Journal of Analytical & Bioanalytical Techniques

Chauhan, J Anal Bioanal Tech 2019, 10:2

Review Article Open Access

Concise Unification of the Viability of Dynamic Vapor Sorption Technique in Science and Technology

Ashish Chauhan*

Small and Medium Pharmaceutical Industry Centre (SMPIC), Mohali, Punjab, India

***Corresponding author:** Ashish Chauhan, Small and Medium Pharmaceutical Industry Centre (SMPIC), Mohali, Punjab, India, E-mail: aashishchauhan26@gmail.com

Received date: October 04,2019; **Accepted date:** October 18,2019; **Published date:** October 25,2019

Abstract

Dynamic Vapor Sorption is an advanced analytical technique that has immense potential to serve and uplift the advancement in Science and Technology. It has numerous applications in the field of pharmaceuticals, food industries, fabrics, polymers, structure designing, constructions, personal care and hygiene etc. The present review is a scientific unification of the viability and scope of the instrument.

Keywords: Sorption technique; Morphological; Absorption; Cellulose fiber

Introduction

Dynamic Vapor Sorption (DVS) is a gravimetric technique that measures the change in weight of the sample as a function of time on alteration of vapor concentration around it (Figure 1). Water vapor is the most commonly used solvent. A wide range of other organic solvents may also be selected to study. Dr Daryl Williams invented Dynamic Vapor Sorption in 1991 and the first instrument was introduced in 1992. It is a fully automated sorption technique that achieves fast equilibrium by its significantly improved kinetics over static sorption system. It has high sensitivity that uses a maximum up to 20 mg of sample by weight. The instrument holds the sample at one water level till the sample weight gets constant. It measures the water content by weight and dynamically moves to next upper level as per the program. The water activity levels are controlled by mixing the dry and wet air [1-6].

Applications

Dynamic Vapor Sorption is a versatile analytical tool that caters to the advancement in technology. Vapor sorption occurs primarily on the surface, inside the micro pores, inter-particle spaces and as chemically reacted species like hydrates. It is extensively used in quality control, research and development, compound stability, surface sorption effect of solvents, permeability studies and polymorphism. It plays a significant role in scale up at pilot plant level to bulk productions for packaging, storage, development and stability profiling. The information derived from DVS in terms of equilibrium vapor sorption isotherms and vapor sorption kinetic may provide fruitful results like [7-17],

1. Shelf Life determination
2. Access the rate constant of adsorption
3. Sorption mechanism
4. Diffusion coefficient for film, powder and fibers
5. Vapor transmission rate
6. Moisture induced phase transformation
7. Moisture uptake behavior in materials
8. Morphological Stability profiling
9. Caking of food ingredients
10. Hygroscopic nature of Active Pharmaceutical Ingredients
11. Formation of hydrates and solvates
12. Detection of amorphous content
13. Moisture diffusion in packaging systems
14. Material deliquescence
15. Surface energies and surface areas of powders
16. Processing and performance related challenges
17. Drying analysis
18. Heat of sorption
19. Hydrate and solvate formation
20. Screening the variance in behavior

