicines to customers, which included extracts like morphine, quinine, and strychnine.^[96] Therapeutically important drugs like camptothecin (from *Camptotheca acuminata*, used in traditional Chinese medicine) and taxol (from the Pacific yew, *Taxus brevifolia*) were derived from medicinal plants.^{[97][33]} The Vinca alkaloids vincristine and vinblastine, used as anti-cancer drugs, were discovered in the 1950s from the Madagascar periwinkle, *Catharanthus roseus*.^[98]

Hundreds of compounds have been identified using ethnobotany, investigating plants used by indigenous peoples for possible medical applications.^[99] Some important phytochemicals, including curcumin, epigallocatechin gallate, genistein and resveratrol are pan-assay interference compounds, meaning that *in vitro* studies of their activity often provide unreliable data. As a result, phytochemicals have frequently proven unsuitable as the lead substances in drug discovery.^{[100][101]} In the United States over the period 1999 to 2012, despite several hundred applications for new drug status, only two botanical drug candidates had sufficient evidence of medicinal value to be approved by the Food and Drug Administration.^[3]

The pharmaceutical industry has remained interested in mining traditional uses of medicinal plants in its drug discovery efforts.^[33] Of the 1073 small-molecule drugs approved in the period 1981 to 2010, over half were either directly derived from or inspired by natural substances.^{[33][102]} Among cancer treatments, of 185 small-molecule drugs approved in the period from 1981 to 2019, 65% were derived from or inspired by natural substances.^[103]

Safety

Plant medicines can cause adverse effects and even death, whether by side-effects of their active substances, by adulteration or contamination, by overdose, or by inappropriate prescription. Many such effects are known, while others remain to be explored scientifically. There is no reason to presume that because a product comes from nature it must be safe: the existence of powerful natural poisons like atropine and nicotine shows this to be untrue. Further, the high standards applied to conventional medicines do not always apply to plant medicines, and dose can vary widely depending on the growth conditions of plants: older plants may be much more toxic than young ones, for instance.^{[105][106][107][108][109][110]}

Plant extracts may interact with conventional drugs, both because they may provide an increased dose of similar compounds, and because some phytochemicals interfere with the body's systems that metabolise drugs in the liver including the cytochrome P450 system, making the drugs last longer in the body and have a cumulative effect.^[111] Plant medicines can be dangerous during pregnancy.^[112] Since plants may contain many different substances, plant extracts may have complex effects on the human body.^[5]

Quality, advertising, and labelling

Herbal medicine and dietary supplement products have been criticized as not having sufficient standards or scientific evidence to confirm their contents, safety, and presumed efficacy.^{[113][114][115][116]} A 2013 study found that one-third of herbal products sampled contained no trace of the herb listed on the label, and other products were adulterated with unlisted fillers including potential allergens.^{[117][118]} Companies often make false claims about their herbal products

promising health benefits that aren't backed by evidence to generate more sales. The market for dietary supplements and nutraceuticals grew by 5% during the COVID-19 pandemic, which led to the United States taking action to stop the deceptive marketing of herbal products to combat the virus.^{[119][120]}

Threats

Where medicinal plants are harvested from the wild rather than cultivated, they are subject to both general and specific threats. General threats include climate change and habitat loss to development and agriculture. A specific threat is over-collection to meet rising demand for medicines.^[121] A case in point was the pressure on wild populations of the Pacific yew soon after news of taxol's effectiveness became public.^[33] The threat from over-collection could be addressed by cultivation of some medicinal plants, or by a system of certification to make wild harvesting sustainable.^[121] A report in 2020 by the Royal Botanic Gardens, Kew identifies 723 medicinal plants as being at risk of extinction, caused partly by over-collection.^{[122][103]}

III. RESULTS

Herbal medicine (also called herbalism, phytomedicine or phytotherapy) is the study of pharmacognosy and the use of medicinal plants, which are a basis of traditional medicine.^[1] With worldwide research into pharmacology, some herbal medicines have been translated into modern remedies, such as the anti-malarial group of drugs called artemisinin isolated from *Artemisia annua*, a herb that was known in Chinese medicine to treat fever.^{[2][3]} There is limited scientific evidence for the safety and efficacy of many plants used in 21st-century herbalism, which generally does not provide standards for purity or dosage.^{[1][4]} The scope of herbal medicine sometimes include fungal and bee products, as well as minerals, shells and certain animal parts.^[5]

