Global Journal of Engineering Education

The evaporation of water and oil absorption during the vacuum frying of fruit chips

Jamaluddin†, Budi Rahardjo‡, Pudji Hastuti‡, Rochmadi‡ & Gufran D. Dirawan†

Makassar State University, South Sulawesi, Indonesia†
Gajah Mada University, Yogyakarta, Indonesia‡

ABSTRACT: Fruit chips are now popular and enjoyed by consumers world-wide due to their unique properties: they are tasty, savoury and crunchy. During the frying process, heat and mass transfer occur simultaneously. Heat transfer occurs from the hot oil to the surface and propagates into the solids, so that the water content in the solids comes to the surface of the solids as vapour, while at the same time, the solids absorb the oil. The aim of this research was to develop a mathematical model of heat and mass transfer when frying fruit pieces in a vacuum. The samples were jackfruit fried at a temperature of 70-100^{O}C, in an old frying pan for 15-60 minutes and with a vacuum pressure of 80-90 kPa. Changes in water content, oil content, starch and sucrose concentration, when reducing sugar levels and β-carotene levels in solids were taken into account during the model's development. The model is based on the concept of *lump capacitance*. The shape is reflected in first order ordinary differential equations that are solved with the aid of the Runge-Kutta numerical method. Simulation results, including the rise in temperature, moisture reduction and absorption of oil during the frying process in a vacuum, illustrate that mathematical models can be developed quite well, when used to explain the phenomenon of heat and mass transfer during the frying process of fruit in a vacuum. This experimental procedure may be particularly useful for postgraduate education.

Keywords: Evaporation of water, oil absorption, vacuum frying

INTRODUCTION

When frying fruit pieces in a vacuum, heat and mass transfer occur simultaneously. Heat transfer arises from the hot oil to the surface and propagates into the fruit, so that the water content in the fruit comes to the surface of the fruit in the form of water vapour. Then, at the same time, the fruit absorbs the oil. These conditions lead to many changes in the fruit, both physical and chemical. Physical changes result in it ripening faster, developing a crunchy texture and developing flavour, whereas chemical changes occur through the evaporation of water, oil absorption, starch gelatinisation, protein denaturation, non-enzymatic browning and discolouration of the fried ingredients from their natural colour (Farkas et al [1], Yamsaengsung and Moreira [2].

Various approaches have been made to describe the conditions and changes that occur during the process of frying food. Ateba and Mittal [3] and Supriyanto [4] developed a model of mass transfer and heat emerging simultaneously during the process of frying food. However, their study only took into account the presence of heat energy for gelatinisation process, phase changes and cooking ingredients, while the thermal energy for the process of denaturation, browning and changing the natural colour of the product had not been incorporated into the model. The model developed described the changes that occur during the frying process, but it did not explain the relationship between the characteristics of the raw materials and processes with changes in the final product.

Farkas et al [5] developed a model of heat and mass transfer when frying potato chips. Ni and Datta [6] developed a model to simulate a multiphase porous medium for frying potato chips based on the Whitaker approach [7]. This model involves the flow caused by pressure, but the model does not include the oil phase, and does not take into account changes in the porosity of the product and its influence on the heat and mass transfer system. Some research has revealed discoloration during heating or frying foods. Garayo and Moreira [8], conducted a study on frying potatoes in a vacuum and, then, explained that the dark colour and red on the potato chips product is due to the reaction between the amine group and the reduction of sugar (non-enzymatic browning reaction/Maillard reaction).

A mathematical model has been developed also with regard to frying products (Rice and Gamble [9], Ateba and Mittal [3], Moreira et al [10], Dincer and Yildiz [11]). However, the developed model has not, so far, shown a relationship between the frying conditions with discoloration caused by changes in water content, sucrose content, reducing sugar content and β-carotene levels in the product. Nevertheless, undesirable colour changes occur in some food during frying, for example, in fruit chips and vegetables. These conditions can be minimised, if the process can be controlled by observing changes in the material during the frying process.

The purpose of this research was to develop a mathematical model of heat and mass transfer occurring during the fruit frying process in a vacuum when taking into account the moisture content, oil content, starch, sucrose concentration, and when the reduction of sugar levels and β-carotene content of the raw materials is imputed into the model.

