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Isothermal Dehydration and Kinetics of locally made Brown Sugar in Zaria, Northern Nigeria

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ABSTRACT

Brown sugar as an aggregate of sucrose crystals and molasses was understudy for the rate of its moisture removal at an isothermal temperature of 120°C over some definite time intervals in minutes (5, 10, 20,30,40,50 & 60 min.)

Five brown sugar samples were obtained in five Zaria Metropolis designated as (A=Kwangilla), (B= Sabo Gari),

(C= Samaru), (D= Tudun Wada) and (E= Zaria city).

The final dehydrated sample weights with respect to 10 g of the initial weights for each of sample A, B, C, D, and E are 1.1 g after 30min,1.3g after 50min, 0.2 g after 50min.,4.6 g after 50min. and 7.0 g after 50min. respectively.

Moisture removal percentage for A,B,C,D and E are 11%,13%,2%,46% and 70% respectively.

Reaction orders (kinetics) were established with each of the crude brown sugar samples.

Sample A, D, and E exhibited second order rate of reaction at correlation level (R^2) of 0.7987, 0.8845 and 0.9488 respectively while sample B and C were of the first-order rate of reaction at correlation level (R^2) of 0.9638 and 0.9664 respectively. This research successfully established the fact that brown and unrefined sugar with some quantity of molasses requires some degrees of moisture that should be defined and regulated, obviously to retain its quality, longer shelf life, conservation of the nutritional values and sound value additional products.

In the light of this, there are needs to regulate, enforce and standardized the needed level of moisture compositions in these products locally and nationwide perhaps by the relevant authority (ies) or organization(s).

KEYWORDS: *Brown sugar, molasses, kinetics, dehydration, nutritional value*

I. INTRODUCTION

Brown sugar is a sucrose sugar product with a distinctive brown color due to the presence of molasses with some percentage of moisture [1]. It is either an unrefined or partially refined soft sugar consisting of sugar crystals with some residual molasses content (natural brown sugar), or it is produced by the addition of molasses to refined white sugar (commercial brown sugar).

The moisture content (1.77% per 100g) of unrefined brown sugar is a critical factor for its transformation into most value-added products [2]. The researches that established the estimation of the moisture content with the food products revealed some couple of methods [3]. Absolute methods like the Karl Fisher method, conductimetry, infrared spectroscopy, dielectric spectrometry or nuclear magnetic resonance spectroscopy (NMR) seemed to fail the requirements of automation in the Industrial setting [4]. Therefore, a need exists in the sugar industry for a precise, reliable, safe and rapid method to determine the moisture content of crystalline or unrefined brown sugar by the loss-on-drying method. This further supports the fact that parameters which include temperature, time, sample size, stand-by temperature and one or two-stage drying could be considered when programming the instruments in obtaining the optimum conditions.

However, understanding the dehydration behavior of brown sugar is critical for improving the efficiency and quality of industrial brown sugar processing.

Meanwhile, there is a gap in existing knowledge about the effect of temperature on drying kinetics of brown sugar. Kinetics as the study of the rate at which processes occur will be very useful in providing information that gives an insight into the mechanisms of changes or transformation involved in brown sugar dehydration over some periods of time and as well allows a prediction of the degree of the change that will occur with respect to time. This concept is certain to empower and advance the sugar industries with respect to moisture control and management of brown sugar essentially for quality value-added products and longer shelf life of such products.

Knowledge of dehydration kinetics of brown sugar is needed for the sugar industry to eventually make high-quality products.

The objective of this study was to study the effect of temperature on the dehydration behavior of locally made brown sugar called "**Masarkwoilla**" in Hausa dialect in Zaria Kaduna State, Northern Nigeria.

II. EXPERIMENTAL

The locally made brown sugars used for this work were sourced for at Kwangilla (A), Sabo gari(B), Samaru(C), Tundun Wada (D) and Zaria city(E) within Zaria Kaduna State, Northern Nigeria.

