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EFFECT OF PROCESSING METHODS AND STORAGE ENVIRONMENT ON MOISTURE ADSORPTION CHARACTERISTICS OF GINGER (*ZINGIBER OFFICIANALE*)

Alakali JS[1], Irtwange SV[2*] and JO Abu[3]

Irtwange Simon

*Corresponding author email: svirtwange@yahoo.com

[1]Senior Lecturer and Deputy Dean: College of Food Technology, Department of Food Science and Technology, University of Agriculture, Makurdi, Nigeria. E-mail: josephalakali@yahoo.co.uk

[2]Associate Professor and Ag. Head: Department of Agricultural and Environmental Engineering, University of Agriculture, Makurdi, Nigeria.

[3]Lecturer I: Department of Food Science and Technology, University of Agriculture, Makurdi, Nigeria. E-mail: joabuza@yahoo.co.uk

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ABSTRACT

The objective of this study was to determine the effect of processing methods and storage parameters on moisture adsorption characteristics of dry matured yellow ginger (*Zingiber officianale*) to provide information for the prediction of shelf life and selection of packaging materials. Moisture adsorption was determined gravimetrically. Saturated solutions of sulphuric acid were prepared to provide constant relative humidity environments. The experimental design was split plot comprising six processing methods (peeled-blanched ginger slice, peeled ginger slice, unpeeled-blanched ginger slice, unpeeled ginger slice, peeled ginger flour and unpeeled ginger flour), four storage temperatures (20, 30, 40 and 50ºC) and six levels of relative humidity in the range of 3.71 – 93.9% which represents some of the environmental conditions that ginger products are exposed to in practice. There was a highly significant processing methods, temperature and water activity effects on the equilibrium moisture content (EMC). For all the processing methods and at all temperature levels, EMC increased with increase in water activity at constant temperature. At constant water activity levels, EMC decreased with increase in temperature. The EMCs of the peeled ginger slices and flours were generally lower than those of the unpeeled ginger at the temperatures and water activities studied. The EMCs of peeled ginger flour were generally higher than the peeled ginger slices at all the temperatures and water activities studied. At any given storage temperature and relative humidity, unpeeled ginger samples were more hygroscopic than the peeled. Also at the temperatures and relative humidities studied, ginger powders absorbed more moisture than the slices. The EMCs of blanched ginger were consistently lower than the unblanched. This implies that blanched ginger has decreased tendency to absorb moisture in storage. Therefore on the basis of shelf stability, Peeled-Blanched Ginger Slice (PBS) is recommended followed by Peeled Ginger Slice (PGS) and Unpeeled-Blanched Ginger Slices (UBS) in that order. The Unpeeled Ginger Slice (UGS), Peeled Ginger Flour (PGF) and Unpeeled Ginger Flour (UGF) did poorly and therefore not recommended.

Key words: Ginger, moisture adsorption, processing, storage

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INTRODUCTION

Ginger (*Zingiber officianale*) is required on a daily basis in most households in the tropics. It is used in the manufacture of items such as ginger ale, ginger beer, ginger bread, ginger sweets, ginger essence, ginger chocolate, pastries and biscuits [1]. The extracts of ginger have multiple pharmacological effects [2].

Dried ginger is likely the most acceptable form of ginger in the local and international market [3]. Different forms of dried ginger are recognized in the spice trade. These include the peeled slices or flours, unpeeled slices or flours and blanched slices or flours [4]. The presence of different grades of ginger on the market presents the need to study their moisture sorption characteristics during storage. Moisture sorption characterizes the water binding at equilibrium of materials at different temperatures and levels of relative humidity. It makes it possible to predict the effect of changes in temperature, water activities and relative humidity on the amount of water absorbed or desorbed by materials [5, 6]. Moisture adsorption characteristics enable prediction of shelf life and selection of packaging materials.

The study of moisture sorption characteristics of different grades of dried ginger will contribute information on shelf stability of the materials at different storage conditions. This information will be useful in identifying the most shelf stable product of dried ginger and appropriate packaging materials. The objective of this work is to study the moisture adsorption characteristics of grades of dried ginger, commonly found in the market, under different storage temperatures and levels of relative humidity.

MATERIALS AND METHOD

Materials

About 10 Kg fresh matured yellow ginger (*Zingiber officianale*) was purchased from a local market in Makurdi, Nigeria. Air tight plastic containers 12.5 cm diameter x 11.8 cm heights of 500 mL capacity were purchased from the same market.