RESEARCH METHODS

Basis Theory and Model Development

The heat and mass transfer is modelled with physical models based on *lump capacitance*. Figure 1 presents the mass balance and heat that flows through the solid material of thickness L and surface area A_φ.

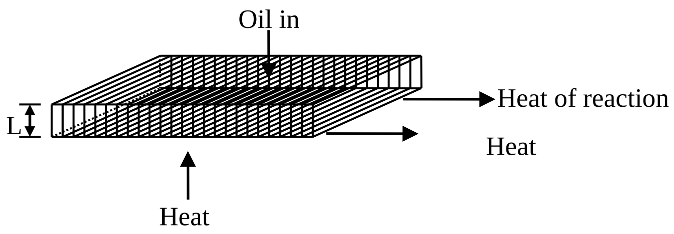


Figure 1: Balance of mass and heat in a sample of solids volume element.

The main assumptions used in preparing the heat and mass transfer models are as follows:

1. The temperature and concentration of ingredients (water, oil, starch, sucrose, sugar reduction and β-carotene) in the solids are considered equal in all solids, including at the surface of solids.
2. The oil absorption occurs during the whole frying process, while during cooling, it is ignored.

The mass balance of each component in the solids volume element based on Figure 1, is structured as follows:

The rate of change in the concentration of water in solids is:

$$\frac{d\overline{C}_a}{dt} = -k_g\left(C_a.C_{pt}\right) - \frac{2}{L}k_{pf}\left(C_a^* - C_a\right) \tag{1}$$

The rate of change in the oil concentration in solids is:

$$\frac{d\overline{C}_m}{dt} = \frac{2}{L}k_m\left(C_m^* - C_m\right) \tag{2}$$

The rate of change in the concentration of starch in solids is:

$$\frac{d\overline{C}_{pt}}{dt} = -k_g(C_a.C_{pt}) \tag{3}$$

The rate of change of the concentration of sucrose in solids is:

$$\frac{d\overline{C}_{sk}}{dt} = -k_{km}(C_{sk}) \tag{4}$$

The rate of change in the concentration of reducing sugar in solids is:

$$\frac{d\overline{C}_{gr}}{dt} = -k_{ml}(C_{gr}.C_{am}) \tag{5}$$

The rate of change of β-carotene concentration in solids is:

$$\frac{d\overline{C}_{\beta k}}{dt} = -k_{\beta k}(C_{\beta k}) \tag{6}$$

The initial condition for Equation (1) to Equation (6) is: t = 0,

$$\overline{C}_a = C_{a,awal}, \overline{C}_m = 0, \overline{C}_{pt} = C_{pt,awal}, \overline{C}_{sk} = C_{sk,awal}, \overline{C}_{gr} = C_{gr,awal}, \overline{C}_{\beta k} = C_{\beta k,awal}$$

Heat Transfer

The heat balance on the solids volume element, based on Figure 1, thickness L, surface area Aφ, is described as follows:

$$\frac{dT}{dt} = \frac{1}{C_p \rho}\left(2h(T_m - T) + \frac{2}{L} r_m \left[C_p (T_m - T)\right] - \frac{2}{L} r_{pf} .\lambda - r_g \Delta H_{Rg} - r_{km} \Delta H_{Rkm} - r_{ml} \Delta H_{rml} - r_{\beta k} \Delta H_{R\beta-k}\right) \quad (7)$$

The initial condition is:

$$t = 0 \longrightarrow T = T\ awal \quad (8)$$

Starting from Equation (1), all the equations to Equation (7) can be solved simultaneously by means of numerical solutions, using the MATLAB program. The evaluation parameters with h constant, Cp, ρ, k_g, k_{pf}, k_m, λ and ΔH_{rg} are performed using the means of minimising the sum of square of errors (Hooke and Jeeves [12]).

Materials

The main ingredient used in this research was jackfruit (based on the properties of the fruit), which has a dense flesh, is juicy and not particularly aromatic. Jackfruit can be purchased from farmers through fruit traders in traditional markets in New Town Yogyakarta, 12-24 hours after harvest.

