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Harvesting and post-harvest processing of medicinal plants: Problems and prospects

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Abstract
Interest in traditional systems of medicine and, in particular, herbal medicines, has increased substantially in both developed and developing countries over the past two decades. Global and national markets for medicinal herbs have been growing rapidly, and significant economic gains are being realized. Despite their widespread use, numerous reports show that the herbal products available to consumers are of variable quality. This disparity in quality of herbal preparations can be attributed to the fact that their production is complicated. In recent years, good agricultural and collection/harvesting practices have been recognized as an important tool for ensuring the safety and quality of a variety of medicinal plants and their products. This article reviews problems, developments and prospects for the strategies concerning the harvesting and post-harvest processing of medicinal plant resources to provide quality herbal drugs on sustainable basis. To obtain a high-quality efficacious herbal drug, the appropriate part of the medicinal plant must be harvested at the optimum stage of development, dried and stored at temperatures and conditions that do not decrease the active ingredients, and processed using a technique that maximizes phytochemical recovery. Only if all these steps are respected a high-quality product showing batch to batch consistency can be maintained. In this way safety, efficacy and quality of the herbal products can be sustained and would capitalize billions of dollars for emerging herbal markets for the country.

Keywords: medicinal plants, collection, post-harvest, processing, phytoconstituents, India

Introduction
Medicinal plants constitute the basis of primary health care for a majority of the population and are a critical source of income for many rural people particularly in area near forests. They are a source of primary health care for more than 80% of the population in developing countries who are dependent on traditional systems of medicine. Moreover, herbal medicines are becoming more popular in recent years with their increasing acceptability in both developing and developed countries. The resurgence of herbal drugs is mainly due to realization of harmful side effects of many modern drugs. The ever increasing demand of herbal drugs led to a spurt of large scale commercial collection from the wild. With the ever increasing demand of medicinal plants the supply line is adversely affected, leading to destructive harvesting and adulteration for genuine drugs (Schippmann, 2002) [14].

Research shows that collection of these medicinal plants from the wild continues to be the major source of supply. At present, 90% collection of medicinal plants is from the wild, generating about four million mandays employment (both part and full time) and since 70% of plants collection involves destructive harvesting, many plants have become endangered or vulnerable or threatened (Anonymous 2000; Larsen and Olsen, 2007; Hamilton, 2008; ISS-MAP) [1, 8, 5]. Due to spurt in demand, medicinal plants are being overexploited and many of them have been pushed to the brink of extinction (Ved and Goraya, 2008) [17]. The quality of medicinal plants depends on the geographical origin, cultivar of the species, stage of growth at the time of collection and post-harvest handling. Hardly due attention is paid to the stage of maturity, processing and storage (Pandey and Das, 2014) [10]. This results in deterioration of quality. The raw material supply situation is mostly shaky, unsustainable and exploitative. The trade is vastly secretive, unregulated and expanding at an enormous pace. Despite the wealth of resources (biological, human and financial) available, the sector has not developed in the absence of sustainable harvesting practices, suitable processing and storage facilities and quality control.

India is warehouse of several important medicinal plants. Information about the major medicinal plants grown and collected in central India is collected from literature and given in

Table 1 (Gupta *et al*., 2005; Pandey and Mandal, 2010; Pandey and Yadav, 2010; Pandey and Mandal, 2012; Pandey and Das, 2014) [4, 11, 13, 12, 10]. It gives the information about their common and botanical names, parts used, medicinal uses and time of harvest. It also gives information about major active ingredients responsible for biological activity.

Table 1: List of important Medicinal plants collected from central India.

