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RESEARCH ARTICLE

APPLICATION OF THIN-LAYER MODELS TO GARIFICATION OF CASSAVA MASH

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ABSTRACT

Cassava particulates obtained from dewatered and unfermented cassava mash were garified using hot air dryer at different temperatures namely; 80°C, 90°C, 100°C, 110°C, and 120°C respectively, until constant weight. The study revealed that increased temperature resulted in reduced garification time. It was observed that garification time was longest at 80°C and shortest at 120°C. Five thin-layer drying models namely Lewis, Page, logarithmic, Fick's law and modified Fick's law models were used for modelling the change in moisture profile of the particulates with respect to time at the different temperatures. The fit quality of the models were compared in terms of statistical parameters - coefficient of determination (R^2), adjusted R^2, root mean square error (RMSE), and sum of square errors (SSE). Page and modified Fick's law models exhibited higher R^2 and lower RMSE and SSE values, and were found to be better models describing the garification characteristics of unfermented cassava mash.

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INTRODUCTION

Cassava (*Manihot species*) is a very popular high energy root crop consumed in the tropics and many regions of the developing world. However, its utilization in fresh and unprocessed form is limited by two factors: First, is that cassava contains naturally occurring toxicants (Ihekoronye and Ngoddy, 1985). Second, is the fact that fresh tubers cannot be stored for more than a few days after harvest. The presence of toxicants implies that cassava can only be consumed after elaborate processing (Kamalu *et al.,* 2012). Garri is the popular most stable, and processed form in which cassava is consumed in Nigeria (Olayade *et al*., 1992; Adindu and Aprioku, 2006), and in many African countries (Ekundayo, 1984; Oluwole *et al.,* 2004). Garri is a free flowing product consisting of cassava particulates, which have been partially gelatinized and dried - a process referred to as garification. Garification at the right temperature and duration precooks the cassava starch, enhances the development of aroma, colour, and other quality characteristics of garri, eliminates most, if not all, the residual toxicants, and lowers the moisture content of the garri to the preferred level for good storage. The objective of this study was to evaluate selected thin layer models, to determine the model that best describes the garification kinetics of unfermented cassava mash.

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MATERIALS AND METHODS

Sample Preparation

Freshly harvested cassava roots cultvar TM 98/0505, were obtained from National Root Crops Research Institute (NRCRI) farm, at Umudike, Abia State, Nigeria. The roots were manually peeled with knife and washed several times with clean water, then grated to obtain cassava mash. The mash was put in cloth bag and dewatered using a local hydraulic press. A sieve of mesh size 1.4mm was used to sieve the dewatered mash to obtain fine particle sizes.

Experimental procedure

Drying experiments were performed in a laboratory type electro-thermal convective oven (Model DHG, E300 serials, Turkey). The study by Ajibola *et al*. (1987) revealed that the drying temperature of cassava mash had to be raised to above 70°C for garification to occur. Mash dried at lower temperatures retained the raw taste of cassava. For this study, the following temperatures were chose; 80°C, 90°C, 100°C, 110°C, and 120°C.

The dryer was adjusted to the selected temperatures for about half an hour before the start of the experiments, in order to achieve the steady state conditions. Then 30g of sieved samples were weighed into preweighed aluminium petri dishes, placed in the dryer and dried at the selected temperatures, with an average relative humidity of 5-14% and a constant air velocity of 2.0m/s. During the drying process, to determine moisture losses, the samples were withdrawn, cooled in a dessicator and reweighed at 5min intervals for the first 30min, then, 10min intervals for the first 1h, and thereafter, at 30min intervals until constant weight was obtained using a digital balance (Mettler, model BB300, Mettler-Toledo AG, Grefense Switzerland) and an accuracy of ±0.1g. Three samples were dried in each run and temperature, and the average of the moisture ratios at each value was used for the drawing of the drying curves. The initial moisture content of the samples was determined using standard method (AOAC, 1990); by drying 30g of sample to constant weight at 80°C This was repeated three times to obtain a reasonable average.

Mathematical modeling

The moisture ratio (MR) of the cassava particulates were calculated using the following equation:

$$MR = \frac{M_t - M_e}{M_o - M_e} \quad \text{................(1)}$$

Where M_t, M_o and M_e are the moisture content at any time (t) of drying (kg water/kg dry matter (dm)), initial moisture content (kg water/kg dm), and equilibrium moisture (kg water/kg dm) respectively. The moisture content at constant weight for each drying temperature was used as the equilibrium moisture content for that temperature.

