UNIVERSITI PUTRA MALAYSIA

***MATHEMATICAL MODELLING OF COMBINED INFRARED AND HOT AIR DRYING OF SLICED SWEET POTATO* (Ipomoea batatas L.)**

ONWUDE DANIEL IROEMEHA CHIKWENDU

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By

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Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfillment of the Requirements for the Degree of Doctor of Philosophy

July 2018

DEDICATION

With all my love, I dedicate this PhD thesis to my precious mum and to the blessed memory of my late dad.

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfillment of the requirements for the degree of Doctor of Philosophy

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July 2018

Chairman : Associate Professor Norhashila Hashim, PhD
Faculty : Engineering

Combined infrared and hot-air drying method has been identified to be able to improve both energy efficiency and quality of dried agricultural crops. However, being a novel drying technique, studies on its application to the drying of industrial crops such as sweet potato are still limited. Particularly, the drying conditions, combination strategies and modelling studies are not properly investigated. This research investigated the potential of combined infrared and hot-air in drying of sweet potato (*Ipomoea batatas L.*) slices. The combined computer vision (CV) and laser-light backscattering imaging was adopted to monitor the shrinkage and quality attributes. The specific energy consumption (SEC), colour and microstructural changes of sweet potato (*Ipomoea batatas L.*) based on experimental set-up of different combined IR and HAD strategies (Simultaneous IR and HAD, two-stage HAD + IR, two-stage IR + HAD, intermittent IR and HAD) were investigated. Mathematical models based on Lambert's equation of electromagnetics for single-phase and multiphase change during the combined IR and HAD of sweet potato were developed and evaluated, using finite element methods in both COMSOL and MATLAB software.

The combined IR and HAD resulted in 69.34 – 85.59% reduction in the SEC of HAD. The specific energy consumption during simultaneous IR and HAD, two-stage HAD+IR, two-stage IR+HAD, and intermittent IR and HAD varied between 174.10-310.93 MJ/kg, 95.80-177.48 MJ/kg, 56.30-68.36 MJ/kg, 99.61-149.18 MJ/kg, respectively. The intermittent IR and HAD was demonstrated to be the most suitable combination strategy based on the combined effect of total drying time, shrinkage, SEC and total colour change. The moisture and temperature distribution results of the single-phase model for simultaneous and intermittent IR and HAD of sweet potato agreed well with experimental drying data. The multiphase simulations results indicated that the model could adequately describe the underling drying mechanism

of combined IR and HAD. The water and vapour fluxes due to gas diffusion and gas pressure resulted to increased drying efficiency of combined IR and HAD. The understanding of these phenomenon could be used to improve food quality and increase energy efficiency. The automation and optimization ability could also be increased.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Doktor Falsafah

MATEMATIK TERHADAP GABUNGAN PENGERINGAN INFRAMERAH DAN OLAKAN UDARA PANAS UNTUK KEPINGAN UBI KELEDEK (*Ipomoea batatas* L.)

Oleh

ONWUDE DANIEL IROEMEHA CHIKWENDU

Julai 2018

Pengerusi : Profesor Madya Norhashila Hashim, PhD
Fakulti : Kejuruteraan

Kaedah gabungan inframerah dan pengeringan secara udara panas telah dikenalpasti mampu untuk meningkatkan kecekapan tenaga dan kualiti keluaran pertanian kering. Walau bagaimanapun, sebagai satu teknik pengeringan novel, kajian berkaitan penggunaannya terhadap pengeringan industri tanaman seperti ubi keledek adalah masih terhad. Khususnya, kinetik pengeringan, keadaan pengeringan, strategi gabungan dan kajian pemodelan tidak dikaji secara teliti. Kajian ini menyelidik potensi teknik gabungan inframerah dan udara panas untuk pengeringan kepingan ubi keledek (*Ipomoea batatas L.*). Gabungan visi komputer (CV) dan pengimejan penghamburan cahaya laser telah diguna pakai untuk memantau proses pengecutan dan sifat kualiti. Kinetik pengeringan, penggunaan tenaga yang tertentu (SEC), warna dan perubahan mikrostruktur ubi keledek berdasarkan penyediaan eksperimen dengan strategi gabungan inframerah (IR) dan pengeringan udara panas (HAD) berbeza (IR dan HAD serentak, dua-peringkat HAD + IR, dua peringkat IR + HAD, IR dan HAD secara selang seli) telah dikaji. Teori pemodelan berasaskan persamaan Lambert tentang elektromagnetik untuk perubahan fasa tunggal dan perubahan fasa yang berbilang semasa gabungan IR dan HAD ubi keledek dibangunkan menggunakan kaedah unsur terhingga dalam perisian COMSOL dan MATLAB. Gabungan IR dan HAD menghasilkankan pengurangan 69.34-85.59% SEC HAD. Penggunaan tenaga yang tertentu semasa IR dan HAD serentak, HAD + IR dua-peringkat, dua peringkat IR + HAD, dan IR dan HAD berselang seli berbagai-bagai dengan masing-masing antara 174.10-310.93 MJ/kg, 95.80-177.48 MJ/kg, 56.30-68.36 MJ/kg, 99.61-149.18 MJ/kg. IR dan HAD yang berselang seli telah menunjukkan sebagai strategi gabungan paling sesuai berdasarkan kesan gabungan jumlah masa pengeringan, pengecutan, SEC dan jumlah perubahan warna. Keputusan pengagihan lembapan dan suhu model fasa tunggal untuk IR dan HAD serentak dan berselang seli keledek adalah selari dengan data pengeringan secara eksperimen. Keputusan kesahihan selanjutnya

menunjukkan bahawa model yang dibangunkan dalam kajian ini menjelaskan secukupnya mekanisme pengeringan secara gabungan IR dan HAD. Fluks air dan wap yang disebabkan oleh penyebaran dan tekanan gas menghasilkan peningkatan kecekapan pengeringan secara gabungan IR dan HAD. Pemahaman tentang fenomena ini boleh digunakan untuk meningkatkan kualiti makanan dan meningkatkan kecekapan tenaga. Keupayaan automasi dan pengoptimuman juga dapat ditingkatkan.

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This thesis was submitted to the Senate of the Universiti Putra Malaysia and has been accepted as fulfillment of the requirement for the degree of Doctor of Philosophy. The members of the Supervisory Committee were as follows:

Norhashila Hashim, PhD
Associate Professor
Faculty of Engineering
Universiti Putra Malaysia
(Chairman)

Khalina Abdan, PhD
Associate Professor
Faculty of Engineering
Universiti Putra Malaysia
(Member)

Rimfiel Janius, PhD
Associate Professor
Faculty of Engineering
Universiti Putra Malaysia
(Member)

Guagnan Chen, PhD
Associate Professor
Faculty of Health, Engineering and Sciences
University of South Queensland
(Member)

____
ROBIAH BINTI YUNUS, PhD
Professor and Dean
School of Graduate Studies
Universiti Putra Malaysia

Date:

Declaration by Members of Supervisory Committee

This is to confirm that:

- the research conducted and the writing of this thesis was under our supervision;
- supervision responsibilities as stated in the Universiti Putra Malaysia (Graduate Studies) Rules 2003 (Revision 2012-2013) were adhered to.

Signature:	
Name of Chairman of Supervisory Committee:	Associate Professor Dr. Norhashila Hashim

Signature:	
Name of Member of Supervisory Committee:	Associate Professor Dr. Khalina Abdan

Signature:	
Name of Member of Supervisory Committee:	Associate Professor Dr. Rimfiel Janius

Signature:	
Name of Member of Supervisory Committee:	Associate Professor Dr. Guagnan Chen

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LIST OF ABBREVIATIONS

M_0	Initial moisture content *(kg water/ kg dry solid)*
M_e	Equilibrium moisture content *(kg water/ kg dry solid)*
M or M_t	Moisture content at any time *t (kg water/ kg dry solid)*
D; D_{eff}; D_{efft}	Effective moisture diffusivity *(m^2 s^{-1})*
E_a	Activation energy *(kJ/mol)*
t	Time *(s)*
r	Radius of cylinder
z	Direction of thickness
h^*	Half thickness sample *(m)*
D_{efy}; D_s; D_{effs}	Effective diffusivity with shrinkage *(m^2 s^{-1})*
V	Sample volume *(m^3)*
V_0	Initial volume of sample *(m^3)*
R^2 or r^2	Coefficient of determination
r ; R	Correlation coefficient
SSE	Sum square error
$RMSE$	Root mean square error
$RMSEP$	Root mean square error of prediction
x^2	Reduced chi-square
MBE	Mean bias error
w	Width (mm) or Width of emitter *(mm)*
$h; z$	Thickness *(mm)*
L	Length *(mm)* or Length of emitter *(mm)*
A	Area *(mm^2)*

T	Temperature *(°C)*
T_a	Ambient temperature *(°C)*
V	Air velocity *(m/s)*
RH	Relative humidity *(%)*
P_d	Power density *(W)*
P	Power intensity *(W/m^2)*
I	Solar intensity *(kW/m^2)*
FIR	Far infrared radiation
IRD	Infrared dryer
IR	Infrared radiation
HAD	Hot-air drying
CHAD	Convective hot-air drying
CD	Convective drying
IR-HAD; IR-CHAD	Simultaneous infrared and hot-air drying
HAD+IR	Two-stage sequential hot-air and infrared drying
IR+HAD	Two-stage sequential infrared and hot-air drying
IIR+HAD; IIRCD	Intermittent infrared and hot-air drying
SEM	Scanning electron microscope
$w.b$	Wet basis
$d.b$	Dry basis
$ANOVA$	Analysis of variance
SEC	Specific energy consumption *(MJ/kg)*
PR	Pulse ratio
DR	Drying rate *(kg/kg min)*
t_{on}	Total infrared "on" time (s)

t_{off}	Total "off" time of infrared radiation (s)
t_{tol}	Total time of drying *(h)*
d_e	Distance between IR emitter and sample *(cm)*
T	Temperature *(°C or K)*
v	Air velocity *(m/s)*
HA	Hot-air
SR	Shrinkage ratio
L*	Lightness index
a*	Redness index
b*	Yellowness index
$\triangle E$	Total colour change
D_{eff}	Effective moisture diffusivity *(m^2/s)*
SR	Shrinkage ratio
V_s	Volumetric shrinkage ratio
S_v	Degree of sample shrinkage *(%)*
A_b	Illuminated area
P	Perimeter
A_0	Initial surface area
P_0	Initial perimeter
A_{0b}	Initial illuminated area
ANN	Artificial neural network
E_1	Energy required for the infrared bulb emitter *(MJ),*
E_2	Energy required for the hot air *(MJ)*
M_w	Total moisture removed by drying *(kg)* or Moisture content (wet basis)

c	Moisture concentration (kg/m^3)
T	Temperature *(^oC)*
ρ	Density (kg/m^3)
C_p ; C_{ps}	Specific heat capacity of sweet potato (J/kgK)
k	Thermal conductivity (W/mK)
QIF	Volumetric infrared heat source *(W/m^3)*
q_{IF}	Heat absorbed by sweet potato *(W)*
α	Absorption coefficient
δ	Infrared penetration depth *(mm)*
P_0	Radiation heat transfer *(W)*
ε_{IF}	Infrared emitter emissivity
ε_s	Emissivity of the sweet potato
$F_{s,IF}$	View factor between the infrared emitter surface and sweet potato
$F_{IF,w}$	View factor between infrared emitter and the wall
$F_{w,s}$	View factor between sweet potato and the wall
σ	Stefan-Boltzmann radiation constant
T_{IF}	Temperature of the emitter *(^oC or K)*
T_s	Temperature of the sample surface *(^oC or K)*
R_t	Total thermal resistivity
m_0	Initial mass of sample *(kg)*
m_d	Mass of dried sample *(kg)*
h_c; h_T	Heat transfer coefficient *(W/m^2K)*
h_m	Mass transfer coefficient *(m/s)*
T_{air}; T_∞	Drying air temperature *(^oC or K)*

$H_{vap};\ h_{fg}$	latent heat of evaporation (J/kg)
c_b	Bulk moisture concentration (kg/m^3)
C_p	Specific heat capacity (J/kgK)
k_p	Thermal conductivity of product (W/mK)
A_0	Initial surface area of sweet potato *(m^2)*
A	Surface area of sweet potato at time, *t* (m^2)
ρ_w	Density of water (kg/m^3)
ρ_s	Density of sweet potato (kg/m^3)
E_a	Activation energy (kJ/mol)
R_g	Universal gas constant (J/mol/K)
D_0	Diffusion integration constant (m^2/s)
ρ_a	Density of air (kg/m^3)
μ_a	Dynamic viscosity of air *(kg/ m.s)*
μ_w	Dynamic viscosity of water *(kg/ m.s)*
μ_v	Dynamic viscosity of vapour *(kg/ m.s)*
v	Drying air velocity *(m/s)*
k_a	Thermal conductivity of air *(W/ (K.m))*
C_{pa}	Specific heat capacity of air (J/kgK)
a_w	Water activity
ΔV	Sum of the gas, water and solid volume (m^3)
ΔV_g	Volume of gas (m^3)
ΔV_w	Volume of water (m^3)
ΔV_s	Volume of solids (m^3)
φ	Apparent porosity
S_g	Gas saturation

S_w	Water saturation
K_{evap}	Evaporation constant
M_v	Molecular weight of vapour *(kg mol^{-1})*
M_a	Molecular weight of air *(kg mol^{-1})*
M_g	Molecular weight of gas *(kg mol^{-1})*
P_{amb}	Ambient pressure *(Pa)*
P_w	Total flux of liquid water
R_{evap}	Liquid water evaporation to water vapour (kg/m^3s)
K_g	Intrinsic permeability of gas *(m^2)*
P_{vair}	Air vapour pressure *(Pa)*
D_{va}	Binary diffusivity (m^2/s)
C_{pv}	Specific heat capacity of vapour (J/kgK)
C_{pw}	Specific heat capacity of water (J/kgK)
$K_{th,s}$	Thermal conductivity of sweet potato (W/mK)
$K_{th,g}$	Thermal conductivity of gas (W/mK)
$K_{th,w}$	Thermal conductivity of water (W/mK)
W_v	Vapour mass fraction
MLP	Multi-layered perceptrons
CCD	Charge-coupled device
CV	Computer vision
PLS	Partial least square regression

CHAPTER 1

INTRODUCTION

1.1 Background of Study

Sweet potato is the fourth most important food crop after the cereal wheat, rice and corn in global crop production. According to FAO statistics, the world output in 2016 was 105 million tons harvested on 8.6 million hectares of land with an average yield of 12.2 tonne/ha (FAO, 2018). In developing countries, Asia in particular has focused on sweet potato's potential for continued rapid expansion in the decades ahead (Singh, 2008; Walker et al., 2011). Opportunities for industries are a topic of added interest given the magnitude of future food requirements in the wake of rising incomes, growing urbanization, and the sheer numbers of Asian consumers (Scott and Suarez, 2012).

Most food and agro-allied industries around the world, including Malaysia, rely heavily on sweet potato slices to produce flour, starch, flake, crisps and chips. Sweet potato is rich in vitamins, minerals, antioxidant, dietary fibre and fatty acids which are important to human health (Andre et al., 2017; Lee & Lee, 2017; Nabubuya, 2012; Oladejo et al., 2017). The processing of sweet potato into flour, flake, starch and other bakery products is the most satisfactory method of creating a product that is not only functionally adequate, but also remains stable for an extended period without spoilage (Hanim et al., 2014). Sweet potato flour can also be used to produce cakes, muffins, cookies and noodles, extruded snacks and chiffons (Zainun et al., 2005). Overall, sweet potato can enhance human health, improve the revenue of farmers and processors, and ultimately generate wealth for a country. However, the efficient production of sweet potato and its products has been limited due to inadequate processing and preservation techniques (Yadav et al., 2006a; Yadav et al., 2006b). Therefore, adequate processing and preservation techniques for agricultural crops, sweet potato in particular, must be developed to reduce wastage, promote food security and improve product quality.