Sample Preparation

Fresh yellow ginger was thoroughly washed and rinsed with clean water. The washed ginger rhizomes were randomly selected and divided into two portions. One portion was peeled using stainless steel knife and sliced to 3 mm thickness. The peeled ginger slices were divided into three equal lots. One of the lots was blanched at 60-65ºC for 3 minutes using a laboratory water bath. The second portion (unpeeled) was also sliced to the same thickness and divided into three equal lots. One of the lots was also blanched at 60-65ºC for 3 minutes using the laboratory water bath. All the samples (six lots) were dried to constant weight in an air convective electric oven (Model T12H Genlab, England) at 85ºC for 24 hours. One lot each from peeled and unpeeled portions, both unblanched, were milled using a bench top hammer mill (Model Brook Compton Series 2000, England) and sieved through 500 µm mesh screen. The resulting six samples were namely: Peeled Ginger Slice (PGS), Peeled Ginger Flour

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(PGF), Peeled-Blanched Ginger Slice (PBS), Unpeeled Ginger Slice (UGS), Unpeeled Ginger Flour (UGF) and Unpeeled-Blanched Ginger Slices (UBS). The powders were further dried in desiccators over concentrated sulphuric acid for seven days to remove residual moisture. The samples were then packed in 10 g sachets using heat sealable polythene bags (2 mm thick) and sealed with an impulse sealer (Model 210-SE).

Establishment of Constant RH Environments

Saturated solutions of sulphuric acid were prepared to provide constant relative humidity ranging from 3.71% to 93.9% at 20, 30, 40 and 50ºC respectively. Sulphuric acid required to give the desired relative humidity was pipetted into distilled water [7].

Determination of Sorption Isotherms

Moisture adsorption was determined gravimetrically [8]. A Randomized Complete Block Design (RCBD) comprising six processing methods (PGS, PGF, PBS, UGS, UGF and UBS), four temperatures (20, 30, 40 and 50^{o}C) and six water activities ranging from 0.371 to 0.939 were used. Moisture adsorption characteristics were determined by exposing the samples to atmospheres of known relative humidity [7]. For each case, triplicate samples each weighing 0.5 g were placed in sample holders over a wire gauze, held above the sulphuric acid solutions in 500 mL plastic containers. The plastic containers were covered with lids and allowed to equilibrate at the selected temperature (20, 30, 40 and 50ºC) in a Gallenkamp incubator (Model INF 600.010R). These temperatures were monitored and controlled within ±1ºC. The samples were removed and weighed at 48 hours interval until three successive readings were each less than 0.5% of the previous weight of the sample at the last reading [9].

RESULTS

The effect of processing methods on Equilibrium Moisture Content (EMC) at various temperature and water activity (a_w) levels is presented in Table 1 while the analysis of variance (ANOVA) is summarized in Table 2. Mean values of EMCs were plotted against water activities to obtain moisture sorption isotherms. Typical moisture sorption isotherms of the samples at 20, 30 40 and 50ºC are presented in Figures 1-4.

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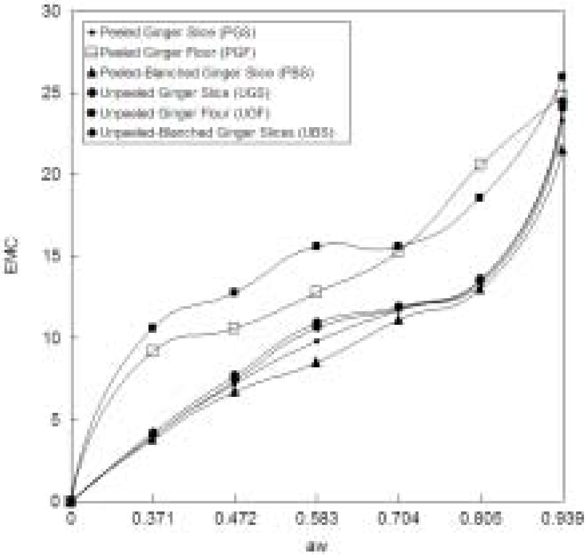