Table 1. Selected thin-layer models used for modelling

Model name	Expression	Reference
Lewis	MR = exp (-at)	Lewis (1921)
Page	MR = exp (-at^b)	Page (1949)
Logarithmic	MR = aexp (-bt)+c	Togrul and Peblivan (2002)
Fick's law	MR = aexp (-bt)	Jena and Das (2007)
Modified Fick's law	MR = aexp (-bt^n)	

MR versus t data were used to interpret the drying kinetics by fitting the selected thin layer models presented in Table 1, for each experimental condition. These models depict the moisture ratio as a function of time (h), whereas a, b, c, and n are the coefficients of the models. Goodness of fit of the models is characterized by root mean square error (RMSE), sum of square errors (SSE) and coefficient of determination (R^2). These parameters can be calculated as follows

$$R^2 = \frac{SSTotal - SSError}{SSTotal} \quad \text{.................(2)}$$

Where $SSError = \sum_{i=1}^{N} (MR_{\exp,i} - MR_{pred,i})^2$

and $SSTotal = \sum_{i=1}^{N} (MR_{\exp i} - MR_{avg})^2$

$$R\,MSE = \sqrt{\frac{\sum_{i=1}^{N} (MR_{\exp i} - MR_{predi})^2}{N}} \quad \text{............... (3)}$$

Where $MR_{\exp}$ is the experimentally observed moisture ratio, MR_{pred} is the predicted moisture ratio from the model stated, MR_{avg} is the average value of moisture ratio, N is the number of observations taken. The model coefficients and goodness of fit parameters were estimated by non-linear regression technique using Matlab curve fitting tool (Matlab version 7.9.0, MathWorks Inc.). The model indicating minimum RMSE as well as SSE and maximum R^2 value was considered the best.

RESULTS AND DISCUSSION

Effect of air drying temperature on garification characteristics

The change in moisture profile with respect to time for the garification of unfermented cassava mash at different temperatures is presented in terms of moisture ratio versus time graph shown in Fig. 1. Garification time is estimated from the onset of drying (time=0) to when the product attains equilibrium moisture (MR=0). It can be observe that the drying curves exhibited steeper slope for higher temperatures. This clearly shows that temperature has a significant effect on garification characteristics of cassava mash. From the range analysis of the experiment, it can be found that the garification time is longest at 80°C, and shortest at 120°C. Fig 1 shows that increasing the garification temperature from 80°C to 120°C caused a decrease in garification time from 2h to 1.167h. This trend was similar in accordance with an earlier study (Nwafor, 2008), and could be attributed to increase in moisture diffusivity with temperature (Doymaz and Ismail, 2011). This behavior of decreasing time with increasing drying temperature has been reported for many foodstuffs such as olive cake (Akgun and Doymaz, 2005), apple pomace (Wang *et al.*, 2007) and pumpkin slice (Doymaz, 2007).

Mathematical modelling of garification characteristics

The five selected thin-layer models were compared in terms of the statistical parameters - R^2, adjusted R^2, RMSE and SSE.

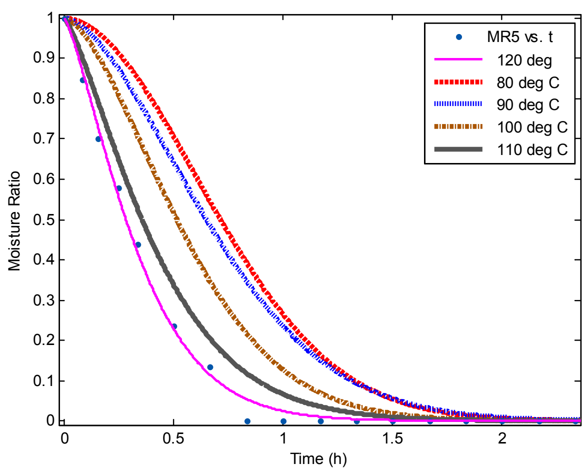

Figure 1. Moisture ratio variation with drying time at different temperatures using Page model

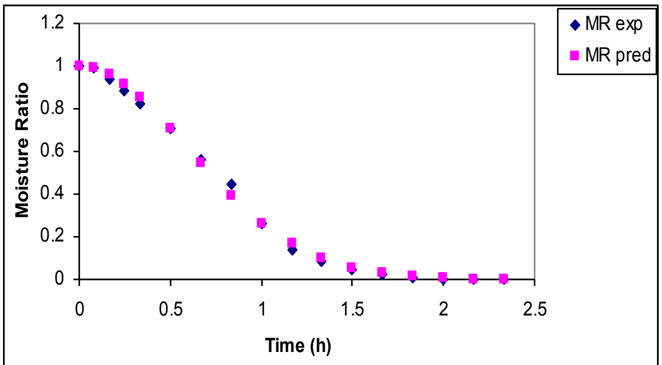

Figure 2 Comparison of experimental and predicted moisture ratio with time at 80 deg C

