DRYING TECHNOLOGIES FOR GOOD QUALITY CRUDE DRUG

PRODUCTION OF MEDICINAL PLANTS – A REVIEW

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ABSTRACT
Drying of medicinal plant parts is an inevitable process in the postharvest handling and drug development process in phyto – pharmaceutical industries. The medicinal crude drugs can be dried either naturally under the influence of solar energy or wind or artificially under controlled conditions of temperature, humidity and airflow. The crude drugs can be dried naturally by air drying, sun drying as well as using different kinds of solar driers like direct, indirect, mixed mode and hybrid solar driers. Mechanical drying can be done in equipment working in atmospheric pressure conditions like, kiln driers, cabinet driers, tunnel driers, fluidised bed driers, spray driers, microwave driers and infrared radiation driers. Equipment working under reduced pressure conditions commonly called sub – atmospheric driers which include, vacuum driers and freeze driers can also be used that are highly efficient compared to atmospheric driers. Osmotic dehydration is yet another innovative drying technique which can modify the crude drug and create a new product with the use of osmotic agents like sugar, salt etc. Among the different drying techniques available, an ideal method for a particular crude drug can be standardised only by comparing the existing drying techniques since, the drying process depends on several parameters of crude drug as well as the technique adopted.

KEYWORDS: Mechanical, Natural, Osmotic, Vacuum, Freeze

INTRODUCTION
Mother earth has bestowed to the mankind with various plants having healing ability for curing the ailments of human being. This unique feature has been identified since pre - historic times. Crude drugs are plant parts or plant materials in the raw or processed state (containing certain excipients like solvents, diluents or preservatives) containing active ingredients possessing therapeutic activities (WHO, 2003). It can be roots (Dasamula), stem (Achorus calamus), bark (Saraca asoka), leaf (Indigofera tinctoria), flower (Mimisops elengi), fruit (Solanum sp.), seed (Datura sp.) or even whole plant (Phyllanthus niruri) (Mir, 2007). According to EMA (2006) primary processing of medicinal plants include crude drug collection, washing, size reduction, drying and storing of the crude drug. Large scale commercial herbal drug manufacturers go for making the extract of the crude drugs like essential oil, oleoresin etc. and it is then dried and stored.

In commercial herbal drug production, for both small and large scale producers drying techniques are an essential tool which, reduces the moisture content of harvested produce from 60 -80% moisture to 10 – 14% for enhancing storage stability and better shelf life (Raaman, 2006). The long- time practice has established that for
drying the plants containing essential oils the maximum temperature should not exceed 35-40°C and for those containing alkaloids and glycosides it ranges between 50 and 60°C. Drying helps to prevent enzymes action, avoid bacterial and fungi attack which results in a severe quality loss also, it causes a huge reduction in weight of the produce and makes storage and transportation easy (UPM, 2005). Drying can sometimes result in variation in the constituents of drugs as reported by Menon (1999) that drying alone can reduce the plumbagin content in the roots of *Plumbago zeylanica* and *Plumbago rosea* to 61.0% and 68.3% respectively.

**TYPES OF DRYING**

The methods available for drying medicinal plants can be grouped into natural and mechanical drying on the basis of heat source or energy utilization (Cai *et al.*, 2004). The former being done under the influence of solar energy or wind and the later by the application of artificial heat under controlled conditions of temperature, humidity and air flow.

**NATURAL DRYING**

**Air Drying**

Air drying the crude drugs is done by hanging it on roof of shade houses or spreading as thin layers on floor or by using drying frames specially made for the purpose. When sunlight causes discoloration or warping/ shrivelling shade dry it in specialized shade houses. While drying in shade houses or drying frames stirring or turning has to be done frequently to avoid mould formation. For getting adequate air circulation the drying frames should be located at a sufficient height above the ground and sufficient space has to be provided in between two shelves of frames (WHO, 2003).