Figure 1: Moisture sorption isotherms of ginger at 20°C

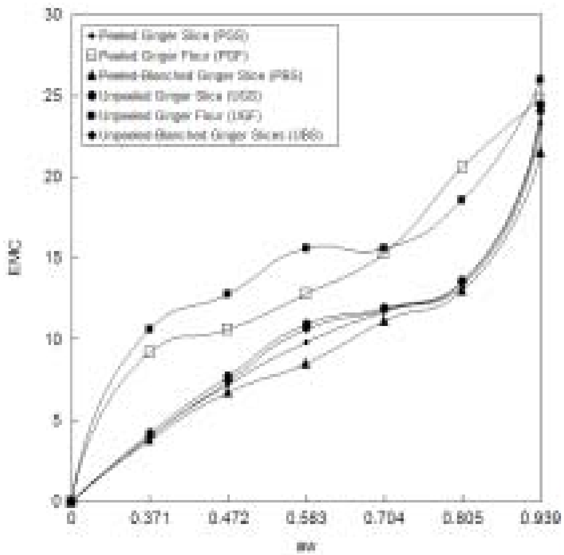

Figure 2: Moisture sorption isotherms of ginger at 30°C

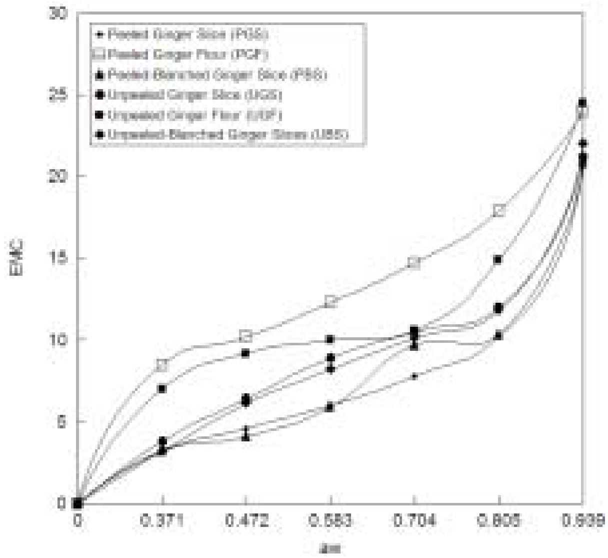

Figure 3: Moisture sorption isotherms of ginger at 40°C

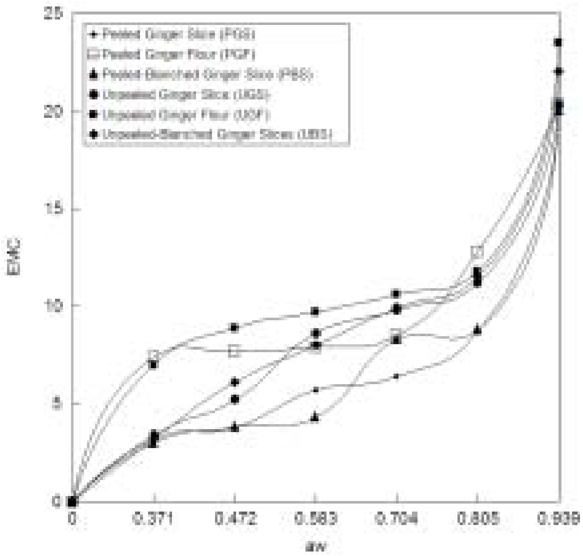

Figure 4: Moisture sorption isotherms of ginger at 50°C

Effect of Processing Methods

The results show that EMCs increased with increase in a_w at all processing methods and temperature levels. For example, for PGS at 20°C, EMCs increased from 4.0 gH_2O/100g solid at a_w of 0.371 to 23.3 gH_2O/100g solid at a_w of 0.939. The EMCs also decreased with increase in temperature for all the processing methods at all a_w levels. For example, for UGS at a_w of 0.371, EMC decreased from 4.2 gH_2O/100g solid at 20°C to 3.4 gH_2O/100g solid at 50°C. The results also indicate that the peeled ginger slices and flours gave lower EMCs when compared to the unpeeled at all temperature and water activity levels. At 40ºC and water activity of 0.472, the EMC of PGS was 4.60 gH_2O/100g solid compared to 6.40 gH_2O/100g solid for UGS. Similarly, the EMC of PGF was 8.50 gH_2O/100g solid compared to 9.20 gH_2O/100g solid of UGF. The EMCs were also generally higher in the flours than in the slices at all temperature and water activity levels. At 30ºC and water activities of 0.371, the EMC for PGF was 8.5 gH_2O/100g solid compared to 3.3 gH_2O/100g solid for PGS. Blanched ginger slices were found to be less hygroscopic than unblanched. At 20ºC and a_w of 0.583, the EMC of PBS was 8.5 gH_2O/100g solid, and lower than 10.9 gH_2O/100g solid for unblanched (UGS). The analysis of variance (Table 2) shows highly significant processing methods, temperature and a_w effects. A 2-tailed Fishers Least Significance Difference (F-LSD) test at the 5% level of significance at all six levels of a_w and four levels of temperature representing 24 mean comparisons shows that between PGS and PGF, 4.2% of the mean comparisons were non-significant. Similarly, 79.2% non-significance was observed in the mean comparisons between PGS and PBS, 41.7% between PGS and UGS, 0% between PGS and UGF, 50% between PGS and UBS, 12.5% between PGF and PBS, 20.8% between PGF and UGS, 25% between PGF and UGF, 20.8% between PGF and UBS, 37.5% between PBS and UGS, 4.2% between PBS and UGF, 45.8% between PBS and UBS, 16.7% between UGS and UGF, 91.7% between UGS and UBS, and 12.5% between UGF and UBS.