S. No.	Common Name	Botanical Name	Part Used	Uses	Month in which harvested/ collected	Major active ingredients
1	Aonla	*Phyllanthus emblica*	Fruit pulp	Promote longevity, enhance digestion good source of vitamin C	Fruits are harvested Dec-Jan	Ascorbic acid, gallic acid, phenols, tannins.
2	Arjuna	*Terminalia arjuna*	Bark	Cardiac tonic, coronary disease	Bark is harvested Feb-Mar	Tannins, phenols, arjunic acid
3	Ashwagandha	*Withania somnifera*	Roots	Tonic, aphrodisiac	Roots are harvested Feb.-Mar	Withanoloids and withanins
4	Bach	*Acorus calamus*	Rhizome	diarrhoea, dysentery	Rhizomes are harvested Nov-Dec.	α and β asarone, acoric acid
5	Bahera	*Terminalia bellerica*	Fruit rind	heart diseases, anaemia	Fruits are harvested in Dec- Jan	Beta sitosterol, gallic acid and bellericanin
6	Bala	*Sida cordifolia*	Entire plant, root	Rheumatism, general debility	Mature plants are harvested	Ephedrine, Pseudoephedrine, Indole alkaloids
7	Bael	*Aegle marmelos*	Fruit, leaf	Purgative, cooling, diarrhoea, antidiabetic	Fruits are harvested Feb-March	Aegelin, rutin, sitosterol, marmesenin, marmeline
8	Bhelwa	*Semecarpus anacardium*	Fruit	Anti-inflammatory, antioxidant, anti-cancer.	Fruits are harvested Dec.-Feb.	Biflavonoids, phenolic compounds, bhilawanols, minerals
9	Bhui Aonla	*Phyllanthus amarus*	Entire plant	Jaundice, diarrhoea	Entire plant is harvested in July-Aug.	Alkaloids, terpenoids, phyllanthin, b-sitosterol and gallic acid
10	Brahmi	*Bacopa monnieri*	Leaf, entire plant	Memory enhancer	Mature herb is harvested Jan-Feb.	Bacoside, saponin glycosides
11	Dhawaifool	*Woodfordia fruticosa*	Flower	Diarrhoea, fermenting agent in Asava and Arishta	Flowers are harvested in May-June	More harvested today due to new demand
12	Ghrit Kumari	*Aloe vera*	Leaf/gel	Cooling, cosmetic	Mature leaves are harvested	Aloin, emodine
13	Giloe	*Tinospora cordifolia*	Stem	Immunomodulator, antipyretic,	Stem is harvested in Nov-Dec.	Tinosporoside, cordioside
14	Gurmar	*Gymnema sylvestre*	Leaves	Diabetes	Leaves are harvested in Sep and June	Gymnemic acid
15	Harad	*Terminalia chebula*	Pericarp of the fruit	Purgative	Fruits are collected Dec.-Jan, Feb.	Chebulin, chebulinic acid, tannins, gallic acid
16	Jamun	*Syzygium cumini*	Fruit, seed, bark	Diabetes	Fruits are collected July-August	Anthocyanins, glucoside, ellagic acid, myrecetin. Seeds contain alkaloid, jambosine, and glycoside jambolin
17	Kalmegh	*Andrographis paniculata*	Entire plant	Anti-malarial, liver tonic	Plants are cut in Oct.-Nov.	Andrographolide, diterpene lactone.
18	Karanj Seed	*Pongamia pinnata*	Seed, leaf	Insecticide,	Fruits are collected May-June	Fatty oils, karanjin
19	Kauch	*Mucuna pruriens*	Fruit/ seed	Parkinson disease, sexual disorders	Mature Fruits/pods are harvested	L- Dopa,
20	Khair	*Acacia catechu*	Bark, wood	Mouth ulcer, psoriasis and anaemia	Wood is harvested Dec.-Feb.	Tannins, gallic acid
21	Long Pipal	*Piper longum*	Fruit	bronchitis, asthma	Fruits are harvested	Piperine and piplartine
22	Mandukparni	*Centella asiatica*	Entire plant	skin diseases and memory enhancer	Entire plant is harvested by cutting	Asiaticoside, indocentellosid,thankuniside
23	Maida	*Litsea glutinosa*	Bark	Bonefracture, joints and healing	Bark is harvested in Nov-Dec.	Tannins, mucilage, phenols.
24	Neem seed	*Azadirachta indica*	Seed, leaf, pulp	Insecticide	Seeds are harvested in June-July	Azadirachtin, fatty oil
25	Periwinkle/	*Catharanthus*	Roots,	Cancer, diabetes	Mature roots are	alkaloids vincristine and

