AU J.T. 9(2): 121-125 (Oct. 2005)

The Effects of Moisture-Sorption Cycles on Some Physical Properties and Nutritional Contents of Agricultural Grains

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Abstract

Three types of grains (maize, sorghum, and millet) were stored under the condition of continuous moisture-sorption cycles from 0% RH to a near 100%. Then the effects of this treatment on the physical characteristics of size, shape, surface texture and color, nutritional content, rate of weight loss, and viability, were evaluated. Analysis showed that moisture-sorption cycles caused pronounced shrinkage evidenced by lower diameters and thickness recorded for the treated samples. Ageing was also at a faster rate indicated by the change in color and texture. Moreover, both nutrient content and weight loss were observed to be at a faster rate for treated samples.

Keywords: *Stored grains, maize, sorghum, millet, nutrition, relative humidity.*

1. Introduction

Moisture-sorption is the general term used to describe the movement of water in porous materials. It could be adsorption (that is the uptake of water vapor), absorption (the intake of liquid water) or desorption (the removal of water from the adsorbent).

All biological materials are hygroscopic in nature. That is, they posses the ability to respond to the moisture content (m.c.) of their surroundings in an attempt to keep their m.c. in an equilibrium state with their surroundings. However, under normal storage conditions, products seldom, if ever, attain equilibrium state except for a very short period of time. This is due to the continuous change in the thermodynamic properties of the storage system. As a result, stored products that are not sealed always undergo this continuous sorption cycle during storage. The objective of this paper is to evaluate the effects of this continuous sorption cycle on the physical characteristics, nutritive content, and viability of stored grains.

In hygroscopic materials, equilibrium moisture content (e.m.c.) of the material, rather than the relative humidity (RH) of the system, is of more importance. Water in stored product produces a relative vapor pressure (p) that is indicative of the degree of saturation of the materials. It is the fraction of this pressure compared to the saturated vapor pressure (p_o) at specified temperature that defines water activity (A_w) (Young 1993).

Agricultural grains are made up of tissues. The tissues are characterized by a random network of small pores of various diameters and lengths. These pores are inter-connected cylinders or spheroidal ink-bottle configuration (Ajisegiri 1987). Moisture is moved from one location to another in accordance with the variability in vapor pressure, properties of the grain, and temperature gradient (Ajisegiri and Igbeka 1985). This implies that at all times a mass of grains continuously exchanges moisture either with the surrounding fluid or with contacting grains, or both, due to the differential moisture levels created by changes in the system properties. Many attempts have been made to quantify the energy balance involved in this mass transfer. But progress has so far been hampered by the irreversible nature of moisture-sorption process (Ajisegiri and Chukwu 2004a).

It has been confirmed that energy is involved in this process (Ajisegiri and Chukwu 2004b). The nature of such energy, however, has not been determined. Most work in this area has been empirical in nature. No known effort has been made to quantify the influence of moisture-sorption cycles on product properties, quality, and storage stability of stored grains. This was the main objective of this study: to evaluate the influence of continuously fluctuating moisture conditions on the storability of agricultural grains.

2. Materials and Methods

The experiment essentially consisted of storing small quantities of the grain samples in simulated natural environmental moisture condition in order to evaluate the influence of moisture variation on the grains. In nature, moisture variation in form of relative humidity fluctuation is a continuous process. This is done to separately quantify this specific effect on grain quality. The experimental rig was as reported by Ajisegiri (1987) and Ajisegiri and Sopade (1990). It consisted of sealed equilibrium chambers in which equilibrium was achieved by saturated salt solution submerged in a thermostatically controlled water bath at 25^{o}C. The weight variation was monitored by a sensitive digital electronic weighing balance with bottom loading device.

Eleven RH conditions were created between 0 and 100% RH with phosphorous pentoxide and 2% sodium hydroxide for 0 and 100%, respectively. Each of these salts was prepared in triplicate.

Three major agricultural grains - maize *(Zea mays)*, sorghum *(Sorghum vulgare)*, and millet *(Pennisetum tyhoides)* - were used for the experiment. The grains were harvested fresh from the farm, shelled by hand (to prevent mechanical damage) and conditioned. The conditioning consisted of drying 2 kg of each of the grains in a vacuum oven at 50^{o}C ± 1^{o}C until constant weight was recorded for three successive times at an interval of six hours. The grains were then cooled in a sealed desiccator containing anhydrous silica gel.

Twenty grams of each of the conditioned grains were weighed and placed in specially prepared sample dishes made out of wire netting. These dishes were suspended in the chambers above the saturated salt solutions. Magnetically activated fans were installed in the chambers containing salts that produce high RH (70% and above) to prevent mould growth. Each of the grains was allowed in this position for 30 hours before being moved to the next level of RH. Under each RH, each sample was moved to the next in an ascending and then descending order. That is, grain from 0% RH was moved next to 10, 20% and so on until it reached 100%. Thereafter, it was returned to 90, 80% down to 0%. The whole process was reversed for ten cycles after which the grains were evaluated and analyzed for changes in physical properties, nutritive stability, and viability changes, and compared to the control sample that was the conditioned grain. In all, 99 samples were involved in the experiment (three grain triplicates in 11 RH levels, i.e. 3x3x11).