Paraherbalism describes alternative and pseudoscientific practices of using unrefined plant or animal extracts as unproven medicines or health-promoting agents.^{[1][4][6][7]} Paraherbalism relies on the belief that preserving various substances from a given source with less processing is safer or more effective than manufactured products, a concept for which there is no evidence.^[6]

Archaeological evidence indicates that the use of medicinal plants dates back to the Paleolithic age, approximately 60,000 years ago. Written evidence of herbal remedies dates back over 5,000 years to the Sumerians, who compiled lists of plants. Some ancient cultures wrote about plants and their medical uses in books called *herbals*. In ancient Egypt, herbs are mentioned in Egyptian medical papyri, depicted in tomb illustrations, or on rare occasions found in medical jars containing trace amounts of herbs.^[8] In ancient Egypt, the Ebers papyrus dates from about 1550 BC, and covers more than 700 compounds, mainly of plant origin.^[9] The earliest known Greek herbals came from Theophrastus of Eresos who, in the 4th century BC, wrote in Greek *Historia Plantarum*, from Diocles of Carystus who wrote during the 3rd century BC, and from Krateuas who wrote in the 1st century BC. Only a few fragments of these works have survived intact, but from what remains, scholars noted overlap with the Egyptian herbals.^[10] Seeds likely used for herbalism were found in archaeological sites of Bronze Age China dating from the Shang dynasty^[11] (c. 1600 – c. 1046 BC). Over a hundred of the 224 compounds mentioned in the *Huangdi Neijing*, an early Chinese medical text, are herbs.^[12] Herbs were also commonly used in the traditional medicine of ancient India, where the principal treatment for diseases was diet.^[13] *De Materia Medica*, originally written in Greek by Pedanius Dioscorides (c. 40 – c. 90 AD) of Anazarbus, Cilicia, a physician and botanist, is one example of herbal writing used over centuries until the 1600s.^[14]

Modern herbal medicine

The World Health Organization (WHO) estimates that 80 percent of the population of some Asian and African countries presently use herbal medicine for some aspect of primary health care.^[15]

Some prescription drugs have a basis as herbal remedies, including artemisinin,^[16] digitalis, quinine and taxanes.

Regulatory review

In 2015, the Australian Government's Department of Health published the results of a review of alternative therapies that sought to determine if any were suitable for being covered by health insurance; herbalism was one of 17 topics evaluated for which no clear evidence of effectiveness was found.^[17] Establishing guidelines to assess safety and efficacy of herbal products, the European Medicines Agency provided criteria in 2017 for evaluating and grading the quality of clinical research in preparing monographs about herbal products.^[18] In the United States, the National Center for Complementary and Integrative Health of the National Institutes of Health funds clinical trials on herbal

compounds, provides fact sheets evaluating the safety, potential effectiveness and side effects of many plant sources,^[19] and maintains a registry of clinical research conducted on herbal products.^[20]

According to Cancer Research UK as of 2015, "there is currently no strong evidence from studies in people that herbal remedies can treat, prevent or cure cancer".^[5]

Prevalence of use

The use of herbal remedies is more prevalent in people with chronic diseases, such as cancer, diabetes, asthma, and end-stage kidney disease.^{[21][22][23]} Multiple factors such as gender, age, ethnicity, education and social class are also shown to have association with prevalence of herbal remedies use.^[24]

Herbal preparations

There are many forms in which herbs can be administered, the most common of which is a liquid consumed as a herbal tea or a (possibly diluted) plant extract.^[25]

Herbal teas, or tisanes, are the resultant liquid of extracting herbs into water, though they are made in a few different ways. Infusions are hot water extracts of herbs, such as chamomile or mint, through steeping. Decoctions are the long-term boiled extracts, usually of harder substances like roots or bark. Maceration is the cold infusion of plants with high mucilage-content, such as sage or thyme. To make macerates, plants are chopped and added to cold water. They are then left to stand for 7 to 12 hours (depending on herb used). For most macerates, 10 hours is used.^[26]

