EFFECT OF PRE- DRYING AND FRYING KINETICS OF SWEET POTATO (IPOMOEA BATATAS L.) CHIPS

JAGAMOHAN MEHER1, BRAJA KISHORI MISHRA1, PRAKASH NAYAK2* AND VISHAL SINGH3
1Centre for Food Science and Technology,
Sambalpur University, Jyoti vihar, Burla, Odisha - 768 001, INDIA
2Department of Food Processing Technology,
Central Institute of Technology, Kokrajhar, Assam - 783 370, INDIA
3Department of Agricultural Engineering, School of Agriculture Science,
Centurion University of Technology and Management, Odisha - 761 211, INDIA
e-mail: pk.nayak@cit.ac.in

ABSTRACT
Experiments were conducted at different drying temperature (40, 60 and 80ºC) and frying time (60, 120, 180, 240 and 300 Second). MINITAB statistical software was used to study the statistical analysis of independent and dependent variables in terms of ANOVA. Page’s model is showing best model with high coefficient of regression ($r^2$) 0.9980, 0.9994 and 0.9980 than Exponential models, ($r^2$) 0.9948, 0.9988 and 0.9950 for 20 mm thick slice at a temperature 40, 60 and 80ºC respectively. Oil content of 20 and 30 mm thick sweet potato chips were reported, 68.1 and 68.7% for fresh sample and after drying up to 5% moisture (db), oil content reduced up to 11.4 and 13.2% respectively. Optimum quality of Sweet potato chips (Moisture content 1.25 % db, 39.1 % oil content and hardness 5.02 N) were obtained at fried temperature of 170ºC for 180 seconds and the sensory ratings were observed as $R_a = 5.8$, $R_e = 6.4$, $R_w = 6.1$, $R_n = 6.8$. For colour of fried chips, moisture content and frying time have significant effect ($p<0.05$) and Pre-drying temperature was non-significant ($p>0.05$) for hardness of chips. The chips dried to lower moisture content had more hardness. Based on sensory rating chips dried at 200% db at a temperature of 60ºC and fried at 170ºC for 180 s resulted best quality of chips.

INTRODUCTION
Sweet Potato (Ipomoea batatas L) is a tuberous root plant, originally from the Central and Southern America and classified according to the format, size and internal colour (Peixoto and Miranda, 1984). Root crops like Sweet potato were treated as more potential food in drought tolerant area to promote food security than any other food crops (Gunjan Jha, 2011). Drying is depend upon the factors like moisture content, temperature and relative humidity (Gopalan et al., 1999) and frequently used as industrial preservation method to minimized the water activity to retard the biochemical, chemical and microbiological deterioration of vegetables (Doymaz and Pala, 2003). Natural colour and textural properties of the food materials have an important aspect for consumer attraction which can be preserved with the adequate drying (Dhanapal et al., 2013). Drying characteristics of sweet potato chips were studied with the help of mathematical modelling. Bouchan and Payal (2004) revealed that oil absorption increased with reducing the thickness of food sample (Mehta and Swinburn, 2001) and Gamble et al., (1987), have found that absorption of oil influenced during frying with the variation in slice thickness and moisture content of potato and potato chips packed into polythene bag after frying enhance the quality standards and shelf life (Bal, 1990). The best frying temperature and time for frying vary with the variety, specific gravity of the tubers (Nema et al., 2004) and drying demands special attention for preservation of vitamins and minerals present within fruits and vegetables (Gopalan et al., 1999). Goburdhun and Jhurree (1992) have observed non-significant reduction of fatty acids in treated oils compared to pure soybean oil. Alberto et al., (1998), have studied that frying at lower temperature extended the processing time. Potato chips absorbed nearly 38 % and 65 % of the total oil content during frying and cooling stage respectively (Dura et al., 1998). Rojas et al., (2006), have observed the deep-fat frying had no significant effect on carotenoid contents at any frying conditions. Pedreschi et al., (2007), have studied the soaking of potato slices in sodium chloride solution before frying dramatically reduces acryl amide formation in potato chips. Marique et al., (2003), have studied the colour variation of individual chips during frying for apex, centre and the basal parts. Tendency of people to consume processed and packaged food products are gradually increasing which encourage the food industries to launch new and innovative varieties of food products having lesser oil content and lower cost because high fat content food materials are decreasing the consumer preferences.

