PREDICTING WEIGHT CHANGE IN GARI IN TWO PACKAGING MATERIALS

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ABSTRACT

An equation for predicting moisture loss or gain by gari grain packed in two types of materials was developed. From this, it may be possible to establish the storability of gari in these two packaging material. The equation took into account the permeabilities of the materials, which were determined experimentally. The validity of the equation was tested experimentally. High correlation coefficients were received for small packages, while observed values were found to be consistently lower than the predicted values with packages 25cm x 20cm x 1Ocm in size and above.

1. INTRODUCTION

Gari is the most popular form in which cassava is consumed in West Africa, especially for the urban dwellers; and it contributes to as much as 60 percent of the total calorie intake of the population in some areas. The bulk of gari consumed is still produced by rural farmers, although, considerable mechanization has been introduced, of recent, into gari production by a few integrated factories which produce graded gari, mainly in consumer packets. The locally produced gari is ungraded and has short shelf-life of 4 to 6 weeks.

The causes of this short shelf life could be two fold. Firstly, it may be that the gari grains were not fried to the correct moisture content initially or that the fried gari was not allowed to cool fully before bagging. Secondly, it could be that the gari was over-fried and over- dehydrated, making it highly susceptible to moisture intake and hence short shelf life. Whatever is the cause of the short shelf life, the consumer would like to buy gari that has kept it's quality after some months of storage. At this point, it is necessary to define what is generally accepted as a good quality gari. According to the "Food and Drug Act of 1974, good quality gari is described as one having moisture content not more than 12% wet basis, total ash not more than 2.8%, crude fibre not more than 2%, acidity not more than 2.0 parts per million of hydrocyanic acid and not less than 0.6% and not more than 1.0% of total acidity calculated as lactic acid. For the purpose of this paper, it is assumed that for a particular batch of gari, the only thing that can change with time is the moisture content, This may in effect change the proportion of any of the other components.

Gari is usually sold in consumer packages made of polythene bags but stored in bulk in two types of packaging materials - jute and synthetic fibre (hessian) bags. These bag materials being permeable to water vapor, it is therefore expected that the gari in them will not maintain their quality with long storage.

The main objective of this paper is to establish an expression for predicting the moisture gain of gari in these two packaging materials. The expression is later tested experimentally, for its validity. From the moisture gain it may be possible to establish the storability of gari. Storability here is defined as the minimum time to take the gari bulk to attain a specified undesirable moisture level, at a given storage condition.

2. REVIEW OF LITERATURE

Actual prediction of storage Life as a function of efficiency of packaging materials and that of environmental storage condition was initiated on a large scale after the World War II (Karel et al 1975). To establish effective Storage life of food, apparently a lot of information is needed as regards the moisture sorption or desorption phenomena, method and effectiveness of processing and the type and manner of packaging. Karel et al(1975) suggest that for adequate evaluation of a storability of any packaged food product, the following questions need to be answered (a) What are the optimal conditions for storage of the particular food product in terms of the important environmental factors. (b) What are the external environmental conditions to which the package is likely to be exposed? (c) What barrier properties are required in order to maintain an optimal internal environment?

The answers to these questions are known for some food products and packaging materials but not for gari grains, which can be classified as a new food product, localized only in West Africa.

A recent work (Anon, 1980) which involved the microbial deterioration of gari stored in hessian and polythene bags, showed that the polythene bag gave a better result when gari was stored at moisture content of 11.2% wet basis. Mizrahi et al (1970) using dehydrated cabbage packed in two types of packaging materials predicted value of increase of moisture content due to permeation.

The Food and Drug Act of Nigeria (1974) classified gari as fine, standard and coarse. We are interested in the standard quality. Standard gari is one having moisture content not more than 12% wet basis, and of which not more than 20% is retained on a sieve having round holes of 1.00mm in diameter, but more than 80% is retained on a sieve having round holes of 425μm in diameter.