The main tool is a vacuum fryer equipped with a data logger computer system created especially for a laboratory scale and designed according to the needs of this research, while there is a supporting tool for the analysis of water content, oil content, starch, sucrose concentration, reducing sugar content and β-carotene levels and Universal Testing Machine Do-FBO.STS (Zwich/Zo.5).

Observation and Analysis

Temperature observations - during the process of frying in oil, the temperature changes when observed at the surface and at the midpoint of the sample, with a K type thermocouple data logger equipped with reading and having $\pm 1^{O}$C accuracy.

Analysis of water content - the water content of the sample before and after frying was analysed using the vacuum oven method [13], the sample size of 10 g were made by 3.

Analysis of the oil content - the oil levels before and after frying samples were analysed using the Soxhlet method [13], with the material previously smoothed by means of distillation Soxhlet, before being extracted for three to four hours, and the oven balanced until it reached a constant weight.

Analysis of starch, sucrose and reducing sugars - samples of starch, sucrose and reducing sugars before and after frying were analysed by a special method (spectrophotometry, Nelson-Somogyi method [13]).

Analisis β-karoten - samples of β-carotene levels before and after frying were analysed by the Carr Price method.

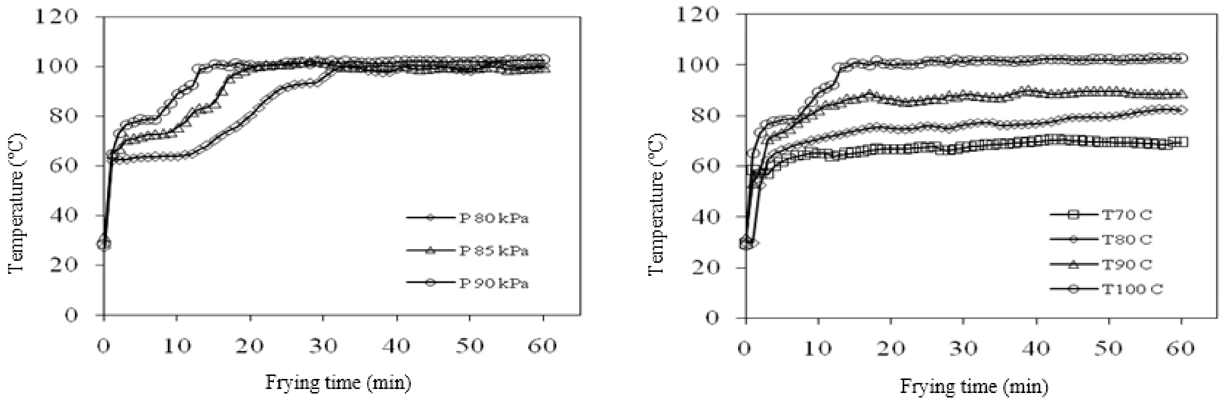
The numerical solution - numerical methods were used to solve ordinary first order differential Equations (1) to (7) simultaneously with the help of the MATLAB program. They included: mass transfer consisting of changes in moisture content, oil content, starch, sucrose concentration, reducing sugar levels and levels of β-carotene, as well as heat transfer.

RESULTS AND DISCUSSION

Changes in Temperature, Evaporation of Water and Oil Absorption during Vacuum Frying

Changes in the temperature of the jackfruit are presented in Figures 2a and 2b. The vacuum pressure and oil temperature during frying were kept at 90 kPa and 100^{O}C. From the graphs, it appears that the jackfruit's temperature increased very rapidly from the beginning to five minutes.