Drying is one of the oldest and important food processing and preservation method. It involves the removal of moisture from a material due to simultaneous heat and mass transfer (Hashim et al., 2014; Akpinar, 2006). Drying increases shelf life, reduces product weight and volume thereby reducing the cost of storage, packaging and transportation (Doymaz, 2005). Drying may also be the most important unit operation for most industrial processes (Onwude et al., 2016). However, it is the most energy intensive process that could consume up to 10-25% of total energy required in most industrial processes (Chua et al., 2000), and about 10-15% of the total energy demands of food and agro-allied industries in most developing countries (Klemes et al., 2008). Furthermore, drying affects the quality of dried products including discoloration, loss of flavour, textural changes, degradation of bioactive compounds, changes in shape and physical appearance (Erbay & Icier, 2009; Firouzi et al., 2017; Salarikia et al., 2016). Recently, novel hybrid drying technologies have emerged as potential methods to reduce the energy demands and improve the qualities of dried food and agricultural commodities.

The combination of infrared (IR) heating and hot-air drying (HAD) technique have been investigated as a viable method for obtaining high quality dried food stuffs, including fruits, vegetables and grains (Chayjan et al.,2014; Hafezi et al., 2015; Hebbar et al., 2004; Pekken et al., 2013; Tog, 2006). However, as the application of this drying technique on agricultural crops is still in its infancy, several aspects regarding to its effectiveness in order to encourage commercialisation and industrial acceptability have not yet been investigated and fully understood. Therefore, a comprehensive study that will include the potential of applying non-destructive monitoring approach, the most suitable combination strategy and the development of adequate theoretical model in oder to improve efficiency becomes indispensable.

Physical properties of agricultural crops, including moisture content, shrinkage and colour, are important quality parameters that affect the acceptability of dried agricultural products (Onwude et al., 2017). The monitoring of these physical properties of fruits and vegetables during drying is still carried out using conventional techniques.

Conventional method of monitoring the drying process of most fruits and vegetables includes measuring the changes in sample weight using weighing balance. This approach is erroneous as the sample may lose or gain some moisture content due to heat loss or gain in the surrounding. Besides, alternative practice involving contact measurements, like the use of colorimeter still lack the accuracy to explain the overall quality in varying samples during drying. More so, the quality of the final product is affected by changes in the textural and structural properties. These changes, which is caused by shrinkage of samples, is determined by analyzing the sample size and change in volume (Yadollahinia & Jahangiri, 2009), which is often done destructively. The shrinkage values obtained using these destructive methods could affect the accuracy and efficiency of the drying process in terms of optimization and modelling, as they are required drying parameters. Therefore, monitoring the shrinkage and changes in color parameters during drying process will need a more efficient, non-destructive and rapid equipment to overcome the problem. Consequently, inspection systems for fruits and vegetables during drying by using the backscattering imaging system couple with computer vision becomes a viable alternative for conventional methods.

Computer vision (CV) has increasingly been applied in most post-harvest processes, including drying. It has been used as a non-destructive method for detecting various quality properties of different agricultural crops, such as ripeness, colour, moisture content, shrinkage, firmness and soluble solids contents (SSC) (Hashim et al., 2010; Mohd Ali, Hashim et al., 2017). Although, CV may be suitable in monitoring the quality properties of agricultural commodities during several postharvest processes, it is inadequate in describing the changes in the tissue of agriculture crops during drying. Thus, the application of laser-light backscattering imaging system as a rapid and concise non-destructive monitoring technique becomes a viable option.

Laser-light induced backscattering imaging has recently been developed for monitoring changes in the quality parameters during the post-harvest processing of fruits and vegetables (Adebayo et al., 2016). This technique has the potential to provide a low-cost rapid evaluation for the drying process. The combination of computer vision and laser-light backscattering imaging technique provides an even more novel, rapid and objective medium of quality evaluation during drying. However, studies using these non-destructive imaging approach in monitoring the changes in shrinkage and colour parameters during drying of sweet potato slices do not exist.

Apart from the non-destructive monitoring of quality parameters during combined IR and HAD of sweet potato, the overall quality of the dried products also relies on the different modes of heat interaction such as simultaneous heating, intermittent heating and the two-stage sequential heating (Zhang et al., 2017b). This is because of the vast differences in internal and external properties of agricultural commodities, resulting in different degree of deterioration, discolouration, energy requirement, drying rate, shrinkage amongst others. It is therefore pertinent to determine the most appropriate infrared and hot-air combination strategies in order to improve the overall drying efficiency and enhance the quality of dried sweet potato slices. In these regards, the most suitable infrared and hot-air combination strategies have not been developed.

Mathematical modelling studies of the different combination strategies for IR and HAD of agricultural crops remain under-developed. In fact, there is no mathematical modelling study on the IR and HAD of sweet potato. The determination of mathematical modelling parameters regarding to changes in the physical properties of agricultural crops during drying is still carried out using conventional montoring techniques. There is no modelling study on the use of non-destructive method to monitor the changes in product's physical properties during IR and HAD. The development of physics-based theoritical models for IR and HAD of agricultural crops is essential to give a physical interpretation of the heat and mass transfer mechanism, improve the efficiency of the drying process, optimise the drying process and to improve the final product quality. Therefore, this study aims to develop a comprehensive study including mathematical models for IR and HAD of sweet potato slices.

1.2 Problem Statement

Conventional drying methods are widely used for preserving and processing of agricultural commodities in the industry. In particular, HAD method is most common for commercial and industrial processing of food. This drying technique is naturally harmless and non-toxic. However, it is energy demanding and could affect the quality of final product due to longer drying duration (Łechtańska et al., 2015; Zhang et al., 2017). Consequently, novel and innovative drying techniques have gained significant interest in recent years. IR and HAD of agricultural crops have been studied as one of the novel drying techniques with particular emphasis on its design, and drying kinetics. There are also few studies on its energy demand and effects of drying condition on product final quality. However, a comparative study on IR and HAD of agricultural crops is required. This is important in identifying the most suitable drying condition for optimising IR and HAD parameters.

Considering the complex nature of IR and convective heating, couple with the complexity of food product properties, an appropriate IR and HAD combination strategy is required for increased efficiency, reduced energy consumption and to improve quality of final product. In this regard, there is no known study on the performance of different IR and HAD combination strategies.

Sweet potato, just like other vegetables undergo prominent changes ranging from physical to mechanical during the drying process. These changes include: porosity, textural, density, volume, colour, size and cellular changes amongst others. A common phenomenon associated with some of these changes is the shrinkage effect. Moreover, during the drying process, the colour of a product begins to change due to degradation in some phytochemical properties such as carotenoid content (Bualuang et al., 2017; Ong & Law, 2016; Yadav et al., 2006). All these processes that takes place in the product tissues during drying need to be properly understood and monitored in order to improve the drying process and also relevant equipment design. The evaluation of shrinkage and colour properties is currently carried out using conventional methods. There are few studies on the use of combined computer vision and laser-light backscattering imaging system as an accurate, rapid and affordable technique to monitor and evaluate the changes in product quality during drying of agricultural products (Udomkun, Nagle, Argyropoulos, Mahayothee, & Müller, 2016; Udomkun, Nagle, Mahayothee, & Müller, 2014). These studies did not consider the effect of sample thickness on shrinkage and only focused on the use of optical area and intensity parameters in predicting the shrinkage of papaya during drying based on multilinear regression technique. This statistical approach may also not provide adequate relationship between input parameters and shrinkage parameters and may be difficult to employ in in-line monitoring, control and optimisation of shrinkage phenomenon during drying. To the candidate's knowledge, studies on the use of combined CV and laser-light backscattering monitoring techniques for sweet potato during drying do not exist. In view of this, an extensive study on combined CV and laser light backscattering imagingsystem for monitoring the changes in physical properties of sweet potato during drying is required.

In practice, water loss in food and agricultural products are often described and modelled as a lumped process, which assume no internal water movement in the tissue (Nadi et al., 2012; De Smedt et al., 2002). Such empirical model offers no physical meaning in the actual water transport processes within the tissue. For this reason, Kucuk et al. (2014) recently criticized the use of empirical models in describing the drying process of agricultural crops. Thus, more advanced models, which will include the heat and mass transport of moisture in the tissue becomes indispensable.

Recently, a few researchers have developed heat and mass transfer models for infrared and infrared assisted drying (Jaturonglumlert & Kiatsiriroat, 2010; Salagnac et al., 2004). However, these models did not consider key drying phenomenon such as shrinkage and evaporation. For better understanding of the heat and mass transfer mechanism during combined IR and HAD, more robust mathematical model that will take cognisance of key drying factors as well as phase change and fluxes inside the product during drying is essential. However, such a model does not exist. In addition, there is no known heat and mass transfer model for the intermittent IR and HAD of agricultural crops. Therefore, a comprehensive mathematical model representing the physics behind heat and mass transfer mechanism for combined infrared and hot-air drying of sweet potato is needed. Thus, mathematical models considering single phase and non-equilibrium multi-phase change were developed in this study.

1.3 Objectives

The primary objective of this study is to investigate experimentally, the efficacy of combined infrared and hot-air drying of sweet potato slices and to develop a comprehensive mathematical model to describe the physics behind the heat and mass transfer process. In order to achieve the primary objective, the specific objectives of this study are:

i. To investigate the potential of computer vision and laser-light backscattering imaging system in evaluating the shrinkage of sweet potato during drying and to model the shrinkage of sweet potato slices during drying using artificial neural network (ANN).
ii. To investigate the potential of using computer vision and laser light backscattering imaging system in monitoring and predicting quality properties of sweet potato during drying.
iii. To determine the efficacy of convective hot-air, infrared, and combined infrared and convective hot-air drying methods for sweet potato.
iv. To evaluate the performance of different strategies for combined infrared and hot-air drying of sweet potato.
v. To evaluate a single-phase coupled heat and mass transfer model for describing the mechanism of simultanous combined infrared and hot-air drying of sweet potato.
vi. To model the single-phase transport process of sweet potato during intermittent infrared and hot-air drying.
vii. To develop a multiphase theoretical model for combined infrared and hot-air drying of sweet potato considering transport of liquid water, vapour and air fluxes.

1.4 Significance and scope of study

This study has investigated the application of computer vision couple with laser-light backscattering imaging system emitting at 658 nm wavelength in evaluating the changes in the physical properties of sweet potato (*Ipomoea batatas L.)* slices during drying. The imaging parameters were extracted based on an algorithm developed using MATLAB software (Version R2016a; Mathworks Inc., Natick, MA, USA). ANN and PLS were used in developing a correlation between the imaging parameters and the physical properties of shrinkage, moisture content, and colour of sweet potato (*Ipomoea batatas L.)* slices. This imaging technique provides an accurate and rapid means of determining shrinkage and colour parameters used in evaluating the drying process performance and also in developing mathematical models. The findings of this study are essential in optimising the drying parameters in order to improve product quality based on physical properties.

The efficacy of combined IR and HAD for sweet potato (*Ipomoea batatas L.)* slices was also studied. This was done by comparing the performance of combined IR and HAD with those of HAD and IR alone based on physical properties of sweet potato slices. The drying parameters used were IR intensity of 1,100 and 1,400 W/m^2, drying air temperature 50 – 70 ºC, air velocity of 1.16 m/s and sweet potato slice thickness of 4-6 mm. The findings of this investigation are useful in selecting the most suitable drying parameters and thickness for mathematical model validation. The results of this study can also describe the comparative advantages of combined IR and HAD over other thermal drying methods.

The performance of simultaneous, intermittent and two stage combined IR and HAD strategies was investigated for sweet potato (*Ipomoea batatas L.)* with varying drying air temperature from 50 – 70 ºC, 1.2 m/s air velocity, IR intensity of 1100 W/m^2 and 4 mm sweet potato slice thickness. The essence was to identify the best combination strategy for reduced energy consumption and improve quality of final product, in terms of physical product attributes which are important factors for the industrial selection of an ideal drying approach.

This research also developed a novel and the only comprehensive mathematical model of combined IR and HAD, for better understanding of the heat and mass transfer process for sweet potato (*Ipomoea batatas L.)*. The model considered 3D and 2D electromagnetics for IR heating and different components of phase change during heat and mass transfer. The water fluxes, vapour fluxes, temperature distribution and re-distribution during the drying process were studied. Since these phenomena are the key to avoiding overheating during drying process, the developed models can therefore contribute immensely in improving the quality of dried products. In this study, the IR heating source were modelled based on Lambert's Law of radiation. The single-phase and multiphase model simulations were done using COMSOL commercial finite element engineering software, and MATLAB software (Version R2016a; Mathworks Inc., Natick, MA, USA) installed on a local computer (window 10, 12GB ram, core i5), respectively. The developed models and simulations are essential in the drying field, for all stake holders in the value chain of agricultural crop processing. These mathematical models are based of fundamental theories and therefore can be easily modified and adapted to any agricultural crop with little effort. The models developed in this study will also help future researchers in developing similar models for other food and agricultural processing systems, as well as their optimization. The implementation of these models in the food and agro-allied industries can also reduce the energy consumption, increase drying efficiency, improve final product quality and reduce the overall cost of production.

1.5 Thesis Layout

This thesis is organised into ten chapters. The background of the study, the knowledge gap, problem statement, research objectives, significance and scope of research are described in Chapter 1. Chapter 2 gives a comprehensive review of the study based on the study objectives. A review on sweet potato, non-destructive imaging methods, combined infrared and hot-air drying, and heat and mass transfer modelling is presented in Chapter 2. Furthermore, the chapter also presents key literature findings and gaps.

The potential of computer vision and laser-light backscattering imaging system in evaluating the changes in shrinkage, moisture content and colour properties of sweet potato during drying is presented in Chapter 3 and Chapter 4. Chapter 3 gives a detail study on the application of computer vision couple with laser-light backscattering imaging and artificial neural network (ANN) modelling in evaluating the shrinkage of sweet potato during drying. The evaluation of moisture content and colour changes during drying using combined computer vision and laser-light backscattering imaging parameters are presented in Chapter 4.

Chapter 5 and Chapter 6 presents the performance of IR and HAD as well as the different combination strategies for sweet potato. A comparative study of combined IR and HAD, IR, and HAD for sweet potato based on drying kinetics, specific energy consumption, effective moisture diffusivity, colour and microstructural changes is presented in Chapter 5. Chapter 6 gives a detailed study on the performance of simultaneous, intermittent and two-stage combined IR and HAD of sweet potato based on drying kinetics, drying time, shrinkage, specific energy consumption, colour and microstructural changes.

The gradual development of comprehensive IR and HAD models are presented in Chapter 7-9. Chapter 7 gives detail study of the development and validation of a single-phase couple heat and mass model for simultaneous combined IR and HAD of sweet potato. A single-phase couple heat and mass model for intermittent combined IR and HAD of sweet potato is presented in Chapter 8. Chapter 9 presents the development and validation of multiphase couple heat and mass transfer models for both simultaneous and intermittent IR and HAD of sweet potato. The general conclusion and recommendations of this study is presented in Chapter 10. Chapters 2-9 contribute to individual publications for this study. An overview of the thesis Chapters is presented in Figure 1.1.