3. THEORETICAL ANALYSIS

The storability of a product in any packaging material will depend on the rate at which the packaging material takes in moisture vapor into the product under the storage environment. Therefore, the knowledge of the permeability of the packaging materials is important in predicting the storability of gari in a storage package.

The standard method of determining permeability of materials in sheet form is by using the water-vapor transmission method (ASTM standard Methods No. E96-66). The material to be tested fastened over the mouth of a dish which contains either a desiccant or water. The assembly is placed in an atmosphere of constant temperature and relative humidity; the weight gain or loss of the assembly is used to calculate the rate of water vapor movement through the sheet under the prescribed conditions.

A second, method, which was adapted for this study, allows the estimation of permeability constant on the packages as they are actually used in the storage study. This method has been found to be valid as compared with the standard method Mizrahi et al, 1970.

3.1. Derivation of Prediction Equation

For estimating the permeability for a particular Interval tx and assuming the moisture sorption isotherm of gari is linear over this time interval. then

$$m = ka \qquad (1)$$

where m is the moisture content (H_2O/g solid)

a is the water activity
k is a constant
In terms of rate equation.

$$\frac{dm}{dt} = k\,(a_{out} - a_{in}) \qquad (2)$$

where

$\frac{dm}{dt}$ is the rate change of moisture with
a_{out} = water activity outside the package
a_{in} = water activity inside the package
and the constant is described as

$$K = \frac{100\,(b\,Po\,A)}{S\,(\Delta\theta)}$$

where
b = the permeability of the packaging material (gm. mill) m $^{-2}$ day -1 Torr -1) or (gm. Mill cm -2 day -1 Bar -1)

Po = vapor pressure of water at ave. storage temp (Bars or Torr)
A = area of material (m^2) or (cm^2)
S = wt. of solids in package (gm)
$\Delta\theta$ = thickness of material (mil)

The water activity inside the package, a_{in} is taken to be in equilibrium with the moisture content of the food product inside the packages. This is only on the assumption that there is no significant moisture gradient within the food product, that is, resistance of the food to water transport is negligible compared to the resistance of the packaging material. This assumption is always justified when the mean thickness of the package is small; 2cm and less (Nizrehi et al,(1970)

$$a = \frac{P}{Po} \qquad (4)$$

then from equation (1)

$$k = \frac{mPo}{k} \qquad (5)$$

Assuming that the relative humidity outside is kept on constant at

$$H_1 \text{ then } H_1 = \frac{P_{out}\,(100)}{Po} \qquad (6)$$

where Pout = Partial pressure outside package. As an increase in the moisture content, m, of the product in the package is equal to the amount of water diffusing through the material, divided by the weight of solid, then equation (2) in terms of partial pressure becomes

$$\frac{dm}{dt} = \frac{b\,A}{(\Delta\theta)S}\,(P_{out} - P_{in}) \qquad (7)$$

where P_{in} = partial pressure inside package. Substituting in equation (7), we have:-

$$\frac{dm}{dt} = \frac{b\,A}{(\Delta\theta)S}\;\frac{H_1\,Po}{100}\;\frac{m\,Po}{k} \qquad (8)$$

$$= \frac{b\,A}{(\Delta\theta)S}\;\frac{H_1\,Po}{100}\;\frac{Po}{k}$$

$$\frac{dm}{dt} = \frac{b\,A}{(\Delta\theta)SK}\;\frac{H_1\,Po}{100}\;\left(m_3 - m\right) \qquad (9)$$

where m_e = Moisture content in equilibrium with outside relative humidity and equal to $\frac{H_1\,K}{100}$

