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STORAGE STABILITY INDICES FOR MAIZE FLOUR

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ABSTRACT

Maize has maintained an important position in the dietary habits of many people in developing countries. It becomes low-moisture food when processed into flour although it may still be susceptible to deleterious effect of exogenous (fungi, bacteria and insects) factors whose activities are climatic dependent after processing to flour. However, one of the central areas of research in food processing is to ensure quality stability of food items or products in storage structures in order to conserve the nutritional composition and ensure its availability during the off-season periods.

In an attempt to ensure durability for maize flour, an analysis of moisture sorption data was undertaken to determine storage environment boundaries and moisture content levels at which the activities of exogenous factors will be inhibited for the flour under tropical practical storage conditions.

Consequently, water activity (a_w) range of 0.05 to 0.61 and moisture contents of 6.66 to 7.22 (%, dry basis) was estimated to ensure quality stability for maize flour, when storage structures are exposed to a tropical situation of temperature 27°C to 40°C and water activity of 0.10 to 0.80. BET monolayer moisture content varied between 3.47 and 4.59 %, dry basis. The information can benefit stakeholders in the maize processing sector to ensure the availability of high quality flour as a food ingredient in various forms and for industrial utilisation. This has high tendency to improve customer's satisfaction and invariably provoke growth in the profit margin of the food processing sector.

Keywords: *maize flour, sorption, storage, stability*

Introduction

Maize plays a very important role in food security of many developing countries in Africa such as Togo, Nigeria, Cameroon, Sierra-Leone and Ghana (Tagne et al 2003). On-farm harvesting for maize grains at varying moisture contents due to many interwoven factors that include climatic conditions, farming system and the available technology for the farm operations is a common phenomenon. In this situation, the grain can assume a moisture value which makes it susceptible to storage molds especially during the warm months of the year (Reed et al, 2007). To extend the durability of the grains, fresh maize are usually dried and milled to flour in order to make its use elastic in regards to food ingredients and industrial applications. Although dried maize products are intrinsically more stable than fresh grains, their deterioration can be caused by exogenous factors such as fungi, bacteria and insects. These deteriorative agents require combined effect of water and temperature for their activities. The various ranges of water activities (a_w) for the spoilage organisms to grow in food products are: 0.75 to 0.99 (bacteria), 0.62 to 0.90 (yeasts) and 0.61 to 0.96 for moulds (Butt et al, 2006). A_w can be influenced by the availability of free water in foods. Consequently, the free water can either directly or otherwise affect the shelf-life of stored food products or items through its effects on the stability of the components in food.

However, stability of components in food under preservation is a variable index for determining quality. Food components can be stable when environmental factors such as a_w, relative humidity and pH in the food are maintained at a state that is not favourable to deleterious organisms (Cardello, 1998; Chinachoti, 1998; Yang, 1998). Invariably shelf-life will be enhanced because of the inhibition of fungal growth and mycotoxin production during storage practices which may adversely affect quality (Samapundo et al, 2007). Whilst in storage with regard to stability, water migration in relation to its translational mobility influences the physicochemical and biological attributes of foods. Water migration is presumed as most important aspect in food drying and packaging technology. The implication is that the rate at which moisture is lost in food that is being stored can affect its quality (Chinachoti, 1998).

Thus, water activity in the storage chambers and its effect on food composition are the main factors that control the quality and stability of low-moisture foods. This category of foods could be considered stable when they are stored in various cool and dry conditions close to the BET monolayer values and corresponding a_w of 0.2 to 0.4 (Butt et al, 2006). Because of the interlocking effect of temperature and moisture on the rate at which food deteriorate in storage, there is evidence to suggest that relationship between a_w and moisture content can stand as index for determining the effects of water content on its stability (Samapundo et al, 2007).

