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Determination and effective parameters for drying of Millets

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ABSTRACT

One of the oldest methods used for preservation of fruits, vegetables, millets and other food products to increase their shelf life is drying. Cereals have a significant share in millet production both in the world and china. It acts a source of raw material for many food products. The important parameters of drying includes temperature, velocity and relative humidity. Drying and drying rate curves should be plotted to determine the drying kinetics of the products. Experiments are conducted in a tray dryer using different kinds of millets (foxtail millet ,little millet, kodo millet) for various drying temperatures (30- 60˚C) and with different time intervals .The temperature and time are measured and recorded for every 15 minutes. The measured data is used to obtain drying and drying rate curves. The curves indicate that drying process takes place in the falling rate period If drying is continued, the slope of the curve, the drying rate, becomes less steep (falling rate period) and gradually tends to nearly horizontal at very long times. The product moisture content will become constant at the "equilibrium moisture content", from the data collected during falling rate period and is calculated. Time and temperature are used as a parameters for the dried millet quality. It is essential to follow up drying course and to decide whether it is obtained or not by drying processing method. Too long drying course may have bad effects for quality and food safety because of high fermentations and mould growth. Also, drying to a too low moisture content can result in income losses.

Keywords: *Drying, Equilibrium moisture content, Drying kinetics.*

1. INTRODUCTION

Drying is used to remove excess moisture or other volatiles by using various substrates. Reducing and control of moisture levels in solid materials through heated drying is a important role in the manufacture of many products. Drying is a complex phenomenon involving heat and mass exchange. Drying ovens can be either Batch or Conveyor style. These ovens can be designed and manufactured to meet your specific applications. Drying is used in multiple industries for a wide range of applications. This can include paint drying, drying glass and plastics, ink, adhesives, and removing excess water from filter material etc; one of the oldest methods used for preservation of fruits, vegetables, millets and other food products to increase their shelf life is drying. Cereals have a significant share in millet production both in the world and china. It acts a source of raw material for many food products. The objectives of drying are as follows:-

a. For the purpose of storage and transport.

b. To protect from contamination

c. To increase the shelf-life

d. To make it attractive for the consumers.

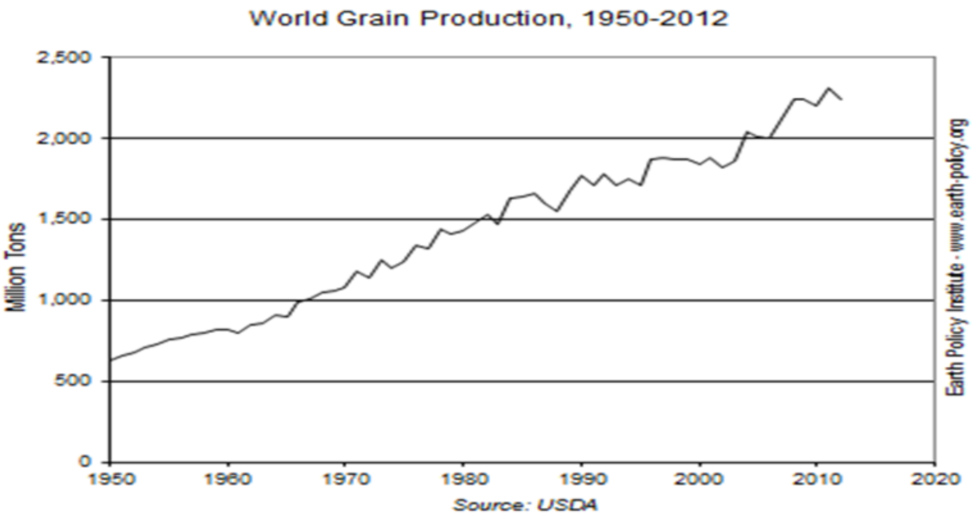
Drying is carried by using different types of equipment:

a. Drying that is carried out in perforated conveyor beds is called Shallow – bed dryers.

b. Drying that occurs in bins is called as Deep-bed dryers.

c. To dry liquid foods and food slurries spray driers are used.

d. Freeze dryers are used to dry soup ingredients, beverage extracts.