Effect of Temperature

On the effect of temperature, the results show that EMC decreased with increase in temperature at constant a_w. At water activity of 0.583, the EMC decreased from 9.8 to 5.7 gH_2O/100g solid for PGS, 12.8 to7.9 for PGF, 8.5 to 4.3 for PBS, 10.9 to 8.6 for UGS, 15.6 to 9.7 for UGF and 10.6 to 8.0 for UBS. A 2-tailed F-LSD test at the 5% level of significance shows that in the case of UBS, all the 15 EMC mean comparisons were found to be statistically different at all levels of temperature. In the case of PGS and UGS, statistical difference was observed at all temperature levels except 50°C and 20°C respectively where 2 and 1 out of 15 mean comparisons respectively indicated non-significance. In the cases of PGF, PBS and UGF, statistical differences were observed between all EMCs at 20 and 30°C, but at 40°C, 6, 2 and 2 and at 50°C, 6, 3 and 2 mean comparison differences respectively out of 15 indicated non significance.

Effect of Water Activity

The results also show that at constant temperature, the EMCs increased with increase in water activity. For water activity range of 0.583 to 0.939 at constant temperature of

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50°C, EMC of PGS increased from 5.70 to 20.00 $gH_2O/100g$ solid, PGF from 7.90 to 20.4 $gH_2O/100g$ solid, UGF from 9.7 to 23.5 $gH_2O/100g$ solid, UBS from 8.00 to 22 $gH_2O/100g$ solid and PBS from 4.30 to 20 $gH_2O/100g$ solid. A 2-tailed F-LSD test at the 5% level of significance indicates that the EMCs were found to be statistically different at all a_w levels for PGS except at a_w level of 0.371 where non significance was observed in three out of six mean comparisons and at a_w levels of 0.583 where one non significance level was observed. For PGF statistical difference was observed at all a_w levels except at a_w level of 0.371 where one non significance difference was observed. In the case of PBS, non significance was observed at 0.371, 0.472 and 0.704 where three, one and one non-significance differences respectively were observed. Similarly, for UGS, two non significance differences were each observed at a_w levels of 0.371 and 0.583 respectively and for UGF, one non significance difference each was observed at all a_w levels except at 0.939 where all the six mean comparison differences were significant. However, for UBS, one out of six non significance differences were observed at a_w levels of 0.583, 0.704 and 0.805, two out of six at a_w level of 0.472 and three out of six at a_w levels of 0.371 and 0.939.

DISCUSSIONS

Effect of Processing Methods

For all the processing methods and at all temperature levels, EMCs increased with increase in a_w. Also for all the processing methods at all a_w levels, EMCs decreased with increase in temperature. The isotherms exhibited sigmoid shapes described as type II in the isotherm classification [10, 11] which presents a unique property of the ginger products. Type II isotherm describes adsorption on macroporous absorbents with strong adsorbate-adsorbent interaction [12]. Generally, the greater the non significance percentage differences in the mean comparisons indicated by the 2-tailed F-LSD test at 5% level of significance, the closer the similarity between the processing methods. The EMCs of the peeled ginger slices and flours were generally lower than those of the unpeeled at the temperatures and water activities studied. Similar trends were observed at all the temperatures and water activities studied. Naturally, it was expected that peeled ginger samples should be more hygroscopic due to increased exposure of the surface and consequently the surface area of sorption. However, the unpeeled ginger was found to absorb more moisture. The high EMCs of unpeeled ginger could be attributed to the presence of pentosan which is known to be hygrophillic. The moisture adsorption characteristics of peeled ginger flours and slices show that the EMCs of PGF were generally higher than the PGS at all the temperatures and water activities studied. This result was expected since ginger flours would have greater surface area of sorption and more sorption sites thereby favoring the absorption of moisture. This is disadvantageous to storage since at any water activity and temperature, more water will be available for biochemical and microbial actions in peeled ginger flours than the slices. Consequently, ginger slices are preferred for shelf stability, since peeled ginger slices are less hygroscopic. The effect of blanching as pretreatment of ginger slices rather shows that blanched ginger slices were generally less hygroscopic than unblanched. The EMCs of blanched ginger slices were consistently lower than the unblanched. The low moisture adsorption