	Sadabahar	*roseus*	leaves, flowers		harvested	vinblastine
26	Sarpagandha	*Rauvolfia serpentina*	Roots	Hypertension, insomnia	Roots are harvested in Dec.-Jan	Alkaloids, Serpentine
27	Safed musli	*Chlorophytum borivilianum*	Roots	Tonic, aphrodisiac	Roots are harvested Dec-Jan.	Saponins
28	Satavar	*Asparagus racemosus*	Roots, leaves	Tonic, sexual weaknesses, leucorrhoea	Dec.-Mar. Roots are dug	Saponins, sapogenin, shatavarin
29	Tulsi	*Ocimum sanctum*	Leaf, seeds	leucoderma, asthma, heart disease	Leaf and branches are harvested July-November.	Terpenes, sesquiterpenes, uric acid
30	Vasaka	*Adhatoda vasica*	Leaf	bronchitis, asthma,cold	Leaves are harvested after flowering	Alkaloids, vascine and vasicinone

The yield and quality of medicinal plants are related to a variety of internal and external factors, for example, proper identification of species, the harvesting/collection time and method, post-harvest practices like drying, storage, packaging and processing.

Identification

The fact that most medicinal plants used by the traditional practitioners and manufacturers of *Ayurvedic* products are collected from the wild have problems for identification and obtaining material of uniform quality due to anumber of reasons. Sometimes a plant name may refer to more than one species: the name 'Brahmi' can refer to either *Bacopa monneiri* or *Centella asiatica*, which have entirely different phyto-chemical compositions. Shankhpushpi is one of the Rasayana drugs in Ayurveda and several plant species are being reported as Shankhpushpi, viz. *Convolvulus pluricaulis, Clitoria ternatea*, *Evolvulus alsinoides* and *Tephrosia purpurea* in different regions in India but in Ayurvedic Pharmacopoeia of India *Convolvulus pluricaulisis* is the official drug (Shah and Bole, 1961; Singh and Vishwanathan, 2000) [15, 16]. Also the effect of agro-climatic conditions on the chemical composition and therapeutic properties of a medicinal plant species is well-known; seven varieties of *Terminalia chebula* originating in different parts of India are known to have different therapeutic properties.

Developmental Stage of Harvest

Medicinal plants should be harvested during an appropriate season or time period to ensure the best possible quality of source materials. It is well known that the concentration of required chemical constituents (active ingredients) is strongly influenced by its developmental stage of growth as well as the season (Pandey and Das, 2014) [10]. Developmental stage of plant directly influences the phytochemical concentration. *Andrographis paniculata* (Kalmegh) is an important herb used in several ayurvedic formulations as heaptoprotective herb. A study conducted by Pandey and Mandal (2010) [11] revealed that the maximum amount of andrographolide (2.85%) was found in *A. paniculata* when harvested after 130-150 days of planting (at the time of initiation of flowering). Brahmi is used as brain tonic in Ayurveda. The activity is due to presence of Bacosides. Bacoside-A content of herb was reported to be high from September through March and in June. Suitable harvest times for high yields of bacoside-A were June and September through November (Mathur *et al*, 2002).

Adhatoda vasica (Adusa or Vasaca) is bronchodilator drug of Ayurevda. The plant shows wide seasonal variation in vasicine content in its leaves. It exhibited higher levels of vasicine twice in a year i.e. 3.0% in March and 1.4% in September. Interestingly, it coincided with the flowering of the plant. In March, it was full bloom condition and in September, it was partial flowering. During the vegetative stage, the plant contained very low concentration of vasicine. (Bagachi *et al*., 2003) [3]. The stage of maturation of the plant parts to be collected is another important factor: the root of *Wihania somnifera* (Ashwaganda) is dug out just 130-180 days after planting, while the stem of *Tinospora cordifolia* (Giloe) is collected at full maturity (after 15 months). Quantitative analysis revealed that all the phytoconstituents increased with the increase in diameter of the stem except alkaloid content (Pandey and Das, 2014) [10].