World Grain Production 1950-2012

2. DRYING MECHANISM

Some products have a high initial moisture content, an initial linear reduction of the average product moisture content as a function of time may be observed for a limited time, is also called as"constant drying rate period". Usually, in this period, it is surface moisture outside individual particles that is being removed. The drying rate during this period is mostly dependent on the rate of heat transfer to the material being dried. Therefore, the maximum achievable drying rate is considered to be heat-transfer limited. If drying is continued, the slope of the curve, the drying rate, becomes less steep (falling rate period) and eventually tends to nearly horizontal at very long times. The product moisture content is then constant at the "equilibrium moisture content", where it is, in practice, in equilibrium with the dehydrating medium. In the falling-rate period, water migration from the product interior to the surface is mostly by molecular diffusion, i,e. the water flux is proportional to the moisture content gradient. This means that water moves from zones with higher moisture content to zones with lower values, a phenomenon explained by the second law of thermodynamics. If water removal is considerable, the products usually undergo shrinkage and deformation, except in a well-designed freeze-drying process. The drying rate in the falling-rate period is controlled by the rate of removal of moisture or solvent from the interior of the solid being dried and is referred to as being "mass-transfer limited". This is widely noticed in hygroscopic products such as fruits and vegetables, where drying occurs in the falling rate period with the constant drying rate period said to be negligible. The process of thermally removing moisture to yield a solid product is called drying. Moisture can be found as bound or unbound in the solid. Moisture, which produces a vapour pressure less than that of pure liquid, is called bound moisture while moisture in more of bound moisture is called unbound moisture. When a wet solid is kept to thermal drying, two processes occur simultaneously:

- Transfer of energy (mostly as heat) from the surrounding environment to evaporate the surface moisture.
- Transfer of internal moisture to the surface of the solid and its rapid evaporation due to process

1. Energy acts as heat from the surrounding environment to the wet solid can occur as a result of convection, conduction, or radiation and in some case as a result of a combination of these effects. In most cases heat is transferred to the surface of the wet solid and then to the interior. However, in dielectric, radio frequency (RF), or microwave freeze drying, energy is supplied to generate heat internally within the solid and flows to the exterior surface.

Process 1, the removal of water as vapour from the material surface, depends on the external conditions of humidity, temperature and pressure, area of exposed surface, and velocity of the area.

Process 2, the movement of moisture internally within the solid is a function of the physical nature of the solid, moisture content, and its temperature.

Drying is a complex operation involves transfer of heat and mass along with several processes, such as physical or chemical transformations which, in turn, may cause changes in product quality as well as the mechanisms of heat and mass transfer. Physical changes that may occur include puffing, glass transitions, crystallization, and shrinkage. In some cases, desirable or undesirable chemical or biochemical reactions may occur, leading to changes in Color, texture, odours, or other properties of the solid product. Drying occurs by affecting vaporization of the liquid by supplying heat to the wet product. Heat may be supplied by convection (direct dryers), by conduction (contact or indirect dryers), radiation or volumetrically by placing the wet material in a microwave or

RF electromagnetic field.

Transport of moisture within the solid may occur by any one or more of the following mechanisms of mass transfer: Liquid diffusion, if the wet solid is at a temperature below the boiling point of the liquid, Vapour diffusion, if the liquid vaporizes within material, Knudsen diffusion, if drying takes place at very low temperatures and pressures, e.g., in freeze drying, Surface diffusion (possible although not proven), Hydrostatic pressure differences, when internal vaporization rates exceed the rate of vapour transport through the solid to the surroundings, Combinations of the above mechanisms.