Moisture sorption relates to the ability of water molecules to penetrate into, diffuse within the food or escape out of the food matrix to the enveloping environment. Specifically, the rate of diffusion is affected by the driving force which is linked to the water chemical potential difference between the food and the environment. Migration of moisture at the microscopic, macroscopic and molecular levels can be controlled through water activity or relative vapour pressure. This can have effect on the sorption characteristics of food products. Therefore, sorption data could be used to predict the stability of food products in storage because its application provides an understanding of the relationship between a_w and moisture content which is an absolute necessity to achieve optimal storage stability in food products (Samapundo et al, 2007., Lasekan & Lasekan, 2000., Ajisegiri, 1987). This aspect has not been investigated a prior for maize flour in relation to Nigerian climatic conditions and many other developing countries despite the economic impacts of maize and its associated products in the emerging economies and beyond.

In a previous paper by Oyelade et al, (2008), five widely recommended isotherms (GAB, Modified GAB, Modified Oswin, Modified Henderson & Modified Chung-Pfost) equations were used to fit experimental sorption data under practical storage conditions for maize flour. In this study an analysis of the experimental sorption data was undertaken to estimate the water activity range required in the ideal storage structures for maize flour, and the moisture contents at which the flour can be produced and maintained during storage in order to retain good quality when storage is carried out in the selected tropical environment.

Materials and methods

Determination of the monolayer moisture content for maize flour

To calculate the monolayer moisture value for maize flour in this study, the least square and linear regression method of Murray (1981) was used: BET plots for the flour using the experimental sorption data for maize flour (Table 1) were made for this purpose by using the Brunneur-Emmet-Teller expression in the form of equation (1):

$$\frac{a_w}{M(1-a_w)} = \frac{1}{M_o} + \frac{c-1}{M_o} a_w \quad \text{.........} \quad (1)$$

Where,

a_w = water activity ; M = moisture in the equilibrated samples (%, dry basis); M_o = moisture content of monomolecular layer; c = constant.

From the plots, the monolayer moisture contents were calculated from the expression shown in equation (2):

$$Monolayer = \frac{1}{(Intercept + Slope)} \quad \text{........} \quad (2)$$

Determination of water activity range suitable for storing maize flour

The local isotherm concept (LI) was adopted to relate the isotherm curves that were previously obtained for maize flour at 27, 32, 37 & 40°C by Oyelade et al, 2008 to storage environment according to the procedure reported by Igbeka et al, (1975). This was done by linearising the Henderson equation (3) as shown:

$$(1-a_w) = e^{-KTM^n} \quad \text{...............} \quad (3)$$

$$= \log KT + n \log M \quad \text{............} \quad (4)$$

Where, n and k are constants.

Equation (4) was interpreted graphically by plotting $\log[-\ln(1-a_w)]$ against $\log M$ and used to determine the suitable a_w at which the flour could be stored through the application of points at which LI breaks occur in the Henderson plot.

Determination of moisture stability isotherms of maize flour

The procedure of Ajisegiri (1987) was used to generate the parameters used to plot maize flour moisture stability curves. Therefore, the ratio of differential equilibrium moisture content to differential relative humidity $\left(\frac{eM}{eRH}\right)$ between n and (n+1) points was plotted against M. The RH values were obtained as a_w multiplied by a factor of 100, respectively. Where eM and eRH are differential changes in equilibrium moisture contents and relative humidity from one relative humidity point to the other during study into sorption phenomena.

Results and discussion

Monolayer moisture content

There is high tendency for all food materials to equilibrate with the environment when they are stored, and this depends on several factors such as the moisture and temperature. Moisture in food when combined with the effect of temperature determines the sorption phenomena in food products in relation to the prevailing humidity, and invariably the susceptibility of physicochemical properties to changes due to its implications on microbial and chemical deteriorations (Al-Muhtaseb et al, 2002). Physical adsorption forces between food solid matrixes had been implicated to indicate that dispersion forces represent the major contribution to total energy of adsorption. This energy is vital to the rate at which solid food structure attains equilibrium in the storage climate (Ngoddy & Bakker-Arkema, 1972). Rizvi & Benado (1984) had provided evidence to suggest that this energy, energy of adsorption is affected by the moisture content of the food as well as the storage temperature because the water imbibed have structural, dynamic and thermodynamic effects.

