



## **Drying Modelling, Moisture Diffusivity and Sensory Quality of Thin Layer Dried Beef**

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### **Abstract**

The objective of the present study was to determine the drying kinetics, moisture diffusivity and sensory quality of convective air dried beef. The effect of temperature of drying (30-60°C) and thickness of samples (2.5-10 mm) on the convective thin-layer drying kinetics of beef dried in a cabinet dryer was evaluated. Five semi-theoretical models were fit to the drying experimental data with the aim of predicting drying characteristics of beef and fitting quality of models determined using the standard error of estimate (SEE) and coefficient of determination ( $R^2$ ). Determination of effective moisture diffusivity ( $D_{eff}$ ) from the experimental drying data was done and sensory quality of the optimized dried cooked and uncooked beef samples evaluated. Drying time and rate of drying increased with an increasing temperature but decreased with increased slice thickness. However, there was overlapping of drying curves at 40-50°C. Among the selected models, Page model gave the best prediction of beef drying characteristics. Effective moisture diffusivity ( $D_{eff}$ ) ranged between  $4.2337 \times 10^{-11}$  and  $5.5899 \times 10^{-10}$  m<sup>2</sup>/s, increasing with an increase in air temperature and beef slice thickness. Of all the sensory parameters evaluated, texture was the only attribute that gave significantly different ( $P \leq 0.05$ ) scores between the cooked and uncooked dried beef samples.



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### **Introduction**


Drying is a unit operation whereby heat and mass transfer processes occur simultaneously. Heat penetrates into the product and causes transfer of moisture from within the food product to its surface with subsequent evaporation to the air stream as vapour<sup>1</sup>. The reasons for drying different types of

food products are extremely diverse: from reducing bulk during transportation to increasing the shelf-life of agricultural commodities. As one of the most extensively used methods of food preservation, drying prevents the deterioration of perishable products and ensures their availability during periods of scarcity.

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Some important areas in drying technology include modelling of the dehydration process as well as the drying equipment<sup>2</sup>. Drying simulation for many food products can be represented by a set of mass and heat transfer equations describing the moisture and heat exchange within the product and between the product and air<sup>3</sup>. In various studies, thin-layer drying procedure is quite a reliable tool for evaluating the drying kinetics of a wide range of products<sup>4-6</sup>. Mathematical modelling of the thin layer drying process is critical for managing operating conditions during drying and for predicting the performance of a drying process<sup>7</sup>.

Thin layer drying generally means that drying is done as a single layer of slices or sample particles<sup>2</sup>. The categories of thin layer drying models currently being applied in evaluation of the drying characteristics of food products include; empirical, theoretical and semi-theoretical models. For the empirical and semi-theoretical models only external resistance to movement of moisture from the sample to the air is taken into account<sup>8</sup>, while the theoretical model considers the resistance to moisture movement from within the product<sup>9</sup>. Theoretical models can be used at all process conditions as they clearly explain the drying behaviors of products. However many assumptions are made<sup>10</sup> causing considerable errors. In deriving most semi-theoretical models, the use of Fick's second law of diffusion is very common in literature. However, the validity of these models is only within the experimental conditions applied<sup>11</sup>. Similar to the semi-theoretical models, empirical models are strongly dependent on the drying conditions. However, information given on the drying behavior of the material is limited<sup>12</sup>.

The drying rate of a food product describes the rate of conversion of moisture to vapor by evaporation and depends on the pressure gradient existing between the product and air due to an established temperature gradient<sup>13</sup>. On the other hand, the rate of transfer of moisture internally within a material during drying is described by an effective diffusivity ( $D_{eff}$ ). It depends on the product's moisture content, temperature of the drying air, and the physical nature of the solid. The temperature and moisture content dependence of moisture diffusivity has been verified for various products<sup>14</sup>. Generally, the properties of agricultural products, such and moisture diffusivity

are also required for the ideal dryer design and operation<sup>15</sup>.

Currently, there are many researches reporting on drying modelling and moisture diffusivity of different products as influenced by drying temperature and thickness of the product<sup>4,16-18</sup>. However, similar reports on beef drying are limited. Trujillo *et al.*,<sup>6</sup> used different drying methods to experimentally determine the moisture diffusivity of beef in the range of 6.6-40.4°C whereas Chabbouh *et al.*,<sup>19</sup> examined dehydration of beef during salting and drying steps of Kaddid meat's production. In the present study, drying curves were generated from experimental data of beef drying processes at different temperatures and sample thicknesses. Some selected semi-theoretical models were used to simulate the moisture removal behaviour of beef and the suitability of the models for characterizing the drying process was investigated. Influence of drying temperature and slice thickness on the effective moisture diffusivity of beef was assessed and the sensory quality of the optimized dried beef samples evaluated.