In European countries, temperature and humidity control inside the dryer is a difficult affair which needs to have an air heater attached to the unit for providing sufficient heat during unfavourable weather conditions. NC State University (2008) has developed a herbal drier containing shelves for holding the crude drugs. It is sufficiently ventilated by providing holes and windows for proper air circulation. During winter season, air is heated and conveyed through pipes attached to these vents and an exhaust fan also has to be operated for intermittent heated air flow and uniform drying of the produce so that the dryer can function round the year. Such a type of drier was used to dry *Hyssopus officinalis* by Raila *et al.* (2009). They have used ambient as well as heated air at different air velocities and reported that heated air can dry it faster than ambient air in all velocities tried and also, as air velocity increases faster drying was made possible.

Air drying is purely a weather dependent process, even pre-harvest as well as postharvest weather conditions can affect the quality of dried produce and its drying behavior. A study done by CSIR - CIMAP (2014) on Sweet basil to find out the effect of harvesting and drying season on oil yield and reported that late October harvest and shade drying basil leaves to 25% weight loss can give more oil on distillation. Not only yield but also quality of oil can be improved by drying as reported by Andras *et al.* (2015) on Caraway. High quality caraway oil having high carvone and low limonene (fetches high value in the market) was reported to be obtained from shade dried caraway leaves than mechanical drying in a convective laboratory drier. In another study Auria and Racioppi (2015) reported that in some selected herbaceous medicinal plants a variation in some chemical constituent can happen by drying. In *Salvia officinalis* 1,8 – cineole and camphor decreases, β – thujone and β – pinene increases but, trans-caryophyllene concentration remains constant even after drying. Whereas when *Rosmarinus officinalis* was dried α – pinene, limonene and camphor content decreases and camphene and β – pinene concentration reported to be increased.
Sun Drying

Sun drying is adopted for crude drugs that are not adversely affected by excessive sunlight. Sun drying is usually done by spreading the produce as thin layer in floor or in drying frames under open sun (Raaman, 2006). Sun drying requires more space and labour as well as time up to days or even weeks. It is exclusively weather dependent so it can get damaged by birds, insects, pathogens, wind-blown debris etc. quality loss can occur due to volatalisation loss (Martynenko et al., 2006). Also, uniform drying is not always possible by sun drying which favours microbial growth and production of aflatoxins. Aflatoxins (AFs) are highly toxic secondary metabolic products of Aspergillus flavus, Aspergillus parasiticus, Aspergillus nomius and Aspergillus pseudeotamarii. AFs have carcinogenic, mutagenic and teratogenic effect on humans (Set and Erkmen, 2010). Sun dried and powdered red chillies were analysed for aflatoxins (AFs, sum of B1, B2, G1 and G2) and AFB1 contamination by Ozkan et al. (2015). Out of 180 samples 49 samples have AFB1 and in 37 samples, AFs were higher than legal limits. Aflatoxin level in Neem and Adathoda dried leaves were done by Sharma et al. (2013). Mycoflora and mycotoxins associated with these leaves were investigated from 50 market samples obtained from eight districts of Jammu and Kashmir. Aflatoxin B1, aflatoxin B2 and patulin were detected from dried leaves of Azadirachta indica whereas aflatoxin B1, aflatoxin B2 and zearalenol were detected from dried leaves of Justicia adhatoda.

Solar Drying

Constraints of sun drying can be solved to an extent by using solar drying techniques as here, drying takes place in enclosed structures. A solar dryer is simple to construct. It has a dryer cover and a dryer base. Both are square wooden frames covered around with insect screen nets. The dryer cover is protected also with a UV treated polyethylene or polystyrene film. There are different types of solar driers like, direct solar drier, in-direct solar drier, mixed mode solar driers and hybrid solar driers. The drier has to be set up in the field at an angle so as to face away from the noon sun and also to drain away unexpected rain (El-Sebaii et al., 2002).

Direct Solar Drier

In a direct solar drier, cold dry air enters the drying chamber through the air inlet. The solar rays enter the cabinet through the transparent covering material where they are converted into heat energy thereby increasing the temperature inside causing a greenhouse effect. Due to this heat moisture will escape as vapours the crude drugs kept inside got dried off. The heated moist air goes out through the air outlet at the high end of the drier.