Integrating equation (9) and realising that the process is sorption, we have

$$\text{In}\,\frac{M_e - M_t}{M_e - M_i} = \frac{b\,A\,Po}{\Delta\theta\,SK}\,tx \qquad (10)$$

where
M_i = initial moisture content
M_t = moisture content at time,
t_x = time, in days
From equation (10) the permeability, b, can be got as

$$b = \frac{M_e - M_t}{M_e - M_i} = \frac{(\Delta\theta)SK}{A\,P_o\,t_x} \qquad (11)$$

where k is calculated as M_e/a. We are interested in Mt and tx when predicting moisture gain or loss by a food product. Therefore, the required prediction equation is

$$b = \frac{M_e - M_t}{M_e - M_i} = \frac{b\,A\,P_o}{\Delta\theta\,Sk}\,t_x \qquad (12)$$

3.2 Validity of Equation:

The equation shows that the predicted time is independent of the thickness of the food product but depends on the thickness of the packaging material. Gari is usually stored in jute and hessian bags, filled to form a cylindrical package of about 40m in diameter. Although, the permeability of the material was derived with the assumption that the thickness of the package was 2cm or less and the resistance to moisture transfer through the food product (gari) was negligible, the actual storage package (when filled) is about 40cm thick
and about 60cm high. Also under the storage conditions, resistance to moisture transfer through the food product is not negligible. But we are more interested in the total gain in moisture by the food product. This means that the gain in moisture could just be localized in the first 2cm depth of the food product and this wouldn't affect the validity of the equation.
It is important to note that the equation may not be applied when uniformity of the moisture distribution within the food product is necessary. This situation required the moisture transfer coefficient (diffusivity) and porosity of the food product. Then the time for a particular point within the package to deteriorate can be predicted.

4. MATERIALS AND METHODS

4.1 Experimental Design
Two sets of experiments were conducted. The first was to determine the permeabilities of the packaging materials and the second was to verify the derived equation. The two sets of the experiments were very similar. While the permeability experiments were short (24 hours) and with very small packages, the storage experiments were long (144 hours), and with bigger packages.

4.2 Permeability:

Two types of packing materials were tested - Jute material and synthetic hessian fibre material. Gari, produced in the conventional method (Igbeka, 1983) and the dried to a moisture content of 5 per cent wet basis, was used.
Packaging materials, made into small pounches (4.5 x 6.0 cm) were stuffed with gari, of known weight to a thickness of between 1.0 and 1.2 cm. The stuffed pounches were then placed in constant temperature and high relative humidity (70-90%) chambers. The pounches were weighed constantly until a substantial amount of moisture had been gained. From the data, the permeabilities were calculated. Experiments were performed at three temperature levels - 25^{0}C, 30^{0}C and 40^{o}c and at three relative humidity levels 75%, 82%% and 92%. At 400C tests were carried out at only one R.H. level (75%) because above this R.H it was noticed that moisture condensed on the paunches thus fouling the results. An average of three tests at each level was taken as the final value.
4.3 Storage Tests:
The tests were conducted at a temperature level of 30^{o}C, which is the most prevailing temperature in the tropics, in general and Nigeria in particular. Only one relative humidity level was used - 82%. In all the tests, the two types of packing materials were used. Three sizes of storage packages were tested; (1) pouch measuring 7.0 x 5cm and stuffed to 1.5cm thickness (2) pouch measuring 15 x 10cm and stuffed to al thickness of 3.0cm (3) consumer package measuring 25 x 20cm and stuffed to a thickness of 1Ocm designated as package A, B and C respectively. All moisture contents were experimentally determined by the oven method.

4.4 Storage Quality Test:
Throughout the period of the experiment visual observations were made. At the end of the six days, the packages were opened and the quality of the products analysed.

5. RESULTS AND DISCUSSION.
Table 1 shows the values of permeability for both types of bag.

In all the cases the values for jute bag are greater than those for hessian bag which implies that the jute bag admits water vapor more than the hessian bag at a given time.

The effect of outside relative humidity on permeability is evident from the table. Permeability increases with relative humidity at any given temperature. In contrast, the effect of a moderate change of temperature is quite small.