In view of the above, this research has been focused on moisture removal pattern with drying and oil absorption during frying of dried chips and as well as studied the fittest combination of frying temperature and moisture of dried chips for minimum oil absorption.
MATERIALS AND METHODS

Materials

The Sweet potato (*Ipomoea batatas* L. Lam) of uniform shape and size without any defect on visual inspection was procured from a local farmer near Central Institute of technology, Kokrajhar, India. Stainless steel core extractor diameters of 3 cm were used for slicing of sweet potato. A laboratory scale Precision rice cooker (Make: RE Pabst CO, U.S.A; Model: PCS 3E) with temperature control (range: 0ºC to 250ºC) and perforated frying container was used as deep fat fryer (Alberto et al., 1998). A solvent extractor (Make: Buchi; Switzerland, Model: E-914) with petroleum ether (BP: 40º - 60ºC) was used to measure the oil content of chips (Meireles, 2009). A digital thermometer was used to record the temperature during frying of sweet potato chips. Moisture content of fresh sweet potato chips has been measured with oven drying method (AOAC, 1999).

Experimental designs

The full factorial experimental design was adopted. The experimental plan is summarized in the following Table 1.

### Methods

Fresh white sweet potato was first peeled using peeler than sliced using a hand operated slicer with thinness of 5 mm. Sweet potato chips were blanched with 0.1 % KMS to retain the colour by preventing the browning (Sra et al., 2011). After blanching, frying was done in two phases. In first phases fresh samples were dried at 40ºC, 60ºC and 80ºC to the predetermined moisture content then fried at 170ºC for different frying times. Fried chips were kept on blotting paper and cooled at room temperature for 5-7 minutes. Then chips were packed in polyethylene bags (thickness 95 micron, density 0.92) and stored at room temperature.

### Hardness and crispness

Hardness of fried Sweet potato chips was measured using a texture analyser (Make: Stable Micro System, UK; Model: TA – Hdi) (Harry Chandler, 1999) with placing the sample on *crisp fracture support rig (HDP/CFS)* using 25kg load cell on heavy duty platform (HDP/90) and using 5mm spherical stainless probe (P/SS). Measurement was carried out at Pre-Test Speed of 1.0 mm/s, Test Speed of 1.0 mm/s, Post-Test Speed of 10.0 mm/s, Distance of 3mm and Trigger Force of...

---

**Table 1: Experimental design with dependent and independent variables**

<table>
<thead>
<tr>
<th>Independent Variables</th>
<th>Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Slice Thickness</td>
<td>5 mm</td>
</tr>
<tr>
<td>Oil type</td>
<td>Refined Oil (Soybean)</td>
</tr>
<tr>
<td>Frying temperature</td>
<td>180ºC</td>
</tr>
<tr>
<td>Drying temperatures</td>
<td>3 (40ºC, 60ºC and 80ºC)</td>
</tr>
<tr>
<td>Time of frying</td>
<td>5 (60, 120, 180, 240, 300 sec)</td>
</tr>
</tbody>
</table>

**Dependent Variables**

- Oil content of fried chips (%).
- Moisture content of fried chips (% db).
- FFA Content of oil.
- Hardness.
- Colour.