Since the physical structure of the drying solid is subject to change during drying, the mechanisms of moisture transfer may also change with elapsed time of drying. Process 1:

External Conditions The essential external variables are temperature, humidity, velocity and direction of air, the physical form of the solid, the desirability of agitation, and the method of supporting the solid during the drying operation. External drying conditions are especially important during the initial stages of drying when unbound surface moisture is removed. In certain cases, for example, in materials like ceramics and timber in which considerable shrinkage occurs, excessive surface evaporation after the initial free moisture has been removed sets up high moisture gradients from the interior to the surface. This is liable to cause over drying and excessive shrinkage and consequently high tension within the material, resulting in cracking and warping. In these cases surface evaporation should be retarded through the employment of high air relative humidity while maintaining the highest safe rate of internal moisture movement by heat transfer.

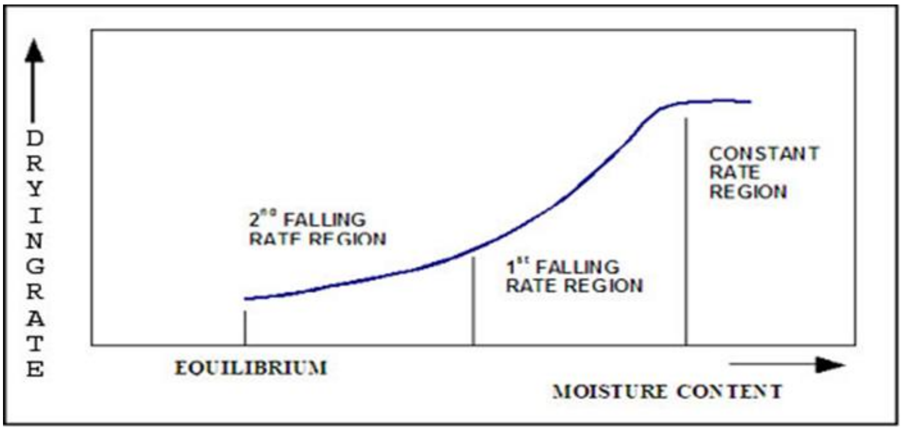
Process 2: Internal Conditions As a result of heat transfer to a wet solid, a temperature gradient develops within the solid while moisture evaporation occurs from the surface. This produces a migration of moisture from within the solid to the surface, which occurs through one or more mechanisms, capillary flow, internal pressures , diffusions set up by shrinkage during drying, and, in the case of indirect (conduction) dryers, through a repeated and progressive occurring vaporization and recondensation of moisture to the exposed surface. Variables such as temperature, air velocity which normally increases the rate of surface evaporation, are of decreasing importance except to promote the heat transfer rates

Drying Mechanism Moisture in solid may be either unbound or bound.

There are two methods of removing unbound moisture: evaporation and vaporization.

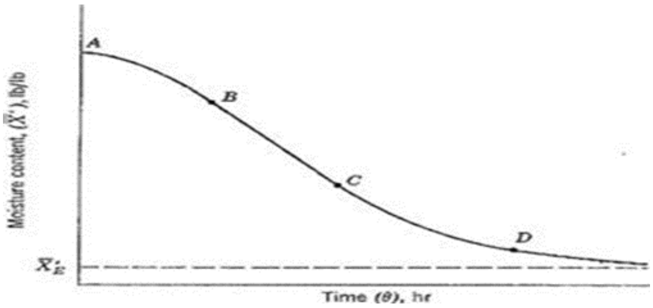
Evaporation occurs when the vapour pressure of the moisture on the solid surface is equal to atmospheric pressure. This is done by increasing the temperature of the moisture to the boiling point. The boiling point where evaporation occurs is the temperature which could be lowered by lowering the pressure; if the dried material is sensitive to heat.

Further, in vaporization, convection drives the drying by the mean of the heat transfer from passing warm air through the product. While the temperature of warm air decreases, the specific humidity increases because of moisture content of the product.