3. Results and Discussion

Changes in the physical characteristics of size and shape before and after the moisture sorption cycles were monitored. Measurements were taken using micrometer screw gauge (0-100mm) with a four digit reading capability. The results in Tables 1-5 are the means of 30 readings--i.e., ten samples from each triplicate dish.

Color and texture were evaluated by visual inspection and feel. The result is presented as Table 2. The nutrient contents of the grain samples were also analyzed and presented as Table 3.

Furthermore, a germination test was carried out to determine the effect of sorption cycle on viability. The result is presented as Table 5.

The analysis of variance carried out on the collected data indicated a significant difference between the physical properties of treated samples and those of untreated samples when a *t* test was used to analyze the difference of the two means. The analysis showed the LSD (0.05) for major diameter to be 0.848, 0.660 and 0.095 for maize, sorghum and millet reduction in diameter respectively. This showed that a significant difference existed between the sizes of the grains before and after

Table 1. Sizes and shapes of maize, sorghum and millet

A. Fresh

Grain	Major diameter (∅mi)	Minor diameter (∅mn)	Thickness (t) (A_p)	Projected area (A_c)	Circular area	Sphericity
Maize ξ	10.894	8.699	5.100	70.312	84.102	0.863
S.D	0.770	1.530	0.917	11.128	21.632	0.084
Sorghum ξ	4.563	3.998	2.662	16.620	16.400	0.883
S.D	0.462	0.216	0.187	1.680	1.680	0.041
Millet ξ	3.082	2.502	1.719	6.820	8.028	0.826
SD	0.136	0.924	0.547	2.338	1.364	0.207

B. After Sorption Cycle

Grain	Major diameter (∅mi)	Minor diameter (∅mn)	Thickness (t) (A_p)	Projected area (A_c)	Circular area	Sphericity
Maize ξ	9.822	8.021	5.072	58.290	76.831	0.823
S.D	1.161	1.066	0.802	12.590	17.151	0.120
Sorghum ξ	4.810	4.211	2.772	16.106	18.241	0.875
S.D	0.294	0.366	0.170	2.923	2.187	0.050
Millet ξ	3.065	2.389	1.791	6.802	7.170	0.782
S.D	0.141	0.224	0.155	0.730	1.015	0.086

treatment. The same analysis showed significant reduction after the sorption cycle in minor diameter and thickness in both millet and sorghum. However, changes in both projected and circular areas were significant in maize only.

Changes in sphericity were significantly lower in sorghum and maize but not in millet. This showed that each grain responded to moisture-sorption effects differently but in the same pattern. The combined significant difference was adequate to conclude that

Table 2. Surface texture before and after sorption cycles

A. Fresh

Grain	Surface texture	Color
Maize	smooth and partially shiny	light-deep yellow
Millet	shiny, slippery and smooth	milky white
Sorghum	slightly rough	light reddish brown

B. After Sorption Cycle

Grain	Surface texture	Color
Maize	smooth with white deposit	deep yellow tending to brown with discoloration at germ
Millet	rough with slightly powdery appearance	light reddish brown
Sorghum	smooth and slightly slippery	light brown

Table 3. Nutrient content before and after sorption cycles

A. Fresh

Grain	Protein	Fat	Fiber	Ash	Starch	Sugar
Maize	9.35	3.87	1.64	2.86	78.25	4.20
Sorghum	10.16	3.08	1.83	2.44	78.50	4.70
Millet	11.20	4.33	1.06	1.82	76.80	4.90

B. After Sorption cycle

Grain	Protein	Fat	Fiber	Ash	Starch	Sugar
Maize	8.86	3.90	1.60	2.73	78.01	3.96
Sorghum	9.84	3.09	1.66	2.64	78.39	4.42
Millet	10.81	4.44	1.04	2.01	76.70	4.76

Table 4. Weight loss before and after sorption cycles (%)

Grain	Fresh	Sorption cycle
Maize	0.320	0.493
Sorghum	0.430	0.503
Millet	0.670	0.778

Table 5. Germination percentage before and after sorption cycles

Grain	Fresh	Sorption cycle
Maize	85	70
Sorghum	30	50
Millet	70	70

sorption cycle affects the stability of sizes and shapes in agricultural grains.

There was a distinct difference between the behaviour of maize and millet under similar moisture condition while grain sorghum exhibited similarities with maize. The difference in response may be due to different compositions of each grain resulting in unequal dimensional changes, characteristic all plant cells when exposed to moisture sorption.