## Methodology

### Preparation of Beef Samples

Beef meat was taken from the hind quarter round of a Zebu (*Bos indicus*) carcass. Its collection and preparation was done as described by Mewa *et al.*,<sup>20</sup> giving 100 mm long and 30 mm wide beef strips with thicknesses of 2.5, 5.0, 7.5 and 10 mm. For determination of the sample's initial moisture content, the oven method was used at 105 °C for 3 h<sup>21</sup>.

### Drying Apparatus

Drying was done using a "Hohenheim HT mini" type of cabinet dryer (*Innotech-ingenieursgesellschaft GmbH*, Altdorf, Germany) containing six perforated trays (420 x 440 mm each). The cabinet drier has a fan for air circulation and an exhaust flap that opens and closes to release exhaust air and attain maximum heating respectively. Heating power was provided by a heater 1.5-3 kW that was connected to a thermostat for automatic switching on and off. The dryer operates using application of the over current principle in which inlet air splits and moves between the trays and over all the layers of beef. This in combination with a registered profiled

layout of the trays ensured the desired uniform air distribution inside the drying chamber. The dryer was started and the set temperature attained before each drying run.

**Experimental**

The drying of beef samples was conducted at temperatures of 30, 40, 50, and 60°C and airflow fixed at a 24 V voltage. About 220 g of the slices of beef with different thicknesses were put on the perforated trays as a single layer for each drying run. The trays and sample weights were noted before being inserted into the drier. To ensure uniform drying conditions, all trays were inserted into the dryer. As drying progressed, the trays were taken out after every 15 min and weighed using an electronic balance (ESA 600, Salter Brecknell, UK) before being returned to the dryer, ensuring the weighing process was done within 1 min. The experiments were repeated 3 times until the dried products had between 10–20% moisture content (dry weight basis) which corresponds to the moisture content range for meat products dried traditionally in tropical countries<sup>22</sup>. The dried beef was allowed to cool and then packaged in low-density polyethylene (LDPE) bags.

**Mathematical Modelling**

During the drying process, the moisture content of beef samples was determined as shown in the following equation:

$$M_t = (W_0 - W) - W_1 / W_1 \quad \dots(1)$$

where  $M_t$  is the product's moisture content (g water/100 g dry matter or % dry weight basis(dwb))

at time t,  $W_0$  is weight of sample before drying (g),  $W$  is the amount of evaporated moisture (g), and  $W_1$  is the sample's dry matter content (g).

Drying curves were represented as moisture content as a function of time and drying rate (DR) as a function of moisture content graphs. The drying rate (DR) of beef slices was determined as given below:

$$DR = (M_t - M_{t+\Delta t}) / \Delta t \quad \dots(2)$$

where  $M_{t+\Delta t}$  is the moisture content at time 't+Δt' (% dwb) and t is time (min).

To the beef experimental data, Fick's diffusion equation was used as shown below.

$$MR = M_t - M_e / M_0 - M_e \quad \dots(3)$$

where MR represents the dimensionless moisture ratio;  $M_e$  is equilibrium moisture content (% dwb);  $M_t$  is moisture content at time t (% dwb) and  $M_0$  is the initial moisture content (% dwb).

Compared to values of  $M_t$  and  $M_0$ , the value of  $M_e$  is relatively smaller<sup>23</sup>, so the equation can be reduced to

$$MR = M_t / M_0 \quad \dots(4)$$

The experimental data were presented as moisture ratio vs drying time graphs and fitted into five different models shown in Table 1.

**Table 1: Mathematical models used for fitting to the experimental drying data**

Model	Equation	References
Newton	MR=exp (-kt)	7
Logarithmic	MR=a exp (-kt)+c	24
Page	MR=exp (-kt <sup>n</sup> )	25,26
Handerson and Pabis	MR=a exp (-kt)	27
Two-term exponential	MR=aexp (-kt)+(1-a)exp(-kat)	28

where t is time (min), a, n and c are drying constants and k is the drying rate constant (min<sup>-1</sup>).