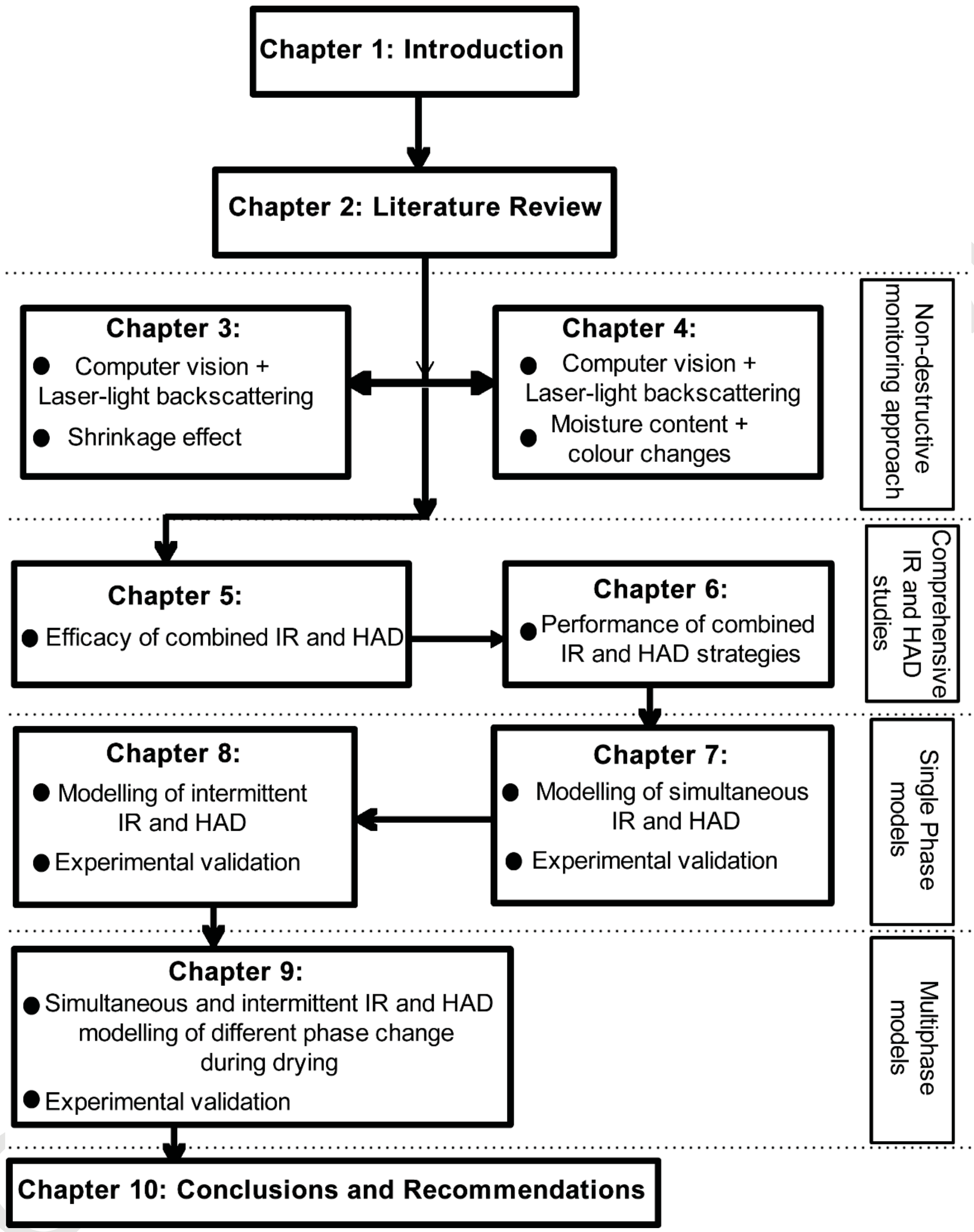

Figure 1.1 : Organisation of the thesis chapters

REFERENCES

Abdelillah, E., Elhussein, A., & Selin, Ş. (2018). Drying behaviour , effective diffusivity and energy of activation of olive leaves dried by microwave , vacuum and oven drying methods. *Heat and Mass Transfer*, *54*(7), 1901–1911.

Abdoli, B., Zare, D., Jafari, A., & Chen, G. (2018). Evaluation of the air-borne ultrasound on fluidized bed drying of shelled corn: Effectiveness, grain quality, and energy consumption. *Drying Technology*, *0*(0), 1–18. https://doi.org/10.1080/07373937.2018.1423568

Abraham, J. P., & Sparrow, E. M. (2003). Three-dimensional laminar and turbulent natural convection in a continuously/discretely wall-heated enclosure containing a thermal load. *Numerical Heat Transfer; Part A: Applications*, *44*(2), 105–125. https://doi.org/10.1080/713838194

Abraham, J. P., & Sparrow, E. M. (2004). A simple model and validating experiments for predicting the heat transfer to a load situated in an electrically heated oven. *Journal of Food Engineering*, *62*(4), 409–415. https://doi.org/10.1016/S0260-8774(03)00265-6

Adebayo, S. E., Hashim, N., Abdan, K., & Hanafi, M. (2016). Application and potential of backscattering imaging techniques in agricultural and food processing - A review. *Journal of Food Engineering*, *169*, 155–164. https://doi.org/10.1016/j.jfoodeng.2015.08.006

Adebayo, S. E., Hashim, N., Abdan, K., Hanafi, M., & Mollazade, K. (2016). Prediction of quality attributes and ripeness classification of bananas using optical properties. *Scientia Horticulturae*, *212*, 171–182. https://doi.org/10.1016/j.scienta.2016.09.045

Aghbashlo, M., Hosseinpour, S., & Ghasemi-Varnamkhasti, M. (2014). Computer vision technology for real-time food quality assurance during drying process. *Trends in Food Science and Technology*, *39*(1), 76–84. https://doi.org/10.1016/j.tifs.2014.06.003

Aghbashlo, M., Hosseinpour, S., & Mujumdar, A. S. (2015). Application of Artificial Neural Networks (ANNs) in Drying Technology—A Comprehensive Review. *Drying Technology*, (May 2015), 150501115909008. https://doi.org/10.1080/07373937.2015.1036288

Aghbashlo, M., Kianmehr, M. H., Khani, S., & Ghasemi, M. (2009). Mathematical modelling of thin-layer drying of carrot. *International Agrophysics*, *23*, 313–317.

Aghilinategh, N., Rafiee, S., Gholikhani, A., Hosseinpur, S., Omid, M., Mohtasebi, S. S., & Maleki, N. (2015a). A comparative study of dried apple using hot air, intermittent and continuous microwave: evaluation of kinetic parameters and physicochemical quality attributes. *Food Science & Nutrition*, *3*(6), 519–526. https://doi.org/10.1002/fsn3.241

Aghilinategh, N., Rafiee, S., Gholikhani, A., Hosseinpur, S., Omid, M., Mohtasebi, S. S., & Maleki, N. (2015b). A comparative study of dried apple using hot air, intermittent and continuous microwave: evaluation of kinetic parameters and physicochemical quality attributes. *Food Science & Nutrition*, n/a–n/a. https://doi.org/10.1002/fsn3.241

Aguilera, J. (2003). Drying and dried products under the microscope. *Food Science and Technology International*, *9*(3), 137–143. https://doi.org/10.1177/108201303034640

Aina, A. J., Falade, K. O., Akingbala, J. O., & Titus, P. (2009). Physicochemical properties of twenty-one Caribbean sweet potato cultivars. *International Journal of Food Science and Technology*, *44*(9), 1696–1704. https://doi.org/10.1111/j.1365-2621.2009.01941.x

Akoy, E. O. . (2014). Experimental characterization and modeling of thin-layer drying of mango slices. *International Food Research Journal*, *21*(5), 1911–1917.

Akpinar, E. K. (2006). Determination of suitable thin layer drying curve model for some vegetables and fruits. *Journal of Food Engineering*, *73*, 75–84. https://doi.org/10.1016/j.jfoodeng.2005.01.007

Akpinar, E. K. (2006). Mathematical modelling of thin layer drying process under open sun of some aromatic plants. *Journal of Food Engineering*, *77*, 864–870. https://doi.org/10.1016/j.jfoodeng.2005.08.014

Aktaş, M., Şevik, S., & Aktekeli, B. (2016). Development of heat pump and infrared-convective dryer and performance analysis for stale bread drying. *Energy Conversion and Management*, *113*, 82–94. https://doi.org/10.1016/j.enconman.2016.01.028

Aktaş, M., Şevik, S., Özdemir, M. B., & Gönen, E. (2015). Performance analysis and modeling of a closed-loop heat pump dryer for bay leaves using artificial neural network. *Applied Thermal Engineering*, *87*, 714–723. https://doi.org/10.1016/j.applthermaleng.2015.05.049

Aktaş, M., Sözen, A., Amini, A., & Khanlari, A. (2016). Experimental Analysis and CFD Simulation of Infrared Apricot Dryer with Heat Recovery. *Drying Technology*, *3937*(September), 07373937.2016.1212871. https://doi.org/10.1080/07373937.2016.1212871

Ali, F., Ranneh, Y., Ismail, A., & Esa, N. M. (2015). Identification of phenolic compounds in polyphenols-rich extract of Malaysian cocoa powder using the HPLC-UV-ESI—MS/MS and probing their antioxidant properties. *Journal of Food Science and Technology*, *52*(4), 2103–2111. https://doi.org/10.1007/s13197-013-1187-4

Alonge, A. F., & Onwude, D. I. (2013). Estimation of Solar Radiation for Crop Drying in Uyo, Nigeria Using a Mathematical Model. *Advanced Materials Research*, *824*, 420–428. https://doi.org/10.4028/www.scientific.net/AMR.824.420

Amiri Chayjan, R., Bahrabad, S. M. T., & Rahimi Sardari, F. (2014). Modeling infrared-covective drying of pistachio nuts under fixed and fluidized bed conditions. *Journal of Food Processing and Preservation*, *38*(3), 1224–1233. https://doi.org/10.1111/jfpp.12083

An, K., Zhao, D., Wang, Z., Wu, J., Xu, Y., & Xiao, G. (2016). Comparison of different drying methods on Chinese ginger (Zingiber officinale Roscoe): Changes in volatiles, chemical profile, antioxidant properties, and microstructure. *Food Chemistry*, *197*, 1292–1300. https://doi.org/10.1016/j.foodchem.2015.11.033

Andre, C. M., Burgos, G., Ziebel, J., Guignard, C., Hausman, J. F., & Felde, T. zum. (2017). In vitro iron bioaccessibility and uptake from orange-fleshed sweet potato (Ipomoea batatas (L.) Lam.) clones grown in Peru. *Journal of Food Composition and Analysis*, (July), 0–1. https://doi.org/10.1016/j.jfca.2017.07.035

Antonio, G.C., Takeiti, C.Y., De Oliveira, R.A., Park, K. J. (2011). Sweet potato: production , morphological and physicochemical characteristics, and technological process. *Fruit, Vegetable and Science and Biotechnology*, *5*(2), 1–18.

Aprajeeta, J., Gopirajah, R., & Anandharamakrishnan, C. (2015). Shrinkage and porosity effects on heat and mass transfer during potato drying. *Journal of Food Engineering*, *144*, 119–128. https://doi.org/10.1016/j.jfoodeng.2014.08.004

Aral, S., & Bese, A. V. (2016). Convective drying of hawthorn fruit (Crataegus spp.): Effect of experimental parameters on drying kinetics, color, shrinkage, and rehydration capacity. *Food Chemistry*, *210*, 577–584. https://doi.org/10.1016/j.foodchem.2016.04.128

Arévalo-Pinedo, A., & Murr, F. E. X. (2006). Kinetics of vacuum drying of pumpkin (Cucurbita maxima): Modeling with shrinkage. *Journal of Food Engineering*, *76*(4), 562–567. https://doi.org/10.1016/j.jfoodeng.2005.06.003

ASAE. (2005). Moisture Measurement — Unground Grain and Seeds. *American Society of Agricultural and Biological Engineers*, *1988*, 2–4.

Asiah, N., Djaeni, M., & Hii, C. L. (2017). Moisture Transport Mechanism and Drying Kinetic of Fresh Harvested Red Onion Bulbs under Dehumidified Air. *International Journal of Food Engineering*, *13*(9), 1–8. https://doi.org/10.1515/ijfe-2016-0401

Ayeleso, T. B., Ramachela, K., & Mukwevho, E. (2016). A review of therapeutic potentials of sweet potato: Pharmacological activities and influence of the cultivar. *Tropical Journal of Pharmaceutical Research*, *15*(12), 2751–2761. https://doi.org/10.4314/tjpr.v15i12.31

Babalis, S. J., Papanicolaou, E., Kyriakis, N., & Belessiotis, V. G. (2006). Evaluation of thin-layer drying models for describing drying kinetics of figs (Ficus carica), *75*, 205–214. https://doi.org/10.1016/j.jfoodeng.2005.04.008

Baini, R., & Langrish, T. a. G. (2008). An assessment of the mechanisms for diffusion in the drying of bananas. *Journal of Food Engineering*, *85*(2), 201–214. https://doi.org/10.1016/j.jfoodeng.2007.06.035

Bansal, H. S., Takhar, P. S., & Maneerote, J. (2014). Modeling multiscale transport mechanisms, phase changes and thermomechanics during frying. *Food Research International*, *62*, 709–717. https://doi.org/10.1016/j.foodres.2014.04.016

Barati, E., & Esfahani, J. a. (2011). Mathematical modeling of convective drying: Lumped temperature and spatially distributed moisture in slab. *Energy*, *36*(4), 2294–2301. https://doi.org/10.1016/j.energy.2010.06.007

Barbosa de Lima, A. G., Delgado, J. M. P. Q., de Farias Neto, S. R., & Franco, C. M. . (2016). Intermittent Drying: Fundamentals, Modeling and Applications. In J. M. P. Q. Delgado & A. G. Barbosa de Lima (Eds.), *Drying and Energy Technologies* (pp. 19–41). Switzerland: Springer International Publishing. https://doi.org/10.1007/978-3-319-19767-8

Barbosa de Lima, A. G., Delgado, J. M. P. Q., Silva, E. G., de Farias Neto, S. R., Santos, J. P. S., & Barbosa de Lima, W. M. P. (2016). Drying and energy technologies. In J. M. P. Q. Delgado & A. G. Barbosa de Lima (Eds.), *Drying and Energy Technologies, Advanced Structured Materials* (pp. 89–110). Heidelberg: Springer. https://doi.org/10.1007/978-3-319-19767-8

Barrett, D. M., Beaulieu, J. C., & Shewfelt, R. (2010). Color, flavor, texture, and nutritional quality of fresh-cut fruits and vegetables: desirable levels, instrumental and sensory measurement, and the effects of processing. *Critical Reviews in Food Science and Nutrition*, *50*(5), 369–389. https://doi.org/10.1080/10408391003626322

Barzegar, M., Zare, D., & Stroshine, R. L. (2015). An integrated energy and quality approach to optimization of green peas drying in a hot air infrared-assisted vibratory bed dryer. *Journal of Food Engineering*, *166*, 302–315. https://doi.org/10.1016/j.jfoodeng.2015.06.026

Bean, R. (2014). *Lighting: Interior and Exterior*. Taylor & Francis. Retrieved from https://books.google.com.my/books?id=nSmvAgAAQBAJ

Bear, J. (1972). *Dynamics of fluids in porous media*. Courier Corporation.

Behroozi Khazaei, N., Tavakoli, T., Ghassemian, H., Khoshtaghaza, M. H., & Banakar, A. (2013). Applied machine vision and artificial neural network for modeling and controlling of the grape drying process. *Computers and Electronics in Agriculture*, *98*, 205–213. https://doi.org/10.1016/j.compag.2013.08.010

Benjamin, C. (1991). *Laser Light Scattering: Basic Principles and Practice*. boston: Academic press.

Bernstein, A., & Norena, C. P. Z. (2014). Study of Thermodynamic, Structural, and Quality Properties of Yacon (Smallanthus sonchifolius) During Drying. *Food and Bioprocess Technology*, *7*(1), 148–160. https://doi.org/10.1007/s11947-012-1027-y

Bird, R. B., Stewart, W. E., & Lightfoot, E. N. (2002). *Transport Phenomena*. *John Wiley & Sons, Inc* (2nd ed.). New York: John Wiley & Sons, Inc.

Birth, G. (1978). The Light Scattering Properties of Foods. *Journal of Food Science*, *43*, 916–925. https://doi.org/10.1111/j.1365-2621.1978.tb02455.x

Bishop, M. J., & Plank, G. (2014). Simulating photon scattering effects in structurally detailed ventricular models using a Monte Carlo approach. *Frontiers in Physiology*, *5 AUG*(September), 1–14. https://doi.org/10.3389/fphys.2014.00338

Bovell-Benjamin, A. C. (2007). Sweet potato: a review of its past, present, and future role in human nutrition. *Advances in Food and Nutrition Research*, *52*, 1–59.