The solid samples were crushed into powder before setting up for dehydration in an oven with porcelain crucible Moisture removal was adopted using Genlab MINO/75/F/DIG oven dryer and according to the standard method **[5].**

The dehydration kinetics in terms of zero order [Concentrations against Time], the first order [In Concentration against Time] and second order [1/Concentration against Time] was estimated in each case of the sample at an initial weight of 10g, Isothermal temperature of 102°C and period of 5min, 10min, 20min, 30min, 40min, 50min, and 60min.

III. RESULTS AND DISCUSSION

TableI. Dehydration Kinetics (0,1st and 2nd Order) of Crude brown Sugar of Sample A and B

Sample A	Time (min)	0 order	1st Order	2nd Order	Sample B	Time (min)	0 order	1st Order	2nd Order
		Net weight(C) (g)	In C	1/C			Net weight(C) (g)	In C	1/C
	0	10.0	2.3026	0.1000		0	10.0	2.3026	0.1000
	5	5.9	1.7750	0.1695		5	7.8	2.0541	0.1282
	10	5.6	1.7228	0.1786		10	7.4	2.0015	0.1351
	20	2.7	0.9933	0.3704		20	5.3	1.6677	0.1887
	30	1.1	0.0953	0.9091		30	2.6	0.9555	0.3846
	40	1.1	0.0953	0.9091		40	1.8	0.5878	0.5556
	50	1.1	0.0953	0.9091		50	1.3	0.2624	0.7692
	60	1.1	0.0953	0.9091		60	1.3	0.2624	0.7692

TableII. Dehydration Kinetics (0,1st and 2nd Order) of Crude brown Sugar of Sample C and D

Sample C	Time (min)	0 order	1st Order	2nd Order	Sample D	Time (min)	0 order	1st Order	2nd Order
		Net weight(C) (g)	In C	1/C			Net weight(C) (g)	In C	1/C
	0	10.0	2.3026	0.1000		0	10.0	2.3026	0.1000
	5	5.8	1.7579	0.1724		5	6.8	1.9169	0.1471
	10	5.5	1.7048	0.1818		10	6.5	1.8718	0.1539
	20	3.6	1.2809	0.2778		20	5.8	1.7579	0.1724
	30	1.7	0.5306	0.5882		30	5.5	1.7048	0.1818
	40	0.5	-0.6932	2.0000		40	5.0	1.6094	0.2000
	50	0.2	-1.6094	5.0000		50	4.6	1.5261	0.2174
	60	0.2	-1.6094	5.0000		60	4.6	1.5261	0.2174

TableIII. Dehydration Kinetics (0,1st and 2nd Order) of Crude brown Sugar of Sample E

Sample E	Time (min)	0 order	1st Order	2nd Order
		Net weight(C) (g)	In C	1/C
	0	10.0	2.3026	0.1000
	5	8.9	2.1861	0.1124
	10	8.7	2.1633	0.1149
	20	8.2	2.1041	0.1220
	30	7.9	2.0669	0.1266
	40	7.6	2.0282	0.1316
	50	7.0	1.9460	0.1429
	60	7.0	1.9460	0.1429

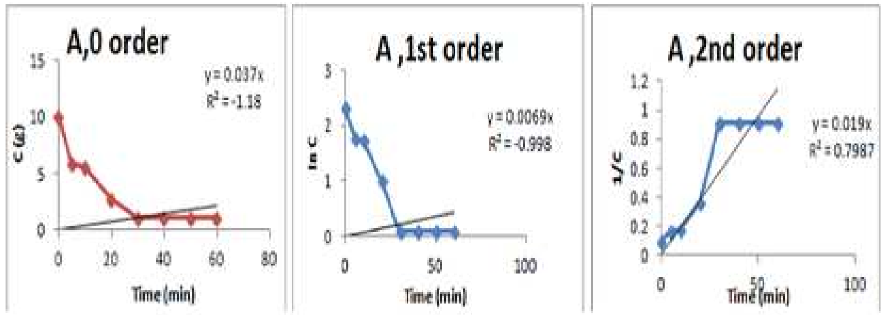

Figure l. Zero, first and second orders moisture dehydration plots of locally made brown sugar (Sample A)