### Statistical Analysis

Drying data analysis was done by using Minitab (Version 17.0, Minitab Inc., USA) software package and Excel 2008 (Microsoft Corporation, USA). Nonlinear regression was done based on the Gauss-Newton algorithm in order to estimate the model parameters. The model's fitting quality to the drying data was assessed using the coefficient of determination ( $R^2$ ) Eq. (5) calculated numerically by Excel and the standard error of estimate (SEE) Eq. (6) generated by Minitab. The ideal value of SEE is "zero", and a small value means that the data points fall closer to the curved fitted line<sup>29</sup>. For goodness of fit of the curve to the equation, a high  $R^2$  value and a low SEE value were taken<sup>30</sup>.

$$R^2 = \frac{\sum_{i=1}^N (MR_{pre,i} - MR_{exp,avg})^2}{\sum_{i=1}^N (MR_{exp,i} - MR_{exp,avg})^2} \quad \dots(5)$$

$$SEE = \sqrt{\frac{\sum_{i=1}^N (MR_{exp,i} - MR_{pre,i})^2}{N}} \quad \dots(6)$$

where N is the number of observations,  $MR_{pre,i}$  is the predicted dimensionless moisture ratio,  $MR_{exp,i}$  is the *i*th experimental moisture ratio and  $MR_{exp,avg}$  is the average experimental moisture ratio

### Effective Moisture Diffusivity ( $D_{eff}$ ) determination

The drying process of most food materials has been described using Fick's second law of diffusion<sup>31</sup> in which the drying process occurs in the falling rate period<sup>32</sup> as given below:

$$\partial M / \partial t = \nabla[D_{eff}(\nabla M)] \quad \dots(7)$$

where effective moisture diffusivity ( $m^2/s$ ) is given by  $D_{eff}$  (the term used to represent all moisture transport mechanisms within a sample), *t* is time (s) and *M* is the local moisture content (% dwb).

Crank,<sup>33</sup> gives the solution of Fick's second law as shown in Eq. (8), considering constant moisture diffusivity, uniform initial moisture distribution and infinite slab geometry<sup>13</sup>.

$$MR = \frac{8}{\pi^2} \sum_{n=0}^{\infty} \frac{1}{(2n+1)^2} \exp\left(-\frac{(2n+1)^2 \pi^2 D_{eff} t}{4L^2}\right) \quad \dots(8)$$

where *n* represents a positive integer and *L* the slab's half thickness (m).

Only the first term of Eq. (8) is normally applied, giving:

$$MR = \frac{8}{\pi^2} \exp\left(-\frac{\pi^2 D_{eff} t}{4L^2}\right) \quad \dots(9)$$

The slope of a normalized plot of experimental moisture ratio,  $\ln(MR)$  vs time (s) can be used to obtain the  $D_{eff}$  of a sample, for corresponding temperature data using the following equation<sup>34</sup>

$$D_{eff} = -\text{slope } 4L^2 / \pi^2 \quad \dots(10)$$

### Sensory Quality Evaluation

For sensory quality evaluation, beef samples with 5.0 mm thickness dried at 60°C were used. These optimized samples were selected based on the physical and microbiological quality studies of dried beef by Mewa *et al.*,<sup>20</sup>. The samples were cooked at 100°C for 20 minutes and cut into cubes of sizes 2 cm x 2 cm x thickness. The cooked and uncooked samples were labelled with random 3-digit codes and presented randomly to panellists consisting of 15 volunteers who had been selected and trained. Uncooked samples of dried beef were observed for their colour, odour, appearance and overall acceptability whereas the cooked samples were evaluated and compared with uncooked control samples for their colour, odour, flavour, texture, appearance and overall acceptability. The beef samples were placed into white saucers and sensory attributes tested on a nine point hedonic scale, where 1 = dislike extremely, 2 = dislike very much, 3 = dislike moderately, 4 = dislike slightly, 5 = neither like nor dislike, 6 = like slightly, 7 = like moderately, 8 = like very much and 9 = like extremely.

### Statistical Analysis

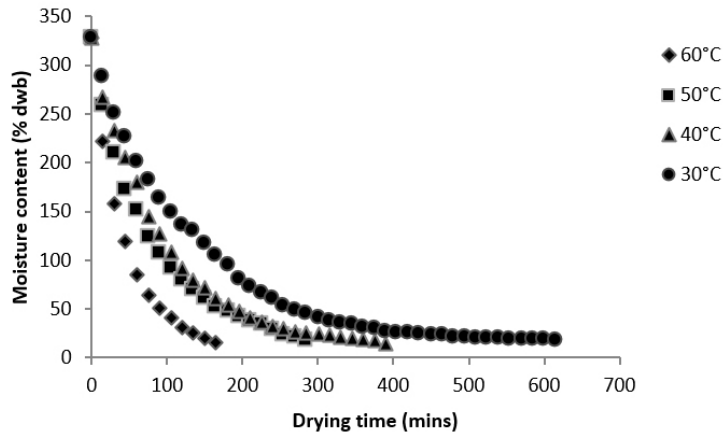
In order determine effect of drying on the sensory quality characteristics beef, the data were analysed using t-test to evaluate the differences in means between cooked and uncooked dried beef samples. The P-value was used to determine the level of significance at  $\alpha \leq 0.05$  using GenStat Edition 13 software (VSN International Ltd, UK).