A study done on solar drying of turmeric by Borah et al. (2015) reported that it can be faster and efficient if crude drug is pre-treated by slicing the whole turmeric and drying in a solar drier which could gain an internal temperature of 39 – 51°C. By 12 hours of drying in solar drier the moisture content of fresh turmeric was reduced from 78.65% to 6.36% (whole turmeric) and 5.50% (sliced turmeric) which is definitely faster than conventional sun drying of turmeric which needs five to seven days or more depending on weather conditions.

In-Direct Solar Drier

In an in-direct type solar drier, the sun does not act directly on the material to be dried. The products are dried by hot air heated in a platform and conveyed to the chamber containing the crude drugs so that uniform heat distribution is made possible which in turn could increase the drying efficiency (Pardhi and Bhagoria, 2013). The efficiency of the system can be further increased by the use of an electric motor for conveying heated air to the chamber and keeping an exhaust fan inside to maintain a uniform air velocity as in a study conducted by Sallam et al. (2015) for drying mint leaves. Another
innovation tried by Shalaby and Bek (2015) for increasing the efficiency of an in-direct solar drier for drying *Nerium oleander* is by incorporating a phase changing material like paraffin wax (12 kg) as an energy storage medium in the lowermost chamber of the drier. The system showed an improved efficiency since, it could maintain a uniform temperature of 50°C for seven consecutive hours inside the chamber. Also, even after sunset the temperature is kept 2.5–5.0°C more than the ambient condition. Hence, drying of *Nerium oleander* could be achieved within a day.

**Mixed - Mode Solar Drier**

In a mixed mode solar drier the top portion of the chamber is kept transparent so that, drying is made possible by the combined action of solar radiation incident on the material to be dried and the air preheated in solar collector (Pardhi and Bhagoria, 2013).

**Hybrid Solar Drier**

In a hybrid solar drier, although sun’s energy is used to dry the crude drugs, other technologies like fans powered by solar photo-voltaic cells are added in the system for continuous air movement inside the drier (Pardhi and Bhagoria, 2013). A renewable energy based solar drying system using a solar collector and an electric heater for heating the drying air and a photovoltaic – wind hybrid system to supply the required electrical energy to the drier was developed by Nafeh et al. (2013).

A hybrid solar drier exclusively for drying medicinal crude drugs was developed by Solar Energy Research Institute of Malaysia (Fudholi, 2012). Reports say that using that drier it is possible to dry turmeric, ginger and lemon grass from moisture content of 83%, 89%, and 65% (wet basis) to final moisture content about 8% (wet basis) within 3.5 h, 4 h and 4.5 h respectively. For drying onion from moisture content of 78% to moisture content of about 10% it took only 4.5 h.

Solar drying is 65% faster than sun drying and requires no need of fuel or electricity. Good quality less contaminated product can be prepared with minimum cost compared to conventional driers. The major disadvantages are initial investment cost and maintenance required over a period (Sontakke and Salve, 2015).

**MECHANICAL DRYING**

In mechanical driers artificial heat is provided under controlled conditions of temperature, humidity and air flow for drying the raw materials. In some mechanical driers, pressure is also reduced for easy drying operation called as sub-atmospheric driers and those driers working under atmospheric pressure conditions are called atmospheric driers (US EPA, 2000). Atmospheric driers include stationary or batch driers (kiln, tower, and cabinet driers) and continuous driers (tunnel, continuous belt, belt-trough, fluidized-bed, air lift drier, spray, explosion puffing, foam-mat, drum or roller, and microwave-heated driers). Sub-atmospheric driers are vacuum shelf, vacuum belt, vacuum drum and freeze driers. Among these Kiln, Cabinet, Fluidised bed and Spray driers are the different types of air convection driers commonly used for drying crude drugs (Kathirvel et al., 2006).