Tinctures are alcoholic extracts of herbs, which are generally stronger than herbal teas.^[27] Tinctures are usually obtained by combining pure ethanol (or a mixture of pure ethanol with water) with the herb. A completed tincture has an ethanol percentage of at least 25% (sometimes up to 90%).^[26] Non-alcoholic tinctures can be made with glycerin but it is believed to be less absorbed by the body than alcohol based tinctures and has a shorter shelf life.^[28] Herbal wine and elixirs are alcoholic extract of herbs, usually with an ethanol percentage of 12–38%.^[26] Extracts include liquid extracts, dry extracts, and nebulisates. Liquid extracts are liquids with a lower ethanol percentage than tinctures. They are usually made by vacuum distilling tinctures. Dry extracts are extracts of plant material that are evaporated into a dry mass. They can then be further refined to a capsule or tablet.^[26]

The exact composition of a herbal product is influenced by the method of extraction. A tea will be rich in polar components because water is a polar solvent. Oil on the other hand is a non-polar solvent and it will absorb non-polar compounds. Alcohol lies somewhere in between.^[25]

Many herbs are applied topically to the skin in a variety of forms. Essential oil extracts can be applied to the skin, usually diluted in a carrier oil. Many essential oils can burn the skin or are simply too high dose used straight; diluting them in olive oil or another food grade oil such as almond oil can allow these to be used safely as a topical. Salves, oils, balms, creams, and lotions are other forms of topical delivery mechanisms. Most topical applications are oil extractions of herbs. Taking a food grade oil and soaking herbs in it for anywhere from weeks to months allows certain phytochemicals to be extracted into the oil. This oil can then be made into salves, creams, lotions, or simply used as an oil for topical application. Many massage oils, antibacterial salves, and wound healing compounds are made this way.^[29]

Inhalation, as in aromatherapy, can be used as a treatment.^{[30][31][32]}

Safety

Consumption of herbs may cause adverse effects.^[34] Furthermore, "adulteration, inappropriate formulation, or lack of understanding of plant and drug interactions have led to adverse reactions that are sometimes life threatening or lethal."^[35] Proper double-blind clinical trials are needed to determine the safety and efficacy of each plant before medical use.^[36]

Although many consumers believe that herbal medicines are safe because they are natural, herbal medicines and synthetic drugs may interact, causing toxicity to the consumer. Herbal remedies can also be dangerously contaminated, and herbal medicines without established efficacy, may unknowingly be used to replace prescription medicines.^[37]

Standardization of purity and dosage is not mandated in the United States, but even products made to the same specification may differ as a result of biochemical variations within a species of plant.^[38] Plants have chemical defense

mechanisms against predators that can have adverse or lethal effects on humans. Examples of highly toxic herbs include poison hemlock and nightshade.^[39] They are not marketed to the public as herbs, because the risks are well known, partly due to a long and colorful history in Europe, associated with "sorcery", "magic" and intrigue.^[40] Although not frequent, adverse reactions have been reported for herbs in widespread use.^[41] On occasion serious untoward outcomes have been linked to herb consumption. A case of major potassium depletion has been attributed to chronic licorice ingestion,^[42] and consequently professional herbalists avoid the use of licorice where they recognize that this may be a risk. Black cohosh has been implicated in a case of liver failure.^[43] Few studies are available on the safety of herbs for pregnant women,^[44] and one study found that use of complementary and alternative medicines are associated with a 30% lower ongoing pregnancy and live birth rate during fertility treatment.^[45]

Examples of herbal treatments with likely cause-effect relationships with adverse events include aconite (which is often a legally restricted herb), Ayurvedic remedies, broom, chaparral, Chinese herb mixtures, comfrey, herbs containing certain flavonoids, germander, guar gum, liquorice root, and pennyroyal.^[46] Examples of herbs that may have long-term adverse effects include ginseng, the endangered herb goldenseal, milk thistle, senna (against which herbalists generally advise and rarely use), aloe vera juice, buckthorn bark and berry, cascara sagrada bark, saw palmetto, valerian, kava (which is banned in the European Union), St. John's wort, khat, betel nut, the restricted herb ephedra, and guarana.^[35]

