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Comparison of Methods for Determination of Moisture in Food

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Abstract: Water is the most common substances on earth and an essential component of all food. The amount of water in food (known as percent water) influences the appearance, texture, and flavor of the food. Water makes up 70% or more of the weight of most fresh (unprocessed) food. Even "dry" food like beans, flour and cereals contain some water. A number of techniques had been developed for this purpose, which vary in their accuracy, cost, speed, sensitivity, specificity, ease of operation, etc. The choice of any procedure for particular application depends on the nature of the food being analyzed and the reason the information is need. In addition, the moisture monitoring techniques will provide for better control of processing for value added applications and improved end product In this paper a study for some of technique namely, the Infrared, Microwave, oven dry and differential gravimetric analysis was done. A comparison of this technique and the choice of the easy, fast, low in cost technique was recommended. It was found that the technique is the one which can be recommended.

Key words:

INTRODUCTION

The propensity of microorganisms to grow in food depends on water content as they need water to dissolve the food they use. It is known that the outside of every kernel of grain and bean hosts thousands of fungi spores and bacteria. Fungi produce toxins such as aflatoxins and feminizing that are serious health hazards to human been and animals that use these products for food and feed. Therefore, better information on the moisture levels of products can be of significant value in maintaining quality and preventing losses and contamination[1]. The problem lies in that at moisture levels between 13, 5% to 15%[2] some fungal species are able to grow and reproduce. Arabic bacteria (needing free oxygen to survive) require moisture in the 20% range. Microorganisms, specifically bacteria, molds and yeasts, can cause food to spoil. For example, microorganisms that break down fats in unsalted butter can cause it to become rancid. Bacteria that breaks down protein in meat (proteolysis bacteria) and results in foul odors. Also, if milk is kept too long or at improper temperatures, it will sour. For these reasons many foods are dried below some critical moisture content no more than 10%. An exception to this is raw peanuts which are particularly susceptible to an Aspergillus's mold growth that produces aflatoxin (a type of mycotoxine) and should be stored with 8% moisture content or less. So, moisture content is the single most important quality characteristic that determines the safe storage potential for cereal grains and oilseeds, price discounts and premiums, as well as grain storability which may affect economic return. Excessive moisture is also usually undesirable and can cause rot in wood or other organic material, corrosion in metals, and electrical short circuits.

Drying is one of the methods of food preservation that is simple, safe and easy to learn. It removes enough moisture from the food so bacteria yeast and molds can’t grow Drying also slows done the action of enzymes because it removes moisture, the food shrinks, and it becomes lighter in weight. When food is ready for use add water. Better information of moisture will provide for better control of processing for value added applications and improved end product quality, significant energy savings in grain drying operations.

Water Molecule in Food[3,4]: Although the water content of a food is expressed as a percent, this number does not reflect how water exists in food. Water in food is classified according to its availability or biological activity and is either "free" or "bound". Free water is not bound to any component in food; it can be used for microbial growth and is also available for chemical reactions. Bound water is physically bound to large (molecules) components in the food. It is not available to microorganisms for their growth and it cannot participate in chemical reactions. Despite having the same chemical formula (H_2O) the water molecules in food may be present in verity of different molecular environments depending on their interaction with the surrounding molecules and have different physicochemical properties.

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The Bulk Water: in witch the water molecule is surrounded only by other water molecule and has physicochemical properties that are the same as those of pure water, e.g., melting point, boiling point, density, compressibility, heat of vaporization, electromagnetic absorption spectra.

Capillary or Trapped Water: Is another type in which water is held in narrow channels between certain food components because of capillary forces. It is held within spaces within a food are surrounded by physical barrier that prevents the water molecules from easily escaping, e.g., an emulsion droplet or biological cell. The majority of this type of water is involved in normal water-water bound and so it has physicochemical properties similar to that of bulk water.

Physically Bound Water: [5] in which water molecules are surrounded by other water molecules, but are in molecular contact with other food constituents, e.g. protein, carbohydrates or minerals, and the bonds between them are often significantly different from normal water-water bonds and so this type of water has different has physicochemical properties than that of bulk water e.g., melting point, boiling point, density, compressibility, heat of vaporization, electromagnetic absorption spectra.