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capacity of blanched ginger when compared to unblanched was expected since hot water blanching may lead to gelatinization of some inherent ginger starch [13] possibly creating a less hygroscopic polymer network around the blanched ginger surfaces, thus disfavoring moisture adsorption. Blanching of the ginger would probably result in marginal reduction in good quality color, freshness and the spicy flavor.

Effect of Temperature

The results show that as the temperature was increased at constant a_w, the EMC decreased. At any given EMC, there was consistent shift of equilibrium relative humidity to higher values with an increase in temperature. This indicated that at any relative humidity (Rh), the ginger samples became less hygroscopic with increase in temperature. Consequently, in an atmosphere of constant relative humidity, the sample can absorb more moisture at lower than at higher temperature. Similar trends were observed for fish flour [14], freeze dried blue berries [15], tropical fresh water crayfish [12] and common beans flour [16].

Effect of Water Activity

Water activity had effect on the EMC of all the samples. The EMC of all the samples increased with an increase in water activity at constant temperature. These reports are consistent with reports by other researchers [17, 18, 19]. Since dried ginger in the form of slices or flours is potentially the most acceptable form of ginger in the local and international markets, the results from this study would be applicable to field production conditions. This is because the study has captured some of the environmental conditions that ginger products are exposed to in practice.

CONCLUSION

The study concludes that there is a highly significant processing methods, temperature and water activity effect on the equilibrium moisture content. For all the processing methods and at all temperature levels, EMC increased with increasing water activity whereas for all the processing methods at all water activity levels, EMC decreased with increasing temperature. Peeled-Blanched Ginger Slices (PBS) were more shelf stable than the other samples followed by Peeled Ginger Slice (PGS), Unpeeled-Blanched Ginger Slices (UBS), Unpeeled Ginger Slice (UGS), Peeled Ginger Flour (PGF) and Unpeeled Ginger Flour (UGF) in that descending order.

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Table 1: Effect of processing methods on Equilibrium Moisture Content of ginger at various temperature and water activity levels*

Processing methods	Temperature, °C	Water activity, a_w 0.371	0.472	0.583	0.704	0.805	0.939
		Equilibrium Moisture Content (EMC) $gH_2O/100g$ solid					
Peeled Ginger Slice (PGS)	20	4.0	7.2	9.8	11.7	13.3	23.3
	30	3.3	5.3	7.5	10.2	11.4	21.5
	40	3.2	4.6	6.0	7.8	10.3	20.6
	50	3.2	3.8	5.7	6.4	8.7	20.0
Peeled Ginger Flour (PGF)	20	9.2	10.6	12.8	15.3	20.6	24.8
	30	8.5	10.2	12.3	14.7	17.9	24.0
	40	8.2	8.5	8.8	9.2	14.3	22.8
	50	7.4	7.7	7.9	8.5	12.8	20.4
Peeled-Blanched Ginger Slice (PBS)	20	3.8	6.7	8.5	11.1	13.0	21.5
	30	3.5	5.0	6.7	10.0	11.3	21.0
	40	3.2	4.1	5.9	9.7	10.3	21.0
	50	3.0	3.8	4.3	8.3	8.8	20.0
Unpeeled Ginger Slice (UGS)	20	4.2	7.7	10.9	11.9	13.6	24.4
	30	4.0	7.3	9.2	11.0	12.6	23.7
	40	3.8	6.4	8.9	10.5	12.0	21.2
	50	3.4	5.2	8.6	9.8	11.2	20.3
Unpeeled Ginger Flour (UGF)	20	10.6	12.8	15.6	15.6	18.6	26.0
	30	9.2	10.6	10.6	11.9	14.9	25.6
	40	7.0	9.2	10.0	10.6	14.9	24.5
	50	7.0	8.9	9.7	10.6	11.8	23.5
Unpeeled-Blanched Ginger Slices (UBS)	20	4.0	7.4	10.6	11.8	13.5	24.0
	30	3.5	7.1	9.0	10.8	12.2	22.2
	40	3.2	6.1	8.2	10.1	11.8	22.0
	50	3.2	6.1	8.0	9.9	11.5	22.0