The moisture content at any time during the storability test was calculated from the gain in weight, knowing the initial weight and moisture content. Plots of the predicted and experimental moisture content with time are given in figures 1 and 2.

The correlation between the experimental and predicted values was highest with-the small pouch and lowest Within the consumer-size package; although the three packages showed good correlation, about 0.8, (Table 2). This was expected because of the initial assumption that there was no resistance within the gari bulk. The validity of this assumption decreases with the increase in thickness of the gari bulk in the package, because the resistance to moisture transfer becomes more evident as the gari bulk thickness increases.

Storage Quality:

As the main aim of the work was not to determine the storage quality, no attempt was made to analyse the products chemically before and after. So only the visual and physical analyses were used to characterize the deterioration of the product.

At the end of the six days, the products in the jute packages showed evidence of more deterioration than those in the hessian packages. The product in package A (small size) was moist, getting soft, off-odor and off-flavor. Microbial growth was already starting in the jute package. The product in the medium-size package was also deteriorating but was not as moist and soft as in the small-size package.

It also had bad odor and flavor. In the large-size package, deterioration had started only on the products near the walls of the package. The products near the middle were still dry, firm, normal color, odor and flavor, while those near the walls of the package were already browning, with bad odor and flavor. The deterioration of any part of the product of a package makes the package unacceptable to the consumer. Therefore, to establish the storability of a product in a package, it is enough to predict or determine when any part of the product shows an evidence of deterioration, although it will be desirable to predict how and when such deterioration progresses within the product. This aspect of storage is a topic for further research.

The effect of this resistance will not affect the result significantly as we are only interested in the total gain in weight and in the uniformity of moisture within the bulk.

The plots show that with the thicker package, the observed values were consistently lower than the predicted and this deviation will increase as the package becomes thicker. This is because, theoretically, only the weight of the gari grain affects the moisture content and hence the gain in weight. But what happened in reality is that after the first few hours (about 24 hours) the first layer of the product very close to the package materials come into equilibrium with the environment and the rate of moisture sorption now depends on the rate at which the moisture is transported through the bulk of the gari grain.

As the resistance to moisture transfer through the product is not zero, as assumed in the equation, the observed rate of moisture grain will be less than the predicted. The same reasoning explains why with time, say after six days, the observed weights send to approach a constant; while the predicted values are still increasing. Therefore for packages which are of sizes 25 x 20 x 10cm and above, it will be necessary to occasionally shake and mix the contents if the prediction equation is to be successfully applied. There was not much

Table 1: Permeabilities of Hessian and Jute bag Materials.

Relative humidity	Permeabilities in gm. mill cm^{-2} day^{-1} bar^{-1}			
		25^0C	30^0C	40^0C
92%	1	1.8	1.1	-
	2	5.8	3.8	-
	1	1.00	0.8	-
	2	3.1	2.5	-
	1	0.5	0.4	0.2
	2	2.1	1.2	0.5