**Results and Discussion**

**Influence of Air Temperature on Drying Curves of Beef**

The average moisture content of fresh beef was 328.69% (dwb) and drying time for all the beef samples ranged between 2.5 and 30 h. Moisture

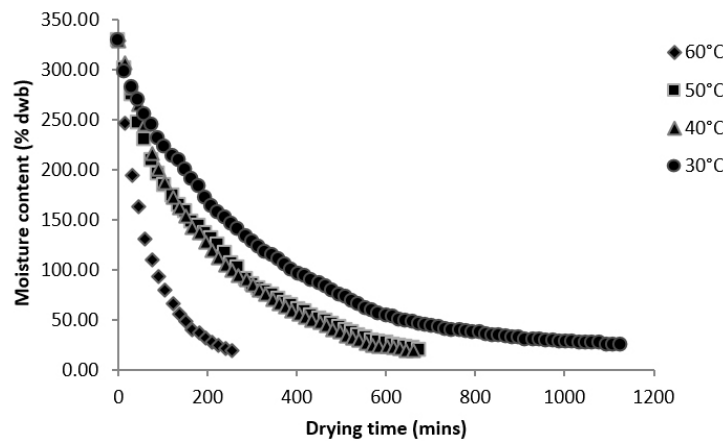
content vs time graph for 2.5 and 5.0 mm thick beef samples are shown in Figures 1 and 2 respectively. To reach the desired moisture contents, drying time was 535, 345, 275 and 150 min at 30, 40, 50 and 60°C, respectively (Figure 1).



**Fig. 1: Drying curve of beef (2.5 mm thick slices) at different temperatures**

The drying process was enhanced by increasing the drying temperature within this temperature range, thus shortening the time of drying. The reduction in time with increasing temperature is attributed to increased thermal energy which speeds up the transfer of water molecules within the meat<sup>35</sup>. The higher temperatures also create large water to vapor

pressure deficit; one of the driving forces for moisture transfer externally: from the surface of the meat to the air<sup>36</sup>. Similar results have been reported for drying curves of other food materials<sup>37,38</sup>. The relationship between temperature and drying time still followed the same trend when the thickness of the meat was increased to 5.0 mm (Figure 2).

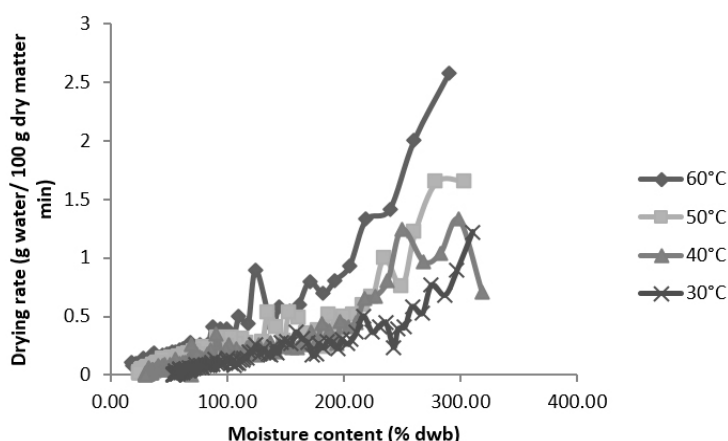


**Fig. 2: Drying curve of beef (5.0 mm thick slices) at different temperatures**

The lowest effect of temperature on reduction of drying time was between 40 and 50°C which resulted in overlapping of drying curves at this temperature range. When drying beef samples, Chabbouh *et al.*,<sup>19</sup> observed that after 30 minutes of dehydration, samples dried at 50°C lost moisture slower than those dried at 40°C. This was explained by the fact that during high temperature drying, rapid evaporation of water from the surface of the meat allowed crust formation due to case hardening, presenting a high resistance to moisture movement from within the meat thus lowering the drying rate<sup>39</sup>. This effect could have been overcome at 60°C due to change in internal meat structure as a result of

changes in physico-chemical properties of beef. Different meat proteins denature during heating at different temperatures, causing changes to the structure of the meat. Denaturation of connective tissue proteins occurs at 60-70°C, which causes the shrinkage of connective tissue fibres and muscle fibres longitudinally, giving large extracellular voids<sup>40</sup>. Together with a higher heat transfer, these could have promoted a faster moisture movement at 60°C.

The drying rate vs moisture content curve for 10 mm thick beef slices at various temperatures is given in Figure 3.