*Values of EMC are a mean of three replicates

Fishers Least Significant Difference (F-LSD)
F-LSD (P = 0.05) of the difference between two processing methods means = 0.9268
F-LSD (P = 0.05) of the difference between two temperature means = 0.3705
F-LSD (P = 0.05) of the difference between two water activity means = 1.1959

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Table 2: Summary of ANOVA on effect of processing methods on Equilibrium Moisture Content (EMC) of ginger at various levels of water activity and temperature

Source of variation	Degrees of freedom	EMC of ginger	5%	1%
Water activity	5	373.33**	2.60	3.86
Processing methods	5	33.55**	2.60	3.86
Error (a)	25			
Temperature	3	119.00**	2.72	4.04
Interaction	15	3.86**	1.795	2.27
Error (b)	90			

**Highly significant (P=0.01)

REFERENCES

1. **Rodnquez DW** A Short Economic History of Ginger Commodity. Bull. No. 4. Agricultural Planning Unit, Ministry of Agriculture and Fisheries, Jamaica, 1971.

2. **Guyer D** Advance Medical Centre. http://www.daleguyermd.com/pages/ginger/zingiber officianale. htmp.jof3. 2003. Date assessed: 6/8/06.

3. **NRCRI.** Ginger Production. Agricultural Extension Research Liaison and Training Bulletin, National Root Crop Research Institute (NRCRI), Umudike, 1987:1-5.

4. **Kochhar A** Tropical Crops. A Textbook of Economic Botany. Macmillan Press Limited, London, 1981: 268-270.

5. **Fortes M and MR Okos** Non-Thermodynamic Approach to Heat and Mass Transfer in Corn Kernels. *Trans ASAE* 1981; **24** (3): 761-769.

6. **Gevauden A, Chuzel G, Didier S and J Abdvien** Physical Properties of Cassava Mesh. *Int. J. of Food Sc and Tech.* 1989; **24**: 637-645.

7. **Weast RC and MJ Astle** CRC Handbook of Chemistry and Physics, Baca Raton Florida, CRC Press, 1989: 44.

8. **Mok C and NS Hettiarachchy** Moisture Sorption Characteristics of Ground Sunflower Nutmeat and its Products. *J. Food Sc.* 1990; **55**: 786-789.

9. **Spiess WH and W Wolf** Critical Evaluation of Methods to Determine Moisture Sorption Isotherms. **In**: ED Rockland (Ed). Water Activity, Theory and Application to Foods. New York Press, 1986:123.

10. **Bolin RH** Relation of Moisture to Water Activity in Prunes and Vaisin. *J. Food Sc.* 1980; **45**: 1190-1192.

11. **Iglasias AM and J Chirife** Water Sorption Isotherms of Sugar Beat Roots. *J. Food Tech.* 1982; **10**: 238-244.

12. **Ariahu CC, Kaze SA and CD Achem** Moisture Sorption Characteristics of Tropical Fresh Water Crayfish (*Procambarus clarkia*). *J. Food Eng.* 2006. www.elsevier.com/locat/foodeng.

13. **Whistter RL and JR Daniel** Carbohydrates. **In**: OR Fennema (Ed). Food Chemistry 2nd Edition. New York. Marcel Dekker, 1985: 69-125.

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14. **Labuza TP, Kannene A and JY Chen** Effect of Temperature on the Moisture Sorption Isotherms and Water Activity Shift of Two Dehydrated Foods. *J. Food Sc.* 1985; **50**: 391-395.

15. **Loong TL, Jumming T and H Jianshan** Moisture Sorption Characteristics of Freeze Dried Blue Berries. *J. Food Sc.* 1995; **60** (4): 810-813.

16. **Menkov ND, Durakowa AG and A Krastera** Moisture Sorption Isotherms of Common Bean Flour at Several Temperatures. *Elec. J. Env. Agric. and Food Chem.* 2005; **4** (2): 892-897.

17. **Labuza TP** Sorption Phenomena in Foods. *J. Food Tech.* 1968; **22** (3):15-24.

18. **Wang N and JG Brennan** Moisture Sorption Characteristics of Potatoes at Four Temperatures. *J. Food Eng.* 1991; **14**: 269-287.

19. **Palou EA, Lopez-Malo A and A Argatz** Effect of Temperature on the Moisture Sorption Isotherm of Cookies and Corn Snacks. *J. Food Sc.* 1997; (3): 85-93.