There is also concern with respect to the numerous well-established interactions of herbs and drugs.^{[35][47]} In consultation with a physician, usage of herbal remedies should be clarified, as some herbal remedies have the potential to cause adverse drug interactions when used in combination with various prescription and over-the-counter pharmaceuticals, just as a customer should inform a herbalist of their consumption of actual prescription and other medication.^{[48][49]}

For example, dangerously low blood pressure may result from the combination of a herbal remedy that lowers blood pressure together with prescription medicine that has the same effect. Some herbs may amplify the effects of anticoagulants.^[50] Certain herbs as well as common fruit interfere with cytochrome P450, an enzyme critical to much drug metabolism.^[51]

In a 2018 study, FDA identified active pharmaceutical additives in over 700 of analyzed dietary supplements sold as "herbal", "natural" or "traditional".^[52] The undisclosed additives included "unapproved antidepressants and designer steroids", as well as prescription drugs, such as sildenafil or sibutramine.

Labeling accuracy

A 2013 study found that one-third of herbal supplements sampled contained no trace of the herb listed on the label.^[38] The study found products adulterated with contaminants or fillers not listed on the label, including potential allergens such as soy, wheat, or black walnut. One bottle labeled as St. John's wort was found to actually contain *Alexandrian senna*, a laxative.^{[38][53]}

Researchers at the University of Adelaide found in 2014 that almost 20 percent of herbal remedies surveyed were not registered with the Therapeutic Goods Administration, despite this being a condition for their sale.^[54] They also found that nearly 60 percent of products surveyed had ingredients that did not match what was on the label. Out of 121 products, only 15 had ingredients that matched their TGA listing and packaging.^[54]

In 2015, the New York Attorney General issued cease and desist letters to four major U.S. retailers (GNC, Target, Walgreens, and Walmart) who were accused of selling herbal supplements that were mislabeled and potentially dangerous.^{[55][56]} Twenty-four products were tested by DNA barcoding as part of the investigation, with all but five containing DNA that did not match the product labels.

Practitioners of herbalism

In some countries, formalized training and minimum education standards exist for herbalists, although these are not necessarily uniform within or between countries. In Australia, for example, the self-regulated status of the profession (as of 2009) resulted in variable standards of training, and numerous loosely formed associations setting different educational standards.^[57] One 2009 review concluded that regulation of herbalists in Australia was needed to reduce the risk of interaction of herbal medicines with prescription drugs, to implement clinical guidelines and prescription of herbal products, and to assure self-regulation for protection of public health and safety.^[57] In the United Kingdom, the training of herbalists is done by state-funded universities offering Bachelor of Science degrees in herbal medicine.^[58] In the United States, according to the American Herbalist Guild, "there is currently no licensing or certification for

herbalists in any state that precludes the rights of anyone to use, dispense, or recommend herbs."^[59] However, there are U.S. federal restrictions for marketing herbs as cures for medical conditions, or essentially practicing as an unlicensed physician.

United States herbalism fraud

Over the years 2017–2021, the U.S. Food and Drug Administration (FDA) issued warning letters to numerous herbalism companies for illegally marketing products under "conditions that cause them to be drugs under section 201(g)(1) of the Act [21 U.S.C. § 321(g)(1)], because they are intended for use in the diagnosis, cure, mitigation, treatment, or prevention of disease and/or intended to affect the structure or any function of the body" when no such evidence existed.^{[60][61][62]} During the COVID-19 pandemic, the FDA and U.S. Federal Trade Commission issued warnings to several hundred American companies for promoting false claims that herbal products could prevent or treat COVID-19 disease.^{[62][63]}

Government regulations

The World Health Organization (WHO), the specialized agency of the United Nations (UN) that is concerned with international public health, published *Quality control methods for medicinal plant materials* in 1998 to support WHO Member States in establishing quality standards and specifications for herbal materials, within the overall context of quality assurance and control of herbal medicines.^[64]