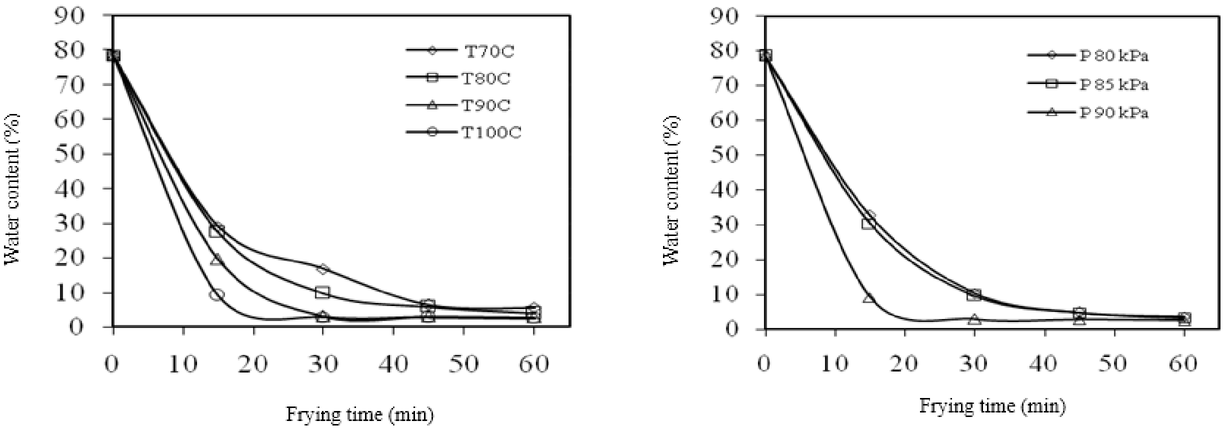
After 5 to 10 minutes it appears that there was a tendency for the solids to maintain the temperature at 60 to 80^{O}C for some time. At the time when the temperature of the jackfruit solids reached a temperature of 60 to 80^{O}C, the thermal energy was used for the water evaporation process.



a) b)

Figure 2: History of the jackfruit solids' temperature during the frying process; a) temperature variation in the vacuum pressure of 90 kPa; and b) vacuum pressure variation in the oil temperature of 100^{O} C.

The period of evaporation is affected by temperature and vacuum pressure, the higher the temperature and vacuum pressure, the shorter the evaporation period, and on the other hand, the lower the temperature and vacuum pressure, the longer the evaporation period. Due to the frying process with a higher temperature and vacuum pressure, the temperature of the boiling point of water also becomes higher, so that the heat energy that goes into solids tends to be large when compared with lower temperature and vacuum pressure, and *vice versa*. So, solids are fried at a high temperature and high vacuum pressure would be quicker to mature when compared with a low temperature and low vacuum pressure. After the evaporation of water from the solids is completed, the retained temperature slowly rises to near the temperature of the cooking oil until the end of the process. At that time, the temperature in the solids tends to be constant, apparently more heat energy is used for cooking and the evaporation process until the end of the frying process or until the solids become ripe. The results are consistent with the research by Winarno and Fardiaz [14], which revealed that if the temperature is low, a longer heating time occur, otherwise, if high temperature heating is used, the required time will be shorter.

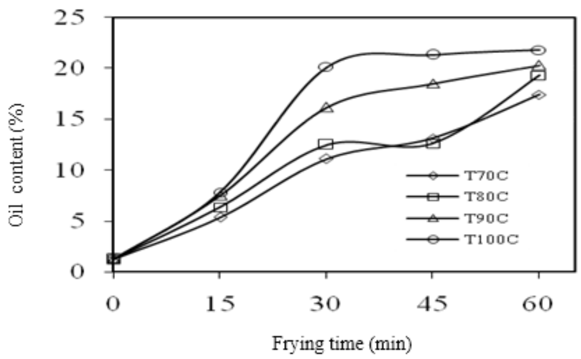


a) b)

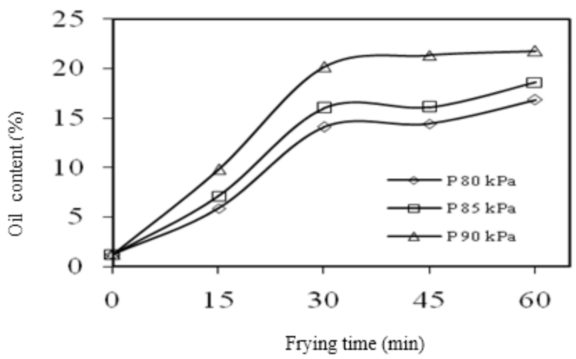
Figure 3: Decrease of the water content of jackfruit solids during frying; a) temperature variation in the vacuum pressure of 90 kPa; and b) vacuum pressure variation in the oil temperature of 100^{O}C.