**Fig. 3: Drying characteristic curve of beef (10 mm thick slices) at different temperatures**

There was a continuous decrease of drying rate with decrease in moisture content and drying rate was highest at the highest temperature (60°C). The beef drying process occurred predominantly in the falling rate period and there was no constant drying rate period. The lack of constant rate period may be due to the fact that at the beginning of drying, the surface of meat dries out very quickly, generating a partial barrier which resists free moisture movement<sup>29</sup>. This means that the dominant physical mechanism controlling moisture movement within the beef was diffusion, as obtained for most agricultural products<sup>41</sup>.

#### **Influence of Sample Thickness on Beef Drying Curves**

Influence of beef sample thickness on the drying curves is shown in Figures 4 and 5. Drying time increased with an increased beef sample thickness

(Figure 4). For thicker beef samples, the amount of water that needs to be moved from the center of the meat to its surface is more<sup>42</sup> thus increasing the time needed for drying the slice to the same level of moisture content<sup>31</sup>.

The curve of drying rate vs moisture content at 60°C (Figure 5) shows that beef with the smallest thickness value (2.5 mm) had the highest drying rate as compared to thicker samples.

At the initial stages of drying, drying rates were high and continuously decreased as moisture content decreased for all beef samples (Figures 3 and 5). With the moisture content decreasing continuously during drying, the presence of water in the free form diminishes: the moisture-food interactions become stronger<sup>43</sup> causing a reduction in drying rate.

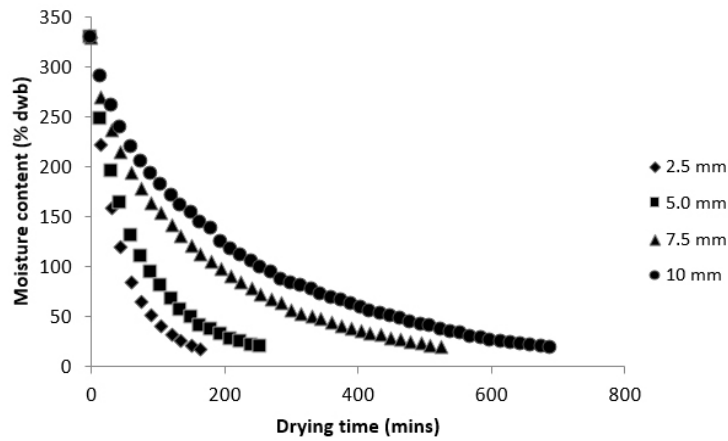


Fig. 4: Drying curve for beef of different thicknesses at 60°C

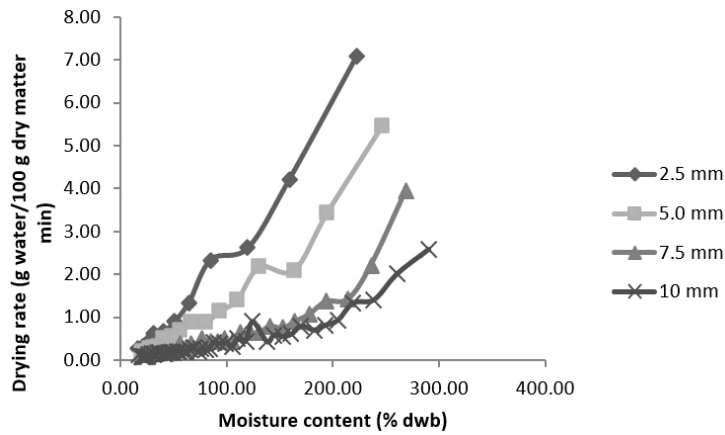


Fig. 5: Drying characteristic curve of beef of different thicknesses at 60°C

**Mathematical Modelling**

The influence of temperature on the regression coefficients for five drying models was represented by the experimental results of 5.0 mm thick beef slices (Table 2). To evaluate the effect of slice thickness, experimental results for beef samples dried at 40°C were randomly selected (Table 3). Specific model constants and statistical parameters ( $R^2$  and SEE), for assessing the goodness of fit of each of the selected drying models are given in Tables 2 and 3. Increasing temperature enhanced the rate of drying (Table 2) as indicated by the  $k$  values for the two-term exponential and the page models. Increasing beef slice thickness reduced the drying rate (Table 3) and the  $k$  values decreased for each of the drying models.