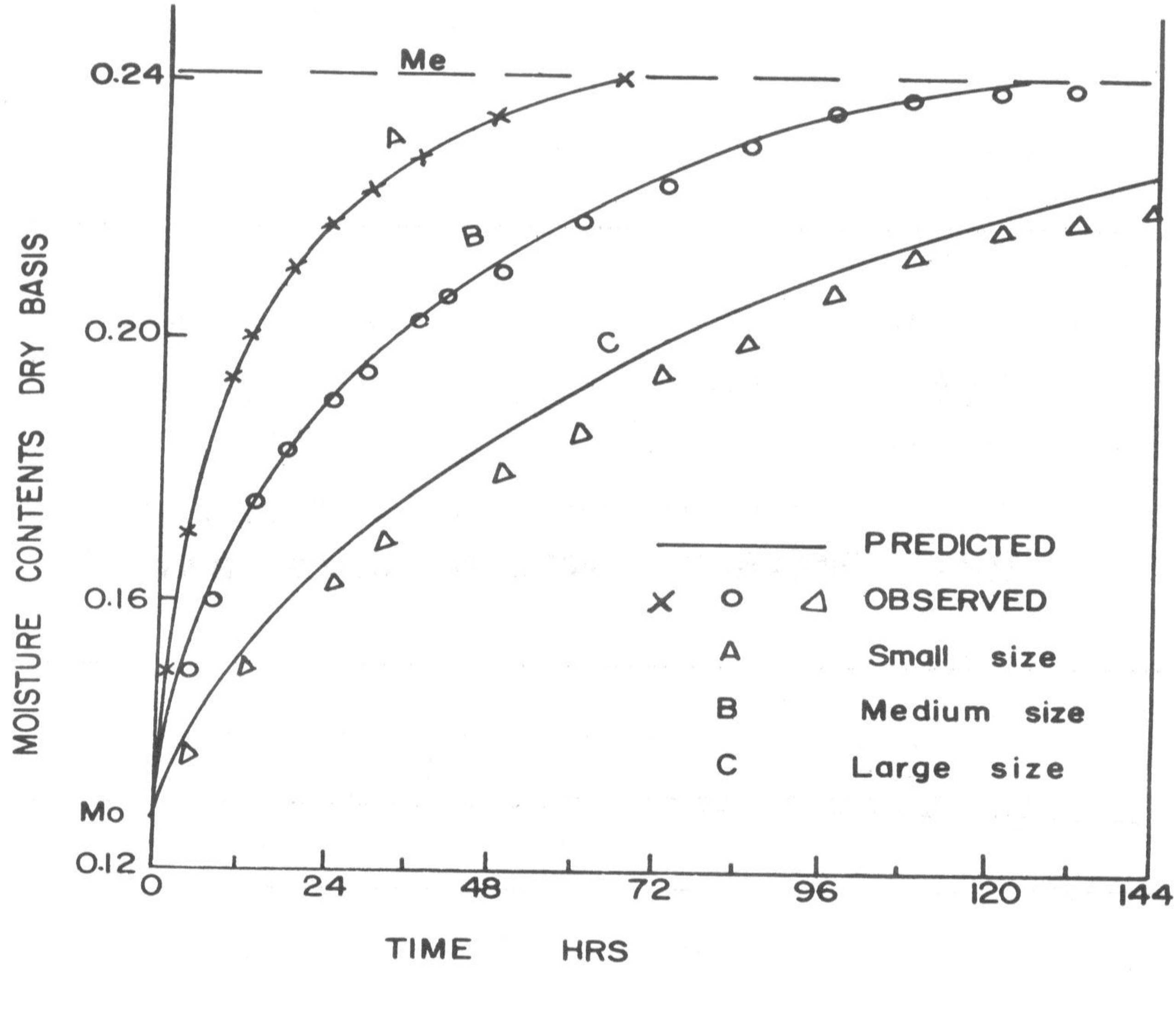

FIG. I : MOISTURE HISTORY OF GARI STORED IN THREE DIFFERENT SIZES OF

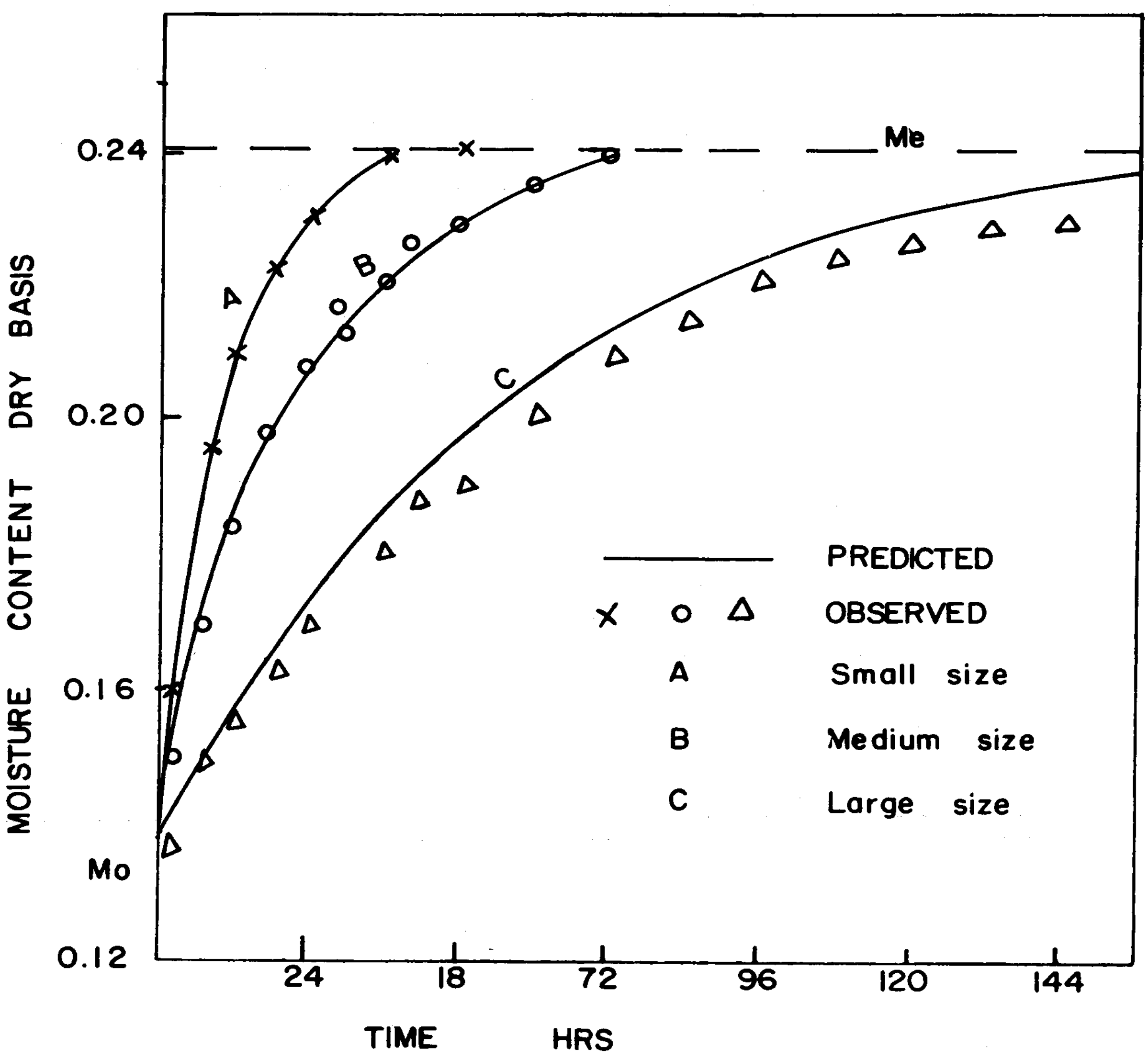

Fig : 2 MOISTURE HISTORY OF GARI STORED IN THREE DIFFERENT SIZES OF JUTE BAG.

Table 2: Correlation Coefficient values between the predicted and observed moisture contents

Size cm3	Hessian	Jute
A		
7x 5 x 1.5	0.997	0.998
B		
15 x 10 x 3	0.975	0.981
C		
25 x 20 x 10	0.861	0.856

difference between the observed and predicted values for the package that was 3.0cm thick.

As was expected, the product in the jute bag took in more moisture at any given time than that in the hessian bag. Thus, the hessian bag will be preferred to the jute bag for storing gari grains especially in the humid tropics, where moisture sorption is more likely.

Other Applications:

Before the equation can be applied to other products, their moisture sorption or desorption isotherms must have been established. The equation can also be applied to predict moisture loss from any packaged produce. It will be very useful for normal consumer packages of flour, ground pepper and other granular food produces.

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