Bualuang, O., Onwude, D. I., & Pracha, K. (2017). Microwave drying of germinated corn and its effect on phytochemical properties. *Journal of the Science of Food and Agriculture*, *97*(9), 2999–3004. https://doi.org/10.1002/jsfa.8140

Bualuang, O., Tirawanichakul, Y., & Tirawanichakul, S. (2013). Comparative study between hot air and infrared drying of parboiled rice: Kinetics and qualities aspects. *Journal of Food Processing and Preservation*, *37*(6), 1119–1132. https://doi.org/10.1111/j.1745-4549.2012.00813.x

Burri, B. J. (2011). Evaluating Sweet Potato as an Intervention Food to Prevent Vitamin A Deficiency. *Comprehensive Reviews in Food Science and Food Safety*, *10*(2), 118–130. https://doi.org/10.1111/j.1541-4337.2010.00146.x

Campos-Mendiola, R., Hernández-Sánchez, H., Chanona-Pérez, J. J., Alamilla-Beltrán, L., Jiménez-Aparicio, A., Fito, P., & Gutiérrez-López, G. F. (2007). Non-isotropic shrinkage and interfaces during convective drying of potato slabs within the frame of the systematic approach to food engineering systems (SAFES) methodology. *Journal of Food Engineering*, *83*(2), 285–292. https://doi.org/10.1016/j.jfoodeng.2007.02.027

Cao, Z., Zhou, L., Bi, J., Yi, J., Chen, Q., Wu, X., … Li, S. (2016). Effect of different drying technologies on drying characteristics and quality of red pepper (*Capsicum frutescens* L.): a comparative study. *Journal of the Science of Food and Agriculture*, *96*(10), 3596–3603. https://doi.org/10.1002/jsfa.7549

Castell-Palou, A., & Simal, S. (2011). Heat pump drying kinetics of a pressed type cheese. *LWT - Food Science and Technology*, *44*(2), 489–494. https://doi.org/10.1016/j.lwt.2010.09.007

Castro, A. M., Mayorga, E. Y., & Moreno, F. L. (2018). Mathematical modelling of convective drying of fruits: A review. *Journal of Food Engineering*, *223*, 152–167. https://doi.org/10.1016/j.jfoodeng.2017.12.012

Cengel, Y. A., & Ghajar, A. J. (2011). *Heat and Mass Transfer: Fundamentals and Applications*. 2 Penn Plaza, New York: McGraw-Hill Education.

Chayjan, R. A., Salari, K., Abedi, Q., & Sabziparvar, A. A. (2013). Modeling moisture diffusivity, activation energy and specific energy consumption of squash seeds in a semi fluidized and fluidized bed drying. *Journal of Food Science and Technology*, *50*(4), 667–677. https://doi.org/10.1007/s13197-011-0399-8

Chen, C., Abdelrahim, K., & Beckerich, I. (2010). Sensitivity analysis of continuous ohmic heating process for multiphase foods. *Journal of Food Engineering*, *98*(2), 257–265. https://doi.org/10.1016/j.jfoodeng.2010.01.005

Chen, D., Kai, L., & Xifeng, Z. (2012). Determination of Effective Moisture Diffusivity and Activation Energy for Drying of Powdered Peanut Shell Under Isothermal Conditions. *BioResources*, *7*(3), 3670–3678.

Chen, N. N., Chen, M. Q., Fu, B. A., & Song, J. J. (2017). Far-infrared irradiation drying behavior of typical biomass briquettes. *Energy*, *121*(January), 726–738. https://doi.org/10.1016/j.energy.2017.01.054

Chen, Q., Bi, J., Wu, X., Yi, J., Zhou, L., & Zhou, Y. (2015a). Drying kinetics and quality attributes of jujube (Zizyphus jujuba Miller) slices dried by hot-air and short- and medium-wave infrared radiation. *LWT - Food Science and Technology*, *64*(2), 759–766. https://doi.org/10.1016/j.lwt.2015.06.071

Chen, Q., Bi, J., Wu, X., Yi, J., Zhou, L., & Zhou, Y. (2015b). Drying kinetics and quality attributes of jujube (Zizyphus jujuba Miller) slices dried by hot-air and short-and medium-wave infrared radiation. *LWT - Food Science and Technology*, *64*(2), 759–766. https://doi.org/10.1016/j.lwt.2015.06.071

Chua, K. J., & Chou, S. K. (2005). Original article A comparative study between intermittent microwave and infrared drying of bioproducts. *International Journal of Food Science and Technology*, *40*, 23–39. https://doi.org/10.1111/j.1365-2621.2004.00903.x

Chua, K. J., Mujumdar, A. S., Chou, S. K., Hawlader, M. N. ., & Ho, J. C. (2000). Convective Drying of Banana, Guava and Potato Pieces : Effect of Cyclical Variations of Air Temperature on Drying Kinetics and Color Change. *Drying Technology*, *18*(4-5), 907–936. https://doi.org/10.1080/07373930008917744

Crank, J. (1979). *The Mathematics of Diffusion*. Clarendon Press. Retrieved from https://books.google.com.my/books?id=eHANhZwVouYC

Curcio, S., & Aversa, M. (2014). Influence of shrinkage on convective drying of fresh vegetables: A theoretical model. *Journal of Food Engineering*, *123*, 36–49. https://doi.org/10.1016/j.jfoodeng.2013.09.014

Curcio, S., Aversa, M., Chakraborty, S., Calabro, V., & Iorio, G. (2016). Formulation of a 3D conjugated multiphase transport model to predict drying process behavior of irregular-shaped vegetables. *Journal of Food Engineering*, *176*, 36–55. https://doi.org/10.1016/j.jfoodeng.2015.11.020

da Silva, W. P., Rodrigues, A. F., e Silva, C. M. D. P. S., de Castro, D. S., & Gomes, J. P. (2015). Comparison between continuous and intermittent drying of whole bananas using empirical and diffusion models to describe the processes. *Journal of Food Engineering*, *166*, 230–236. https://doi.org/10.1016/j.jfoodeng.2015.06.018

da Silva, W. P., Rodrigues, A. F., Silva, C. M. D. P. S. e., & Gomes, J. P. (2017). Numerical approach to describe continuous and intermittent drying including the tempering period: Kinetics and spatial distribution of moisture. *Drying Technology*, *35*(3), 272–280. https://doi.org/10.1080/07373937.2016.1172316

Dadali, G., Demirhan, E., & Özbek, B. (2007). Color Change Kinetics of Spinach Undergoing Microwave Drying. *Drying Technology*, *25*(10), 1713–1723. https://doi.org/10.1080/07373930701590988

Darıcı, S., & Şen, S. (2015). Experimental investigation of convective drying kinetics of kiwi under different conditions. *Heat and Mass Transfer*, *51*(8), 1167–1176. https://doi.org/10.1007/s00231-014-1487-x

Das, I., & Arora, A. (2017). Alternate microwave and convective hot air application for rapid mushroom drying. *Journal of Food Engineering*, *223*, 208–219. https://doi.org/10.1016/j.jfoodeng.2017.10.018

Dash, K. K., Gope, S., Sethi, A., & Doloi, M. (2013). Study on Thin Layer Drying Characteristics of Star Fruit Slices. *International Journal of Agriculture and Food Science Technology.*, *4*(7), 679–686.

Datta, A. K. (2007). Porous media approaches to studying simultaneous heat and mass transfer in food processes. II: Property data and representative results. *Journal of Food Engineering*, *80*(1), 96–110. https://doi.org/10.1016/j.jfoodeng.2006.05.012

Datta, A. K., & Ni, H. (2002). Infrared and hot-air-assisted microwave heating of foods for control of surface moisture. *Journal of Food Engineering*, *51*(4), 355–364. https://doi.org/10.1016/S0260-8774(01)00079-6

De Smedt, V., Barreiro, P., Verlinden, B. E., Veraverbeke, E. A., De Baerdemaeker, J., & Nicola??, B. M. (2002). A mathematical model for the development of mealiness in apples. *Postharvest Biology and Technology*, *25*(3), 273–291. https://doi.org/10.1016/S0925-5214(01)00185-5

Dehghannya, J., Hosseinlar, S., & Heshmati, M. K. (2018). Multi-stage continuous and intermittent microwave drying of quince fruit coupled with osmotic dehydration and low temperature hot air drying. *Innovative Food Science and Emerging Technologies*, *45*(October 2017), 132–151. https://doi.org/10.1016/j.ifset.2017.10.007

Demirhan, E., & Özbek, B. (2009). Color Change Kinetics of Microwave-Dried Basil. *Drying Technology*, *27*(1), 156–166. https://doi.org/10.1080/07373930802566101

Demirhan, E., & Özbek, B. (2010). Microwave-drying characteristics of basil. *Journal of Food Processing and Preservation*, *34*(3), 476–494. https://doi.org/10.1111/j.1745-4549.2008.00352.x

Diamante, L. M., & Munro, P. A. (1991). Mathematical modeling of hot air drying of sweet potato slices. *International Journal of Food Science and Technology*, *26* , p. 99.

Dissa, A. O., Desmorieux, H., Koulidiati, J., & Lyon, C. B. (2016). A Convective Thin Layer Drying Model with Shrinkage for Kent Mango Slices. *Advances in Chemical Engineering and Science*, *6*(January), 20–28.

Donghai Wenyi Quartz Products Co., L. (2016). Infrared heating tube.

Dorouzi, M., Mortezapour, H., Akhavan, H. R., & Moghaddam, A. G. (2018). Tomato slices drying in a liquid desiccant-assisted solar dryer coupled with a photovoltaic-thermal regeneration system. *Solar Energy*, *162*(January), 364–371. https://doi.org/10.1016/j.solener.2018.01.025

Doymaz, I. (2005). Drying behaviour of green beans. *Journal of Food Engineering*, *69*, 161–165. https://doi.org/10.1016/j.jfoodeng.2004.08.009

Doymaz, I. (2007). The kinetics of forced convective air-drying of pumpkin slices. *Journal of Food Engineering*, *79*, 243–248. https://doi.org/10.1016/j.jfoodeng.2006.01.049

Doymaz, I. (2012). Infrared drying of sweet potato (Ipomoea batatas L.) slices. *Journal of Food Science and Technology*, *49*(6), 760–766. https://doi.org/10.1007/s13197-010-0217-8

Du, C.-J., & Sun, D.-W. (2004). Recent developments in the applications of image processing techniques for food quality evaluation. *Trends in Food Science Technology*, *15*, 230–249. https://doi.org/10.1016/j.tifs.2003.10.006

Ebrahimi, M. A., Mohtasebi, S. S., Rafiee, S., & Hosseinpour, S. (2012). Investigation of banana slices shrinkage using image processing technique. *Australian Journal of Crop Science*, *6*(5), 938–945.

Ebrahimi, M. A., Mohtasebi, S. S., Rafiee, S., & Hosseinpour, S. (2013). Using online image processing technique for measurement the browning in banana during drying (a new and automatic method) scheme. *Agric Eng Int: CIGR Journal*, *15*(4), 220–227.

Elisabeth, D. A. A. (2015). Added Value Improvement of Taro and Sweet Potato Commodities by Doing Snack Processing Activity. *Procedia Food Science*, *3*, 262–273. https://doi.org/10.1016/j.profoo.2015.01.029

El-mesery, H. S., & Mwithiga, G. (2015). Performance of a convective , infrared and combined infrared- convective heated conveyor-belt dryer. *Journal Food Science Technology*, *52*(5), 2721–2730. https://doi.org/10.1007/s13197-014-1347-1

El-sebaii, A. A., & Shalaby, S. M. (2012). Solar drying of agricultural products : A review. *Renewable and Sustainable Energy Reviews*, *16*(1), 37–43. https://doi.org/10.1016/j.rser.2011.07.134

Erbay, Z., & Icier, F. (2009). Optimization of Drying of Olive Leaves in a Pilot-Scale Heat Pump Dryer. *Drying Technology*, *27*(March 2015), 416–427. https://doi.org/10.1080/07373930802683021

Erbay, Z., & Icier, F. (2010). A review of thin layer drying of foods: theory, modeling, and experimental results. *Critical Reviews in Food Science and Nutrition*, *50*(5), 441–464. https://doi.org/10.1080/10408390802437063

Ertekin, C., & Firat, M. Z. (2017). A Comprehensive Review of Thin Layer Drying Models Used in Agricultural Products. *Critical Reviews in Food Science and Nutrition*, *57*(4), 701–717. https://doi.org/10.1080/10408398.2014.910493

Fadavi, A., & Mehrabi, A. A. (2013). Mechanical processing and temperature effect on lime shrinkage. *Agric Eng Int: CIGR Journal*, *15*(3), 238–242.

Fadhel, M. I., Abdo, R. A., Yousif, B. F., Zaharim, A., & Sopian, K. (2011). Thin-Layer Drying Characteristics of Banana Slices in a Force Convection Indirect Solar Drying. In *EE'11 Proceedings of the 6th IASME/WSEAS International Conference on Energy and Environment, February 23–25,* (pp. 310–315). Cambridge, United Kingdom,.

Faggion, H., Tussolini, L., Freire, F. B., Freire, J. T., & Zanoelo, E. F. (2016). Mechanisms of heat and mass transfer during drying of mate (Ilex paraguariensis) twigs. *Drying Technology*, *34*(4), 474–482. https://doi.org/10.1080/07373937.2015.1060498

Falade, K. O., & Solademi, O. J. (2010). Modelling of air drying of fresh and blanched sweet potato slices. *International Journal of Food Science and Technology*, *45*(2), 278–288. https://doi.org/10.1111/j.1365-2621.2009.02133.x

Farinu, A., & Baik, O.-D. (2007). Thermal Properties of Sweet Potato with its Moisture Content and Temperature. *International Journal of Food Properties*, *10*(4), 703–719. https://doi.org/10.1080/10942910601137482

Feng, H., Tang, J., Plumb, O. A., & Cavalieri, R. P. (2004). Intrinsic and relative permeability for flow of humid air in unsaturated apple tissues. *Journal of Food Engineering*, *62*(2), 185–192. https://doi.org/10.1016/S0260-8774(03)00231-0

Fernández, L., Castillero, C., & Aguilera, J. M. (2005). An application of image analysis to dehydration of apple discs. *Journal of Food Engineering*, *67*(1-2), 185–193. https://doi.org/10.1016/j.jfoodeng.2004.05.070

Filippin, A. P., Molina Filho, L., Fadel, V., & Mauro, M. A. (2018). Thermal intermittent drying of apples and its effects on energy consumption. *Drying Technology*, *0*(0), 1–16. https://doi.org/10.1080/07373937.2017.1421549

Firouzi, S., Alizadeh, M. R., & Haghtalab, D. (2017). Energy consumption and rice milling quality upon drying paddy with a newly-designed horizontal rotary dryer. *Energy*, *119*, 629–636. https://doi.org/10.1016/j.energy.2016.11.026

Fu, B. A., Chen, M. Q., & Huang, Y. W. (2015). Heat transfer characteristics on lignite thin-layer during hot air forced convective drying. *Fuel*, *154*(MAY), 132–139. https://doi.org/10.1016/j.fuel.2015.03.075

Fu, B. A., Chen, M. Q., Li, Q. H., & Song, J. J. (2018). Non-equilibrium thermodynamics approach for the coupled heat and mass transfer in microwave drying of compressed lignite sphere. *Applied Thermal Engineering*. https://doi.org/10.1016/j.applthermaleng.2018.01.036

Fu, M., He, Z., Zhao, Y., Yang, J., & Mao, L. (2009). Antioxidant properties and involved compounds of daylily flowers in relation to maturity. *Food Chemistry*, *114*(4), 1192–1197. https://doi.org/10.1016/j.foodchem.2008.10.072

Gan, P. L., & Poh, P. E. (2014). International Journal of Science and Engineering (IJSE) Investigation on the Effect of Shapes on the Drying Kinetics and Sensory Evaluation Study of Dried Jackfruit. *International Journal of Science and Engineering (IJSE)*, *7*(October), 193–198.