Moisture reduction in jackfruit solids during vacuum frying is presented in Figures 3a and 3b. Based on the graphs, it appears that with higher temperatures and pressure, there is a tendency for the vacuum evaporation rate of water to occur more quickly. This study supports Garayo and Moreira [8] and explains that potatoes fried at a higher temperature with the same vacuum pressure require less time to reach the same moisture content. In addition, it appears that the rate of decline in the water content of jackfruit solids is approximately constant until the water content reaches 15%, then, it slows down after the water content drops below 15%. The decreased water levels, associated with long periods seem to keep the solids' temperature constant at 60 to 80 ^{O}C. High temperature in solids begins to increase once the water level is approaching 15%, then, it reaches the frying temperature. The rate of temperature increase of solids towards the frying temperature appears to resemble the temperature rise at the beginning of the heating.

Increased levels of oil in jackfruit solids during frying are presented in Figure 4a and 4b. The increased oil content in the solids seems equal to the rate of decrease in the water content. The change point in the rate of oil absorption generally takes place rapidly until the 15th minute and a few moments later it slows and, eventually, becomes constant. The oil absorption rate of the change point seems to be influenced by temperature and vacuum pressure: the higher the temperature and vacuum pressure, the more oil the solids absorb, and *vice versa*, the lower the temperature and vacuum pressure, the less oil the solids absorb.



a)

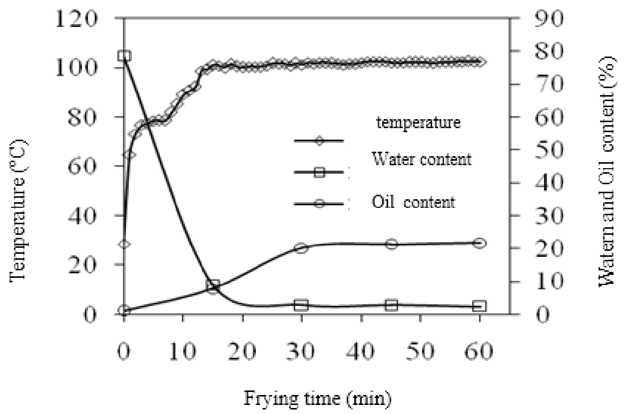


b)

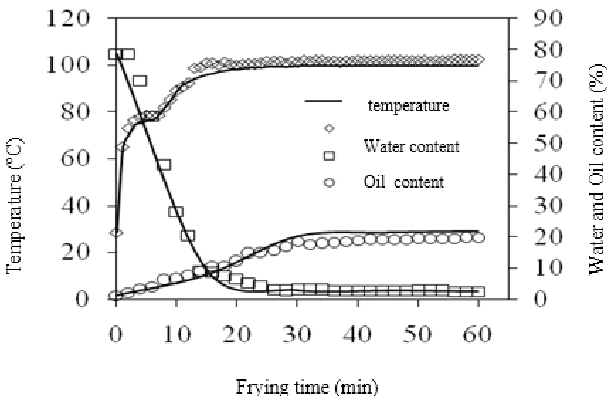
Figure 4: Increased levels of oil in jackfruit solids; a) temperature variation in the vacuum pressure of 90 kPa; and b) vacuum pressure variation in the oil temperature of 100^{O}C.

The results of this study are in accordance with research by Math et al [15] that stated that in a frying pan with a higher oil temperature, the oil absorption is greater than if the oil temperature is lower. But, research by Saguy et al [16], seems to be at odds with this study although the data are not convincing. It seems that the longer and lower the temperature of the cooking oil, the higher the oil content in fried potato products. It goes slowly from the beginning of the frying oil absorption in solids when the water level is not constant until it reaches 15%, but shortly after, the moisture content is below 15%, and the oil absorption process in solids becomes faster. This change seems to be of relevance when there is a decrease in the water content in solids. The incorporation rate of temperature, evaporation of water and oil absorption may show the relationship in these three processes.