The determined monolayer moisture contents (M_o) for maize flour were affected by the emc values during the sorption experiment and were determined as 4.58, 4.22, 3.87 and 3.49% at 27, 32, 37 and 40°C, respectively during the adsorption process. Slightly higher values of 4.59, 4.33, 3.93 and 3.47%, dry basis at 27, 32, 37 and 40°C, respectively were determined from the desorption isotherms (Table 2). This trend in monolayer values which showed higher values because of higher emc during desorption cycles compared to the adsorption cycles agreed with the trend that Samapundo et al (2007) determined for whole yellow dent corn. Climatic temperature also has effect on the monolayer moisture contents because the values decrease as the storage temperature increases in the sorption process. This consequently reflects the temperature dependence of equilibrium moisture content which has important practical bearing on chemical and microbiological reactions that are associated with food spoilage (Al-Muhtaseb et al, 2004). At the same moisture content, there is high tendency of increase in rates of deterioration because higher temperatures entail a higher a_w (Van den Berg & Bruin, 1981).

The M_o value has been reported to correspond to the least water content required in the food for stability because it is the index that approximates the number of sorption sites in the food products (Ajisegiri, 1987). Moreira et al (2002) had suggested that food substances should be maintained at the monolayer values as it minimizes spoilage reactions. It has also been emphasised that monolayer moisture values could be considered a critical parameter in food storage and package selection (Kumar, 2000; Ertugay & Certel, 2000). The determined m_o values are significantly less than the estimated values of 10.27% reported for degermed corn flour by Kumar (1974) and 6.03 – 8.47 that were reported for whole yellow dent corn by Samapundo et al (2007). The variation in values in this study could be due to effect of variety and the degerming process. However, the trend in the M_o in this study corroborated the earlier observation presented by researchers that it is a temperature dependent function, and as such should be of importance in storage phenomena (Diosady et al. ,1996; Sopade et al, 1994).

Storage Environment

The application of a modified Henderson (1952) approach known as LI concept is required in the use of moisture isotherms to predict product stability during storage (Labuza & Bell, 2000). The moisture isotherms that were constructed for maize flour in a previous study by Oyelade et al (2008) were demarcated into LI-I, LI-II and LI-III and shown in Fig.1 using previously applied LI-concept by Igbeka (1987). The apparent point of intercepts (Table 3) of the plots were used to determine the range of a_w suitable for storing the maize flour by relating the constructed graph to the generally known quadratic equation in the form of $y = mx + c$. These were calculated as 0.05 – 0.61, 0.17 – 0.57, 0.35 – 0.50 and 0.50 – 0.55 at 27, 32, 37 and 40°C, respectively. The trend is an indication that temperature has effect on the range of humidity at which maize flour can maintain their inherent physicochemical properties to ensure quality stability during practical storage conditions. Hygroscopicity of food products can impair physicochemical properties of foods (Diosady et al, 1996), and the rate at which this occurs may be affected by the humidity in the food storage chamber. Over all, the study determined that maize flour could be stored in storage environment over a_w range of between 0.26 (±0.00) and 0.45 (±0.00) at temperature range of 27 and 40°C. This agrees with the known range of a_w of 0.2 to 0.4 for food storage that inhibits deleterious effects of micro-organisms. At this storage parameters specifications, none of the yeasts, bacterial and mould which require various range of humidity of 0.67 to 0.99 to thrive, and hence probably initiate spoilage activities to maize flour during storage are not expected to grow (Butt et al, 2006).

