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Better Understanding of Food Material on the Basis of Water Distribution Using Thermogravimetric Analysis

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Abstract

The prime objective of dryingis to enhance shelf life of perishable food materials .As the process is very energy intensive in nature, researchers are trying to minimise energy consumption in the drying process.In order to determine the exact amount of energy needed for drying a food product,understanding the physics of moisture distribution and bond strength of water within the food material is essential. In order understand thecritical moisturecontent,moisture distribution andwater bond strength in food material,Thermogravimetric analysis (TGA) can be properly utilised. This work has been conducted to investigate moisture distribution and water bond strength in selected food materials; apple, banana and potato. It was found that moisture distribution and water bond strength influence moisture migration from the food materials. In addition, proportion of different types of water (bound, free, surface water) has been simply identified using TGA. This study provides a better understanding of water contents and its role in drying rate and energy consumption.

Keywords: *Drying, food materials, moisture distribution,energy, drying rate.*

1. Introduction

The issue of dried food quality has received considerable attention. Fruits and vegetables are important sources of essential dietary nutrients such as vitamins, minerals and fibre. Since the moisture content of fresh fruits and vegetables is more than 80%, they are classified as highly perishable commodities [1]. Food is one of the most complex materials in natural form and the fundamental understanding of food drying has not been fully established. Lack of proper processing causes considerable damage and wastage of seasonal fruits in many countries, which is estimated to be 30–40% in developing countries [2]. Drying of foodstuffs is an important and the oldest method of food processing. Many physical and chemical changes occur in foods during the drying process. The quality of dehydrated product is affected by a number of factors and is dependent on the quality of raw material, method of preparing, processing treatments and drying conditions [3]. Most of food materials contain a porous skeleton of carbohydrates or proteins, in which water and/or fat bound physically and chemically. Therefore, food structure is one of the complex arenas that are not yet comprehensively understood as it undergoes material changes, including alterations of the tissue and cell wall structure throughout growth and evenduring processes[4]. Foods, in general, can be considered hygroscopic although there are some exceptions. Although having unique molecular formula, water exists with different physiochemical properties due to variation of its surrounding molecular environments. Water inside cells is known as intracellular, which is about 90% of the total water [5], and rest of the water is intercellular which exists incapillaries as shown in the Figure 1. Water, generally in plant foods, may exist in any one of the following forms: Free water, physically bound water and chemically bound water. Pursuing this further, free water only surrounded by other water molecules or act as a solvent of crystalloids. On the other hand, physicallybounded water absorbed on the surface of cell wall or completely surrounded by other constituents of food materials. In addition, rest of the water, chemically bond water, refers to the water of hydration in the in chemical combination with different components as carbohydrates and hydrates of various salts [6]. Taken together, the obstaclesof water migration significantly depend on the compositions and structure of the plant food tissue. As food processing is very energy intensive, better understanding of water bonding in food structure will lead to huge energy saving in food processing industry [7]. Furthermore, water migration during drying processes and influence the quality attributes of plant foods [8-10]. A considerable amount of study has attempted to investigate the structure property relationships in foods. Due to the porous nature of plant tissues,food materials show the tendency of collapsing when these are subjected to drying [11].In particular, it has been demonstrated that many desirable attributes of food such as texture, colour, or flavour, are changed depending on the way foods are structured [12].

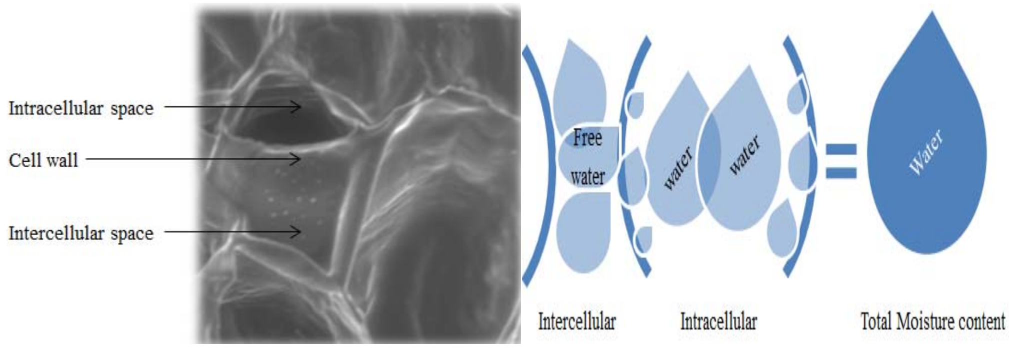

Fig.1. Water distribution in plant food tissue (Apple)