Merger and Simulation of Changes in Temperature, Evaporation of Water and Oil Absorption during Frying in Vacuum



a)



b)

Figure 5: History temperature, moisture reduction and oil absorption simultaneously in jackfruit solids during the frying process at the oil temperature of 100^{O}C with the vacuum pressure of 90 kPa; a) observational data; and b) the results of simulation models.

Figure 5a presents the incorporation rate of temperature change, moisture reduction and oil absorption during frying jackfruit solids at the temperature of 100^{O}C with the vacuum pressure of 90 kPa. From the graphs, three processes of heat transfer relationships can be seen: decreased levels of water and oil absorption during frying jackfruit solids in a vacuum. The increase in temperature starts from the initial temperature and changes rapidly until it reaches a temperature of 80^{O}C. In these conditions, most of the heat energy received is used to raise the temperature of the fried jackfruit solids. By the time the temperature reaches 80^{O}C, which is the boiling temperature of water at a pressure of 90 kPa in a vacuum, the temperature is maintained at 80^{O}C as long as there is free water in the solids, so that all the heat supply is used for the evaporation of water. When the oil temperature is below 60 ^{O}C, it seems that the evaporation that occurs does not mean an increase after the temperature above 60^{O}C.

If there is a limited presence of free water and bound water in the form of live cells in a solid structure, it appears that the evaporation rate decreases, so that the temperature of solids increases until it reaches or is equal to the frying temperature. At that time, the frying process of jackfruit solids is on-going and a further evaporation process takes place. Similarly, the same process appears with the oil absorption. The presence of water in the oil appears to affect the absorption in solids, where the oil can get into the pores of the solids left by the water. At first, the oil absorption takes place slowly during the evaporation of water and is not constant when the water content is above 15%, but sometime after, the evaporation of water becomes constant with the moisture content. Below 15%, an increase in the rate of absorption of oil is high enough. Such changes appear to occur when the water level reaches 10% on the condition of the water coming out and leaving the pores of the solids to be replaced by oil.

The calculation of the temperature rise, reduction of water content in solids and oil absorption during frying jackfruit is carried out in Equation (1) to Equation (7), solved simultaneously when using the numerical method of Runge-Kutta. The results of the simulation temperature rise, reduction of water content and oil absorption during frying jackfruit simultaneously in a vacuum based on changes in the value of the constant h, C_p, ρ, k_g, k_{pf}, k_m, λ and ΔH_{rg} are included in Table 1. Changes in the constants sought in the data can be done by using the optimisation method (Hooke and Jeeves [12]).

Table 1. Changes in the value of the constant heat transfer, the rate of evaporation of water and oil absorption in jackfruit during vacuum frying.

Constants	Notation	Unit	Value
Density	ρ	Kg/m^3	2,775
Heat type	C_p	$J/kg\ ^OC$	3919,3
Heat transfer coefficient	h	$W/m^2\ ^OC$	1091,6
Gelatinisation reaction rate constants	k_g	m/s	167.10^{-4}
Mass transfer coefficient phase change	k_{pf}	m/s	10^{-4}
Mass transfer coefficient oil	k_m	m/s	7.10^{-4}
Energy for the reaction process of gelatinisation	ΔH_{rg}	J/kg	$3,34.10^{-2}$
Energy for the phase change process	λ	J/kg	$6,13.10^4$

At a temperature of solids used simulation boundary conditions that the temperature will remain 80^{O}C if the water content is greater than 10%. During the temperature rise of preheating to a temperature of 80^{O}C, constant temperature until the water level reaches 10%. After that, a further temperature rise is calculated by using the convection coefficient h. Up to the evaporation temperature of less than 80^{O}C, significant evaporation is considered to take place. But, after the evaporation temperature reaches 80^{O}C and until the moisture content reaches 10% and less than 10% the use rate of constant mass of water is moved by convection of KPF. As for the rate of mass oil move, before the water level reaches 10% and after the water content of less than 10%, oil km mass transfer coefficient is used.