Chemically Bound Water: Some of eater molecules present in food may be chemically bounded to other molecule as water of crystallization or hydrates e.g., Na_2SO_4 $10H_2O_4$.These bounds are much stronger than the normal water-water bonds and therefore chemically bound water has very

Physicochemical properties to bulk water e.g. lower melting point, higher boiling point, higher density, lower compressibility, higher heat of vaporization different electromagnetic absorption spectra.

How to Preserve Food from Moisture: Food can be dried in an oven or in food dehydrator by using the right combination of warmth, low humidity and air current.

In drying, a warm temperature allows the moisture to evaporate. Air current speeds up drying by moving the surrounding moisture air away from the food. Low humidity allows moisture to remove from the food to the air.

Drying food is a slow process. It will take 6 or more hours in a dehydrator, and in an oven it will take 8 or more hours. Drying time depends on type of food, thickness, and type of dryer. If the drying time is speed by turning up the oven the food may be cooked on the outside before it dries on the inside. The food may appear dry on the outside but may be wet on the inside. Moisture left in the food will cause it to mold.

After foods are dried, allow 30 minutes to one hour cooling time to prevent condensation. However, too long a cooling period allows moisture from air to re-enter the food.

Proper storage prevents insects and rodents from eating food. It also keeps moisture out and saves valuable nutrients. Glass jars, metal cans or boxes with new tight fitting lids, or vapor-proof freezer cartons make good containers. The jars do not need to be heat processed. Heavy duty plastic bags with press together seals are acceptable, but are not insect and rodent proof.

Dried foods will keep from four to twelve months, but proper storage is very important. Cool, dry, dark are best. For best quality, the storage temperature should not go over 15ºC. Refrigerator or freezer storage does provide a low temperature which extends the shelf life.

After packing, check container within seven to ten days to see if any moisture is present. If any is seen, food must be dried. If it is moldy, discard the food. Dried fruits can be eaten as nutritious snacks, or they can be soaked for one to two hours and used in favorite recipes.

The Most Important Techniques Developed to Measure the Moisture Content of Foods Are:[6,7,8,9,10,11]

1-Evaporation methods:

2-Distillation Methods:

3-Chemical Reaction Methods:

4-Physical Methods: A number of analytical methods have been developed to determine the moisture content of foods that are based on the fact that water has appreciably different bulk physical characteristics than the food matrix, e.g., density, electrical conductivity or refractive index. These methods are usually only suitable for analysis of foods in which the composition of the food matrix does not change significantly, but the ratio of water-to-food matrix changes. For example, the water content of oil-in-water emulsion can be determined by measuring their density or electrical conductivity because the density and electrical conductivity of water are significantly higher than those of oil. If the composition of the food matrix changes as well as the water content, then it may not be possible to accurately determine the moisture content of the food because more than one food composition may give the same value for the physical property being measured. In these cases, it may be possible to use a combination of two or more physical methods to determine the composition of the food, e.g., density measurements in combination with electrical conductivity measurements.

Spectroscopic Methods: Spectroscopic method utilize the interaction of electromagnetic radiation with materials to obtain information about their composition, e.g., X-rays, UV-visiable, NMR, microwaves and IR. The[13,14,15] spectroscopic methods developed to measure the moisture content of foods are based on the fact that water absorbs electromagnitic radiation at characteristic wavelengh that are different from the other components in the food matrix. The most widely used physsical methods are based on measurements of the absorption of microwave of infrared energy by foods. Microwave and infrared radiation are absorbed by materials due to their ability to promote the vibration and/or roration of molecules. The analysis is carried out at a wavelenth where the water molecules absorb radiation, but none of the other components in the food matrix do. Ameasurement of the absorbtion of radiation at this wavelength can then be usedto determine the moisture content: the higher the moisture content, the greater the absorbtion. Istruments based on this principle are commercially available and can be used to determine the moisture content in a few minutes or less. It is important not to confuse infrared and microwave ***absorbtion*** methods with infrared lamp and microwave ***evaporation*** methods. The former use low energy wave that cause no physical changes in the food, whereas the latter use high-energy waves to evaporate the water. The major advantage of these methods is that they are capable of rapidly determining the moisture content of a food with little or no sample preparation and are therefore particularly useful for quality control purposes or rapid measurements of many samples.