Statistical analysis carried out on changes in nutrient stability showed the difference between treated and untreated samples to be significant for protein, ash, and fat. This may be due to increased germ physio-activities. The germ in this condition probably fluctuated between metabolic activities required for germination and dormancy. When RH is at the high side (80% and above) grains may be trying to germinate but as the process is continually altered, the grain germ would return to dormant position at low RH. This alteration may lead to increase metabolic activities that would rapidly deplete dry matter content. This seemed to be of significant importance to grains quality to infer that sorption cycle causes definite alterations to the chemical composition of stored grains. Table 3 shows that all the grains indicated a decrease in protein, fiber, starch, and sugar content which forms over 98% of the total dry matter. The general decrease experienced by these grains was probably due to increase in the rate of respiration and other physio-chemical reactions during moisture fluctuation. As metabolism involves the utilization of these components, a decrease seems to indicate that fluctuation in m.c. leads to increased rate within the grain. This was further monitored through changes in total dry matter content between the two samples (Table 4). The observed changes indicate that the loss in dry matter content by grains is more rapid in a condition where RH constantly fluctuates than at constant RH environment.

Analysis of the results also showed the effect of sorption cycle on the viability of grains. From these, sorption cycles appeared to improve the germinability of sorghum but reduced germination of maize with no apparent effect on the viability of millet. Further work is required in this aspect for a full explanation. The only explanation on sorghum germination improvement is that perhaps the cycle breaks dormancy in grains.

Sorption cycles were also suspected to affect grain properties in two ways: water, acting as a solvent seems to impart mobility to chemical constituents of grains by dissolution. This would account for the increased rate of chemical reaction and of course loss of dry matter content. In addition, it explains the noticeable dimensional changes in the configuration. As the dry matter content is being depleted, the grain size would decrease leading to shrinkage as observed.

Secondly, it is also suspected that variation in m.c. caused phase changes in the product; that is, changed the lattice structure. As the moisture molecules entered and left the crystal lattices, holes in form of pathways might have been created due to continuous entry and exit of the water molecules. As sorption process involves temporary bond formation in all biomaterials, this process might have had a significant effect on the structure of the grains. This, in turn, may have weakened the grain structure and probably accounted for the dull appearance of all the grains after sorption cycle. It is also suspected that such grains would have little resistance to microbial and insect attack.

The experiments passed the grains through two extremes of moisture availability. Degradation (physical, chemical, and biological) could, therefore, be of the type caused by lipid oxidation, auto-oxidation, enzymatic, and non-enzymatic reactions, subject to spells of instability.

From these studies the following could be inferred:

(a) Sorption cycles cause changes in the size, shape, color, and texture of stored grains.
(b) Sorption cycles lead to a faster rate of ageing.
(c) Sorption cycles adversely affect nutritional composition of grains.
(d) Sorption cycles increase the rate of dry matter loss in grains stored.

4. Conclusion

This study showed that grain quality and stability is affected by moisture sorption cycles. They cause perceptible dimensional changes due to contraction and expansion of lattice structure and hence weakening of the grain structure. Sorption cycles also adversely affects the stability of nutritional content and influences germination percentage. In addition, sorption cycles increase the rate of dry matter loss in all the grains and affect the color and texture of grains. It is therefore desirable to control moisture alteration during storage.

To keep the m.c. of a stored grain at constant level and thereby stop sorption cycles, continuous alteration of stored grains using air of desired m.c. and temperature is required. This seems to be the only feasible means of arresting the deteriorative effects of sorption cycles.

5. References

Ajisegiri, E.S.A. 1987. Sorption Phenomena and Storage Stability of Some Tropical Agricultural Products. Unpublished Ph.D. Thesis, Dept. of Agricultural Engineering, Univ. of Ibadan, Ibadan, Nigeria.

Ajisegiri, E.S.A.; and Igbeka, J.C. 1985. Technique for Faster Determination of Equal Moisture Content of Biological Materials. Nigerian Society of Agricultural Engineers, pp. 85-029, Owerri, Nigeria.

Ajisegiri, E.S.A.; and Chukwu, O. 2004a. Moisture-sorption Pattern of Kulikuli and Fura, Landzun. J. Engin. Approp. Tech. 2: 1-3.

Ajisegiri, E.S.A.; and Chukwu, O. 2004b. Influence of water on stability of chemical composition of agricultural grains during storage. Savannah J. Sci. Tech. (in press).

Ajisegiri, E.S.A.; and Sopade, P.A. 1990. Moisture-sorption isotherms of Nigerian millet at varying temperatures. J. Food Engin.12: 283-92.

Young, J.H. 1993. Moisture in Instrumentation and Measurements for Environmental Sciences. B.W. Mitchel, Ed., American Society of Agricultural Engineers, pp. 13-82, Michigan, USA.