Ghaboos, S. H. H., Ardabili, S. M. S., Kashaninejad, M., Asadi, G., & Aalami, M. (2016). Combined infrared-vacuum drying of pumpkin slices. *Journal of Food Science and Technology*, *53*(5), 2380–2388. https://doi.org/10.1007/s13197-016-2212-1

Ghaitaranpour, A., Rastegar, A., Tabatabaei Yazdi, F., Mohebbi, M., & Alizadeh Behbahani, B. (2017). Application of Digital Image Processing in Monitoring some Physical Properties of Tarkhineh during Drying. *Journal of Food Processing and Preservation*, *41*(2), e12861. https://doi.org/10.1111/jfpp.12861

Ginting, E., & Yulifianti, R. (2015). Characteristics of Noodle Prepared from Orange-fleshed Sweet Potato, and Domestic Wheat Flour. *Procedia Food Science*, *3*, 289–302. https://doi.org/10.1016/j.profoo.2015.01.032

Glato, K., Aidam, A., Kane, N. A., Bassirou, D., Couderc, M., Zekraoui, L., … Vigouroux, Y. (2017). Structure of sweet potato (Ipomoea batatas) diversity in West Africa covaries with a climatic gradient. *PLoS ONE*, *12*(5), 1–17. https://doi.org/10.1371/journal.pone.0177697

Golestani, R., Raisi, A., & Aroujalian, A. (2013). Mathematical Modeling on Air Drying of Apples Considering Shrinkage and Variable Diffusion Coefficient. *Drying Technology*, *31*(1), 40–51. https://doi.org/10.1080/07373937.2012.714826

Guiné, R. P. F., Pinho, S., & Barroca, M. J. (2011). Study of the convective drying of pumpkin (Cucurbita maxima). *Food and Bioproducts Processing*, *89*(4), 422–428. https://doi.org/10.1016/j.fbp.2010.09.001

Gulati, T., Zhu, H., Datta, A. K., & Huang, K. (2015). Microwave drying of spheres: Coupled electromagnetics-multiphase transport modeling with experimentation. Part II: Model validation and simulation results. *Food and Bioproducts Processing*, *96*, 326–337. https://doi.org/10.1016/j.fbp.2015.08.001

Hafezi, N., Mohammad Javad Sheikhdavoodi, & Sajadiye, S. M. (2014). The Effect of Drying Kinetic on Shrinkage of Potato Slices. *International Journal of Advanced Biological and Biomedical Research Journal*, *2*(11), 2779–2782. https://doi.org/10.1111/j.1745-4603.2009.00187.x

Hafezi, N., Sheikhdavoodi, M. J., & Sajadiye, S. M. (2015). Evaluation of Quality Characteristics of Potato Slices during Drying by Infrared Radiation Heating Method under Vacuum, *4*(3), 1–8.

Halder, A., & Datta, A. K. (2012). Surface heat and mass transfer coefficients for multiphase porous media transport models with rapid evaporation. *Food and Bioproducts Processing*, *90*(3), 475–490. https://doi.org/10.1016/j.fbp.2011.10.005

Halder, A., Dhall, A., & Datta, A. K. (2007). An Improved, Easily Implementable, Porous Media Based Model for Deep-Fat Frying. *Food and Bioproducts Processing*, *85*(3), 209–219. https://doi.org/10.1205/fbp07033

Hamuda, E., Glavin, M., & Jones, E. (2016). A survey of image processing techniques for plant extraction and segmentation in the field. *Computers and Electronics in Agriculture*, *125*, 184–199. https://doi.org/10.1016/j.compag.2016.04.024

Hashim, N., Daniel, O., & Rahaman, E. (2014). A Preliminary Study: Kinetic Model of Drying Process of Pumpkins (Cucurbita Moschata) in a Convective Hot Air Dryer. *Agriculture and Agricultural Science Procedia*, *2*, 345–352. https://doi.org/10.1016/j.aaspro.2014.11.048

Hashim, N., Janius, R. Bin, Baranyai, L., Rahman, R. A., Osman, A., & Zude, M. (2012). Kinetic Model for Colour Changes in Bananas During the Appearance of Chilling Injury Symptoms. *Food and Bioprocess Technology*, *5*(8), 2952–2963. https://doi.org/10.1007/s11947-011-0646-z

Hashim, N., Onwude, D., & Rahaman, E. (2014). A Preliminary Study : Kinetic Model of Drying Process of Pumpkins (Cucurbita Moschata) in a Convective Hot Air Dryer. *Agriculture and Agricultural Science Procedia 2*, *2*, 345–352. https://doi.org/10.1016/j.aaspro.2014.11.048

Hashim, N., Pflanz, M., Regen, C., Janius, R. B., Abdul Rahman, R., Osman, A., … Zude, M. (2013). An approach for monitoring the chilling injury appearance in bananas by means of backscattering imaging. *Journal of Food Engineering*, *116*(1), 28–36. https://doi.org/10.1016/j.jfoodeng.2012.11.018

Hashim, N., Pflanz, M., Regen, C., Janius, R. B., Rahman, A., Osman, A., … Zude, M. (2010). Application of RGB and Backscattering Imaging to Detect Chilling Injury Symptoms in Banana. In *CIGR Workshop on Image Analysis in Agriculture* (pp. 66–77). Budapest.

Hashimoto, A., & Kameoka, T. (1997). Penetration of Infrared Radiation within a Vegetable Model. *Food Science Technology International*, *3*(4), 373–378.

Hassini, L., Azzouz, S., Peczalski, R., & Belghith, A. (2007). Estimation of potato moisture diffusivity from convective drying kinetics with correction for shrinkage. *Journal of Food Engineering*, *79*(1), 47–56. https://doi.org/10.1016/j.jfoodeng.2006.01.025

Hebbar, H. U., Vishwanathan, K. H., & Ramesh, M. N. (2004). Development of combined infrared and hot air dryer for vegetables. *Journal of Food Engineering*, *65*(4), 557–563. https://doi.org/10.1016/j.jfoodeng.2004.02.020

Henriques, F., Guiné, R. P. F., & Barroca, M. J. (2012). Infl uence of Drying Treatment on Physical Properties of Pumpkin. *Croatian Journal of Food Technology, Biotechnology and Nutrition*, *7*, 53–58.

Henríquez, C., Córdova, A., Almonacid, S., & Saavedra, J. (2014). Kinetic modeling of phenolic compound degradation during drum-drying of apple peel by-products. *Journal of Food Engineering*, *143*, 146–153. https://doi.org/10.1016/j.jfoodeng.2014.06.037

Honarvar, B., & Mowla, D. (2012). Theoretical and experimental drying of a cylindrical sample by applying hot air and infrared radiation in an inert medium fluidized bed. *Brazilian Journal of Chemical Engineering*, *29*(2), 231–242. https://doi.org/10.1590/S0104-66322012000200004

Horuz, E., Bozkurt, H., Karataş, H., & Maskan, M. (2017a). Effects of hybrid (microwave-convectional) and convectional drying on drying kinetics, total phenolics, antioxidant capacity, vitamin C, color and rehydration capacity of sour cherries. *Food Chemistry*, *230*, 295–305. https://doi.org/10.1016/j.foodchem.2017.03.046

Horuz, E., Bozkurt, H., Karataş, H., & Maskan, M. (2017b). Simultaneous application of microwave energy and hot air to whole drying process of apple slices: drying kinetics, modeling, temperature profile and energy aspect. *Heat and Mass Transfer*. https://doi.org/10.1007/s00231-017-2152-y

Hosseinpour, S., Rafiee, S., & Mohtasebi, S. S. (2011). Application of Image Processing to Analyze Shrinkage and Shape Changes of Shrimp Batch during Drying. *Drying Technology*, *29*(12), 1416–1438. https://doi.org/10.1080/07373937.2011.587620

Hosseinpour, S., Rafiee, S., Mohtasebi, S. S., & Aghbashlo, M. (2013). Application of computer vision technique for on-line monitoring of shrimp color changes during drying. *Journal of Food Engineering*, *115*(1), 99–114. https://doi.org/10.1016/j.jfoodeng.2012.10.003

Huang, C.-L., Liao, W. C., Chan, C.-F., & Lai, Y.-C. (2014). Storage performance of Taiwanese sweet potato cultivars. *Journal of Food Science and Technology*, *51*(12), 4019–4025. https://doi.org/10.1007/s13197-013-0960-8

Huang, M., Wang, Q., Zhang, M., & Zhu, Q. (2014). Prediction of color and moisture content for vegetable soybean during drying using hyperspectral imaging technology. *Journal of Food Engineering*, *128*(MAY), 24–30. https://doi.org/10.1016/j.jfoodeng.2013.12.008

Hue, S. M., Chandran, S., & Boyce, A. N. (2012). Variations of leaf and storage roots morphology in Ipomoea batatas L. (Sweet Potato) cultivars. *Acta Horticulturae*, *943*, 73–80.

Hussain Riadh, M., Anom, S., Ahmad, B., Marhaban, H., Azura, &, & Soh, C. (2015). Infrared Heating in Food Drying: An Overview. *Drying Technology*, *33*(3), 322–335. https://doi.org/10.1080/07373937.2014.951124

Hyland, R. W., & Wexter, A. (1983). Formulations for the thermodynamic properties of dry air from 173.15 K to 473.15 K, and of saturated moist air from 173.15 K to 372.15 K, at pressures to 5 MPa. *ASHRAE Transactions*, *89*, 520–535.

Irimpan, L., Dann, V. J., Krishnan, B., Deepthy, A., Nampoori, V. P. N., & Radhakrishnan, P. (2008). Backscattering of laser light from colloidal silica. *Laser Physics*, *18*(7), 882–885. https://doi.org/10.1134/S1054660X08070128

Isleroglu, H., & Kaymak-Ertekin, F. (2016). Modelling of heat and mass transfer during cooking in steam-assisted hybrid oven. *Journal of Food Engineering*, *181*, 50–58. https://doi.org/10.1016/j.jfoodeng.2016.02.027

Jafari, A., & Bakhshipour, A. (2014). Inspection of Quince Slice Dehydration Stages based on Extractable Image Features. *Czech J. Food Sci.*, *32*(5), 456–463.

Jangchud, K., Phimolsiripol, Y., & Haruthaithanasan, V. (2003). Physicochemical properties of sweet potato flour and starch as affected by blanching and processing. *Starch/Staerke*, *55*(6), 258–264. https://doi.org/10.1002/star.200390053

Jaturonglumlert, S., & Kiatsiriroat, T. (2010a). Heat and mass transfer in combined convective and far-infrared drying of fruit leather. *Journal of Food Engineering*, *100*(2), 254–260. https://doi.org/10.1016/j.jfoodeng.2010.04.007

Jaturonglumlert, S., & Kiatsiriroat, T. (2010b). Heat and mass transfer in combined convective and far-infrared drying of fruit leather. *Journal of Food Engineering*, *100*(2), 254–260. https://doi.org/10.1016/j.jfoodeng.2010.04.007

Jindarat, W., Sungsoontorn, S., & Rattanadecho, P. (2015). Analysis of energy consumption in a combined microwave-hot air spouted bed drying of biomaterial: Coffee beans. *Experimental Heat Transfer*, *28*(2), 107–124. https://doi.org/10.1080/08916152.2013.821544

Joardder, M. U. H., Brown, R. J., Kumar, C., & Karim, M. A. (2015). Effect of Cell Wall Properties on Porosity and Shrinkage of Dried Apple. *International Journal of Food Properties*, *18*(10), 2327–2337. https://doi.org/10.1080/10942912.2014.980945

Joardder, M. U. H., Kumar, C., & Karim, M. A. (2017a). Multiphase transfer model for intermittent microwave-convective drying of food: Considering shrinkage and pore evolution. *International Journal of Multiphase Flow*, *95*, 101–119. https://doi.org/10.1016/j.ijmultiphaseflow.2017.03.018

Joardder, M. U. H., Kumar, C., & Karim, M. A. (2017b). Multiphase transfer model for intermittent microwave-convective drying of food: Considering shrinkage and pore evolution. *International Journal of Multiphase Flow*. https://doi.org/10.1016/j.ijmultiphaseflow.2017.03.018

Joardder, M. U. H., Kumar, C., & Karim, M. A. (2017c). Multiphase transfer model for intermittent microwave-convective drying of food: Considering shrinkage and pore evolution. *International Journal of Multiphase Flow*, *95*, 101–119. https://doi.org/10.1016/j.ijmultiphaseflow.2017.03.018

Joykumar Singh, N., & Pandey, R. K. (2012). Convective air drying characteristics of sweet potato cube (Ipomoea batatas L.). *Food and Bioproducts Processing*, *90*(2), 317–322. https://doi.org/10.1016/j.fbp.2011.06.006

Jung, J. K., Lee, S. U., Kozukue, N., Levin, C. E., & Friedman, M. (2011). Distribution of phenolic compounds and antioxidative activities in parts of sweet potato (Ipomoea batata L.) plants and in home processed roots. *Journal of Food Composition and Analysis*, *24*(1), 29–37. https://doi.org/10.1016/j.jfca.2010.03.025

Junqueira, J. R. de J., Corrêa, J. L. G., de Oliveira, H. M., Ivo Soares Avelar, R., & Salles Pio, L. A. (2017). Convective drying of cape gooseberry fruits: Effect of pretreatments on kinetics and quality parameters. *LWT - Food Science and Technology*, *82*, 404–410. https://doi.org/10.1016/j.lwt.2017.04.072

Kadam, D. M., Goyal, R. K., & Gupta, M. K. (2011). Mathematical modeling of convective thin layer drying of basil leaves. *Journal of Medicinal Plants Research*, *5*(19), 4721–4730.

Karunasena, H. C. P., Hesami, P., Senadeera, W., Gu, Y. T., Brown, R. J., & Oloyede, a. (2014). Scanning Electron Microscopic Study of Microstructure of Gala Apples During Hot Air Drying. *Drying Technology*, *32*(4), 455–468. https://doi.org/10.1080/07373937.2013.837479

Kayacan, S., Sagdic, O., & Doymaz, I. (2018). Effects of hot-air and vacuum drying on drying kinetics, bioactive compounds and color of bee pollen. *Journal of Food Measurement and Characterization*, *0*(0), 0. https://doi.org/10.1007/s11694-018-9741-4

Kha, T. C., Nguyen, M. H., & Roach, P. D. (2010). Effects of spray drying conditions on the physicochemical and antioxidant properties of the Gac (Momordica cochinchinensis) fruit aril powder. *Journal of Food Engineering*, *98*(3), 385–392. https://doi.org/10.1016/j.jfoodeng.2010.01.016

Khan, M. I. H., Joardder, M. U. H., Kumar, C., & Karim, M. A. (2016). Multiphase Porous Media Modelling: A novel approach to predicting food processing performance. *Critical Reviews in Food Science and Nutrition*, *8398*(July), 00–00. https://doi.org/10.1080/10408398.2016.1197881

Khan, M. I. H., Kumar, C., Joardder, M. U. H., & Karim, M. A. (2017). Determination of appropriate effective diffusivity for different food materials. *Drying Technology*, *35*(3), 335–346. https://doi.org/10.1080/07373937.2016.1170700

Klemes, J., Smith, R., & Kim, J. K. (2008). *Handbook of Water and Energy Management in Food Processing*. Elsevier Science.

Koca, N., Burdurlu, H. S., & Karadeniz, F. (2007). Kinetics of colour changes in dehydrated carrots. *Journal of Food Engineering*, *78*(August 2005), 449–455. https://doi.org/10.1016/j.jfoodeng.2005.10.014

Kocabiyik, H., Yilmaz, N., Tuncel, N. B., Sumer, S. K., & Burak Buyukcan, M. (2014). The effects of middle infrared radiation intensity on the quality of dried tomato products. *International Journal of Food Science and Technology*, *49*(3), 703–710. https://doi.org/10.1111/ijfs.12353

Kowalski, S. J., & Mierzwa, D. (2013). Numerical analysis of drying kinetics for shrinkable products such as fruits and vegetables. *Journal of Food Engineering*, *114*(4), 522–529. https://doi.org/10.1016/j.jfoodeng.2012.08.037

Krishnamurthy, K., Khurana, H., Jun, S., Irudayaraj, J., & Demirci, A. (2008). Infrared Heating in Food Processing: An Overview. *Comprehensive Reviews in Food Science and Food Safety*, *7*(1), 2–13.

Krokida, M. K., Karathanos, V. T., Maroulis, Z. B., & Marinos-Kouris, D. (2003). Drying kinetics of some vegetables. *Journal of Food Engineering*, *59*(4), 391–403. https://doi.org/10.1016/S0260-8774(02)00498-3

Kucuk, H., Midilli, A., Kilic, A., & Dincer, I. (2014). A Review on Thin-Layer Drying-Curve Equations. *Drying Technology*, *32*(7), 757–773. https://doi.org/10.1080/07373937.2013.873047

Kulshreshtha, M., Singh, A., & Vipul, D. A. (2009). Effect of drying conditions on mushroom quality. *Journal of Engineering Science and Technology*, *4*(1), 90–98.