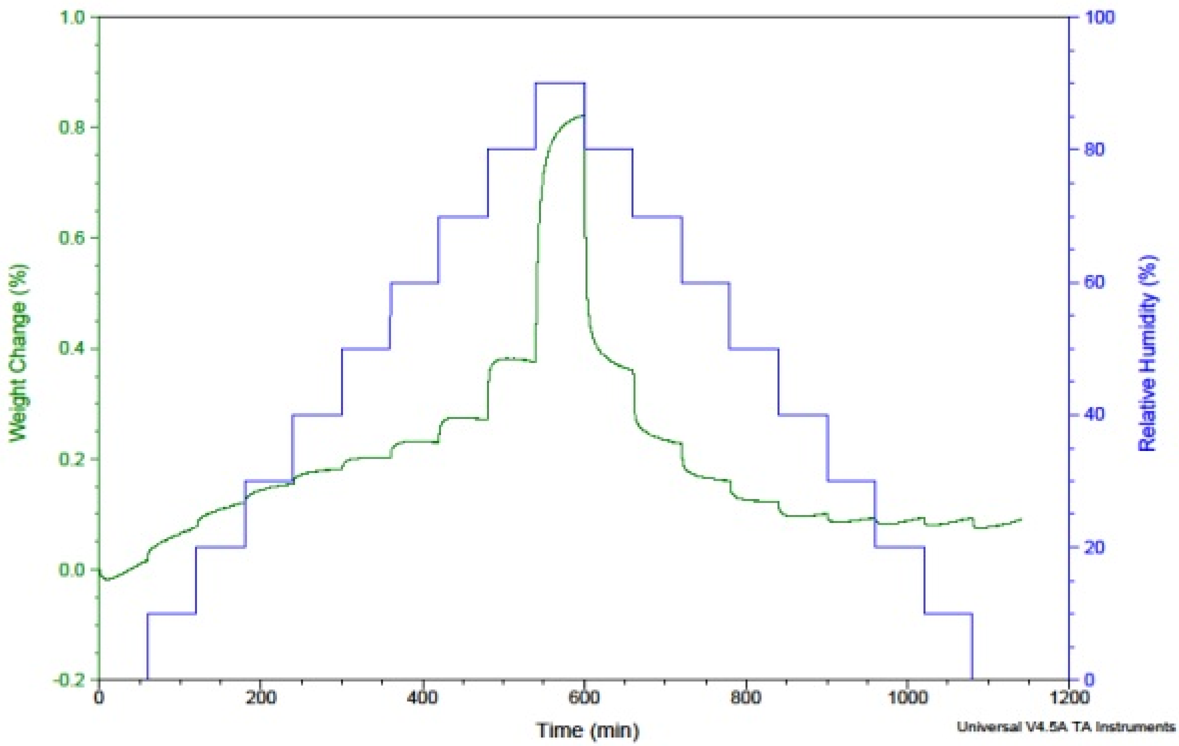

Figure 1: A dynamic water vapor sorption isotherm.

The material may itself be in an inherent amorphous state or while processing occur through milling, compression, freeze-drying or spray-drying. Thermodynamically, amorphous materials are meta-stable as compared to the crystalline state (long-range molecular order, well-defined molecular structure). Some useful properties of amorphous materials are better solubility, enhanced dissolution rate and more compression but decreased physical and chemical stability.

Amorphous solids often absorb relatively large amounts of water vapor compared to their corresponding crystalline phases. Sorbed water often acts as a plasticizing agent, thus significantly lowering the glass transition temperature that causes spontaneous phase transitions and lyophile collapse.

Hence, determining the necessary threshold temperature and humidity conditions to prevent a glass transition is crucial aspect for storage, processing of amorphous materials and a water-induced re-crystallization at a constant temperature.

Plasticizers, often at a lower molecular weight rather than the bulk, can decrease the temperature range. The extent of depression depends on the concentration of the plasticizer and its interaction with the amorphous material. Water is a common plasticizer for a range of materials, thus the water content in amorphous foods, polymers, pharmaceutical ingredients can have a marked decreasing effect on the glass transition temperature. For such materials, the glass transition is co related to relative humidity.

Pharmaceutical Industry has wide applications of DVS instrument to study the moisture sorption properties of excipients, drug formations, packaging film, and solvate/hydrate formation and to evaluate the amorphous content. Variation in moisture sorption behavior ultimately affects the processing, dissolution characteristics, performance, storage, stability and bioavailability of the drug. Pharmacopoeia has recognized for the characterization of solid state dosage forms [6-10].

Food industry

Water is an abundant and an essential substance on earth. It exists in three physical states i.e. solid, liquid and gas. Water is a major component of food ingredients and products that influences the chemistry, morphology, microbiological safety, nutritional content, appearance and taste of the food. Water determines the texture, safety and quality of the food. DVS can screen the moisture induced morphological changes in food ingredients and products. Stability of food ingredients and diffusion in the food packaging materials could be easily accessed by DVS system. It has made it possible to model and engineer the food products judiciously. The rewards are products that maximize safety, quality, and profitability [11-17].

Structural design and construction

Moisture absorption has direct influence on cements, woods, insulations and fibers. Increased moisture content affects building life span, indoor air quality, AC load and growth of termite. Hence, a proper planning and management can help overcome such problems [18,19].

Fiber and polymer materials

Advanced fiber and polymers are useful to the society in several ways. Materials exist mainly in amorphous or crystalline forms. During processing the properties may change and it is worthwhile to check the stage and conditions where the inter conversion of the forms take place. Water plays a significant factor that affects this conversion. Water influences the properties of wood like physical, mechanical properties, dimensional stability, degradation processes, storage, and stability, processing and application performance. The difference between moisture sorption and desorption is termed as hysteresis that proves to be a useful tool in characterizing a material interactions with moisture. Various scientists have studied the moisture uptake behavior of high mechanical strength cellulose fiber like Hibiscus sabdariffa and their graft copolymers [20-24].

Personal care and hygiene

DVS has been immensely useful in the study of personal care materials such as moisturizers, conditioner, chemical treatments, bleaching cream for skin and hair. The hydration behaviors of skin and hair samples, dehydration of contact lenses, diaper have also been benefited by its studies. DVS can effectively be used to study the sorption and desorption properties of skin. The amount of water absorbed in skin is influenced by the RH, the presence of humectants and occlusive agents, and surfactant harshness [25,26].

Soil and environmental monitoring

Automated soil water characteristic curves generate all the correlations with clay activity, surface area and swelling potential. We can estimate the humidity constant and the way soil takes up water into its crystal structure and monitor water content change over time. We can study the rapid Soil-Water characteristic curve generation, soil pollution and soil characterization [27].

Method selection and development of calibration curve depends upon the nature of the sample (hydrophobic/hydrophilic) and how it behaves during the sorption profile in DVS. The method shall be selected based on whether the sample undergoes phase transition re-crystallization or hydrate formation. The three methods generally used are equilibrium moisture content/RH method, water uptake method and residual weight method [6,14,16].