Phytochemical constituents are not evenly distributed throughout the plant. Maximum production of metabolites (active ingredients) depends on age and developmental stage of the plant. Harvesting of crude drugs with higher concentration of active principle is prerequisite in preparation of efficacious drugs. Therefore, medicinal plants need to be harvested at the period of growth or physiological developmental stage at which it accumulates maximum amount of phyto-constituents (active ingredients) and medicinal activity is highest. The concentration of alkaloid in the roots of *Rauvolfia serpentina* is highest at after 18 months of planting in the month of December (Pandey and Mandal, 2010) [11].

Harvest of different plant parts

Different plant parts such as roots, rhizomes, bulbs, bark, leaf, fruit and seeds are collected, processed and used in preparation of herbal drugs. Techniques and time to harvest varies with the species and plant parts. General guidelines about technique and time of harvest for different plant parts are given in Table 2.

Table 2: Time and method of collection of different plant parts.

S. No.	Plant parts	Time and method of collection
1	Bulbs	Late autumn, long after the plant has flowered and fruited. Bulbs should be dug from considerable distance from the main plant. Collect mature big bulbs and leave small bubs for regeneration. Bulbs/roots should be collected only after the seed shedding unless otherwise specified. It facilitates regeneration of species.
2	Bark	Autumn (after leaf fall) or spring (before development of leaves). Remove the bark in long vertical strips using a thin flexible blade/bush knife. Stem bark should not be collected again from same tree unless adequate time has been allowed for it to regenerate completely. Do not practice ring barking, which is the cut of off entire rings around the tree.
3	Root and rhizomes	From annuals shortly before flowering. From biennials during the autumn or winter following the first year growth. From perennials during autumn or winter following the second or third year's growth. Dig the root at a considerable distance, at least 30 cm, from the main stem or tap root. Avoid severing of the tap root. Do not collect all roots from the plant. Collect only the lateral roots.
4	Leaves	Collection should be made in dry weather whilst the plant is flowering. Pluck individual leaves instead of leaf striping and avoid use of sharp pruning shears for leaves. Collection in the morning is providing quality product in some plants (solanaceous leaves). Leaves should be harvested before or at the time of initiation of flowering unless otherwise specified.
5	Flowers	Collection should be made in dry weather and in early hours of the day, after due has dissipated. Harvest flowers carefully without damaging plant main stem. Flowers must be harvested when they have just opened or shortly afterwards to capture its aroma.
6	Seeds and fruits	Collection should be made when fruits are fully grown and ripe or nearly ripe until otherwise it is required. To avoid seed dispersal, it is advantageous to collect slightly earlier. In forest areas, only collect fruits from some trees and leave others completely for regeneration. Branches of the tree or shrub should not be cut for ease of collection of fruits and seeds.
7	Annual herbs/ whole plant	Annual herbs should be harvested at the time of initiation of flowering. Whole population in a given area should never be harvested. Adequate population should be left for regeneration to facilitate future collections.

Source: WHO. 2003; Heron and Maiti, 2010 [1, 6].

Collection/Harvesting of Medicinal plants

Medicinal plants should be collected/harvested during the appropriate season or time period to ensure the best possible quality of both source materials and finished products. It is well known that the quantitative concentration of biologically active phyto constituents varies with the stage of plant growth and development. The best time for collection/harvest (quality peak season/time of day) should be determined according to the quality and quantity of biologically active constituents rather than the total vegetative yield of the targeted medicinal plant parts during harvest (Pandey and Mandal, 2013, Pandey and Das, 2014) [10]. Care should be taken to ensure that no foreign matter, weeds or toxic plants are mixed with the harvested medicinal plant materials.