CONCLUSIONS

The conclusion that can be drawn from these results is that the vacuum pressure and temperature affect the rate of temperature change, evaporation of water and oil absorption during frying of jackfruit solids. The heat transfer rate and the rate of oil absorption are affected by the rate of evaporation of water in accordance with the water content in solids. When the water content in solids is still above 15%, there is a tendency for the solids' temperature to be constant at 60 to 80^{O}C, which is the temperature at which water boils in a vacuum with a pressure of 80 to 90 kPa. Similarly, the oil absorption rate increases when the rate of evaporation decreases, when the water content in solids is under 15%. The mathematical model of heat and mass transfer developed can be applied to estimate the temperature rise, decline in water content and oil absorption by using changes in physical properties during frying.

LIST OF SYMBOLS

A_φ	Surface area	m^2
C	concentration	kg/m^3 total
C_p	Heat type	$J/kg\ ^OC$
h	Heat transfer coefficient	$W/m^2\ ^OC$
k	Constant velocity or mass transfer coefficient	m/s
ΔH	Energy for the process	J/kg
L	Thickness	M
r	Reaction velocity	kg/s
T	Temperatures in the material	^OC
T_m	Oil temperature at the surface of the material	^OC
ρ	Density	Kg/m^3
Subscripts		
a	The water in the solids	
a*	Water outside the solids	
am	Amino acids	
G	Gelatinisation	
gr	Reducing sugar	
km	Caramelisation	
m	Oil in solids	

m_l	Maillard
m*	Oil out solids
pf	Mass change of phase
pt	Starch
sk	Sucrose
β-k	β- carotene

REFERENCES

1. Farkas, B.E., Singh, R.P. and Rumsey, T.R., Modelling heat and mass transfer in immersion frying. I, model development. *J. of Food Engng.*, 29, **2**, 211-226 (1996).
2. Yamsaengsung, R. and Moriera, R.G., Modelling the transport phenomena and structural changes during deep fat frying. Part I: model development. *J. of Food Engng.*, 53, **1**, 1-10 (2002).
3. Ateba, P. and Mittal, G.S., Modelling the deep-fat frying of beef meatballs. *Inter. J. of Food Science and Technol.*, 29, **4**, 429-440 (1994).
4. Supriyanto, The Process of Frying Food Sources of Starch: Amylose Ratio Studies - Amylopectin. Disertasi. Sekolah Pascasarjana. UGM Yogyakarta (2007).
5. Farkas, B.E., Singh, R.P. and Rumsey, T.R., Modelling heat and mass transfer in immersion frying. II, model solution and verification. *J. of Food Engng.*, 29, **2**, 227-248 (1996).
6. Ni, H. and Datta, A.K., Moisture, oil and energy transport during deep frying of food materials. *Trans. of the Institution of Chemical Engineers*, 77, 194-203 (1999).
7. Whitaker, S., Simultaneous heat, mass and momentum transfer in porous media: A theory of drying. *Advances in Heat Transfer*, 13, 119-203 (1977).
8. Garayo, J. and Moriera, R., Vacuum fraying of potato chips. *J. of Food Engng.*, 55, **2**, 181-191 (2002).
9. Rice, P. and Gamble, M.H., Modelling moisture loss during potato slice frying. *Inter. J. of Food Science Technol.*, 24, **2**, 183-187 (1989).
10. Moreira, R.G., Palau, J., Sweat, V,E. and Sun, X., Thermal and physical properties of tortilla chips as a function of frying time. *J. of Food Processing and Preservation*, 19, **3**, 175-189 (1995).
11. Dincer, I. and Yildiz, M., Modelling of thermal and moisture diffusion in cylindrically shaped sausages during frying. *J. of Food Engng.*, 28, **1**, 35-44 (1996).
12. Hooke, R. and Jeeves, T.A., Direct search solution of numerical and statistical problems. *J. of Association for Computing Machinery*, 8, 212-229 (1961).
13. AOAC, Official Methods Analysis of the Associations of Official Analytical Chemists. Association of Official Analytical Chemists, Washington, DC (1970).
14. Winarno., F.G. and Fardiaz, S., *Introduction to Food Technology*. (Edn II), Jakarta: Gramedia (1992).
15. Math, R.G., Velu, V., Nagender, A. and Rao, D.G., Effect of frying conditions on moisture, fat and density of papad. *J. of Food Engng*., 64, **4**, 429-434 (2004).
16. Saguy, I.S., Ufheil, G. and Livings, S., Oil Uptake in Deep-Fat Frying: a Review. Ole´Agineux Corps Gras Lipides, 5, 30-35. SAS Institute, Inc. 1990. SAS Procedures Guide (3rd Edn). Version 6. SAS Institute, Inc., Cary, NC (1998).