Conclusion

Utilizing the functionality of DVS instrument explores the answers to the challenges associated with the material performance, formulation, stability, packaging and storage. The technique has immense viability and scope in numerous applications both in industry and research.

Acknowledgement

I am indebted to the precious blessings and support of my adorable parents Sh Kripal Singh Chauhan and Smt. Madhvi Chauhan. I sincerely thank my wife Priyanka for her suggestions and help. I am grateful to Dr Bharti Mittu, NIPER, Mohali for rendering moral support and motivating me.

References

1. Carter BP, Campbell GS (2008) Fundamentals of Moisture Sorption Isotherms. Pullman: Decagon Devices. Inc pp:139-147.
2. Carter B, Fontana A (2008) Dynamic Dew point Isotherm verses Other Moisture Sorption Isotherm Methods. Decagon Devices, Pulman Washington, USA.
3. Fontana AJ (2007) Appendix D Minimum water activity limits for growth of microorganisms. In: Barbosa CG, Fontana Jr AJ, Schmidt SJ, Labuza TP (eds) Water activity in foods: Fundamentals and applications. Blackwell Publishing, p: 405.
4. Yu X (2007) Investigation of Moisture Sorption Properties of Food Materials Using Saturated Salt Solution and Humidity Generating Techniques PhD thesis (Urbana: University of Illinois at Urbana-Champaign), p: 73.
5. Espinosa RM, Franke L (2006) Influence of the age and drying process on pore structure and sorption isotherms of hardened cement paste. Cem Concr Res 36: 1969-1984.
6. Sneha S, Modi SR, Arvind KB (2014) Dynamic vapor sorption as a tool for characterization and quantification of amorphous content in predominantly crystalline materials. J Pharm Sci 103: 3364-3376.
7. Pikal MJ, Shah S (1990) The collapse temperature in freeze drying: Dependence on measurement methodology and rate of water removal from the glassy phase. Int J Pharm 62: 165.
8. Liu J (2006) Physical characterization of pharmaceutical formulations in frozen and freeze-dried solid states: Techniques and applications in freeze-drying development. Pharm Dev Technol 11: 3-28.
9. Pikal MJ, Shah S (1990) The collapse temperature in freeze drying: Dependence on measurement methodology and rate of water removal from the glassy phase. Int J Pharm 62: 165-186.
10. Liu J (2006) Physical characterization of pharmaceutical formulations in frozen and freeze-dried solid states: Techniques and applications in freeze-drying development. Pharm Dev Technol 11: 3-28.
11. Wolf M, Walker JE, Kapsalis JG (1972) Water vapor sorption hysteresis in dehydrated food. J Agric Food Chem 20: 1073-1077.
12. Fontana AJ (2000) Understanding the importance of water activity in foods. Cereals Food World 45: 7-10.
13. Ahmed J, Ramaswamy HS, Khan AR (2005) Effect of water activity on glass transition of date pastes. J Food Eng 66: 353-258.
14. AOAC (1990) Official methods of analysis (15th edn) Washington, DC: Associates of official analytical chemists. Arlington. VA, USA.
15. Labuza TP (1968) Sorption Phenomena in foods. Food Techno 22: 263-272.
16. Labuza TP (1984) Moisture sorption: Practical aspects of isotherm measurement and use. American Association of Cereal Chemists, St. Paul, MN.
17. Kilcast D (2000) The stability and shelf-life of food. (2nd edn), In: Subramaniam P (ed) CRC Press, London, UK.
18. Belie D, Kratky NJ, Vlierberghe SV (2010) Influence of pozzolans and slag on the microstructure of partially carbonated cement paste by means of water vapour and nitrogen sorption experiments and BET calculations. Cement and Concrete Res 40: 1723-1733.
19. Anderberg A, Wadso L (2008) Method for simultaneous determination of sorption isotherms and diffusivity of cement-based materials. Cement Concrete Res 38: 89-94.
20. Chauhan A, Kaith B (2013) XRD and Physico-chemical evaluation of Hibiscus sabdariffa cellulose-Butyl acrylate-co-vinyl monomer graft. J Biochem Mol Biol 3: 61-70.
21. Chauhan A, Kaith B (2012) Exploring the diversification in grafted copolymer. Int J Fund Appl Sci 1: 14-19.
22. Chauhan A, Kaith B (2012) Screening the change in physical properties of the grafted Sereni fiber. Malaysian Polymer J 7: 1-7.
23. Watt IC (1980) Adsorption: Desorption hysteresis in polymers. J Macromol Sci A 14: 245-255.

24. Serad GE, Freeman BD, Stewart ME, Hill AJ (2001) Gas and vapor sorption and diffusion in Poly(ethylene terephthalate) Polymer 42: 6929.
25. Assaf E, Sagiv, Marcus Y (2003) The connection between in vitro water uptake and in vivo skin moisturization. Skin Res Techno, p: 306.
26. Liverman LTK (2006) Use of the dynamic vapor sorption meter to measure skin hydration properties, in vitro. Skin Res Techno 12: 36-42.
27. Ong SK, Lion LW (1991) Mechanisms for trichloroethylene vapor sorption onto soil minerals. J Enviro Quality 20: 180-188.