**Table 2: Drying behaviour of sweet potato chips at different drying temperatures (40º, 60º and 80º C)**

<table>
<thead>
<tr>
<th>Time (Min)</th>
<th>MC (%) db</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>294.25</td>
</tr>
<tr>
<td>5</td>
<td>272.8</td>
</tr>
<tr>
<td>10</td>
<td>252.08</td>
</tr>
<tr>
<td>15</td>
<td>233.65</td>
</tr>
<tr>
<td>20</td>
<td>218.3</td>
</tr>
<tr>
<td>25</td>
<td>205.59</td>
</tr>
<tr>
<td>30</td>
<td>193.53</td>
</tr>
<tr>
<td>40</td>
<td>172.8</td>
</tr>
<tr>
<td>50</td>
<td>153.36</td>
</tr>
<tr>
<td>60</td>
<td>138.78</td>
</tr>
<tr>
<td>70</td>
<td>121.73</td>
</tr>
<tr>
<td>80</td>
<td>111.56</td>
</tr>
<tr>
<td>90</td>
<td>103.18</td>
</tr>
<tr>
<td>105</td>
<td>91.51</td>
</tr>
<tr>
<td>120</td>
<td>80.86</td>
</tr>
<tr>
<td>135</td>
<td>70.54</td>
</tr>
<tr>
<td>150</td>
<td>61.44</td>
</tr>
<tr>
<td>165</td>
<td>52.66</td>
</tr>
<tr>
<td>195</td>
<td>37.58</td>
</tr>
<tr>
<td>225</td>
<td>25.27</td>
</tr>
<tr>
<td>255</td>
<td>16.47</td>
</tr>
<tr>
<td>285</td>
<td>8.54</td>
</tr>
<tr>
<td>315</td>
<td>5.5</td>
</tr>
<tr>
<td>345</td>
<td>2.66</td>
</tr>
</tbody>
</table>

**Table 2: Drying behaviour of sweet potato chips at different drying temperatures (40º, 60º and 80º C)**

**MC = Moisture Content, db = Dry basis and Min = Minute**
Auto - 5g. Here samples were selecting with most uniformity, i.e. in terms of size and shape, and removed from packets after 12 hours of frying. The initial fracture of the sample was indicated by the first peak force. The maximum peak force during the first compression cycle was taken as the hardness. Each experiment was repeated three times and the data reported were the average of the same.

**Determination of Free Fatty Acids (FFA)**

The percentage of free fatty acids was calculated using the following expression (Ranganna, 2005).

\[ FFA = \frac{28.2 \times TV \times N}{W} \]  

Where,

- **TV** = Volume of NaOH used in ml,
- **N** = Normality of NaOH,
- **W** = Weight of sample in gm

**Data Analysis**

Study the effect of drying on frying behaviour of Sweet potato chips with statistical correlation of data in terms of analysis of variance (ANOVA) between independent and dependent variables was conducted using MINITAB statistical software. ANOVA predicted the level of significance with which a particular operating variable influence the given process. The software measured p-value, where the value (1-p) represented the probability at which the effect of that operating variable was significant. The lower the value of p, the more significantly that operating variables influences the particular process. In this study p-value < 0.05 (indicating 95% confidence level) was taken as basis for deciding whether the effect of a particular variable is significant or not.

**RESULTS AND DISCUSSION**

**Drying behaviour**

The drying behavior of Sweet potato chips were determined for 30 mm slices at temperatures of 40º, 60º and 80ºC to analyze the effect of drying conditions on drying rate. Average drying rate was computed with help of following approximation as suggested (Nema and Prasad, 2004).

\[ \Delta t = \frac{Mt - Mt + \Delta t}{\Delta t} \]  

Where,  

- **Mt** = Moisture content at time t,  
- **Mt + Δt** = Moisture content at time t + Δt,  
- **Δt** = Time interval

The average drying rate represents the rate of moisture removal from time t to t + Δt, attributed to the middle of the time interval. The average rate of drying is expected to continuously decrease with time except for constant rate drying periods. The drying behaviour of chips at different temperatures is shown in Table 1. The table depicts that drying takes place under falling rate and no constant rate period is clearly identifiable. Drying of sweet potato chips up to 2.66, 2.51 and 2.56 (%, db) at temperature of 40, 60 and 80ºC required 345,
and 105 minutes respectively (Table 1), indicates that drying time was decreased with increasing of drying temperature and also noticed that moisture removal rate is maximum but colour and crispiness were degraded in the case of drying at 80ºC.