An air convection drier consists of an insulated enclosure, a means of circulating air through the enclosure and a means of heating air. The air may be heated by direct or indirect methods. In direct heating the air is in direct contact with a flame or combustion gases. In indirect heating the air is in contact with a hot surface such as pipes heated by steam, flame or electricity. The important point is that indirect heat leaves the air uncontaminated (Srivastava and Kumar, 2012).
Atmospheric Driers

Kiln Drier

A kiln drier is a two story construction having a furnace or a burner on the lower floor that generate heat and warm air which is made rise through a slotted floor to the upper story where we can keep the crude drugs for drying. This type of driers are still using in lavender fields for drying the flowers (Chenarbon and Hasheminia, 2011). The hot air ovens using in a laboratory are a type of kiln drier. Muscalu et al. (2011) reported the use of a ceramic coating on the kilns can improve the quality and recovery of crude drugs since with the use of ceramics air got heated by both convection and radiation.

In a hot air oven, air got heated up with the help of a burner and rise up through the raw materials placed in the trays and make it dry. The constraint with this system is that only the trays near to the burner will get the prescribed temperature i.e., uniform drying is not possible with the oven, case hardening of produce may result due to high temperature in the surface and moisture inside the materials will be retained causes mould and bacterial growth (ICS – UNIDO, 2008).

Colour, nutritional composition etc. may also get affected due to high temperature inside the ovens. Sage, thyme, mint and lemon balm were oven dried as well as air dried and compared with the fresh samples for their colour values by Rababah et al. (2015) and reported a significant reduction of colour values was recorded for all the oven dried herbs when compared to the fresh and air dried ones. In tarragon (Artemisia dracunculus) rate of colour change was studied by Pourahmadiyan et al. (2015) and reported that oven drying is better than shade drying since oven drying even upto 100°C didn’t degrade the pigments.

Jatropha multifida is a medicinal plant used widely in several herbal preparations for treating constipation, hypertension etc. In Guinea its young leaves are used for consumption also. A study was done by Oduje and John (2015) for finding the effect of different drying methods and temperature on the nutritional composition of its leaves and reported that shade dried leaves can retain more nutrition than the oven dried ones. For using the leaves for medicinal purpose oven drying at 40°C is reported to be good since it has high phytochemical constituents with average nutritional content.

Cabinet/ Pan/ Tray Drier

This is the widely used type of drier by small scale drug manufactures. A cabinet drier differs from a hot air drier in such a way that when fresh air enters the cabinet it is heated using a heating coil and fans are provided for blowing this air uniformly through the trays containing the raw material to be dried and exhausted. This helps in uniform drying of the material which is very rare when using a hot air oven (ICS – UNIDO, 2008).

The performance of a cabinet drier also depends on several parameters like temperature, air velocity, thickness of sample loading etc. Jebitta et al. (2015) studied the effect of temperature of drying in a cabinet drier on functional groups of Jamun (Syzygium aromaticum) and reported that on varying temperature for drying functional groups are changing. It is reported to be good to dry Jamun fruits in a temperature of 60 - 70°C for obtaining maximum bioactive components. The effect of drying air velocity on Aristolochia cymbifera was studied by Montes et al. (2015) and reported that as the air velocity increased to 2 m/s from 0.2 m/s the drying time reduced from 22 h to 16 h. Change in dry air velocity didn’t impart any change in the major constituent, spathulenol only some minor constituents like germacrene, hex-2-enal, viridiflorol and cedrol had got reduced when air speed was increased.
Singh et al. (2015) reported that thickness of loading the samples into the cabinet also influences drying time. It takes more time for drying thicker layer of Bael fruit (Aegle marmelos) pulp in all the drying temperatures employed in the cabinet. So, optimum conditions for drying Bael fruit pulp is fixed as 2mm thickness at a temperature of 60 – 70°C.

Studies showed that hot air drying in cabinet drier can affect some of the quality aspects of medicinal aromatic plants. Spear mint when dried in a hot air drier at 60°C gave maximum oil yield having good physio – chemical properties like acid value and refractive index as reported by Salim et al. (2015b).

In another study on carvone content of spear mint by same group of scientists (Salim et al., 2015a) reported that oil obtained from spear mint dried in a cabinet drier at 60°C contain significantly higher amount of carvone (82.06%) which determines the market value of the produce.