Drying behaviour of solids is described by measuring the function of moisture content loss versus time

Continuous weighing, humidity difference and intermediate weighing are the used methods. In air drying processes, two drying periods generally occurs as an initial constant-rate period and falling rate period. Constant rate drying occurs with evaporation of pure water. Moisture movement is controlled by internal resistances in the falling rate period... At zero time the initial moisture content is shown at point A. If the beginning the solid is usually at a colder temperature than its ultimate temperature. Alternatively, if the solid is quite hot to start with, the rate may start at point A. Segment AB represents the initial unsteady-state, warming-up period. This initial unsteady-state adjustment period is usually quite short and it is often ignored in the analysis of times of drying. BC is the constant rate period. The same points are marked where the drying rate is plotted against the moisture contents. During the constant rate period, the surface of the solid is initially very wet and a continuous film of water exists on the drying surface. Between point C and D is termed the first falling rate period. During this period the rate of liquid movement to the surface is less than the rate of evaporation from the surface, and the surface becomes continually depleted in liquid water. The entire surface is no longer wetted, and the wetted area continually decrease in the first falling rate period until the surface is completely dry at point D. Beyond point D, the path for transport of both the heat and mass becomes longer and more tortuous as the moisture content continues to decrease. This period is called the second falling rate period. Finally, the vapour pressure of the solid becomes equal to the partial vapour pressure of the drying air and no longer further drying takes place. The limiting moisture content at this stage to which a material can be dried under a given drying condition is referred to as the equilibrium moisture content. Drying Techniques and Dryers several types of dryers and drying methods, each better suited for a particular situation, are commercially used to remove moisture from a wide variety of fruits and vegetables. Conventional drying process ranges from natural sun drying to industrial drying (Leon et al. 2002). Some of the most common types of drying processes and dryers are introduced in the following sections.



Drying Curve, Showing Moisture Content as a Function of Drying Time

Sun Drying

Sun drying has the advantages of simple and the small capital investment. On the other hand, there are many technical problems which are rain and cloudiness, contamination from outer sources and lack of control over drying conditions. It requires large areas and long drying time. The final product may be contaminated from dust and insects and suffer from enzyme and microbial activity. It is limited to climates with hot sun and dry atmosphere with strong winds

Hot Air Drying

In this method, heated air is brought into contact with the wet material to be dried to facilitate heat and mass transfer; convection is mainly involved. Two important aspects of mass transfer are the transfer of water to the surface of the material that is dried and the removal of water vapor from the surface. The hot air dryers generally used for the drying of piece-form fruits and vegetables are cabinet, kiln, tunnel, belt-trough, bin, pneumatic and conveyor dryers. Energy source to heat the air would be electricity or a renewable energy resource such as solar and geothermal energy

Cabinet Dryer

A cabinet dryer can be a small batch tray dryer. Heat from the drying medium to the product is transferred by convection. The convection current passes over the product, not through the product. It is suitable for drying of fruits, vegetables, and meat and its product. The main feature of a cabinet dryer is its small size and versatility. The main problem with cabinet dryer is difficulty in even distribution of heated air over or through the drying material

Tunnel Dryer

The tunnel dryers are of many different configurations in general having rectangular drying chambers. Tunnel dryers are basically a group of truck and tray dryers widely used due to their flexibility for the large-scale commercial drying of various types of fruits and vegetables. Truckloads of the wet material are moved at intervals into one end of the tunnel. The whole string of trucks is periodically advanced through the tunnel until these are removed at the other end of the tunnel. Air movement, circulation, and heating methods vary in tunnel dryers. Three different flow arrangements are counter-flow, parallel flow, and combined flow. These dryers are simple and versatile in comparison with other types of dryers. Food pieces of any shape and size can be handled. If solid trays are incorporated, fluids can also be dried.

Belt-Trough Dryers

Belt-trough dryers are agitated bed, through flow dryers used for the drying of cut vegetables of small dimensions. They consist of metal mesh belts supported on two horizontal rolls; a blast of hot air is forced through the bed of material on the mesh. The belts are arranged in such a way to form an inclined trough so that the product travels in a spiral path and partial fluidization is caused by an upward blast of air.