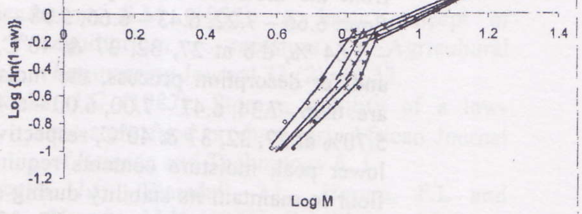

Fig.1: LI demarcation for maize flour

Table 1: Sorption Isotherm Data for Maize Flour at 27, 32, 37 & 40°C

Water Activity (a_w)	Equilibrium moisture content (emc, % dry basis) 27°C Ads	27°C Des	32°C Ads	32°C Des	37°C Ads	37°C Des	40°C Ads	40°C Des
0.10	4.40	5.08	4.06	4.29	3.95	4.06	3.84	3.98
0.15	5.08	5.53	4.97	5.08	4.97	5.05	4.18	5.05
0.20	5.87	6.32	5.53	5.87	5.19	6.00	4.97	5.50
0.25	6.77	6.66	6.21	6.29	5.98	6.00	5.42	5.56
0.30	6.89	6.96	6.43	6.47	5.98	6.06	5.42	5.42
0.35	7.00	7.11	6.55	6.63	6.10	6.17	5.53	5.72
0.40	7.22	7.34	6.66	7.00	6.21	6.43	5.64	5.76
0.45	7.56	7.60	7.00	7.45	6.55	6.77	5.98	6.21
0.50	7.68	8.54	7.56	8.01	7.00	7.22	6.66	6.77
0.55	9.03	9.90	8.92	9.26	8.01	8.24	7.56	7.89
0.60	10.05	11.40	9.82	10.38	9.22	9.59	8.58	9.03
0.65	12.19	12.30	11.40	11.85	11.06	11.06	10.27	10.60
0.70	12.64	13.21	12.42	13.09	11.96	12.53	11.63	11.85
0.75	14.22	15.24	14.00	14.22	13.66	14.00	13.09	13.43
0.80	15.84	15.95	14.79	14.82	14.67	14.67	14.22	14.56
0.85	16.03	16.03	15.01	15.01	14.82	14.82	14.67	14.67

Table 2: BET Monolayer Parameters and Values for Maize Flour

Temperature (°C)	Equation for BET Plots: Adsorption Equation	Adsorption R^2	Desorption Equation	Desorption R^2	Monolayer Moisture (%, d.b) Adsorption	Desorption
27	0.2101x + 8E-05	0.9868	0.2101x + 8E-05	0.9868	4.56	4.76
32	0.2256x + 0.0004	0.9797	0.2256x + 0.0004	0.9797	4.35	4.43
37	0.2441x – 0.0002	0.9791	0.2441x – 0.0002	0.9791	4.06	4.10
40	0.2565x + 0.0016	0.9701	0.2565x -0.0016	0.9701	3.83	3.92

Table 3: Storage Environment Parameters for Maize Flour

Temp. (°C)	Equation of lines a	b	c	R^2 of Equation of lines a	b	c	Intersection points (log M) b & a	c & b
27	2.4869x-2.5648	6.2527x-5.6908	1.2666x-1.3124	0.9806	0.9483	0.9709	0.71	0.80
32	2.5649x-2.5532	4.4190x-3.9946	1.2371x-1.2657	0.9869	0.8885	0.9877	0.74	0.82
37	2.8174x-2.6837	4.6775x-4.0686	1.1215x-1.1234	0.9564	0.8823	0.9876	0.79	0.86
40	3.1892x-2.8161	3.7386x-3.1850	1.0706x-1.0468	0.9766	0.8991	0.9709	0.83	0.88

Moisture stability

The moisture stability curves of Figs. 2 & 3 for maize flour shows that temperature has effect on the range of moisture expected in maize flour under practical storage conditions in order that the inherent physicochemical properties are not affected. In a situation of adsorption process, maize flour will be expected to be stored at the following range of moisture contents that were determined from the moisture stability curves for the maize flour: 6.66 – 7.22, 6.43 – 6.66, 5.98 – 6.21 and 5.42 – 5.64 %, d.b at 27, 32, 37 & 40°C, respectively and for desorption process, the moisture contents are: 6.96 –7.34, 6.47 – 7.00, 6.00 – 6.40 and 5.40 – 5.70% at 27, 32, 37 & 40°C, respectively. Over all, lower peak moisture contents required for maize flour to maintain its stability during storage which were 7.22, 6.66, 6.21, 5.53 at 27, 32, 37 & 40°C, respectively for adsorption compared to higher peak values which were 7.34, 6.63, 6.06, 5.56 at 27, 32, 37 & 40°C, respectively for desorption.