Methods to Determine Water in Different Molecular Environments: The overall water content of a food is sometimes not a very reliable indication of the quantity of a food because the water molecules may exist in different environments within foods, e.g., bound or free as mentioned above. For this reason, it is often useful for food scientists to be able to determine the amount of water in different molecular environments within a food. A variety of analytical methods are available that can provide this type of information.

Vapor Pressure Methods: A physical parameter that is closely related to the amount of free water present in a food is the water activity:

$A_{w = P/Po}$

Where P is the partial pressure of the water above the food and P_o is the vapor pressure of pure water at the same temperature. Bound water is much less volatile than free water, and therefore the water activity gives a good indication of the amount of free water present. A variety of methods are avalible foe measuring the water activity of a sample based on its vapor pressure. Usually, the sample to be analysed is placed in a closed container and allowed to come into equilibrium with its envernoment. The water content in the headspace above the sample is then measured and compared to that of pure water under the same coditions.

Thermogravimetric Methods: Thermogravimetric techniques can be used to continuously measure the mass of the sample as it is heated at a controlled rate. The temperature at which water evaporates depends on its molecular environment: free water normally evaporates at a lower temperature than bound water. Thus by measuring the change in the mass of sample as it loses water during heating it is often possible to obtain an indication of the amounts of water present in different molecular environments.

Calorimetric Method: Calorimetric techniques such as differential scanning calorimeter (DSC) and differential thermal analysis (DTA) can be used to measure changes in the heat absorbed or released by a material as its temperature is varied at a controlled rate. The melting point of water depends on its molecular environment: free water normally melts at higher temperature than bound water. Thus by measuring the enthalpy change of a sample with temperature it is possible to obtain an indication of the amounts of water present in different molecular environments.

Spectroscopic Methods: The electromagnetic spectrum of water molecules often depends on their molecular environment, and some spectroscopy techniques can be used to measure the amounts of water in different environments. One of the most widely used of these techniques is nuclear magnetic resonance (NMR). NMR can distinguish molecules within material based on their molecular mobility, i.e., the distance they move in a given time. The molecular mobility of free water is appreciably higher than that of bound water and so NMR can be used to provide an indication of the concentration of water in "free" and "bound" states.

Experimental Procedure: The moisture content can be determined by an oven method which is a direct method. The grain is weighed and dried, then weighed again according to standardized procedure. The moisture content is calculated using the moisture content equations. The dielectric properties of materials such as grain and oilseeds are also closely related to the amount of water that contain. Consequently, instruments can be designed to sense these dielectric properties and be calibrated to read moisture content.

Most moisture meters measure the electrical properties of grain, which change with the moisture content. This is considered an indirect method and must be calibrated by a direct method. It is important to follow moisture meter direction carefully to achieve an accurate moisture test. A moisture meter should be periodically checked to see if it is accurate. One method of checking the meter is to compare it to at least two other meters. Because the manual laboratory method is relatively slow, automated moisture analyzers have been developed that can reduce the time necessary for test from a couple hours to just a few minutes. These analyzers incorporate an electronic balance with a sample tray and surrounding heating element. Under microprocessor control the sample can be heated rapidly and result computed prior to the completion of the process, based on the moisture loss rate, known as a drying curve.

Sample Preparation: Before moisture testing is beginning it is important, to ensure that the sample is free of dockage, to ensure that the temperature is at 20±1°C.

Selection of a representative sample, and prevent of changes in the properties of the sample prior to analysis, is two major potential sources of error in many food analysis procedures. When determining the moisture content of a food it is important to prevent any loss or gain of water. For this reason exposure of sample to the atmosphere, and excessive temperature fluctuations, should be minimized. Also the moisture content of the sample under test must maintain from the time the sample is obtained until all experiments are finished by storing it in a sealed container.