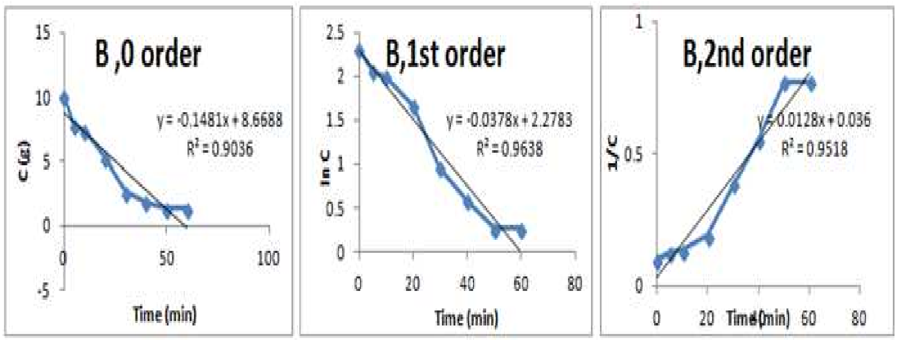

Figure ll. Zero, first and second orders moisture dehydration plots of locally made brown sugar (Sample B)

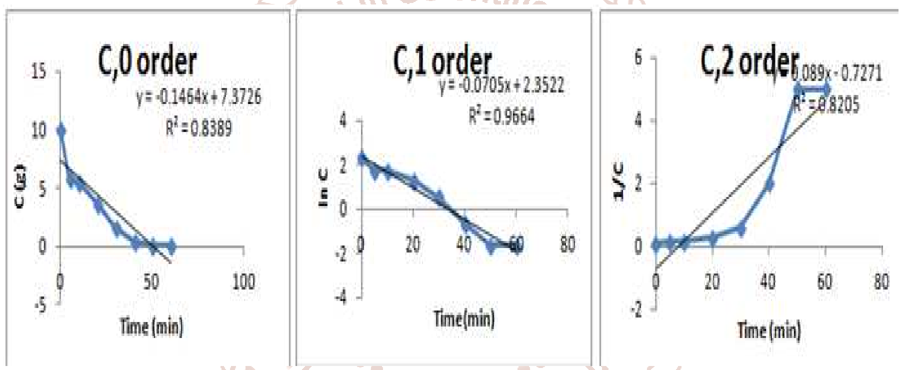

Figure lll. Zero, first and second orders moisture dehydration plots of locally made brown sugar (Sample C)

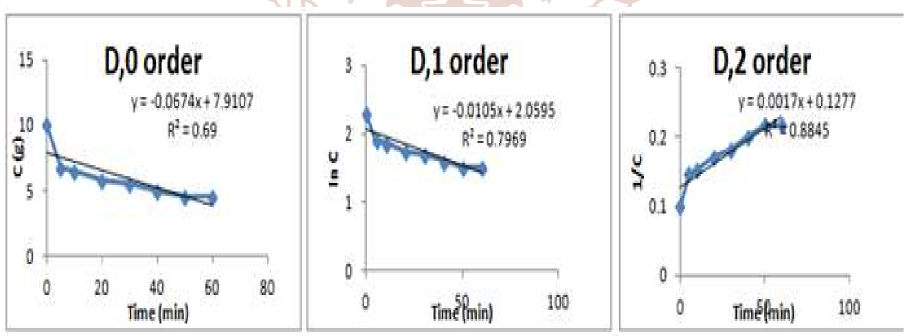

Figure lV. Zero, first and second orders moisture dehydration plots of locally made brown sugar (Sample D)