**Tunnel Drier**

Tunnel driers are elongated cabinets through which trays or carts containing the material to be dried are passed and hot air is blown opposite to these tray under controlled conditions of temperature humidity and air flow (Pandey, 2004). A study was conducted by Central Institute of Postharvest Engineering and Technology (Kadam et al. 2011) using a laboratory tunnel drier running at 30 rpm to find out optimum drying parameters for commercial production of dried mint leaves. They standardized 0.26mm layer thickness and a temperature of 45 -65°C for a period of 4 – 6.5 h as the optimum parameters for complete drying of mint leaves for commercial production.

**Fluidised Bed Drier**

This equipment is a more sophisticated one. Here, heated air is blown up from the bottom of a cylindrical cabin through the raw materials which is contained in it, with just enough force to suspend the particles in a gentle bowling motion. The heated air is actually introduced through a porous plate that supports the raw material and the moist air is exhausted at top and is a continuous process. Facility for spraying a coating agent to the raw material thereby producing encapsulated crude drugs are also equipped in it (Pandey, 2004). Ardestani et al. (2015) studied the optimum drying conditions for mint using a fluidized bed drier by evaluating its colour after drying and reported that when temperature is increased to 60°C a severe chlorophyll degradation occurs which cause remarkable decrease in colour value.

**Spray Drier**

Spray driers are used to produce water soluble powder form of drugs like instant herbal powders, spray dried herbal powder capsules and also for microencapsulated drugs. Spray drying is the process of transformation of feed from a fluid state into a dried particulate form by spraying the feed into a hot drying medium (Jittanit et al., 2010). Here, extracts in the form of liquid is introduced as fine spray or mist using an atomizer into a tower or chamber along with heated air. As the small droplets make intimate contact with the heated air, they flash off their moisture, become small particles and drop to the bottom of the tower as spray dried powders (Phisut, 2012). This technique has got wide application in the production of encapsulated drugs, dietary supplements, nutraceuticals etc. The main problem with the spray dried powders is that it may turn hygroscopic when exposed to ambient temperature conditions. So, it is a general practice to add carrier agents like maltodextrin, gum arabic etc. along with the feed material which can act as a protective coating. Srinivasan and Sivasubramanian (2015) reported that gum arabic encapsulation can retain 73.18% vasicine when compared with maltodextrin encapsulated and capsules of Adathoda vasica prepared by spray drying without any encapsulation.
In, Tamil Nadu Agricultural University a study was done (Delfiya et al., 2014) by combing the carrier materials, maltodextrin and gum arabic in various proportions to find out the encapsulation efficiency of these materials for having maximum curcumin and oleoresin content for encapsulating turmeric. They reported that any of the proportions is not good, gum arabic alone at an inlet temperature of 175°C is reported to be ideal.

Another group of scientists (Krishnaiah et al., 2015) tried out the use of potato starch as a carrier material for spray drying Noni (*Morinda citrifolia*) extract and reported the use of equal amount of potato starch along with extract for making spray dried Noni powder having high antioxidant activity and total phenolic content.

**Microwave Drier**

Microwave drier is a new addition to the existing drying techniques. Microwaves are a form of electromagnetic energy with frequencies that lie between 300 MHz and 300 GHz, generated by magnetrons under the combined force of an electric and a magnetic field perpendicular to each other. During microwave drying, the water molecules of the product to be dried readily absorb this energy, which is converted to heat. Thus, the water vaporizes and diffuses through the product to the surface (Sadi and Meziane, 2015).

Karthirvel et al. (2006) reported that microwave drying was more efficient than conventional hot air drying and 95 – 98% faster. Energy consumption for drying Aswagandha roots in a microwave power of 6W, 60°C and 1m/s is reported as only 0.396 ± 0.047 MJ/kg whereas 2.27 ± 0.12MJ/kg is required for hot air (cabinet) drying. Microwave drying can save nearly 82% energy (Senapati et al., 2014).

**Infrared Radiation Drier**

This is also an innovative drier which work on the principle of infrared radiation. Hot bodies such as quartz, silica etc. are able to emit infrared rays when it is heated to a high temperature and it can penetrate the raw material, vapourises the moisture and make the produce dried. Like the microwave drier it has a cabinet to hold the raw material and infrared radiation is projected from the heat source arranged above the trays of the product (Sharma et al., 2005). Two pepper mint cultivars when dried using infrared drier recorded a significantly higher amount of essential oil when compared to microwave drying (Rubinskiene et al., 2015). Microwave and infrared radiation drying are confined for small scale production of dried crude drugs and research on these two techniques are also limited.