**Modelling of drying behaviour**

The studies carried out on drying, diffusion is generally accepted to be the main mechanism during the transport of moisture to be evaporated from the surface. As the constant rate period was absent in drying of Sweet potato slices (Table 1), the following two commonly used models, which describe the drying behaviour in falling rate period, were tested.

\[
MR = e^{-kt} \quad \text{(Exponential model)} \quad \quad \quad [3]
\]

\[
MR = e^{-ktn} \quad \text{(Page’s model)} \quad \quad \quad [4]
\]

Where,  
\[
MR = \frac{M - M_e}{M_i - M_e}
\]

It can be noted from the drying data that the final moisture content is very small compared to the initial moisture content of 294.25 % db. Equilibrium moisture content is assumed to be negligible and MR is calculated as \(\frac{M_i - M}{M_i - M_e}\). These models were fitted to the experimental data using ‘Curve Expert 1.3’ software to determine the models constants. ‘A’ is the exponential model constant very close to 1 (0.95 to 1.02) and that the value of ‘n’ in page’s model is also close to 1 (0.86 to 1.16) means effect of the both two models are close to each other.

The suitability of the two models was examined on the basis of standard error of estimation (SEE) and coefficient of regression (r²). The model constants along with r² and SEE are presented in the Table 2.

For 20 cm thick slices of chips, coefficient of regression (r²) reported 0.9980, 0.9994 and 0.9980 (Page’s Model) and 0.9948, 0.9988 and 0.9950 (Exponential Model) respectively indicates that for all the drying experiments, r² value for Page’s model are slightly higher and standard error of estimation (SEE) values are less than exponential model concluded that, page’s model is fittest to adequate drying (Table 2).

**Moisture losses during frying**

ANOVA for final moisture content of chips (Table 3) indicates that the effect of diameter (p = 0.043), initial moisture content (p = 0.000) and frying time (p = 0.000) on final moisture content of chips is significant but non-significant for drying temperature (p = 0.604). As the effect of pre-drying temperature on the final moisture content of fried chips is non-significant, the data corresponding to pre-drying temperature is averaged out. Oil absorption characteristics of the sweet potato chips increased with decreasing moisture during frying and obtained most appropriate frying at temperature of 170ºC for 180 second.

**Oil absorption during frying**

The typical representation of the oil content on dry basis is inadequate, when moisture was constant during frying. Therefore, the oil content is converted to moisture free basis (% mfb) along with dry basis oil content. In all the cases, oil content increases with time of frying. Therefore, oil absorption is maximum for fresh (un-dried) slices and minimum for the slices dried to less than 5 % db moisture content. Also as ANOVA indicated the affect of pre-drying temperature on oil absorption is insignificant. From the data it appears that pre-dry the samples is preferred to minimize the oil absorption during frying. The Sweet potato slices dried to less than 5 % db have oil content of 11.4 and 13.2 % mfb and without drying as fresh absorb higher oil content of 68.1 and 68.7 % mfb for 20 and 30 mm diameter during frying respectively.

**Characteristics of Sweet potato Chips after Frying**

**Colour**

Colour of the sample is specified with colour code ranged between 1 (lightest) and 5 (darkest). It was determined by visually comparing with a computer generated colour chart. ANOVA of colour of fried chips (Table 4) shows that the effect...
of diameter \( (p = 0.299) \) and temperature \( (p = 0.056) \) is non-significant where as moisture content \( (p = 0.000) \) and time of frying \( (p = 0.000) \) has a significant effect on colour of chips revealed that moisture content and time of frying influenced the colour of fried chips.