The time of harvest depends on the plant part to be harvested. Detailed information concerning the appropriate timing of harvest is often available in national pharmacopoeias, published standards, official monographs and major reference books. Following are the general guidelines need to be practiced while harvesting/collection of medicinal plants (WHO, 2003) [1]:

1. Medicinal plants should be harvested by following sustainable harvesting practices.
2. Medicinal plants should be harvested under the best possible conditions, avoiding dew, rain or exceptionally high humidity. If harvesting occurs in wet conditions, the harvested material should be transported immediately to an indoor drying facility to expedite drying so as to prevent any possible deleterious effects due to increased moisture levels, which promote microbial fermentation and mould.
3. In general, the collected/harvested plant materials should not come into direct contact with the soil. If underground parts (such as the roots or rhizomes/bulbs) are harvested, any adhering soil should be removed from the plants as soon as they are harvested/collected. Contact with soil should be avoided to the extent possible so as to minimize the microbial load of harvested medicinal plant materials where necessary, large drop cloths, preferably made of clean muslin, may be used as an interface between the harvested plants and the soil.
4. Collected/harvested plant material should be placed in clean baskets, mesh bags, other well aerated containers or cloths that are free from foreign matter, including plant remnants from previous collecting activities. After collection, the plant materials may be subjected to appropriate preliminary processing, including elimination of undesirable materials and contaminants (by hand picking), washing (to remove excess soil), sorting and cutting.
5. The harvested raw medicinal plant materials should be transported promptly in clean, dry conditions. They may be placed in clean baskets, dry sacks, trailers, hoppers or other well-aerated containers and carried to a central point for transport to the processing facility. If the collection site is located some distance from processing facilities, it may be necessary to air or sun-dry the raw medicinal plant materials prior to transport.
6. If more than one part of the medicinal plant are to be collected, the different plant materials should be gathered separately and transported in separate containers. Cross-contamination should be avoided at all times. Any mechanical damage or compacting of the raw medicinal plant materials, as a consequence, for example, of overfilling or stacking of sacks or bags that may result in composting or otherwise diminish quality should be avoided. Decomposed medicinal plant materials should be identified and discarded during harvest in order to avoid microbial contamination and loss of product quality.
7. All containers used for harvest should be kept clean and free from contamination by previously harvested medicinal plants and other foreign matter. If plastic containers are used, particular attention should be paid to

any possible retention of moisture that could lead to the growth of mould. When containers are not in use, they should be kept in dry conditions, in an area that is protected from insects, rodents, birds and other pests, and inaccessible to livestock and domestic animals.

8. The collected medicinal plant materials should be protected from insects, rodents, birds and other pests as well as from livestock and domestic animals.
9. Collecting/harvesting implements (tools), such as machetes, shears and mechanical tools, should be kept clean and maintained in proper condition. Those parts that come into direct contact with the collected medicinal plant materials should be free from excess oil/grease and other contamination. Cutting devices, harvesters, and other machines should be kept clean and adjusted to reduce damage and contamination from soil and other materials. They should be stored in an uncontaminated, dry place or facility free from insects, rodents, birds and other pests, and inaccessible to livestock and domestic animals.

Primary processing

Primary processing practices viz. drying, storage and packaging conditions are very important in order to maintain the quality of herb after harvest. Temperature and relative humidity are the main parameters affecting quality attributes of fresh herb during storage.

Harvested or collected raw plant materials should be promptly unloaded and transported at the processing facility. Different plant parts should be transported separately. Immediately it should be unpacked on arrival at processing centre. Prior to processing, the plant materials should be protected from rain, moisture, heat and any other conditions that might cause deterioration. Medicinal plant materials should be exposed to direct sunlight only where there is a specific need for this mode of drying.

Medicinal plant materials that are to be used in the fresh state should be harvested/collected and delivered as quickly as possible to the processing facility in order to prevent microbial fermentation and thermal degradation. If storage is required, it should be stored under refrigeration, in jars, in sandboxes, or using enzymatic or other appropriate conservation measures immediately following harvest/collection, and transported to the end-user in the most expeditious manner possible. The use of preservatives should be avoided, if used they should conform to national and/or regional regulatory requirements in both the source country and the end-user country.