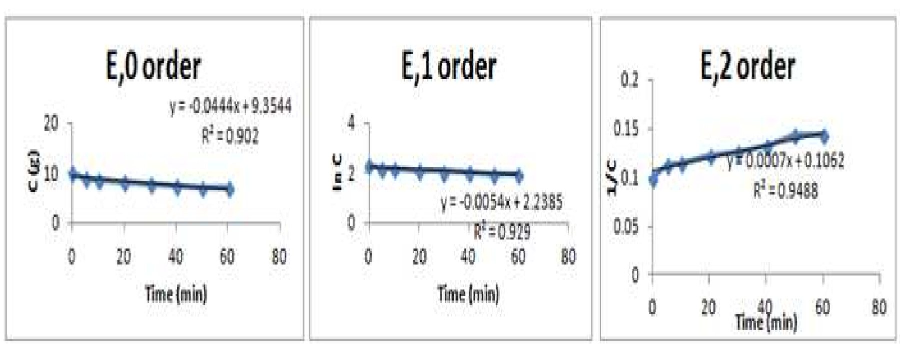

Figure V. Zero, first and second orders moisture dehydration plots of locally made brown sugar (Sample E)

TableIV. Kinetics, regression and percent moisture removal of the five brown sugar samples

Sample	Kinetic Model	Regression (R^2)	% Moisture Removal
A	Second order	0.7987	11
B	First order	0.9638	13
C	First order	0.9664	2
D	Second order	0.8845	46
E	Second order	0.9488	70

IV. Discussion

The final constant weights of the samples (A=1.1g, B=1.3g, C=0.2g, D=4.6g, and E=7.0g) against the initial weight of each of the sample (10.0g) at 120oC was applied in achievement of moisture loss percentage as 11%, 13%, 2%, 46% and 70% for A,B,C,D and E respectively(TableIV). This is also a claim that the process is endothermic in nature as they absorb heat energy for liberation of water molecules and that water molecules distribution is not uniform amongst the five samples obtained.

The kinetics for the process of dehydration in terms of zero, first and second order of crude brown sugar of sample A and B were shown in Tablel above. The empirical dehydration stage, which also translated to zero order reaction of the process, attains final dehydration at a constant weight of 1.1g at 30minutes with sample A and 1.3g at 50minutes with sample B.

Zero, first and second order reaction extensions were theoretically estimated by [Net weight], $\log_e$ [Net weight] and 1/ [Net weight] respectively. Thence, clearly shown in figure l is the order of reaction plots that define sample A to be second order type of reaction with percent moisture removal of 89% (TableIV) and highest regression (R^2= 0.7987) to zero order (R^2= -1.18) and first order (R^2= -0.998).

The order of reaction plots for sample B in figure ll shows first order with percentage moisture removal of 87% (TableIV) and the highest regression(R^2=0.9638) to Zero order(R^2=0.9638) and second order (R^2=0.9518).

The process with sample C and D is on Tablell, where the final dehydration attains constant weight at 0.2g for 50minutes with sample C and 4.6g for 50min with sample D. The order of reaction plots with C shows it is first order with percentage moisture removal of 98% (TableIV) with the highest regression (R^2=0.9664) to zero order (R^2=0.8389), second order (R^2=0.8205). The plots for D shows second order with percentage moisture removal of 54% (TableIV) and with the highest regression of (R^2=0.8845), to zero (R^2=0.69) and first order (R^2=0.7969)

Finally sample E as shown in Tablelll, attained constant weight at 70g at 50minutes and the order of reaction plots revealed it to be second order with percentage moisture removal of 30%(TableIV) and with the highest regression of (R^2=0.9488), to zero (R^2= 0.902) and first order(R^2=0.929).

Conclusion

The kinetics of dehydration for five locally made brown sugar samples A,B,C,D & E has been established at a constant temperature of 120°C for 5,10,20,30,40,50 & 60 minutes. With the outcome that sample A, D, and E presented second order rate which is theoretically proportional to the square of the matrix (sugar crystals molasses) that retains water while B and C presented first order rate which is proportional to the sugar matrices(sugar crystals+ molasses).

Hence, it is an implication that moisture contents of the five samples are more or higher than required for the molasses to be s Table with longer shelf life which by literature retained approximately 1.77% water per 100g brown sugar which will enhance the shelf and inhibit the activities of microorganism [6].

These drive home the facts that brown sugar processing requires strict monitoring, study, and conditioning of moisture compositions. Similarly, the three order of reaction (zero, first and second); all supported the fact that parameters such as temperature and moisture are mutually related to the process. In other words, regulated and standardized amount of temperature (storage) and water contents should be established by the relevant organization within the country and internationally.

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