Kumar, C., Joardder, M. U. H., Farrell, T. W., & Karim, M. A. (2016a). Multiphase porous media model for intermittent microwave convective drying (IMCD) of food. *International Journal of Thermal Sciences*, *104*(September), 304–314. https://doi.org/10.1016/j.ijthermalsci.2016.01.018

Kumar, C., Joardder, M. U. H., Farrell, T. W., & Karim, M. A. (2016b). Multiphase porous media model for intermittent microwave convective drying (IMCD) of food. *International Journal of Thermal Sciences*, *104*, 304–314. https://doi.org/10.1016/j.ijthermalsci.2016.01.018

Kumar, C., Joardder, M. U. H., Farrell, T. W., & Karim, M. A. (2017). Investigation of Intermittent Microwave Convective Drying (IMCD) of Food Materials by a Coupled 3D Electromagnetics and Multiphase Model. *Drying Technology*, *3937*(July), 07373937.2017.1354874. https://doi.org/10.1080/07373937.2017.1354874

Kumar, C., Karim, M. A., & Joardder, M. U. H. (2014a). Intermittent drying of food products: A critical review. *Journal of Food Engineering*, *121*(1), 48–57. https://doi.org/10.1016/j.jfoodeng.2013.08.014

Kumar, C., Karim, M. A., & Joardder, M. U. H. (2014b). Intermittent drying of food products: A critical review. *Journal of Food Engineering*, *121*(1), 48–57. https://doi.org/10.1016/j.jfoodeng.2013.08.014

Kumar, C., Millar, G. J., & Karim, M. a. (2014). Effective Diffusivity and Evaporative Cooling in Convective Drying of Food Material. *Drying Technology*, *33*(2), 227–237. https://doi.org/10.1080/07373937.2014.947512

Kurozawa, L. E., Hubinger, M. D., & Park, K. J. (2012). Glass transition phenomenon on shrinkage of papaya during convective drying. *Journal of Food Engineering*, *108*(1), 43–50. https://doi.org/10.1016/j.jfoodeng.2011.07.033

Lamnatou, C., Papanicolaou, E., Belessiotis, V., & Kyriakis, N. (2010). Finite-volume modelling of heat and mass transfer during convective drying of porous bodies - Non-conjugate and conjugate formulations involving the aerodynamic effects. *Renewable Energy*, *35*(7), 1391–1402. https://doi.org/10.1016/j.renene.2009.11.008

Łechtańska, J. M., Szadzińska, J., & Kowalski, S. J. (2015). Microwave- and infrared-assisted convective drying of green pepper: Quality and energy considerations. *Chemical Engineering and Processing: Process Intensification*, *98*, 155–164. https://doi.org/10.1016/j.cep.2015.10.001

Lee, B. H., & Lee, Y. T. (2017). Physicochemical and structural properties of different colored sweet potato starches. *Starch/Staerke*, *69*(3-4), 1–9. https://doi.org/10.1002/star.201600001

Lee, S. H., Choi, W., & Jun, S. (2016). Conventional and Emerging Combination Technologies for Food Processing. *Food Engineering Reviews*. https://doi.org/10.1007/s12393-016-9145-3

Lertworasirikul, S., & Tipsuwan, Y. (2008). Moisture content and water activity prediction of semi-finished cassava crackers from drying process with artificial neural network. *Journal of Food Engineering*, *84*(1), 65–74. https://doi.org/10.1016/j.jfoodeng.2007.04.019

Li, J., & Qian, Z.-Q. (2016). The Application of Image Acquisition and Analysis Techniques to the Field of Drying. *Food Engineering Reviews*. https://doi.org/10.1007/s12393-016-9146-2

Lim, Y. Y., & Murtijaya, J. (2007). Antioxidant properties of Phyllanthus amarus extracts as affected by different drying methods. *LWT - Food Science and Technology*, *40*(9), 1664–1669. https://doi.org/10.1016/j.lwt.2006.12.013

Link, J. V., Tribuzi, G., & Laurindo, J. B. (2017). Improving quality of dried fruits: A comparison between conductive multi-flash and traditional drying methods. *LWT - Food Science and Technology*, *84*, 717–725. https://doi.org/10.1016/j.lwt.2017.06.045

Litaiem, J., Mihoubi, D., & Touil, A. (2015). Experimental and theoretical investigation of drying behavior of garlic in infrared dryer. *Journal of New Sciences*, (6), 861–867.

Liu, Y., Sun, Y., Yu, H., Yin, Y., Li, X., & Duan, X. (2017). Hot Air Drying of Purple-Fleshed Sweet Potato with Contact Ultrasound Assistance. *Drying Technology*, *35*(5), 564–576. https://doi.org/10.1080/07373937.2016.1193867

Liu, Y., Zhu, W., Luo, L., Li, X., & Yu, H. (2014). A Mathematical Model for Vacuum Far-Infrared Drying of Potato Slices. *Drying Technology*, *32*(2), 180–189. https://doi.org/10.1080/07373937.2013.811687

Loebenstein, G. (2016). Sweet Potato , A Research Neglected Important Food Crop , Regarding Virus Research and Propagation Systems : A Review. *Austin Journal of Plant Biology*, *2*(1), 1–4.

Lorente, D., Zude, M., Idler, C., Gómez-Sanchis, J., & Blasco, J. (2015). Laser-light backscattering imaging for early decay detection in citrus fruit using both a statistical and a physical model. *Journal of Food Engineering*, *154*, 76–85. https://doi.org/10.1016/j.jfoodeng.2015.01.004

Lu, R. (2016). Overview of Light Interaction with Food and Biological Materials Renfu. In R. Lu (Ed.), *Light Scattering Technology for Food Property , Quality and Safety Assessment* (pp. 19–40).

Lu, R., & Peng, Y. (2006). Hyperspectral scattering for assessing peach fruit firmness. *Biosystems Engineering*, *93*(2), 161–171. https://doi.org/10.1016/j.biosystemseng.2005.11.004

Luchese, C. L., Gurak, P. D., & Marczak, L. D. F. (2015). Osmotic dehydration of physalis (Physalis peruviana L.): Evaluation of water loss and sucrose incorporation and the quantification of carotenoids. *LWT - Food Science and Technology*, *63*(2), 1128–1136. https://doi.org/10.1016/j.lwt.2015.04.060

Madhava Naidu, M., Vedhashree, M., Satapathy, P., Khanum, H., Ramsamy, R., & Umesh Hebbar, H. (2015). Effect of drying methods on the quality characteristics of Dill (Anethumgraveolens) greens. *Food Chemistry*, *192*, 849–856. https://doi.org/10.1016/j.foodchem.2015.07.076

Madiouli, J., Sghaier, J., Orteu, J.-J., Robert, L., Lecomte, D., & Sammouda, H. (2011). Non-contact Measurement of the Shrinkage and Calculation of Porosity During the Drying of Banana. *Drying Technology*, *29*(12), 1358–1364. https://doi.org/10.1080/07373937.2011.561460

Martins, R. C., & Silva, C. L. M. (2002). Modelling colour and chlorophyll losses of frozen green beans (Phaseolus vulgaris, L.). *International Journal of Refrigeration*, *25*(7), 966–974. https://doi.org/10.1016/S0140-7007(01)00050-0

Martynenko, A. (2017). Computer Vision for Real-Time Control in Drying. *Food Engineering Reviews*, (1). https://doi.org/10.1007/s12393-017-9159-5

Mayor, L., Moreira, R., & Sereno, A. M. (2011). Shrinkage, density, porosity and shape changes during dehydration of pumpkin (Cucurbita pepo L.) fruits. *Journal of Food Engineering*, *103*(1), 29–37. https://doi.org/10.1016/j.jfoodeng.2010.08.031

Mayor, L., & Sereno, a. M. (2004a). Modelling shrinkage during convective drying of food materials: a review. *Journal of Food Engineering*, *61*(3), 373–386. https://doi.org/10.1016/S0260-8774(03)00144-4

Mayor, L., & Sereno, A. M. (2004b). Modelling shrinkage during convective drying of food materials : a review, *61*, 373–386. https://doi.org/10.1016/S0260-8774(03)00144-4

Meeso, N., Nathakaranakule, A., Madhiyanon, T., & Soponronnarit, S. (2007). Modelling of far-infrared irradiation in paddy drying process. *Journal of Food Engineering*, *78*(4), 1248–1258. https://doi.org/10.1016/j.jfoodeng.2006.01.003

Mendoza, F., & Aguilera, J. M. (2004). Application of image analysis for classification of ripening bananas. *Journal of Food Science*, *69*(9), 471–477. https://doi.org/10.1111/j.1365-2621.2004.tb09932.x

Menges, H. O., & Ertekin, C. (2006). Mathematical modeling of thin layer drying of Golden apples. *Journal of Food Engineering*, *77*(1), 119–125. https://doi.org/10.1016/j.jfoodeng.2005.06.049

Mihindukulasuriya, S. D. F., & Jayasuriya, H. P. W. (2015). Drying of chilli in a combined infrared and hot air rotary dryer. *Journal of Food Science and Technology*, *52*(8), 4895–4904. https://doi.org/10.1007/s13197-014-1546-9

Mireei, S. A., Mohtasebi, S. S., Massudi, R., Rafiee, S., & Arabanian, A. S. (2010). Feasibility of near infrared spectroscopy for analysis of date fruits. *International Agrophysics*, *24*(4), 351–356. Retrieved from https://www.scopus.com/inward/record.uri?eid=2-s2.0-79955023784&partnerID=40&md5=bda54a95925b007416fe8354a2214b79

Moffat, R. J. (1988). Describing the uncertainties in experimental results. *Experimental Thermal and Fluid Science*, *1*(1), 3–17. https://doi.org/10.1016/0894-1777(88)90043-X

Mohd Ali, M., Hashim, N., Bejo, S. K., & Shamsudin, R. (2017a). Laser-induced backscattering imaging for classification of seeded and seedless watermelons. *Computers and Electronics in Agriculture*, *140*, 311–316. https://doi.org/10.1016/j.compag.2017.06.010

Mohd Ali, M., Hashim, N., Bejo, S. K., & Shamsudin, R. (2017b). Quality evaluation of watermelon using laser-induced backscattering imaging during storage. *Postharvest Biology and Technology*, *123*, 51–59. https://doi.org/10.1016/j.postharvbio.2016.08.010

Mohd Ali, M., Hashim, N., Khairunniza-Bejo, S., Shamsudin, R., & Wan Sembak, W. N. F. H. (2017). RGB imaging system for monitoring quality changes of seedless watermelon during storage. *Acta Horticulturae*, (1152), 361–366. https://doi.org/10.17660/ActaHortic.2017.1152.48

Mohd Hanim, A. B., Chin, N. L., & Yusof, Y. A. (2014). Physico-chemical and flowability characteristics of a new variety of Malaysian sweet potato, VitAto Flour. *International Food Research Journal*, *21*(5), 2099–2107.

Moldrup, P., Olesen, T., Yoshikawa, S., Komatsu, T., & Rolston, D. E. (2005). Predictive-descriptive models for gas and solute diffusion coefficients in variably saturated porous media coupled to pore-size distribution: I. Gas diffusivity in repacked soil. *Soil Science*, *170*(11), 843–853. https://doi.org/10.1097/01.ss.0000196769.51788.73

Mollazade, K., Omid, M., Tab, F. A., & Mohtasebi, S. S. (2012). Principles and Applications of Light Backscattering Imaging in Quality Evaluation of Agro-food Products: A Review. *Food and Bioprocess Technology*, *5*(5), 1465–1485. https://doi.org/10.1007/s11947-012-0821-x

Mongpraneet, S., Abe, T., & Tsurusaki, T. (2004). Kinematic Model for a Far Infrared Vacuum Dryer. *Drying Technology*, *22*(7), 1675–1693. https://doi.org/10.1081/DRT-200025628

Moses, J. A., Norton, T., Alagusundaram, K., & Tiwari, B. K. (2014). Novel Drying Techniques for the Food Industry. *Food Engineering Reviews*, *6*(3), 43–55. https://doi.org/10.1007/s12393-014-9078-7

Motevali, A., Minaei, S., Khoshtaghaza, M. H., & Amirnejat, H. (2011). Comparison of energy consumption and specific energy requirements of different methods for drying mushroom slices. *Energy*, *36*(11), 6433–6441. https://doi.org/10.1016/j.energy.2011.09.024

Mozaffari, M., Mahmoudi, A., Mollazade, K., & Jamshidi, B. (2016). A Low-Cost Optical Approach for Non-Contact Predicting Moisture Content of Apple Slices during Hot Air Drying. *Drying Technology*, 1–42.

Mukherjee, J., Maitra, I. K., Dey, K. N., Bandyopadhyay, S. K., Bhattacharyya, D., & Kim, T. H. (2016). Grayscale conversion of histopathological slide images as a preprocessing step for image segmentation. *International Journal of Software Engineering and Its Applications*, *10*(1), 15–26. https://doi.org/10.14257/ijseia.2016.10.1.02

Mulet, a., Garcia-Reverter, J., Bon, J., & Berna, a. (2000). Effect of Shape on Potato and Cauliflower Shrinkage During Drying. *Drying Technology*, *18*(6), 1201–1219. https://doi.org/10.1080/07373930008917772

Nabubuya, A. (2012). Potential Use of Selected Sweetpotato (Ipomea batatas Lam) Varieties as Defined by Chemical and Flour Pasting Characteristics. *Food and Nutrition Sciences*, *03*(07), 889–896. https://doi.org/10.4236/fns.2012.37118

Nadi, F., Rahimi, G. H., Younsi, R., Tavakoli, T., & Hamidi-Esfahani, Z. (2012). Numerical Simulation of Vacuum Drying by Luikov's Equations. *Drying Technology*, *30*(2), 197–206. https://doi.org/10.1080/07373937.2011.595860

Nadian, M. H., Abbaspour-Fard, M. H., Martynenko, A., & Golzarian, M. R. (2017). An intelligent integrated control of hybrid hot air-infrared dryer based on fuzzy logic and computer vision system. *Computers and Electronics in Agriculture*, *137*, 138–149. https://doi.org/10.1016/j.compag.2017.04.001

Nadian, M. H., Rafiee, S., Aghbashlo, M., Hosseinpour, S., & Mohtasebi, S. S. (2015). Continuous real-time monitoring and neural network modeling of apple slices color changes during hot air drying. *Food and Bioproducts Processing*, *94*(February), 263–274. https://doi.org/10.1016/j.fbp.2014.03.005

Nahimana, H., & Zhang, M. (2011). Shrinkage and Color Change during Microwave Vacuum Drying of Carrot. *Drying Technology*, *29*(7), 836–847. https://doi.org/10.1080/07373937.2011.573753

Namo, O. A. T., & Akinbola, O. J. (2016). Sweet Potato: Production, Nutritional Properties and Diseases. In Doris Sullivan (Ed.), *Sweet Potato: Production, Nutritional Properties and Diseases* (pp. 1–33). New York: Nova Science Publishers Inc.