Clean cemented floor or good tarpaulin sheet should be used for laying out the harvested crop. Remove all weeds and other foreign matter.

All medicinal plant materials should be inspected during the primary-processing stages of production, and any substandard products or foreign matter should be eliminated mechanically or by hand. For example, dried medicinal plant materials should be inspected, sieved or winnowed to remove discoloured, mouldy or damaged materials, as well as soil, stones and other foreign matter. Mechanical devices such as sieves should be regularly cleaned and maintained.

All processed medicinal plant materials should be protected from contamination and decomposition as well as from insects, rodents, birds and other pests, and from livestock and domestic animals.

Washing

The harvested material should be washed with clean water. Soil should be removed properly from rhizomes and roots. Do not use contaminated water for washing. Do not wash seeds and delicate parts of the medicinal plants.

All excess water should be drained from the herb before drying.

Drying

Drying is the most common way to preserve quality of medicinal plants. The physical and chemical properties of medicinal plants are determined by their moisture content. The first step in many postharvest operations is removal of water that is, drying. Drying is basically defined as the decreasing of plant moisture content, aimed at preventing enzymatic and microbial activity, and consequently preserving the product to extend shelf life. For this purpose, adequate dryers are needed, using temperature, velocity and humidity values for drying air that provides a rapid reduction in the moisture content without affecting the quality of the active ingredients of medicinal plants.

Drying of medicinal plants must meet the following requirements: (1) Moisture content has to be brought down to be at an equilibrium level that is defined for certain relative air humidity and temperature which is defined as storage condition; (2) minimum quality reduction in terms of active ingredients, colour, flavor and aroma; and (3) microbial count must be below the prescribed limits.

In India, generally herbs are dried either in sun or shade depending upon the requirements. However, traditional drying methods, such as drying in the shade or in the sun, have many drawbacks due to the inability to handle the large capacity of mechanical harvesters and to achieve the high quality standards required for medicinal plants. High ambient air temperature and relative air humidity during the harvesting season promote insect and mould development in harvested crops. Furthermore, intensive solar radiation adversely affects quality, causing losses in essential oils or colour changes in dried plants. Thus, traditional natural drying in the sun or in the shade does not meet the exact required standards. To overcome these problems hot air-convective drying is widely used.

When medicinal plant materials are prepared for use in dry form, the moisture content of the material should be kept as low as possible in order to reduce damage from mould and other microbial infestation.

Medicinal plants can be dried in a number of ways:

1. In the open air (shaded from direct sunlight);
2. Placed in thin layers on drying frames, wire-screened rooms or buildings.
3. By direct sunlight, if appropriate (fleshy material).
4. In drying ovens/rooms and solar dryers.
5. By indirect fire; baking; lyophilization; microwave; or infrared devices.
6. Vacuum drying
7. Spray dryer: Examples: Papaya latex and pectin's, etc.

If possible, temperature and humidity should be controlled to avoid damage to the active chemical constituents. The method and temperature used for drying may have a considerable impact on the quality of the resulting medicinal plant materials.

For example, shade drying is preferred to maintain or minimize loss of colour of leaves and flowers; and lower temperatures should be employed in the case of medicinal

plant materials containing volatile substances. The drying conditions should be recorded. In the case of natural drying in the open air, medicinal plant materials should be spread out in thin layers on drying frames and stirred or turned frequently.

In order to secure adequate air circulation, the drying frames should be located at a sufficient height above the ground. Efforts should be made to achieve uniform drying of medicinal plant materials and so avoid mould formation.

Drying medicinal plant material directly on bare ground should be avoided. If a concrete or cement surface is used, medicinal plant materials should be laid on a tarpaulin or other appropriate cloth or sheet. Insects, rodents, birds and other pests, and livestock and domestic animals should be kept away from drying sites (WHO, 2003) [1].