All the five drying models indicated a good fit as they gave coefficient of determination ( $R^2$ ) values higher than 0.99 at all drying conditions (Tables 2 and 3). The models that gave the lowest SEE and the highest  $R^2$  values were the Page and two-term exponential model and were therefore chosen as the most appropriate models for simulating the drying kinetics of beef slices dried at 40°C and of 5 mm thickness. However, for the whole range of experimental drying data (30-60°C) and (2.5-10 mm thickness), Page model had the best fit. The Page model's goodness of fit for characterizing the meat drying process has also been shown by Ikonic *et al.*,<sup>44</sup>.

**Table 2: Regression coefficients of the drying models for 5.0 mm thick beef slices**

Model	temp	Statistical parameters		Model constants			
	(°C)	R <sup>2</sup>	SEE	k(min <sup>-1</sup> )	a	N	c
Newton	30	0.9977	0.0280	0.0030			
	40	0.9967	0.0197	0.0047			
	50	0.9900	0.0310	0.0045			
	60	0.9944	0.0333	0.0141			
Handerson and Pabis	30	0.9977	0.0184	0.0028	0.9244		
	40	0.9967	0.0171	0.0045	0.9662		
	50	0.9943	0.0210	0.0042	0.9239		
	60	0.9944	0.0280	0.0131	0.9387		
Two-term exponential	30	0.9973	0.0135	0.0074	0.3049		
	40	0.9986	0.0101	0.0086	0.3980		
	50	0.9984	0.0101	0.0238	0.1602		
	60	0.9991	0.0102	0.0452	0.2438		
Page	30	0.9978	0.0116	0.0075		0.8489	
	40	0.9983	0.0110	0.0080		0.9044	
	50	0.9975	0.0125	0.0111		0.8388	
	60	0.9995	0.0064	0.0331		0.8089	
Logarithmic	30	0.9987	0.0088	0.0033	0.9064		0.0486
	40	0.9973	0.0137	0.0051	0.9504		0.0354
	50	0.9944	0.0187	0.0047	0.9063		0.0364
	60	0.9973	0.0148	0.0163	0.9119		0.0597

**Table 3: Regression coefficients of the drying models for beef dried at 40°C air temperature**

Model	Meat thickness	Statistical parameters		Model constants			
	(mm)	R <sup>2</sup>	SEE	k(min <sup>-1</sup> )	a	N	c
Newton	2.5	0.9974	0.0213	0.0102			
	5.0	0.9967	0.0197	0.0047			
	7.5	0.9898	0.0516	0.0034			
	10	0.9918	0.0426	0.0022			
Handerson and Pabis	2.5	0.9961	0.0191	0.0098	0.9652		
	5.0	0.9967	0.0171	0.0045	0.9662		
	7.5	0.9769	0.0367	0.0028	0.8510		
	10	0.9860	0.0284	0.0019	0.8853		
Two-term exponential	2.5	0.9968	0.0165	0.1255	0.0748		
	5.0	0.9986	0.0101	0.0086	0.3980		
	7.5	0.9933	0.0311	0.0065	0.2346		
	10	0.9961	0.0197	0.0046	0.2060		
Page	2.5	0.9976	0.0137	0.0169		0.8943	
	5.0	0.9983	0.0110	0.0110		0.9044	
	7.5	0.9944	0.0164	0.0088		0.7140	
	10	0.9967	0.0131	0.0063		0.7723	
Logarithmic	2.5	0.9990	0.0088	0.0112	0.9505		0.0384
	5.0	0.9973	0.0137	0.0051	0.9504		0.0354
	7.5	0.9932	0.0179	0.0039	0.8468		0.0719
	10	0.9937	0.0182	0.0025	0.8634		0.0687



Figures 6 and 7 give a fitted line plot for moisture ratio against time for experimental and predicted data by the Page and two-term exponential models respectively, with the Page model showing a visually good fit.

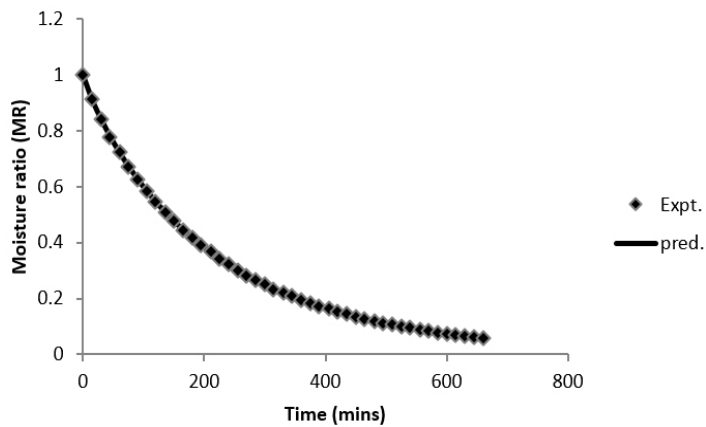
The efficiency of the Page model for evaluating the drying kinetics of beef was further indicated by plotting a curve of predicted moisture ratios vs observed moisture ratios for 5.0 mm thick slices (Figure 8). A good fit for the experimental drying data was given by the predicted model, as indicated

by the linear nature of the curve at 45° slope from the origin<sup>1</sup>.