BIOGRAPHIES

Jamaluddin was born in Enrekang in Sulawesi, the southern province of Indonesia, on 23 July 1967. He worked as a lecturer in agricultural technology education courses in the Engineering Faculty at the State University Makassar with functional positions as an Associate Professor. He graduated with a Bachelor's degree in Education of Mechanical Engineering (Production) from IKIP ujung pandang in 1991, with a Master's degree in Technology of Handling and Agriculture Processing from the University of Gajah Mada in 1998 and with a Doctor's degree in Technology Management and Processing of Agricultural Products from the University of Gajah Mada in 2011. In the last ten years, he was conferred with a first level outstanding lecturers award by the Engineering Faculty in 2012, and in the same year was also awarded a third level award of outstanding lecturers at Makassar State of University.

Budi Rahardjo is a Professor in Agricultural and Biosystems Engineering Department of Agricultural and Biosystems Engineering in the Faculty of Agricultural Technology at Gadjah Mada University. Prof. Rahardjo graduated with a Bachelor's degree in the field of agricultural engineering in the Faculty of Agricultural Technology at Gadjah Mada University (Indonesia). He graduated with a Master and Doctor of Agricultural Engineering from the Ohio State University (Colombus, USA). Prof. Rahardjo specialises in food processing and food engineering; he has professional affiliations in the Indonesian Association of Agricultural Engineering, the Association of Asian Agricultural Engineering and the American Society of Agricultural and Biological Engineers.

Rochmadi is a lecturer in the Department of Chemical Engineering in the Faculty of Engineering at Gadjah Mada University. Prof. Rochmadi graduated with a Bachelor's degree and a Master's degree from the Faculty of Chemical Engineering at Gadjah Mada University (Indonesia) in 1980 and 1985, respectively. He received his doctorate in chemical engineering from the Imperial College of Science and Technology (United Kingdom) in 1991. He has work experience in Gadjah Mada University as Secretary of the Department of Chemical Engineering (April 1999 - March 2003), Assistant Director I (Sector Programme) PAU-Science Engineering (July 1995 - June 2001), Head of the Laboratory of Polymer Technology (July 1993 - present), Chairman of the Laboratory of Heat and Mass Transfer, PAU-Engineering Sciences (June 1993 - June 1995), Administrator of Master Programme in Chemical Engineering (June 1993 - June 2000) and a lecturer (March 1981 - present), in the Faculty of Engineering. He holds society memberships of the IchemE International since 2009, and the PII National, since 1981.

Pudji Hastuti is a lecturer in the Department of Food and Agricultural Product Technology, in the Faculty of Agricultural Technology at Gadjah Mada University. She graduated with her first Bachelor's degree in Technology of Agriculture at Gadjah Mada University (Indonesia) in 1977, and a second Bachelor's degree in Food Science and Technology/Agriculture and Food at the University of Reading, United Kingdom in 1993. She received her Master of Food Science and Technology from Gadjah Mada University (Indonesia) in 1984.

Gufran Darma Dirawan is a lecturer in the Department of Population and Environmental Education (Postgraduate Programme) at Makassar State University. He graduated with a Bachelor's degree in Civil Engineering at Hasanuddin University, Indonesia, in 1995. He received his Graduate Diploma in Environmental Management Development from the Australian National University, Canberra, Australia, in 2000, a Master's degree in Environmental Management Development from the same university in 2001, and a PhD in Management of Natural Resources and the Environment from Bogor Agriculture Institute, Indonesia, in 2006. He became a Professor of Environmental Management at Makassar State University in 2010.