Pneumatic Conveyor Dryers

Pneumatic conveyor dryers are generally used for the finish drying of powders or granulated materials and are extensively used in the making of potato granules. The feed material is introduced into a fast moving stream of heated air and conveyed through ducting of sufficient length to bring about desired drying. The dried product is separated from the exhaust air by a cyclone or filter

Fluidized Bed Dryer

The fluidized bed type of dryer was originally used for the finish drying of potato granules. In fluidized bed drying, hot air is forced through a bed of food particles at a sufficiently high velocity to overcome the gravitational forces on the products. A major limitation is the limited range of particle that can effectively be fluidized.

Microwave Drying

In microwave drying, the product is exposed to very high-frequency electromagnetic waves. The transfer of these waves to the product is similar to the transfer radiant heat. The advantages of using microwave energy are penetrating quality, which effects a uniform heating of materials upon which radiation impinges; selective absorption of the radiation by liquid water; and capacity for easy control so that heating may be rapid if desired.

Spray Drying

The spray drying method is most important for drying liquid food products and has received much experiment study. Spray drying by definition is the transformation of a feed from a liquid state into a dried form by spraying into a hot, dry medium. In general it involves atomization of the liquid into a spray and contact between the spray and the drying medium, followed by separation of dried power from the drying medium.

Freeze-Drying

Freeze-drying, which involves a two-stage process of first freezing of water of the food materials followed by the application of heat to the product so that ice can be directly sublimed to vapor, is already a commercially established process. The advantages of freeze-drying are; shrinkage is minimized; movement of soluble solid 20 minimized; the porous structure of the product facilitates rapid dehydration; and retention of volatile flavor compounds is high.

Osmotic Dehydration

Osmotic dehydration is a water removal process that consists of placing foods, such as pieces of fruits or vegetables, in a hypertonic solution. As this solution has higher osmotic pressure and hence lower water activity, a driving force for water removal arises between solutionand food, whereas the natural cell wall acts as a semi permeable membrane. Direct osmotic dehydration is therefore a simultaneous water and solute diffusion process.