Nathakaranakule, A., Jaiboon, P., & Soponronnarit, S. (2010). Far-infrared radiation assisted drying of longan fruit. *Journal of Food Engineering*, *100*(4), 662–668. https://doi.org/10.1016/j.jfoodeng.2010.05.016

Nazrul, S., Nusrat, T., Begum, P., & Ahsan, M. (2016). Carotenoids and b-carotene in orange fleshed sweet potato: A possible solution to vitamin A deficiency. *Food Chemistry*, *199*, 628–631. https://doi.org/10.1016/j.foodchem.2015.12.057

Nejadi, J., & Nikbakht, A. M. (2016). Numerical Simulation of Corn Drying in a Hybrid Fluidized Bed-Infrared Dryer. *Journal of Food Process Engineering*, (Mujumdar 2006), n/a–n/a. https://doi.org/10.1111/jfpe.12373

Ni, H., Datta, A. K., & Torrance, K. E. (1999). Moisture transport in intensive microwave heating of biomaterials: A multiphase porous media model. *International Journal of Heat and Mass Transfer*, *42*(8), 1501–1512. https://doi.org/10.1016/S0017-9310(98)00123-9

Nilnont, W., Thepa, S., Janjai, S., Kasayapanand, N., Thamrongmas, C., & Bala, B. K. (2012). Finite element simulation for coffee (Coffea arabica) drying. *Food and Bioproducts Processing*, *90*(2), 341–350. https://doi.org/10.1016/j.fbp.2011.06.007

Nowak, D., & Lewicki, P. P. (2004). Infrared drying of apple slices. *Innovative Food Science and Emerging Technologies*, *5*(3), 353–360. https://doi.org/10.1016/j.ifset.2004.03.003

Nowak, D., & Lewicki, P. P. (2005). Quality of Infrared Dried Apple Slices. *Drying Technology*, *23*, 831–846.

Nozad, M., Khojastehpour, M., Tabasizadeh, M., Azizi, M., Miraei Ashtiani, S. H., & Salarikia, A. (2016). Characterization of hot-air drying and infrared drying of spearmint (Mentha spicata L.) leaves. *Journal of Food Measurement and Characterization*, *10*(3), 466–473. https://doi.org/10.1007/s11694-016-9325-0

Nuthong, P., Achariyaviriya, A., Namsanguan, K., & Achariyaviriya, S. (2011). Kinetics and modeling of whole longan with combined infrared and hot air. *Journal of Food Engineering*, *102*(3), 233–239. https://doi.org/10.1016/j.jfoodeng.2010.08.024

Oladejo, A. O., Ma, H., Qu, W., Zhou, C., & Wu, B. (2017). Effects of Ultrasound on Mass Transfer Kinetics, Structure, Carotenoid and Vitamin C Content of Osmodehydrated Sweet Potato (Ipomea Batatas). *Food and Bioprocess Technology*, *10*(6), 1162–1172. https://doi.org/10.1007/s11947-017-1890-7

Oladejo, A. O., Ma, H., Qu, W., Zhou, C., Wu, B., & Yang, X. (2017). Influence of ultrasound pretreatments on diffusion coefficients, texture and colour of osmodehydrated sweet potato (Ipomea batatas). *International Journal of Food Science & Technology*, *52*(4), 888–896. https://doi.org/10.1111/ijfs.13352

Oladejo, A. O., Ma, H., Qu, W., Zhou, C., Wu, B., Yang, X., & Onwude, D. I. (2017). Effects of ultrasound pretreatments on the kinetics of moisture loss and oil uptake during deep fat frying of sweet potato (Ipomea batatas). *Innovative Food Science & Emerging Technologies*. https://doi.org/10.1016/j.ifset.2017.07.019

Oliveira, M. M. De, Tribst, A. A. L., Leite J??nior, B. R. D. C., Oliveira, R. A. De, & Cristianini, M. (2015). Effects of high pressure processing on cocoyam, Peruvian carrot, and sweet potato: Changes in microstructure, physical characteristics, starch, and drying rate. *Innovative Food Science and Emerging Technologies*, *31*, 45–53. https://doi.org/10.1016/j.ifset.2015.07.004

Omid, M., Firouz, M. S., Nouri-Ahmadabadi, H., & Mohtasebi, S. S. (2016). Classification of peeled pistachio kernels using computer vision and color features. *Engineering in Agriculture, Environment and Food*. https://doi.org/10.1016/j.eaef.2017.04.002

Ong, S. P., & Law, C. L. (2016). Drying Kinetics and Antioxidant Phytochemicals Retention of Salak Fruit under Different Drying and Pretreatment Conditions Drying Kinetics and Antioxidant Phytochemicals Retention of Salak Fruit under Different Drying and Pretreatment Conditions. *Drying Technology*, *3937*(February). https://doi.org/10.1080/07373937.2010.503332

Ong, S. P., Law, C. L., & Hii, C. L. (2012). Optimization of Heat Pump–Assisted Intermittent Drying. *Drying Technology*, *30*(15), 1676–1687. https://doi.org/10.1080/07373937.2012.703741

Onwude, D. ., Hashim, N., Janius, R., Nawi, N., & Khalina, A. (2016). Modeling the thin-layer drying of fruits and vegetables – A review. *Comprehensive Reviews in Food Science and Food Safety*. https://doi.org/10.1111/1541-4337.12196

Onwude, D., Hashim, N., Janius, R., Nawi, N., & Abdan, K. (2015). COMPUTER SIMULATION OF CONVECTIVE HOT AIR DRYING KINETICS OF PUMPKIN (CUCURBITA MOSCHATA), 10–12.

Onwude, D. I., Hashim, N., Abdan, K., Janius, R., & Chen, G. (2018). Investigating the influence of novel drying methods on sweet potato (Ipomoea batatas L .): Kinetics, energy consumption, color, and microstructure. *Journal of Food Process Engineering*, *41*(4), e12686. https://doi.org/10.1111/jfpe.12686

Onwude, D. I., Hashim, N., Abdan, K., Janius, R., & Chen, G. (2018). The Potential of Computer vision, Optical Backscattering Parameters and Artificial Neural Network Modelling in Monitoring the Shrinkage of Sweet Potato (Ipomoea Batatas L.) during Drying. *Journal of the Science of Food and Agriculture*, *98*, 1310–1324. https://doi.org/10.1002/jsfa.8595

Onwude, D. I., Hashim, N., Abdan, K., Janius, R., Chen, G., & Kumar, C. (2018a). Modelling of coupled heat and mass transfer for combined infrared and hot-air drying of sweet potato. *Journal of Food Engineering*, *228*, 12–24. https://doi.org/10.1016/j.jfoodeng.2018.02.006

Onwude, D. I., Hashim, N., Abdan, K., Janius, R., Chen, G., & Kumar, C. (2018b). Modelling of coupled heat and mass transfer for combined infrared and hot-air drying of sweet potato. *Journal of Food Engineering*. https://doi.org/10.1016/j.jfoodeng.2018.02.006

Onwude, D. I., Hashim, N., & Chen, G. (2016a). Recent advances of novel thermal combined hot air drying of agricultural crops. *Trends in Food Science & Technology*, *57*, 132–145. https://doi.org/10.1016/j.tifs.2016.09.012

Onwude, D. I., Hashim, N., & Chen, G. (2016b). Recent advances of novel thermal combined hot air drying of agricultural crops. *Trends in Food Science & Technology*, *57*, 132–145. https://doi.org/10.1016/j.tifs.2016.09.012

Onwude, D. I., Hashim, N., Janius, R., Abdan, K., Chen, G., & Oladejo, A. O. (2017). Non-thermal hybrid drying of fruits and vegetables: A review of current technologies. *Innovative Food Science and Emerging Technologies*, *43*, 223–238. https://doi.org/10.1016/j.ifset.2017.08.010

Onwude, D. I., Hashim, N., Janius, R. B., Nawi, N., & Abdan, K. (2016). Modelling Effective Moisture Diffusivity of Pumpkin (Cucurbita moschata) Slices under Convective Hot Air Drying Condition. *International Journal of Food Engineering*, *12*(5), 481–489. https://doi.org/10.1515/ijfe-2015-0382

Onwude, D. I., Hashim, N., Janius, R. B., Nawi, N. M., & Abdan, K. (2016). Modeling the Thin-Layer Drying of Fruits and Vegetables: A Review. *Comprehensive Reviews in Food Science and Food Safety*, *15*(3), 599–618. https://doi.org/10.1111/1541-4337.12196

Onwude, D. I., Hashim, N., Janius, R., & Nawi, N. (2016). Modelling the convective drying process of pumpkin (Cucurbita Moschata) using an artificial neural network. *International Food Research Journal*, *23*(Suppl), S237–S243.

Onwude, D. I., Hashim, N., Janius, R., Nawi, N., & Abdan, K. (2016). Evaluation of a suitable thin layer model for drying of pumpkin under forced air convection. *International Food Research Journal*, *23*(3), 1173–1181.

Onwude, D. I., Hashim, N., Janius, R., Nawi, N. M., & Abdan, K. (2017). Color Change Kinetics and Total Carotenoid Content of Pumpkin as Affected by Drying Temperature. *Italian Journal of Food Science*, *29*(1), 1–18.

Onwude, D. I., Hashim, N., Janius, R., Nawi, N. M., & Abdan, K. (2017). Color change kinetics and total carotenoid content of pumpkin as affected by drying temperature. *Italian Journal of Food Science*, *29*(1).

Onwude, D. I., Hashim, N., & Solehin1, M. (2017). Optical method for the detection of moisture content of pumpkin during drying. *Acta Hortic*, *42*(1152), 313–318. https://doi.org/10.17660/ActaHortic.2017.1152.42

Özdemir, M. B., Aktaş, M., Şevik, S., & Khanlari, A. (2017). Modeling of a convective-infrared kiwifruit drying process. *International Journal of Hydrogen Energy*, *42*(28), 18005–18013. https://doi.org/10.1016/j.ijhydene.2017.01.012

Ozdemir, M., & Devres, Y. O. (2000). The thin layer drying characteristics of hazelnuts during roasting. *Journal of Food Engineering*, *42*(1999), 225–233.

Padda, M. S., & Picha, D. H. (2008). Quantification of phenolic acids and antioxidant activity in sweetpotato genotypes. *Scientia Horticulturae*, *119*(1), 17–20. https://doi.org/10.1016/j.scienta.2008.07.008

Pan, Z., & Atungulu, G. G. (2011). *Infrared Heating For Food And Agricultural Processing*. (Z. Pan & G. G. Atungulu, Eds.). Boca Raton, FL: CRC Press.

Pasban, A., Sadrnia, H., Mohebbi, M., & Ahmad Shahidi, S. (2017). Spectral method for simulating 3D heat and mass transfer during drying of apple slices. *Journal of Food Engineering*. https://doi.org/10.1016/j.jfoodeng.2017.05.013

Pathare, P. B., Opara, U. L., & Al-Said, F. A.-J. (2012). Colour Measurement and Analysis in Fresh and Processed Foods: A Review. *Food and Bioprocess Technology*, *6*(1), 36–60. https://doi.org/10.1007/s11947-012-0867-9

Pekke, M. A., Pan, Z. L., Atungulu, G. G., Smith, G., & Thompson, J. F. (2013). Drying characteristics and quality of bananas under infrared radiation heating. *International Journal of Agricultural and Biological Engineering*, *6*(3), 58–70. https://doi.org/10.3965/j.ijabe.20130603.008

Peng, Y., & Lu, R. (2006). Improving apple fruit firmness predictions by effective correction of multispectral scattering images. *Postharvest Biology and Technology*, *41*(3), 266–274. https://doi.org/10.1016/j.postharvbio.2006.04.005

Peng, Y., & Lu, R. (2008). Analysis of spatially resolved hyperspectral scattering images for assessing apple fruit firmness and soluble solids content. *Postharvest Biology and Technology*, *48*(1), 52–62. https://doi.org/10.1016/j.postharvbio.2007.09.019

Perussello, C. A., Kumar, C., De Castilhos, F., & Karim, M. A. (2014). Heat and mass transfer modeling of the osmo-convective drying of yacon roots (Smallanthus sonchifolius). *Applied Thermal Engineering*, *63*(1), 23–32. https://doi.org/10.1016/j.applthermaleng.2013.10.020

Ponkham, K., Meeso, N., Soponronnarit, S., & Siriamornpun, S. (2012). Modeling of combined far-infrared radiation and air drying of a ring shaped-pineapple with/without shrinkage. *Food and Bioproducts Processing*, *90*(2), 155–164. https://doi.org/10.1016/j.fbp.2011.02.008

Praveen Kumar, D. G., Hebbar, H. U., & Ramesh, M. N. (2006). Suitability of thin layer models for infrared–hot air-drying of onion slices. *LWT - Food Science and Technology*, *39*(6), 700–705. https://doi.org/10.1016/j.lwt.2005.03.021

Pu, Y.-Y., & Sun, D.-W. (2017). Combined hot-air and microwave-vacuum drying for improving drying uniformity of mango slices based on hyperspectral imaging visualisation of moisture content distribution. *Biosystems Engineering*, *156*, 108–119. https://doi.org/10.1016/j.biosystemseng.2017.01.006

Qing, Z., Ji, B., & Zude, M. (2007). Predicting soluble solid content and firmness in apple fruit by means of laser light backscattering image analysis. *Journal of Food Engineering*, *82*(1), 58–67. https://doi.org/10.1016/j.jfoodeng.2007.01.016

Qing, Z., Ji, B., & Zude, M. (2008). Non-destructive analyses of apple quality parameters by means of laser-induced light backscattering imaging. *Postharvest Biology and Technology*, *48*(2), 215–222. https://doi.org/10.1016/j.postharvbio.2007.10.004

Rakesh, V., & Datta, A. K. (2011). Microwave puffing: Determination of optimal conditions using a coupled multiphase porous media - Large deformation model. *Journal of Food Engineering*, *107*(2), 152–163. https://doi.org/10.1016/j.jfoodeng.2011.06.031

Ramallo, L. A., & Mascheroni, R. H. (2013). Effect of shrinkage on prediction accuracy of the water diffusion model for pineapple drying. *Journal of Food Process Engineering*, *36*(1), 66–76. https://doi.org/10.1111/j.1745-4530.2011.00654.x

Ramesh Yadav, A., Guha, M., Tharanathan, R. N., & Ramteke, R. S. (2006). Changes in characteristics of sweet potato flour prepared by different drying techniques. *LWT - Food Science and Technology*, *39*(1), 20–26. https://doi.org/10.1016/j.lwt.2004.12.010

Ramos, I. N., Silva, C. L. M., Sereno, A. M., & Aguilera, J. M. (2004). Quantification of microstructural changes during first stage air drying of grape tissue. *Journal of Food Engineering*, *62*(2), 159–164. https://doi.org/10.1016/S0260-8774(03)00227-9

Raskin, H. (2017). What's the Difference Between Sweet Potatoes and Yams? Retrieved March 20, 2018, from http://dish.allrecipes.com/whats-difference-sweet-potatoes-yams/

Rasouli, M., Seiiedlou, S., Ghasemzadeh, H. R., & Nalbandi, H. (2011). Convective drying of garlic (Allium sativum L.): Part I: Drying kinetics, mathematical modeling and change in color. *Australian Journal of Crop Science*, *5*(13), 1707–1714.