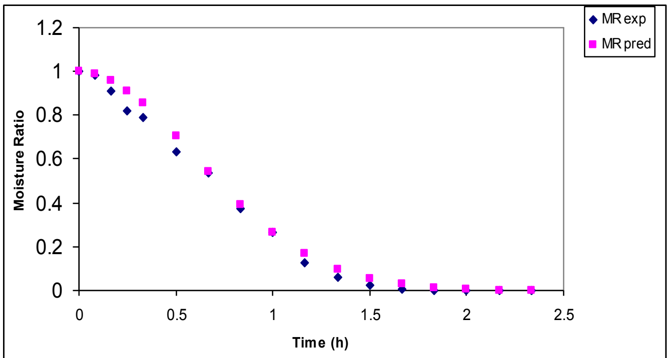

Figure 3 Comparison of experimental and predicted moisture retio with time at 90 deg C

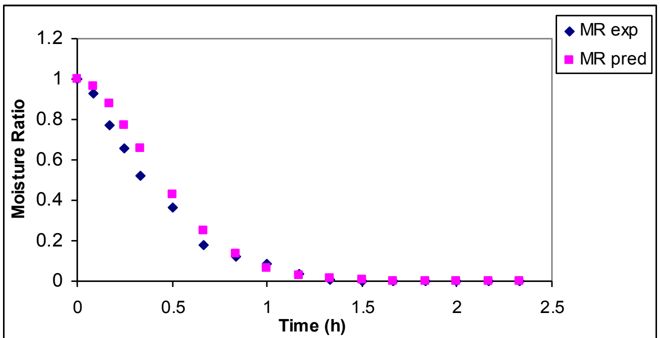

Figure 4 Comparison of experimental and predicted moisture ratio with time at 110 deg C

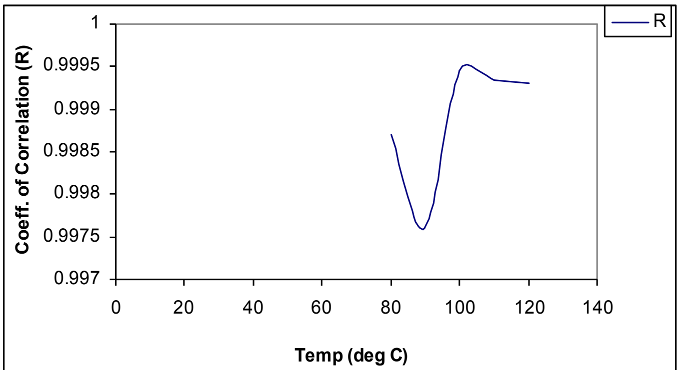

Figure 5 Coefficient of correlation variation with temperature

The model coefficients and statistical analysis results are summarized in Tables 2-6. The R^2 values range between 0.8273 and 0.9989, adjusted R^2 values between 0.8273 and 0.9986, RMSE values between 0.01382 and 0.12630, while SSE range between 0.002666 and 0.4013 . However, in all cases, with the exception of Lewis and Fick's law models, the R^2 values were generally greater than 0.95, indicating a good fit .On the overall, Page and modified Fick's law models gave higher R^2 and lower RMSE and SSE value. Thus, they were chosen, with Page model preferred (for simplicity) to represent the thin layer garification characteristics of unfermented cassava mash. Figs 2-4 compared the experimental data with the predicted ones using Page model, for cassava mash at selected temperatures - 80°C, 90°C and 110°C. It can be observed that the experimental versus predicted moisture ratio for the operational conditions clearly depict good agreement, as they lie close to each other, which proved the suitability of the model. However, a plot of coefficient of correlationtion (R) versus garification (drying) temperature (Fig 5) shows that the best correlation between experimental data and model prediction was obtained at 100°C operational condition.

Conclusion

The garification kinetics of unfermented cassava mash at 80-120°C temperature was studied. Temperature had significant effect on garification rate and hence moisture profile variation. Increase in temperature decreased the garification time. An increase in garification (drying) temperature from 80°C to120°C resulted in decrease in garification time from 2h to 1.667h (that is, 16.7% reduction). Based on non-linear regression analysis, Page and modified Fick's law models were found to be better models for describing the garification characteristics of unfermented cassava mash. A good agreement between experimental data and model prediction was established, while the best correlation was obtained at 100°C operational condition.

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