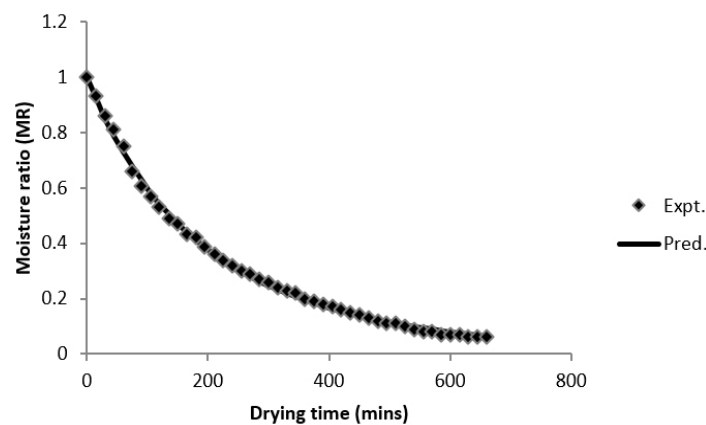
**Effective Moisture Diffusivity ( $D_{eff}$ )**

Figure 9 shows the influence of temperature on the linear relationship between logarithmic moisture ratio vs time for 2.5 mm thick beef slices.

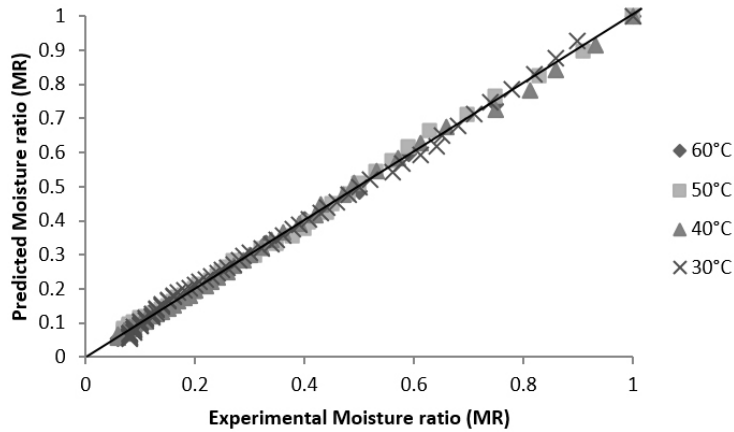
The slopes of the linear graphs were 0.000081, 0.000130, 0.000161 and 0.000297 at 30, 40, 50 and 60°C respectively (Figure 9).



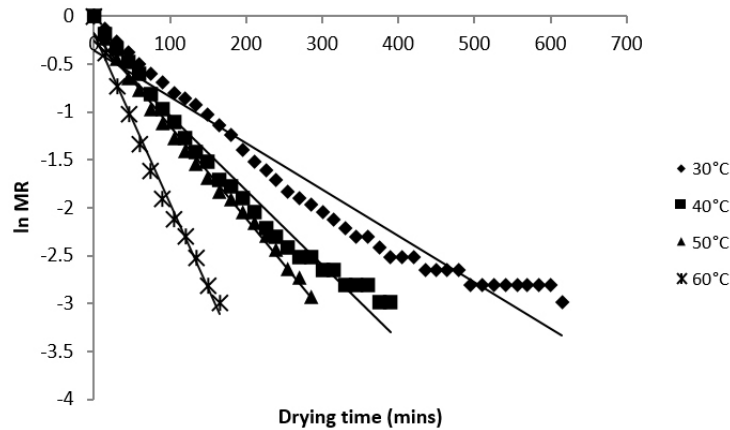
**Fig. 6: Fitted line plot using page model for experimental data at 40°C drying temperature and 5.0 mm slice thickness, where Expt. and pred. are the experimental and predicted moisture ratios respectively**



**Fig. 7: Fitted line plot using Newton model for experimental data at 40°C drying temperature and 5.0 mm slice thickness, where Expt. and pred. are the experimental and predicted moisture ratios respectively**



**Fig. 8: Comparison of predicted MR with experimental MR by page model for beef of 5.0 mm slice thickness dried at different temperatures.**



**Fig. 9: Logarithmic moisture ratio vs drying time graph at various drying temperatures for meat of 2.5 mm thickness**

The  $D_{eff}$  obtained from slope of graphs according to Eq. (9) at all the experimental drying conditions ranged between  $4.2337 \times 10^{-11}$  and  $5.5899 \times 10^{-10}$   $m^2/s$  (Table 4).