For indoor drying, the duration of drying, drying temperature, humidity and other conditions should be determined on the basis of the plant part concerned (root, leaf, stem, bark, flower, etc.) and any volatile natural constituents, such as essential oils.

Vacuum drying

This is conducted in steam- heated ovens with perfect closure, and a pump is used to exhaust the vapour laden air. The low pressure maintained within the oven ensures rapid and complete drying.

Advantages of vacuum drying

1. Rapid drying.
2. Relatively low temperature.
3. Cleanliness and freedom from odour and dust.
4. Independence of climate conditions.
5. Control of temperature.
6. Elimination, of risk of fire.
7. Compactness.

Packaging

1. After removal of damaged material and foreign matter, the good dried crop should be packed in clean, dry sacks, bags or boxes, preferably new.
2. Packaging materials should be stored in a clean dry place free from pests and inaccessible to animals.
3. Reusable packaging materials such as jute sacks, plastic bags, etc., should be well cleaned and dried before re-use.
4. The packed crop should be stored in a dry place away from the wall and off the ground and be protected from pests and farm and domestic animals.
5. Whenever possible, the packaging materials used should be agreed between the supplier and the buyer.

Storage

1. Packed dried crop should be stored in a dry, well ventilated building, with minimal variation in diurnal temperature and with good air ventilation. When necessary, be equipped with air-conditioning and humidity control equipment as well as facilities to protect against rodents, insects and livestock. Shutter and door openings should be protected by wire screens to keep out pests and farm and domestic animals.
2. The floor should be tidy, without cracks and easy to clean. Plant material should be stored on shelves which keep the material a sufficient distance from the walls; measures should be taken to prevent the occurrence of pest infestation, mould formation, rotting or loss of oil; and inspections should be carried out at regular intervals. It is recommended that packed dried crops should be stored: - in a building with concrete floors; - away from the wall; - well separated from all other crops.
3. Continuous in-process quality control measures should be implemented to eliminate substandard materials, contaminants and foreign matter prior to and during the final stages of packaging. Processed medicinal plant materials should be packaged in clean, dry boxes, sacks, bags or other containers in accordance with standard operating procedures and national and/or regional regulations of the producer and the end-user countries.
4. Materials used for packaging should be non-polluting, clean, dry and in undamaged condition and should conform to the quality requirements for the medicinal plant materials concerned. Fragile medicinal plant materials should be packaged in rigid containers.
5. Dried medicinal plants/herbal drugs, including essential oils, should be stored in a dry, well-aerated building, in which daily temperature fluctuations are limited and good aeration is ensured.
6. Fresh medicinal plant materials should be stored at appropriate low temperatures, ideally at 2-8°C; frozen products should be stored at less than -20°C.
7. Small quantity of crude drugs could be readily stored in air tight, moisture proof and light proof container such as tin, cans, covered metal tins or amber glass containers. Wooden boxes and paper bags should not be used for storage of crude drugs (WHO, 2003; Anonymous, 2009) [1, 2].

Personnel

1. Personnel handling medicinal plant material should: - maintain a high degree of personal hygiene; - be provided with suitable changing facilities and toilets with hand washing facilities.
2. Personnel should not be permitted to work in the herbal material handling area if they are known to be suffering from, or to be carriers of, a disease likely to be transmitted through medicinal plant materials, including diarrhoea.
3. Personnel with open wounds, sores, and skin infections should be transferred away from herbal materials handling areas until completely recovered.

Conclusion

The medicinal plant sector has the potential to enhance local peoples' livelihood through collection/harvesting, processing and trade. These activities can become an integral component of country's forest and biodiversity resource management. Through value adding processing at the local level and efficient marketing, the sector can create rural income, employment and livelihood opportunities. Development of small and micro-enterprises, especially for processing and marketing of medicinal plants seem to have the potential to generate income opportunities for the poor. In this way safety, efficacy and quality of the herbal products can be maintained and would capitalize billions of dollars for emerging herbal markets for the country.

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