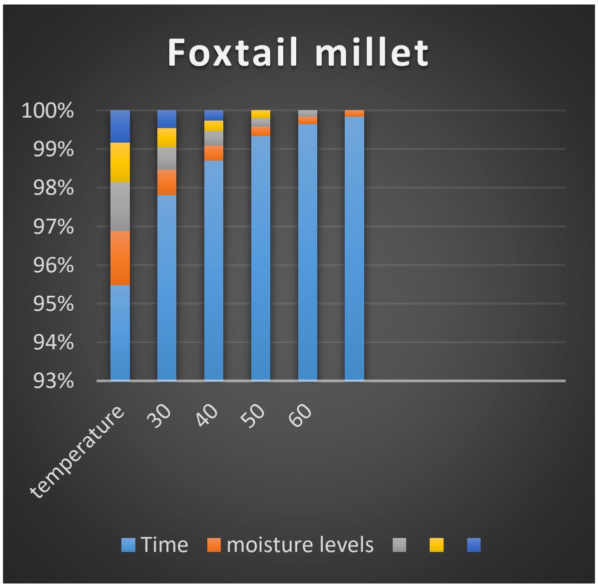
3. MATERIALS AND METHODS

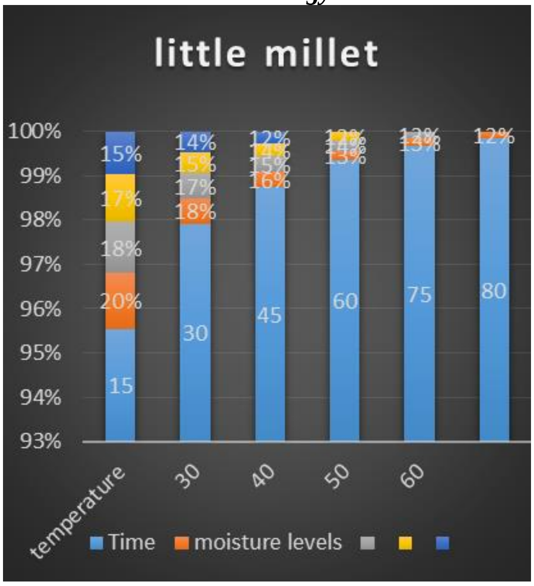
Experimental set up

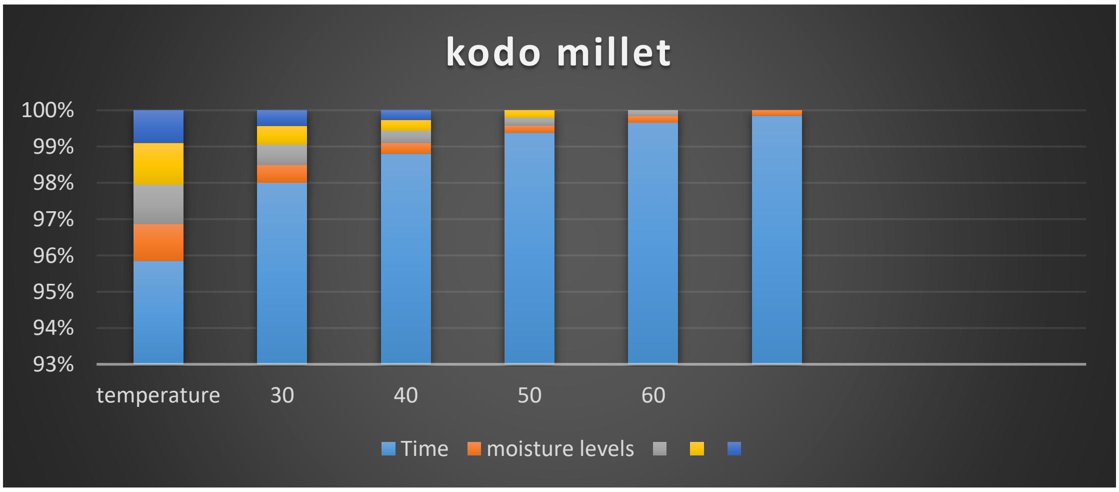
A tunnel dryer with a weigh of 500mm, a width of 400mm and a total length of 3307nm is required to perform the drying characteristics of millets. The dryer consists of air preparation unit and a drying tunnel

Humidifier centrifugal fan, and a heater is present in air preparation unit. After passing through the heater air reaches the section where moisture is added manually to reach the relative humidity.

The millets are brought from the farm and strored in the bags at room temperature .Two different millets where choosen such as little millet ,foxtail millet, kodo millet respectively . millets are subjected to steaming for 30 minutes and subjected to sun drying for 40 min .later, the millets should be kept in the dryer at different temperatures (30,40,50,60) at different Time intervals such as 15,30,45,60,75,80 respectively and moisture is to be calculated .







Moisture Levels of Respective Millets at Different Temperatures by using Different Intervals of Time

Drying of millets is determined according to AOAC 37.1.10. Petri plates are used in the determination of dry matter are considered for the weighing process . Ethyl alchoal is used to clean the dishes that are placed in the temperature that holds at 70±˚C. Dishes are taken from the oven for every 30 min and then weighed and are cooled down to room temperature. 300 gms of cacl2 is added to the desiccator to prevent moisture.

Calculating moisture content from wet weight and dry weight

Moisture Content of grain is usually determined on wet basis (wb)

$$MC_{wb} = \frac{W_i - W_f}{W_i} \times 100 \qquad MC_{db} = \frac{W_i - W_f}{W_f} \times 100$$

MCwb = Moisture content wet basis [%]

MCdb = Moisture content dry basis [%]

Wi = Initial weight

Wf = Final weight

Conversion from MCwb to MCdb and back

Sometimes it is needed to convert from moisture content dry basis to moisture content wet basis.

$$MC_{wb} = \frac{100 \times MC_{db}}{100 + MC_{db}} \qquad MC_{db} = \frac{100 \times MC_{wb}}{100 - MC_{wb}}$$

Weight loss during drying

During drying, paddy grain will loose weight due to loss of moisture:

$$W_f = W_i \times \frac{100 - MC_i}{100 - MC_f}$$

Wi = Initial weight [g]

Wf = Final weight [g]

After estimating the moisture content the product is subjected to packaging.

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