The values of  $D_{eff}$  for this study were within the normal range (between  $10^{-11}$  to  $10^{-9}$   $m^2/s$ ) obtained for most agricultural products<sup>14</sup> and can be compared to  $1.20 \times 10^{-11}$  to  $1.15 \times 10^{-10}$   $m^2/s$  for meat products during drying under different conditions<sup>45,46</sup>. From the results, increasing temperature as well as slice thickness increased the  $D_{eff}$  values. Comparable results have been described for a number of food products<sup>4,47,48</sup>. A higher drying temperature increased thermal energy and subsequently increased the activity of water molecules resulting in high moisture

diffusivity<sup>49</sup>. Nguyen and Price,<sup>50</sup> attributed the increase in diffusivity with thickness of a material to the edge effect (side way diffusion) of thicker slices. The diffusion model used in this study, assumed that diffusion took place from inside to the surface of the slab from one direction. This assumption was more applicable for thinner slabs for which the edge effect was negligible thus giving lower moisture diffusivity values.

The diffusion model fit the drying experimental data better at higher temperatures, as shown by the high values of  $R^2$  (Table 4) and the goodness of fit of the curve (Figure 9) at 60°C compared to 30°C. This could be due to change in boundary conditions with change in temperature, particularly at lower

temperatures. At lower temperatures, the surface dries off slowly at a rate controlled partly by surface resistance. At higher temperatures, the surface dries off quickly and water movement is largely controlled by diffusion within the meat<sup>6</sup>. Therefore, the assumption of negligible external resistance for the diffusion model was more applicable at higher temperatures.

**Table 4: Influence of sample thickness and drying temperature on the effective moisture diffusivity ( $D_{eff}$ ) of beef**

Meat thickness (cm)	Drying temperature (°C)	$D_{eff} \times 10^{-10}$ (m <sup>2</sup> /s)	R <sup>2</sup> (ln MR vs time graph)
0.25	30	0.4234	0.9471
	40	0.6987	0.9742
	50	0.8654	0.9936
	60	1.5964	0.9908
0.5	30	0.8385	0.9755
	40	1.5265	0.9975
	50	1.4190	0.9966
	60	3.8269	0.9958
0.75	30	0.8224	0.8624
	40	1.5480	0.9159
	50	2.4671	0.9836
	60	4.0151	0.9954
1.0	30	1.4620	0.9400
	40	2.3220	0.9745
	50	3.0950	0.9835
	60	5.5899	0.9967

#### Sensory quality

Results of sensory analysis of beef samples dried at

60°C drying temperature and 5.0 mm slice thickness. are shown in Table 5.

**Table 5: Mean sensory analysis scores for cooked and uncooked dried beef samples at 60°C drying temperature and 5.0 mm slice thickness**

Sensory parameter	Uncooked beef samples	Cooked beef samples
Colour	6.73±1.03 <sup>a</sup>	7.20±1.52 <sup>a</sup>
Odour	6.87±1.68 <sup>a</sup>	7.20±1.57 <sup>a</sup>
Flavour	7.04±1.36 <sup>a</sup>	6.93±1.49 <sup>a</sup>
Texture	5.01±1.43 <sup>a</sup>	6.87±1.55 <sup>b</sup>
Appearance	7.00±0.93 <sup>a</sup>	6.60±1.24 <sup>a</sup>
Overall acceptability	7.06±1.10 <sup>a</sup>	7.20±1.15 <sup>a</sup>

Means in the same row with the same superscripts are not significantly different at  $P > 0.05$ .

Generally, both the cooked and uncooked dried beef samples scored well (above average) for all the sensory parameters evaluated. Other than the texture scores, there was no significant difference ( $P > 0.05$ ) in the scores of the other sensory quality parameters for the cooked and uncooked beef samples. This meant that the cooked and uncooked dried beef samples were equally acceptable to the consumers in terms of colour, odour, flavour, appearance and overall acceptability. The high texture scores of the samples which were cooked after drying could be attributed to the increased moisture content as a result of the high rehydration capacity of the samples<sup>20</sup>, which gave more tender meat. According to Youssef *et al.*,<sup>51</sup> moisture content is the primary cause of meat texture and an increase in moisture

content increases the tenderness of meat. The effect of moisture content on the compressive behaviour of dried materials was also assessed by Krokida *et al.*,<sup>52</sup>.

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#### Conflict of Interest

There is no conflict of interest to be declared by the authors of this paper.

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