**Sub - Atmospheric Driers**

In sub – atmospheric driers pressure is reduced to create vacuum and drying process is carried out. Commonly used sub – atmospheric driers are vacuum driers and freeze driers. Moisture is vapourised from the raw material and drying occurs in a vacuum drier whereas water is sublimed to vapour in a freeze drier and the material got dried (ICS – UNIDO, 2008).

**Vacuum Drier**

In a vacuum drier, pressure is reduced so that heat required for drying is reduced and moisture is removed at a temperature below the boiling point of water. In this equipment, air is evacuated, steam is injected as heat source for drying the material and moisture is removed as vapour from produce (ICS – UNIDO, 2008).
There are different kinds of vacuum driers like, vacuum shelf drier, vacuum drum drier and vacuum belt drier. The main advantage of using vacuum driers is that rapid drying is made possible in oxygen free environment to get good quality produce. It is of course expensive and is done mainly for high value materials.

Vacuum drying behavior of Andrographis paniculata at temperatures of 40, 50, and 60°C with vacuum pressures of 10 and 30 kPa was investigated by Hee and Chong (2015) and found that at 60°C and 10KPa the effective diffusivity and active energy for moisture diffusion were higher, 10-13 m²/s and 33.4 KJ/mol, respectively.

Microwave - Vacuum Hybrid Drier

In microwave - vacuum drying, heat is generated by directly transforming the electromagnetic energy into kinetic molecular energy without the interference of air, which makes heat to penetrate deep into the raw material. In this hybrid drying, microwave chambers will be supplied with vacuum so that air is evacuated and drying occurs without its interference which ultimately improves the systems speed and efficiency. Since the temperature required is lower compared to microwave drying nutrients and flavor can be more retained as well as in this technique oxidation damage, hygroscopicity of the produce and product loss in terms of both quantity and quality can be minimized (Law et al., 2010).

Khek et al. (2014) reported that in microwave vacuum hybrid drying only 30 minutes is required for drying Clinacanthus nutans, Strobilanthus crispus, Casia alata, Phyla nodiflora and Andrographis paniculata whereas it took 6.5 hours in a convective drier.

Freeze Drier

A freeze drier works on the principle that when pressure is reduced below triple point of water (for pure water: 6.1 mbar at 0°C) sublimation occurs. Freeze drying of crude drugs is done in two stages like pre – freezing (~ 40 to 50°C) in a deep freezer and as the second stage a high vacuum (30 – 300MTorr) is applied so that sublimation occurs and the produce get dried (Khairnar et al., 2013).

Camu-camu is a rich source of vitamin C, a vitamin which is very difficult to preserve since, it is heat labile. Aguiar et al. (2015) have investigated vitamin C content in freeze dried Camu-camu pulp and reported 10 times more vitamin C in freeze dried ones than fresh pulp. In another study by Oknye et al. (2015) freeze drying helps to retain phenols, flavanoids and antioxidant activity of ginger.

Freeze drying has some more added advantages like, high flavor retention, maximum retention of nutritional value, minimal damage to the product texture and structure, little change in product shape and color, and a finished product with an open structure that allows fast and complete rehydration can be obtained. Disadvantages include high capital investment, high processing costs and the need for special packing to avoid oxidation and moisture gain in the finished product (Khairnar et al., 2013).

Compared to natural drying artificial drying requires only less space and time, uniformly dried high quality produce can be prepared by artificial drying which is weather independent. But, it is highly economic and requires initial investment and maintenance cost (Srivastava and Kumar, 2012).

Osmotic Dehydration

Maftoonazad (2010) defined osmotic dehydration as a dewatering and impregnation soaking process, a combination of dehydration and impregnation processes which can modify the functional properties of raw materials,
thereby creating new products. For osmotically dehydrating a produce, the crude drug has to be soaked in an osmotic solution like sugar syrup, salt or honey and thus, about 50% of water is removed. After osmosis process further drying of the crude drug can be by natural or mechanical drying. Osmotically dehydrated Amla, Aloe vera etc. are now available in the market.