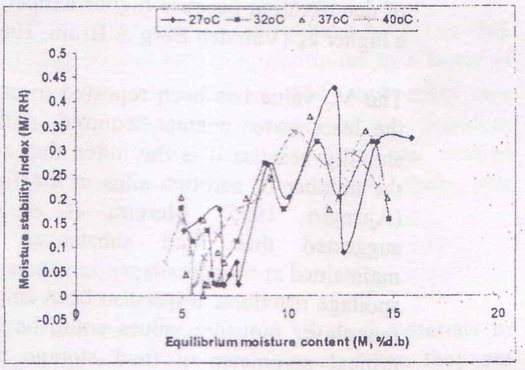

Fig. 2: Moisture Stability Curves for Maize Flour (adsorption)

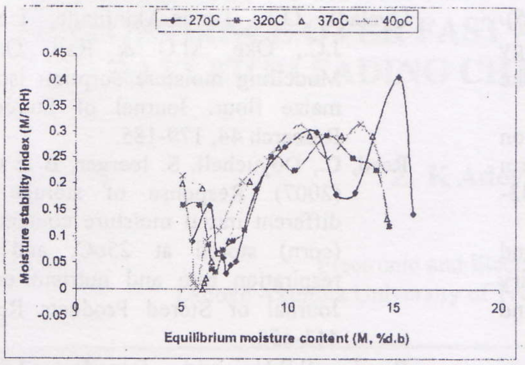

Fig. 3: Moisture Stability Curves for Maize Flour (desorption)

Food products that are stable in storage have a good tendency of retaining inherent physicochemical properties. Also, the overall equilibrium moisture contents values of 6.64 – 8.32 %, d.b obtained during desorption compared to 6.64 – 8.10 %, d.b during adsorption (Figs. 2 & 3) shows that the flour has a greater chance of maintaining stability because of wider moisture range, when equilibration is reached through the latter. This observation agrees with the trend observed for some food grains including maize (Ajisegiri, 1987). The influence of temperature and moisture content as observed in the study further supports the interwoven effect of moisture and temperature in food storage phenomena (Ihekoronye & Ngoddy, 1985). Although, the values of moisture required for stability is higher than the calculated M_o values, it is still comparable to the moisture content at which flour could be considered safe in storage (Lasekan & Lasekan, 2000).

CONCLUSIONS

The following deductions were made from the study:

1. Moisture content at production of the maize flour, temperature and humidity of the storage climate may affect the stability of maize flour during storage in tropical environment.
2. The moisture content range for stability of maize flour, and the expected humidity in the storage structures are within the established safe storage parameters indices for many low-moisture food products in the tropics, hence maize flour may be economically compatible with many other low-moisture foods during practical storage conditions in the tropics.
3. Maize flour has the tendency of better stability when equilibration was reached through desorption.
4. The possibility of enhanced shelf life for maize flour is high at the stipulated storage conditions because of the inhibitory tendency on the growth of its associated spoilage organisms.
5. Higher storage temperature resulted in smaller range of a_w values for clinical storage of maize flour at the investigated tropical condition.

REFERENCES

Ajisegiri, E.S (1987). Sorption Phenomena and Storage Stability of Some Tropical Agricultural Grains. Ph.D Thesis, University of Ibadan, Faculty of Technology, Nigeria.

Al-Muhtaseb, A.H., WcMinn, W.A.M and Magee, T.R.A (2002). Moisture sorption characteristics of food products: a review. Trans IChemE 80 (Part C, June) 118 – 128.

Al-Muhtaseb, A.H., WcMinn, W.A.M and Magee, T.R.A (2004). Moisture sorption isotherms of starch powders Part 1: mathematical description of experimental data. Journal of Food Engineering 61, 297-307.

Brunauer, S., Emmett, P.H and Teller, E, J (1938). Adsorption of gases in multimolecular layers. Journal of American Chemical Society 60, 309.

Butt, M.S., Nasir, M., Akhtar, S and Sharif, K, (2006). Effect of moisture and packaging on the shelf-life of wheat flour. Internet Journal of Food Safety 4 (2006) 1 – 6

Cardello, A.V.,(1998).Perception of food quality in Taub, I.A., Singh, R.P (Eds.), Food Storage Stability, CRC Press LLC, Washington, D.C, 1998, pp. 435 – 458

Chinachoti, P.,(1998).Water migration and food storage stability in Food Storage Stability ed. by Taub, I.A., Singh, R.P (Eds.), Food Storage Stability, CRC Press LLC, Washington, D.C, pp. 245 – 267

Diosady, L.L., Rizvi, S.S.H., Cal, W and Jadgev, D.J (1996). Moisture sorption isotherms of canola meals and application to packaging. Journal of Food Science 61 (1996) 204 – 208.