In the European Union (EU), herbal medicines are regulated under the Committee on Herbal Medicinal Products.^[65]

In the United States, herbal remedies are regulated dietary supplements by the Food and Drug Administration (FDA) under current good manufacturing practice (cGMP) policy for dietary supplements.^[66] Manufacturers of products falling into this category are not required to prove the safety or efficacy of their product so long as they do not make 'medical' claims or imply uses other than as a 'dietary supplement', though the FDA may withdraw a product from sale should it prove harmful.^{[67][68]}

Canadian regulations are described by the Natural and Non-prescription Health Products Directorate which requires an eight-digit Natural Product Number or Homeopathic Medicine Number on the label of licensed herbal medicines or dietary supplements.^[69]

Some herbs, such as cannabis and coca, are outright banned in most countries though coca is legal in most of the South American countries where it is grown. The *Cannabis* plant is used as a herbal medicine, and as such is legal in some parts of the world. Since 2004, the sales of ephedra as a dietary supplement is prohibited in the United States by the FDA,^[70] and subject to Schedule III restrictions in the United Kingdom.

Scientific criticism

Herbalism has been criticized as a potential "minefield" of unreliable product quality, safety hazards, and potential for misleading health advice.^{[1][7]} Globally, there are no standards across various herbal products to authenticate their contents, safety or efficacy,^[38] and there is generally an absence of high-quality scientific research on product composition or effectiveness for anti-disease activity.^{[7][71]} Presumed claims of therapeutic benefit from herbal products, without rigorous evidence of efficacy and safety, receive skeptical views by scientists.^[1]

Unethical practices by some herbalists and manufacturers, which may include false advertising about health benefits on product labels or literature,^[7] and contamination or use of fillers during product preparation,^{[38][72]} may erode consumer confidence about services and products.^{[73][74]}

Paraherbalism

Paraherbalism is the pseudoscientific use of extracts of plant or animal origin as supposed medicines or health-promoting agents.^{[1][6][7]} Phytotherapy differs from plant-derived medicines in standard pharmacology because it does not isolate and standardize the compounds from a given plant believed to be biologically active. It relies on the false belief that preserving the complexity of substances from a given plant with less processing is safer and potentially more effective, for which there is no evidence either condition applies.^[6]

Phytochemical researcher Varro Eugene Tyler described paraherbalism as "faulty or inferior herbalism based on pseudoscience", using scientific terminology but lacking scientific evidence for safety and efficacy. Tyler listed

ten fallacies that distinguished herbalism from paraherbalism, including claims that there is a conspiracy to suppress safe and effective herbs, herbs can not cause harm, that whole herbs are more effective than molecules isolated from the plants, herbs are superior to drugs, the doctrine of signatures (the belief that the shape of the plant indicates its function) is valid, dilution of substances increases their potency (a doctrine of the pseudoscience of homeopathy), astrological alignments are significant, animal testing is not appropriate to indicate human effects, anecdotal evidence is an effective means of proving a substance works and herbs were created by God to cure disease. Tyler suggests that none of these beliefs have any basis in fact.^{[6][75]}

Traditional systems

Africa

Up to 80% of the population in Africa uses traditional medicine as primary health care.^[76]

Americas

Native Americans used about 2,500 of the approximately 20,000 plant species that are native to North America.^[77]

In Andean healing practices, the use of Entheogens, in particular the San Pedro cactus (*Echinopsis pachanoi*) is still a vital component, and has been around for millennia.^[78]

China

Some researchers trained in both Western and traditional Chinese medicine have attempted to deconstruct ancient medical texts in the light of modern science. In 1972, Tu Youyou, a pharmaceutical chemist and Nobel Prize winner, extracted the anti-malarial drug artemisinin from sweet wormwood, a traditional Chinese treatment for intermittent fevers.^[79]

India

In India, Ayurvedic medicine has quite complex formulas with 30 or more ingredients, including a sizable number of ingredients that have undergone "alchemical processing", chosen to balance dosha.^[80] In Ladakh, Lahul-Spiti, and Tibet, the Tibetan Medical System is prevalent, also called the "Amichi Medical System". Over 337 species of medicinal plants have been documented by C.P. Kala. Those are used by Amchis, the practitioners of this medical system.^{[81][82]} The Indian book, Vedas, mentions treatment of diseases with plants.^[83]