Osmotic dehydration depends on several factors like osmotic solution concentration, solution temperature, drying temperature, drying time etc. Pisalkar et al. (2014) studied the effect of parameters affecting osmotic dehydration of Aloe vera cubes and reported that increasing syrup concentration from 30 to 50\(^{\circ}\)Brix increases drying time, but compared to untreated samples it dries faster. 30\(^{\circ}\)Brix is reported to be ideal for Aloe vera drying.

Compared to other drying techniques about 50% of moisture removal is made possible by osmotic solution dip thereby reduces the effect of temperature as well as energy requirement. Osmotic solution prevents enzymatic browning and structural collapse of the drugs thereby a ready to eat produce having superior organoleptic characters will be obtained (Chavan and Amarowicz, 2012).

Several drying techniques are available but, the technique suitable for each type of crude drug depends on several factors like texture, structure, maturity etc. So, a suitable drying technique can be standardized only by studying all the parameters by comparing each and every available technique.

**COMPARISON OF DIFFERENT DRYING TECHNIQUES**

Pattali et al. (2015) reported that dehumidified air drying method can reduce the moisture content of whole leaf Aloe vera slices to 8.57% (dry weight basis) in 11 hours at 55±1°C and 18±1% RH which is faster than open yard sun drying and hot air drying. Solar drying and shade drying of Aonla flakes were done by Kamble and Lavende (2014) and reported that solar drying can reduce drying period by 50 percent compared to conventional shade drying method. Navale et al. (2015) made an attempt to evaluate the performance of cabinet solar dryer and open sun drying to dry the fenugreek leaves. They reported that the samples dried in open sun took seven hours whereas those in cabinet solar dryer took only four hours which showed its higher efficiency (68.12%). Senapati et al. (2014) reported that Ashwagandha roots dried in microwave drier contain 1.94% total alkaloids and possess a higher rehydration ratio (4.16) than sun dried samples. Shade drying, sun drying as well as oven drying of lemon grass yield relatively equal quantity of oil but, good quality oil containing the characteristic compound citral or its derivatives can be obtained by shade drying only (Dutta et al., 2014).

Influence of different drying methods on pepper mint oil composition was studied by Arab et al. (2015) and reported that even though irrespective of the drying methods used, all components are present in the extracts, extracts of shade dried mint leaves contain significantly higher amount of components. Drying methods, temperature and pre-treatment like blanching had a significant effect on ascorbic acid, calcium content, iron content as well as rehydration ratio of curry leaves. Tray drying of blanched curry leaves at 55°C can give good quality dehydrated curry leaves (Kengehe et al., 2015). Irrespective of the drying methods tried all samples of Bush tea (Athrixia phylicoides) exhibited antimicrobial activity against both gram - positive and gram – negative microrganisms with a minimum inhibitory concentration (MIC) value ranging from 3.1 to 6.3 (Mudau and Ngezimana, 2014).

**CONCLUSIONS**

A lot many techniques are available for drying the crude drugs. Each technique depends on several operating parameters as well as the raw material needed to be dried. The raw material characters are like texture, structure, plant part
used, stage of harvest, physio-chemical characteristics, volatile oil composition etc. are crucial in determining the suitable drying method. Among the natural drying methods and for small scale crude drug manufacturers shade drying is the preferably adopted method. Among the air convection driers for small scale operation cabinet driers and for large scale tunnel driers are found ideal. Fluidised bed and spray driers can be used for advanced production functions like preparation of nutraceuticals, dietary supplements, instant herbal powders etc. Microwave drying and infrared radiation drying are still in its infancy for crude drug drying. Even if, several drying techniques are available in the market when we get a crude drug for drying we have to compare all the available means of drying and standardize a suitable method since, the process as well as the produce highly depends on several operating parameters, raw material conditions moreover, economy and scale of production of crude drugs.

REFERENCES