Continuing this idea, physicochemical changes eventually alter the product microstructure [13-15]. Therefore an effective method of taking away moisture from food material has always taken into attention by food researchers. As mentioned earlier, water exists within the food materials with different holding capacity throughout the tissues. It is then important to understand the distribution of water in food material in order to allow proper water migration during drying process. Thermo gravimetric analysis (TGA) deals to figure out the thermal stability of materials. TGA also can determine the distribution (proportion of different classes) of water in food materials. Thisstudy attempted to explore the water holding capacity of food by using of TGA. It would bring a better understanding of drying conditions to remove excess moisture from food materials in order to attain improved quality food.

2. Materials and Method

Proximate analysis and apparent density of three selected foodstuffs; apple, banana and potato areshown in Table1 [16-18].These foodstuff samples were prepared carefully to avoid any types of oil contamination and oxidization by air.

Table.1. Proximate analysis(weight %) of the selected fruits and vegetables

Foodstuff	Water	Fat	Protein	Carbohydrate and /or sugar	Fibre	Ash	Density (kg/m3)
Apple	83.93	0.36	0.19	12.56	2.7	0.26	723
Banana	74.26	0.48	1.03	21.03	2.4	0.8	1034
Potato	79.4	0.1	1.6	15.6	2.4	0.9	1110

All of the samples were cut into the same volume at the weight of approximately 100 mg.TGA Q500 V20.13 Build 39 was being used to assess the stability of the food material. All experiments were conducted under ultrahigh-purity or high-purity nitrogen, with the latter containing no more than 0.1% of impurities. The flow rate of nitrogen purges into the furnace was set at 15 ml/min.

3. Result and discussion

Moisture holding capacity of different food materials

Three different foodstuff; apple, banana and potato were analysed using TGA. In the system all of the food samples were kept at room temperature for 30 minutes. Surface moisture evaporation, as shown in Figure 2, depends not only on the amount of moisture content but also on the composition and structure of food material. For example, potato lost maximum amount of water 20.8% during the initial 30 minutes at room temperature although it contains less water than apple. These points refer to response of water due to higher temperature application on the foodstuffs. Beyond the temperature 85^0 C food materials shows sharp decrease of moisture content along with a higher rate of change of mass transfer as shown in Fig.3. These trends of moisture loss continueup to point where no more free water exist, where it shows almost constant moisture contends. Close investigation of the data manifests that a certain amount of water molecules are closely bonded.