**Hardness**

Hardness of fried Sweet potato chips was measured using a Texture analyzer with three replicates. The ANOVA of hardness (Table 5) depicts that the effect of moisture content and frying time on hardness is significant \( (p<0.05) \), whereas the pre-drying temperature has non-significant effect \( (p>0.05) \).

**Optimization for fittest model**

Production of Sweet potato chips on industrial scale need to be optimized the best fit combination of significant factors. The overall acceptability was considered as main responses for optimization. Due to consideration of all the significant factors as drying temperature, drying time and final moisture content, optimized condition of drying was observed for 60°C, 150 second and 2.51 (% db) respectively and data table of operating conditions and various sensory ratings were rearranged in order of decreasing on the basis of overall acceptability.

The operating conditions resulting in \( R_h \) above 80 percentile \( (i.e., R_h \text{ in top 20%}) \) are identified. Similarly, the sensory ratings based on the other characteristics above 80 percentile are also identified. These are shown in bold in the Table 6.

Research findings also reveals that the operating conditions (Chips diameter, Moisture content before frying and Pre-drying temperature), of drying at moisture content of 200 (% db), temperature of 60°C and frying at 170°C for 180s, results the best quality Sweet potato chips which contain moisture of 1.25 % db and oil of 39.1 (% db) with a moderate crispy nature having hardness of 5.02 N (Table 6). At these conditions the sensory ratings are \( R_h = 5.8, R_o = 6.4, R_m = 6.1, R_c = 6.8 \).

**REFERENCES**


NATIONAL ENVIRONMENTALISTS ASSOCIATION

AND ITS OFFICIAL ORGAN

The Bioscan
An International Quarterly Journal of Life Science

Started in 1988, the National Environmentalists Association has been reorganized in 2006 and now is an association functioning with full vigour and new impetus to meet its objectives with the co-operation of like minded environment conscious academicians from different parts of the nation.

MEMBERSHIP OF THE ASSOCIATION

Any graduate having interest in environmental conservation and protection of nature and natural resources can be the member of the association.

To be the member of the association the application form given below should be duly filled up and sent to the Secretary of the association along with a demand draft of Rs. 750/- (After the 25% concession) for annual membership and Rs. 7500/- (After the 25% concession) for life membership.

FELLOWSHIP OF THE ASSOCIATION

The Association is awarding FELLOWSHIP to deserving academicians / researchers /scientists who are LIFE MEMBERS of the Association after reviewing their bio-data by the Fellows and the Executive Members of the association. The Fellows are privileged to write F.N.E.A. after their names. The prestigious Fellowship also includes a citation in recognition of their contribution to society in general and the endeavour for the noble cause of environment in particular.

AWARDS OF THE ASSOCIATION

The Association in its Seminars and Conferences provides the following category of awards on annual basis.

1. **The young scientists award**: It is given to the researchers below the age of 35 years.

2. **The senior scientists award**: It is awarded to the academicians above the age of 35 years.

3. **The best paper award**: It is awarded to the contributor of the Journal The Bioscan during the year.

4. **The best paper presentation award**: It is awarded to the scholar whose presentation is the best other than the young scientist category.

5. **The best oration award**: It is awarded to the scholar who delivered invited speech.

6. **The recognition award**: It is awarded to those senior scholars who have contributed to the subject through their continued research.

7. **The environmental awareness award**: It is awarded to those who, apart from their research contribution, have done commendable extension work for environmental betterment.

The number of recipients of award in each category will vary depending upon the recommendation of the panel of judges and the executive committee. The association has the provision to institute awards in the name of persons for whom a with desired sum is donated in consultation with the executive body.

PUBLICATION OF THE ASSOCIATION

In order to provide a platform to a vast group of researchers to express their views and finding of research as well as to promote the attitude of quality research among the scholars of younger generation the association publishes an international quarterly journal – THE BIOSCAN (ISSN:0973-7049). For the benefit of the potential contributors instructions to authors is given separately in this journal. However, the details regarding the journal and also the association can be seen on our website www.thebioscan.in.

Cont. ...... P. 538