Indonesia

In Indonesia, especially among the Javanese, the jamu traditional herbal medicine may have originated in the Mataram Kingdom era, some 1300 years ago.^[84] The bas-reliefs on Borobudur depict the image of people grinding herbs with stone mortar and pestle, a drink seller, a herbalist, and masseuse treating people.^[85] The Madhawapura inscription from Majapahit period mentioned a specific profession of herbs mixer and combiner (herbalist), called *Acaraki*.^[85] The book from Mataram dated from circa 1700 contains 3,000 entries of jamu herbal recipes, while Javanese classical literature *Serat Centhini* (1814) describes some jamu herbal concoction recipes.^[85]

Though possibly influenced by Indian Ayurveda systems, the Indonesia archipelago holds numerous indigenous plants not found in India, including plants similar to those in Australia beyond the Wallace Line.^[86] Jamu practices may vary from region to region, and are often not recorded, especially in remote areas of the country.^[87] Although primarily herbal, some Jamu materials are acquired from animals, such as honey, royal jelly, milk, and *Ayam Kampung* eggs.

Beliefs

Herbalists tend to use extracts from parts of plants, such as the roots or leaves,^[88] believing that plants are subject to environmental pressures and therefore develop resistance to threats such as radiation, reactive oxygen species and microbial attack to survive, providing defensive phytochemicals of use in herbalism.^{[88][89]}

Use of plants by animals

Indigenous healers often claim to have learned by observing that sick animals change their food preferences to nibble at bitter herbs they would normally reject.^[90] Field biologists have provided corroborating evidence based on observation of diverse species, such as chickens, sheep, butterflies, and chimpanzees. The habit of changing diet has been shown to

be a physical means of purging intestinal parasites. Sick animals tend to forage plants rich in secondary metabolites, such as tannins and alkaloids.^[9]

IV. CONCLUSION

Traditional medicine (also known as indigenous medicine or folk medicine) comprises medical aspects of traditional knowledge that developed over generations within the folk beliefs of various societies, including indigenous peoples, before the era of modern medicine. The World Health Organization (WHO) defines traditional medicine as "the sum total of the knowledge, skills, and practices based on the theories, beliefs, and experiences indigenous to different cultures, whether explicable or not, used in the maintenance of health as well as in the prevention, diagnosis, improvement and treatment of physical and mental illness".^[1] Traditional medicine is often contrasted with scientific medicine.

In some Asian and African countries, up to 80% of the population relies on traditional medicine for their primary health care needs. Traditional medicine is a form of alternative medicine. Practices known as traditional medicines include traditional European medicine traditional Chinese medicine, traditional Korean medicine, traditional African medicine, Ayurveda, Siddha medicine, Unani, ancient Iranian medicine, traditional Iranian medicine, medieval Islamic medicine, Muti, Ifá and Rongôã. Scientific disciplines that study traditional medicine include herbalism, ethnomedicine, ethnobotany, and medical anthropology.

The WHO notes, however, that "inappropriate use of traditional medicines or practices can have negative or dangerous effects" and that "further research is needed to ascertain the efficacy and safety" of such practices and medicinal plants used by traditional medicine systems.^[1] Its "Traditional Medicine Strategy 2014–2023" said that the WHO would "support Member States in developing proactive policies and implementing action plans that will strengthen the role traditional medicine plays in keeping populations healthy."^[2]

Indigenous medicine is generally transmitted orally through a community, family and individuals until "collected". Within a given culture, elements of indigenous medicine knowledge may be diffusely known by many, or may be gathered and applied by those in a specific role of healer such as a shaman or midwife.^[26] Three factors legitimize the role of the healer – their own beliefs, the success of their actions and the beliefs of the community.^[27] When the claims of indigenous medicine become rejected by a culture, generally three types of adherents still use it – those born and socialized in it who become permanent believers, temporary believers who turn to it in crisis times, and those who only believe in specific aspects, not in all of it

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