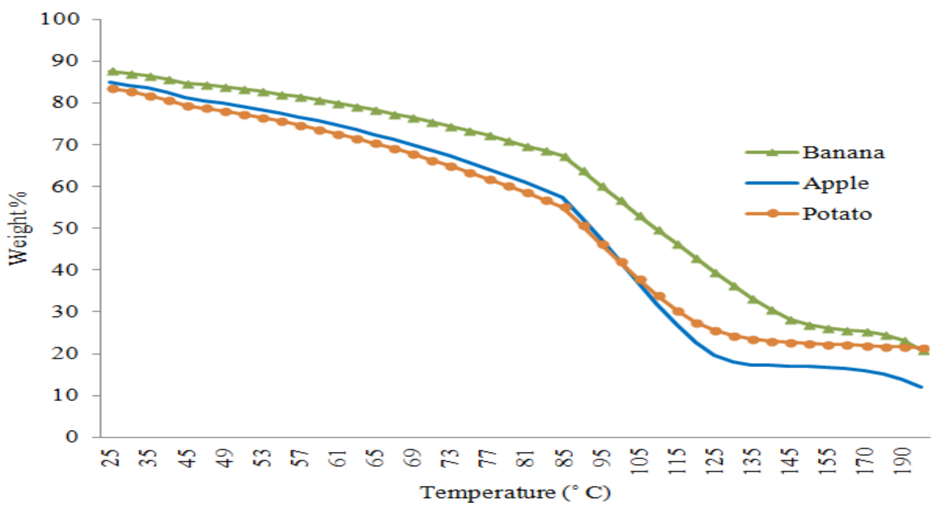

Fig. 2. Thermogravimetric analysis of different food materials

Consequently, even high temperature cannotdehydrate the sample. It seems rest of the water maintain strong Physical and chemicalbond as shown in the table 2 and it is also clearly apparent from Fig.3.

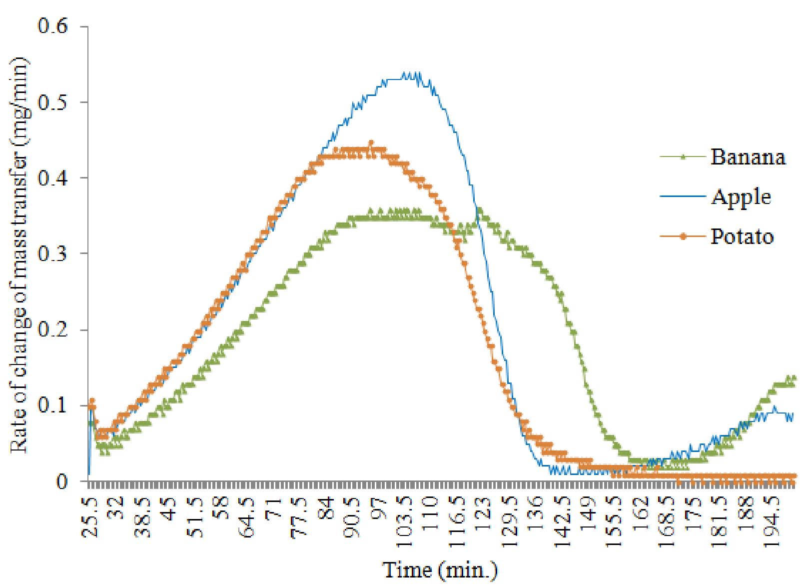

Fig. 3. Rate of moisture change of different food materials at different time

Nonetheless the TGA curve solely cannot differentiate different class of water,therefore, watermigration curve is essential. Figure 4 provides the percentage of water remains with temperature and time as well. It is apparent from Fig.4 at higher temperature approximately 150^{0}C all of the selected food loss whole water it contains.

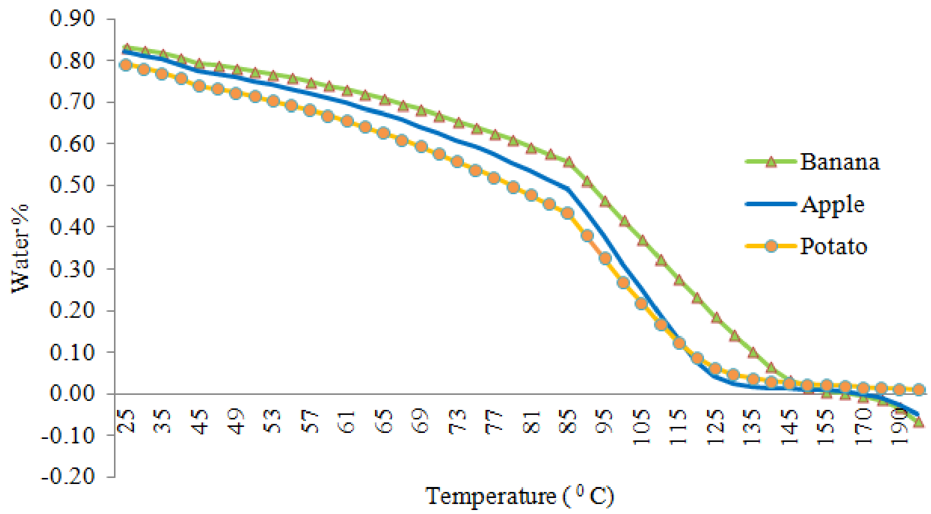

Fig.4. Water fraction retention in food materials (Negative value refers migration of other substance in respect to water percentage)

However, there may be possibility of error as TGA deals both time and temperature as variables. Therefore, two other observations for banana confirm the abovementioned findings. Different heating conditions were applied to banana sample in order to observe the thermal response. All of the three investigations allowed 1^{0}C/min heating rate after 60 minutes, but prior this the food samples were heated differently.