Ertugay, M.F and Certel, M, (2000). Moisture sorption isotherms of cereals at different temperatures Nahrung 44 (2), S.107 – 109.

Henderson, S.M (1952). A basic concept of equilibrium moisture. Agricultural Engineering Journal 33 (2), 29-32.

Igbeka, J.C (1987). Storage stability of a low-moisture food product-gari. African Journal of Science and Technology 6, 1.

Igbeka, J.C., Blaisdell, J.L., Herum, F.L and Hamdy, M.Y (1975). Equilibrium Moisture Content of Cassava and Potato, American Society of Agricultural Engineers, Paper No 75-6527.

Ihekoronye, A.I and Ngoddy, P.O (1985). Integrated Food Science and Technology for the Tropics, London and Basingstoke Macmillan.

Kumar, K. (1974). Water vapour adsorption on whole corn flour, degermed flour and germ flour. Journal of Food Technology 9, 433-444.

Kumar, K.R (2000). Moisture sorption and packaging characteristics of Arabian dry cereal foods. Journal of Food Science and Technology – Mysore 37 (3), 330 – 333.

Labuza, T.P and Bell, L.N (2000). Moisture sorption: practical aspects of isotherm measurement and use. American Association of Cereal Chemists, St. Paul, MN 55121-2097, USA 2000

Lasekan, O.O and Lasekan, W.O (2000). Moisture sorption and the degree of starch polymer degradation on flours of popped and malted sorghum (sorghum bicolour). Journal of Cereal Science 31, 55 – 61.

Moreira, R., Vazqueze, G and Chenlo, F (2002). Influence of the temperature on sorption isotherms of Chick Pea: Evaluation of isosteric heat of sorption. Electronic Journal of Environmental, Agricultural and Food Chemistry.

Murray, R.S (1981). Outline of Theory and Problem of Statistics. Schaum's Outline Series, McGrawHill Pub. Comp; N.Y, St Luis London.

Ngoddy, P.O and Bakker-Arkema, F.W (1975). A generalised theory of sorption phenomena in biological materials part iii – a pore size distribution function of the power law type for biological materials. Transactions of the ASAE 15 (6), 1160 – 1164.

Oyelade, O.J., Tunde-Akintunde, T.Y., Igbeka, J.C., Oke, M.O & Raji, O.Y (2008). Modelling moisture sorption isotherms for maize flour. Journal of Stored Products Research 44, 179-185.

Reed, C., Doyuchell, S. Ioerger, B & Getchell, A (2007). Response of storage molds to different initial moisture contents of maize (corn) stored at 25oC, and effect on respiration rate and nutrient composition. Journal of Stored Products Research 43, 443-458.

Rizvi, S.S.H and Benado, A.L (1984). Thermodynamics properties of dehydrated food. Food Technology 38, 83 – 92.

Samapundo, S., Devlieghere, F., Meulenaer, B., Atukwase, A., Lamboni, Y & Debevere, J (2007). Sorption isotherms and isosteric heats of sorption of whole yellow dent corn. Journal of Food Engineering 79, 168-175.

Sopade, A.A & Ajisegiri, E.S (1994). Moisture sorption study on Nigerian foods: maize and sorghum. Journal of Food Process Engineering 17, 33 – 56.

Tagne, A., Kongsdal, O., Ngoko, Z & Mathur, S.B (2003). Fusarium pallidoroseum in maize samples of three agro-ecological zones of Cameroon. Journal of Stored Products Research 39, 367-374.

Van den Berg, C & Bruin, S (1981). Water activity and its estimation in food systems in L.B Rockland & G.F. Stewart (Eds), Water activity: influences on food quality (pp 147-177), New York: Academic Press.

Yang, T.C.S (1998). Ambient storage in Taub, I.A., Singh, R.P (Eds.), Food Storage Stability, CRC Press LLC, Washington, D.C, pp.435–458.