For all of the above reasons, the samples were maintained inside the champers in small dishes as described below

Chambers for Maintaining the Samples: To insure reliable equilibrium moisture content values for the samples, chambers are constructed from low thermal conductivity material with dimensions 50 cm x 50 cm x 30 cm. It was also necessary to insure isolation of the system from the temperature and humidity of the environment. This was done using Testo 625 sensor. A small hole was made in the center of upper side of the chambers. A fan was fixed in the center of the middle shelf to circulate the air to obtain homogenous relative humidity. The humidity inside the chambers was changed using three different salt solutions maintained inside three dishes. The samples were maintained for two weeks to ensure that the samples have stability moisture content. Each sample was separate into three parts. The first was used to determine the moisture using (IR) apparatus; the second one was used to measure the moisture content using (TGA) apparatus and the third part was used to determine the moisture using micro wave furnace (MW). The results are shown in tables (1, 2 and 3).

Thermal Gravimetric Analysis Procedure (TGA): This method is called "a dynamic mass change method" in which a change in mass of the sample is measured as a function in temperature while the sample is subject to controlled temperature programmed. TGA provides quantitative information on the weight change processes and enables to stoichiometry of reaction to be followed directly.The moisture inside the sample can be determined accurately by this mothide.

Microwave Technique: [16,17,18,19], [20,21,22,23,24] New Kenwood microwave oven is a 900 watt model with 25 Liter capacity, 5 power levels and 9 auto menu programmers was used. It is complies with European Economic Community (Radio Interference Directive: 89/336/EEC). Care was taken to be sure that the electricity supply is the same as that indicating on the rating plate and the apparatus is earthed.

Infrared Technique:

GMK-508-1L Moisture Meter: The measuring principle of GMK-508-1L is based on oven method. It is equipped with a precise balance, which provides directly reading of moisture loss from 0% to 100%. It is, therefore, widely applicable for measuring moisture of all substances which can be dried by infrared heater as beans, concrete, etc.

Results:

Discussion and Coclusion: It is known that EGYPT import a large quantities of grain to be used in the main food of the human been. To be sure that the amount of moisture in this grain is in the permisable value and sure that it will not be spoiled untill be used, the study of the techniques used for its determination was carried out. The most sutible one must be easy, not distractive, can be used for the movable material and not expensive. The prisent study is a step to techel this proplem.

It is known that he classical laboratory method of measuring moisture in solied is the loss on drying. In this technique a sample of material is weighed, heated in an oven for an appropriate peroid, cooled in a dry atmosphere of a dessicator,and then reweighed. This technique gives a good measure of moisture content, but this technique is relatively slow and may take more than several hours. The used techniques in this work reduced the time for the test to just a few minutes.

From the results of tables 1,2,3 it is clear that the moisture data is nearly the same for the three used techniques with a difference of 3.3%which is within the uncertainty of the measurements.The researches showed that using microwave frequancies is better than using lower frequancies. Moisture content is provided

Table 1: Moisture for Samples of Box (1) Contains Potassium Acetate (22.9% moisture).

Sample	Moisture by IR%	Moisture by TGA	Moisture by Microwave
Adas	7.8	7.9	7.8
Rice	9.4	9.4	9.2
Lobya	6.2	6.4	6.4
Beans	5.6	5.8	5.6

Table 2: Moisture for Samples of Box (2) Contains Sodium Bromide (57.3% moisture).

Sample	Moisture by IR%	Moisture by TGA	Moisture by Microwave
Adas	8.2	8.3	8.4
Rice	9.7	9.5	9.4
Lobya	7.4	7.5	7.4
Beans	7.4	7.5	7.4

Table 3: Moisture for Samples of Box (3) Contains Potassium Sulfate (97% moisture).

Sample	Moisture by IR%	Moisture by TGA	Moisture by Microwave
Adas	9.5	9.5	9.4
Rice	10.6	10.5	10.4
Lobya	7.6	7.5	7.3
Beans	8.6	8.6	8.5

independent of densityof the grain , so that relible moisture sensing in moving grain can be achived. The microwave frequancies are also not affected by variation in ionic coductivity,which is responsible for errors in moisture measurement at low frequancies(4).

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