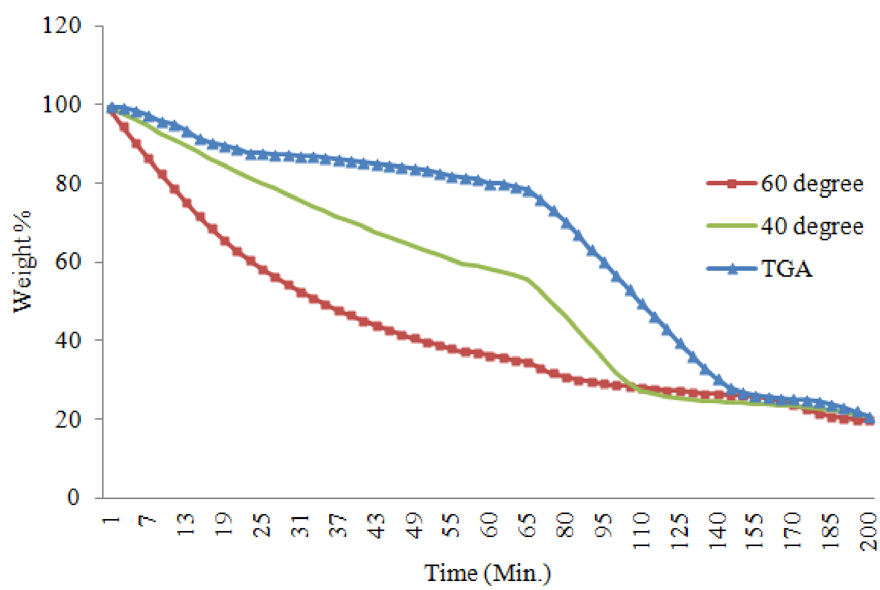

Fig. 4. Thermal response of banana in different types of heating

One of the samples was kept at 60^0C, another one was at 40^0C and one was in 1^0C heating condition in the first 60 minutes. It is clearly apparent in Fig.4 after 60 minutes that all the three samples showed same weight loss behaviour.

Analysing the nature of the curve of the selected food materials in the basis of different physicochemical properties the various kind of water has been identified as shown in the table 2.In order to find out the amount of free water, rate of change of mass transfer has been taken into consideration.

Table 2. Proportion of different class of water within selected foodstuff

Foodstuff	Solid materials	Surface Water	Free water (Including capillary water)	Physically bound water	Chemically bound water
Apple	16.07	17.9	95.7	2.7	1.6
Banana	25.74	16.5	96.6	2.6	0.8
Potato	20.60	20.8	91.2	6.4	2.4

As Table 2shows, most of the water in selected three food materials is present in water-water molecular environments and rest of the water is bounder either physically or chemically.

4. Conclusion

Achieving a better insight of the water distribution in complex food structure is vital for developing proper food processing systems. It has been an essential on-going endeavour of the researchers of the arena of food science and engineering. The water liberation from different fruits and vegetables was examined using TGA measurement in a dynamic environment. It is noticed that with the increase of the sample temperature at a steady rate of 1^0C / min a sample mass undergoes a sharp decrease which is followed by a progressive decrease in the later time of an experiment. From the results, it is apparent that water liberation from food material depends on the water holding capacity and food matrix. The most significant result to emerge from this study is that more than 90% water exists as free water. It also reveals that TGA can detect different classified water with varying holdingcapacity. Therefore, the findings of this study providea simplified approach of identification of water mobility in different food materials.

5. References

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