Rastogi, N. K. (2012). Recent Trends and Developments in Infrared Heating in Food Processing. *Critical Reviews in Food Science and Nutrition*, *52*(9), 737–760. https://doi.org/10.1080/10408398.2010.508138

Ratti, C., Crapiste, G. H., & Rotstein, E. (1989). A New Water Sorption Equilibrium Expression for Solid Foods based on Thermodynamic Considerations. *Journal of Food Science*, *54*(3), 738–742. https://doi.org/10.1111/j.1365-2621.1989.tb04693.x

Ratti, C., & Mujumdar, A. (2014). Infrared Drying. In *Handbook of Industrial Drying, Fourth Edition* (pp. 405–420). CRC Press. https://doi.org/doi:10.1201/b17208-22

Reyes, A., Vega, R., Bustos, R., & Araneda, C. (2008). Effect of Processing Conditions on Drying Kinetics and Particle Microstructure of Carrot. *Drying Technology*, *26*(10), 1272–1285. https://doi.org/10.1080/07373930802307282

Rizzolo, A., Vanoli, M., Spinelli, L., & Torricelli, A. (2010). Sensory characteristics, quality and optical properties measured by time-resolved reflectance spectroscopy in stored apples. *Postharvest Biology and Technology*, *58*(1), 1–12. https://doi.org/10.1016/j.postharvbio.2010.05.003

Rodriguez-Amaya, D. B., Kimura, M., Godoy, H. T., & Amaya-Farfan, J. (2008). Updated Brazilian database on food carotenoids: Factors affecting carotenoid composition. *Journal of Food Composition and Analysis*, *21*(6), 445–463. https://doi.org/10.1016/j.jfca.2008.04.001

Rohde, P. P., Mauerer, W., & Silberhorn, C. (2007). Spectral structure and decompositions of optical states, and their applications. *New Journal of Physics*, *9*. https://doi.org/10.1088/1367-2630/9/4/091

Romano, G., Argyropoulos, D., Gottschalk, K., Cerruto, E., & Müller, J. (2010). Influence of colour changes and moisture content during banana drying on laser backscattering. *International Journal of Agricultural and Biological Engineering*, *3*(2), 46–51. https://doi.org/10.3965/j.issn.1934-6344.2010.02.046-051

Romano, G., Argyropoulos, D., Nagle, M., Khan, M. T., & Müller, J. (2012). Combination of digital images and laser light to predict moisture content and color of bell pepper simultaneously during drying. *Journal of Food Engineering*, *109*(3), 438–448. https://doi.org/10.1016/j.jfoodeng.2011.10.037

Romano, G., Baranyai, L., Gottschalk, K., & Zude, M. (2008). An Approach for Monitoring the Moisture Content Changes of Drying Banana Slices with Laser Light Backscattering Imaging. *Food and Bioprocess Technology*, *1*(4), 410–414. https://doi.org/10.1007/s11947-008-0113-7

Romano, G., Nagle, M., Argyropoulos, D., & Müller, J. (2011). Laser light backscattering to monitor moisture content, soluble solid content and hardness of apple tissue during drying. *Journal of Food Engineering*, *104*(4), 657–662. https://doi.org/10.1016/j.jfoodeng.2011.01.026

Ronsse, F. (2015). Development of a Multi-Scale Model for Deep-Bed Drying of Rice. *Transactions of the ASABE*, (September), 849–859. https://doi.org/10.13031/trans.58.10904

Ruiz-Altisent, M., Ruiz-Garcia, L., Moreda, G. P., Lu, R., Hernandez-Sanchez, N., Correa, E. C., … García-Ramos, J. (2010). Sensors for product characterization and quality of specialty crops-A review. *Computers and Electronics in Agriculture*, *74*(2), 176–194. https://doi.org/10.1016/j.compag.2010.07.002

Russ, J. C. (2015). Image Analysis of Foods. *Journal of Food Science*, *80*(9), 1974–1987. https://doi.org/10.1111/1750-3841.12987

Sadin, R., Chegini, G., & Khodadadi, M. (2014). Development and Performance Evaluation of a Combined Infrared and Hot Air Dryer. *Journal of Biological and Environmental Sciences*, *8*(22), 11–18.

Saeed, I. E., Sopian, K., & Abidin, Z. Z. (2008). Drying characteristics of Roselle (1): Mathematical Modeling and Drying Experiments. *Agric Eng Int: CIGR Journal*, *X*(1), 1–25.

Sagar, V. R., & Suresh Kumar, P. (2010). Recent advances in drying and dehydration of fruits and vegetables: A review. *Journal of Food Science and Technology*, *47*(1), 15–26. https://doi.org/10.1007/s13197-010-0010-8

Sakai, N., & Hanzawa, T. (1994). Applications and advances in far-infrared heating in Japan. *Trends in Food Science and Technology*, *5*(11), 357–362. https://doi.org/10.1016/0924-2244(94)90213-5

Salagnac, P., Glouannec, P., & Lecharpentier, D. (2004). Numerical modeling of heat and mass transfer in porous medium during combined hot air, infrared and microwaves drying. *International Journal of Heat and Mass Transfer*, *47*(19-20), 4479–4489. https://doi.org/10.1016/j.ijheatmasstransfer.2004.04.015

Salarikia, A., Miraei Ashtiani, S.-H., & Golzarian, M. R. (2016). Comparison of Drying Characteristics and Quality of Peppermint Leaves Using Different Drying Methods. *Journal of Food Processing and Preservation*, *00*(Doymaz 2014), 1–13. https://doi.org/10.1111/jfpp.12930

Sanaeifar, A., Bakhshipour, A., & De La Guardia, M. (2016). Prediction of banana quality indices from color features using support vector regression. *Talanta*, *148*, 54–61. https://doi.org/10.1016/j.talanta.2015.10.073

Sarker, M. S. H., Ibrahim, M. N., Ab. Aziz, N., & Mohd. Salleh, P. (2014). Energy and rice quality aspects during drying of freshly harvested paddy with industrial inclined bed dryer. *Energy Conversion and Management*, *77*, 389–395. https://doi.org/10.1016/j.enconman.2013.09.038

Schössler, K., Jäger, H., & Knorr, D. (2012). Effect of continuous and intermittent ultrasound on drying time and effective diffusivity during convective drying of apple and red bell pepper. *Journal of Food Engineering*, *108*(1), 103–110. https://doi.org/10.1016/j.jfoodeng.2011.07.018

Scott, G. J. (1992). Sweet potatoes as animal feed in developing countries- present patterns and future prospects. *Roots, Tubers, Plantains and Bananas in Animal Feeding*.

Scott, G. J., & Suarez, V. (2012). The rise of Asia as the centre of global potato production and some implications for industry. *Potato Journal*, *39*(1), 1–22.

Senadeera, W., Bhandari, B. R., Young, G., & Wijesinghe, B. (2005). Modeling dimensional shinkage of shpaed foods in fluidized bed drying. *Journal of Food Processing and Preservation*, *29*, 109–119.

Seyhun, N., Ramaswamy, H., Sumnu, G., Sahin, S., & Ahmed, J. (2009). Comparison and modeling of microwave tempering and infrared assisted microwave tempering of frozen potato puree. *Journal of Food Engineering*, *92*(3), 339–344. https://doi.org/10.1016/j.jfoodeng.2008.12.003

Shi, J., Pan, Z., McHugh, T. H., Wood, D., Hirschberg, E., & Olson, D. (2008). Drying and quality characteristics of fresh and sugar-infused blueberries dried with infrared radiation heating. *LWT - Food Science and Technology*, *41*(10), 1962–1972. https://doi.org/10.1016/j.lwt.2008.01.003

Singh, H. P. (2008). Policies and strategies conducive to potato development in Asia and the Pacific region. *RAP Publication (FAO)*.

Singh, S., Raina, C. S., Bawa, A. S., & Saxena, D. C. (2006). Effect of Pretreatments on Drying and Rehydration Kinetics and Color of Sweet Potato Slices. *Drying Technology*, *24*(11), 1487–1494. https://doi.org/10.1080/07373930600952834

Singleton, V. L., & Rossi, J. A. (1965). Colorimetry of Total Phenolics with Phosphomolybdic-Phosphotungstic Acid Reagents. *American Journal of Enology and Viticulture*, *16*(3), 144–158.

Souraki, B. A., Ghavami, M., & Tondro, H. (2014). Correction of moisture and sucrose effective diffusivities for shrinkage during osmotic dehydration of apple in sucrose solution. *Food and Bioproducts Processing*, *92*(1), 1–8. https://doi.org/10.1016/j.fbp.2013.07.002

Soysal, Y., Ayhan, Z., Eştürk, O., & Arikan, M. F. (2009). Intermittent microwave-convective drying of red pepper: Drying kinetics, physical (colour and texture) and sensory quality. *Biosystems Engineering*, *103*(4), 455–463. https://doi.org/10.1016/j.biosystemseng.2009.05.010

Sparrow, E. M., & Abraham, J. P. (2002). Heat transfer coefficients and other performance parameters for variously positioned and supported thermal loads in ovens with/without water-filled or empty blockages. *International Journal of Heat and Mass Transfer*, *45*(17), 3597–3607. https://doi.org/10.1016/S0017-9310(02)00064-9

Sparrow, E. M., & Abraham, J. P. (2003). A computational analysis of the radiative and convective processes that take place in preheated and non-preheated ovens. *Heat Transfer Engineering*, *24*(5), 25–37. https://doi.org/10.1080/01457630304049

Stanish, M. A., Schajer, G. S., & Kayihan, F. (1986). A mathematical model of drying for hygroscopic porous media. *AIChE Journal*, *32*(8), 1301–1311. https://doi.org/10.1002/aic.690320808

State, T., Insecurity, F., & Database, F. A. O. (2001). FAO, "The State of Food Insecurity in the World 2001". FAO Database (FAOSTAT). 453, 453–489.

Sturm, B., Hofacker, W. C., & Hensel, O. (2012a). Optimizing the Drying Parameters for Hot-Air–Dried Apples. *Drying Technology*, *30*(14), 1570–1582. https://doi.org/10.1080/07373937.2012.698439

Sturm, B., Hofacker, W. C., & Hensel, O. (2012b). Optimizing the Drying Parameters for Hot-Air–Dried Apples. *Drying Technology*, *30*(14), 1570–1582. https://doi.org/10.1080/07373937.2012.698439

Supmoon, N., & Noomhorm, A. (2013). Influence of Combined Hot Air Impingement and Infrared Drying on Drying Kinetics and Physical Properties of Potato Chips. *Drying Technology*, *31*(1), 24–31. https://doi.org/10.1080/07373937.2012.711792

Swasdisevi, T., Devahastin, S., Sa-adchom, P., & Soponronnarit, S. (2009). Mathematical modeling of combined far-infrared and vacuum drying banana slice. *Journal of Food Engineering*, *92*(1), 100–106. https://doi.org/10.1016/j.jfoodeng.2008.10.030

Taiwo, K. a, & Adeyemi, O. (2009). Influence of blanching on the drying and rehydration of banana slices. *African Journal of Food Science*, *3*(10), 307–315.

Tang, Y., Cai, W., & Xu, B. (2015). Profiles of phenolics, carotenoids and antioxidative capacities of thermal processed white, yellow, orange and purple sweet potatoes grown in Guilin, China. *Food Science and Human Wellness*, *4*(3), 123–132. https://doi.org/10.1016/j.fshw.2015.07.003

Tao, Y., Wang, P., Wang, Y., Kadam, S. U., Han, Y., Wang, J., & Zhou, J. (2016). Power ultrasound as a pretreatment to convective drying of mulberry (Morus alba L.) leaves: Impact on drying kinetics and selected quality properties. *Ultrasonics Sonochemistry*, *31*, 310–318. https://doi.org/10.1016/j.ultsonch.2016.01.012

Thuwapanichayanan, R., Prachayawarakorn, S., & Soponronnarit, S. (2014). Heat and moisture transport behaviour and quality of chopped garlic undergoing different drying methods. *Journal of Food Engineering*, *136*, 34–41. https://doi.org/10.1016/j.jfoodeng.2014.03.017

Tog, H. (2006). Suitable drying model for infrared drying of carrot ˘. *Journal of Food Engineering*, *77*, 610–619. https://doi.org/10.1016/j.jfoodeng.2005.07.020

Tong, C. H., & Lund, D. B. (1990). Effective Moisture Diffusivity in Porous Materials as a Function of Temperature and Moisture Content. *Biotechnology Progress*, *6*(1), 67–75. https://doi.org/10.1021/bp00001a011

Toor, R. K., & Savage, G. P. (2006). Effect of semi-drying on the antioxidant components of tomatoes. *Food Chemistry*, *94*(1), 90–97. https://doi.org/10.1016/j.foodchem.2004.10.054

Tribst, A. A. L., Leite Júnior, B. R. D. C., De Oliveira, M. M., & Cristianini, M. (2016). High pressure processing of cocoyam, Peruvian carrot and sweet potato: Effect on oxidative enzymes and impact in the tuber color. *Innovative Food Science and Emerging Technologies*, *34*, 302–309. https://doi.org/10.1016/j.ifset.2016.02.010

Tuncel, N. B., Yilmaz, N., Kocabiyik, H., Öztürk, N., & Tunçel, M. (2010). The effects of infrared and hot air drying on some properties of corn (Zea mays). *Journal of Food, Agriculture and Environment*, *8*(1), 63–68.

Turner, I. W., & Perre, P. (2004a). Vacuum Drying of Wood with Radiative Heating: I. Experimental Procedure. *Aiche Journal*, *50*(1), 97–107. https://doi.org/Doi 10.1002/Aic.10010

Turner, I. W., & Perre, P. (2004b). Vacuum drying of wood with radiative heating: II. Comparison between theory and experiment. *Aiche Journal*, *50*(1), 108–118. https://doi.org/Doi 10.1002/Aic.10010

Turner, I. W., Puiggali, J. R., & Jomaa, W. (1998). A numerical investigation of combined microwave and convective drying of a hygroscopic porous material: A study based on pine wood. *Chemical Engineering Research and Design*, *76*(2), 193–209. https://doi.org/10.1205/026387698524622

Tzempelikos, D. a., Vouros, A. P., Bardakas, A. V., Filios, A. E., & Margaris, D. P. (2014). Case studies on the effect of the air drying conditions on the convective drying of quinces. *Case Studies in Thermal Engineering*, *3*, 79–85. https://doi.org/10.1016/j.csite.2014.05.001

Tzempelikos, D. a., Vouros, A. P., Bardakas, A. V., Filios, A. E., & Margaris, D. P. (2015). Experimental study on convective drying of quince slices and evaluation of thin-layer drying models. *Engineering in Agriculture, Environment and Food*, 1–9. https://doi.org/10.1016/j.eaef.2014.12.002

Udomkun, P., Nagle, M., Argyropoulos, D., Mahayothee, B., & Müller, J. (2016). Multi-sensor approach to improve optical monitoring of papaya shrinkage during drying. *Journal of Food Engineering*, *189*, 82–89. https://doi.org/10.1016/j.jfoodeng.2016.05.014

Udomkun, P., Nagle, M., Argyropoulos, D., Wiredu, A. N., Mahayothee, B., & Müller, J. (2017). Computer vision coupled with laser backscattering for non-destructive colour evaluation of papaya during drying. *Journal of Food Measurement and Characterization*, *0*(0), 1–9. https://doi.org/10.1007/s11694-017-9598-y

Udomkun, P., Nagle, M., Mahayothee, B., & Müller, J. (2014). Laser-based imaging system for non-invasive monitoring of quality changes of papaya during drying. *Food Control*, *42*, 225–233. https://doi.org/10.1016/j.foodcont.2014.02.010

Udomkun, P., Nagle, M., Mahayothee, B., Nohr, D., Koza, A., & Müller, J. (2015). Influence of air drying properties on non-enzymatic browning, major bio-active compounds and antioxidant capacity of osmotically pretreated papaya. *LWT - Food Science and Technology*, *60*(2), 914–922. https://doi.org/10.1016/j.lwt.2014.10.036

Umesh Hebbar, H., & Rastogi, N. K. (2001). Mass transfer during infrared drying of cashew kernel. *Journal of Food Engineering*, *47*(1), 1–5. https://doi.org/10.1016/S0260-8774(00)00088-1

Valentina, V., Ar, P., Py, H., Ht, T., Jf, H., & Cc, C. (2016). Sensorial Characterization of Foods Before and After. *Austin Food Sciences*, *1*(6), 1–5.

Van Hertem, T., Alchanatis, V., Antler, A., Maltz, E., Halachmi, I., Schlageter-Tello, A., … Berckmans, D. (2013). Comparison of segmentation algorithms for cow contour extraction from natural barn background in side view images. *Computers and Electronics in Agriculture*, *91*, 65–74. https://doi.org/10.1016/j.compag.2012.12.003

Vega, A., Uribe, E., Lemus, R., & Miranda, M. (2007). Hot-air drying characteristics of Aloe vera (Aloe barbadensis Miller) and influence of temperature on kinetic parameters. *LWT - Food Science and Technology*, *40*, 1698–1707. https://doi.org/10.1016/j.lwt.2007.01.001

Vega-Gálvez, a., Lemus-Mondaca, R., Bilbao-Sáinz, C., Fito, P., & Andrés, a. (2008). Effect of air drying temperature on the quality of rehydrated dried red bell pepper (var. Lamuyo). *Journal of Food Engineering*, *85*(1), 42–50. https://doi.org/10.1016/j.jfoodeng.2007.06.032

Vesali, F., Gharibkhani, M., Komarizadeh, M. H., Branch, A., & Club, Y. R. (2011). An approach to estimate moisture content of apple with image processing method. *Australian Journal of Crop Science*, *5*(2), 111–115.

Vimala, B., Nambisan, B., & Hariprakash, B. (2011). Retention of carotenoids in orange-fleshed sweet potato during processing. *Journal of Food Science and Technology*, *48*(4), 520–524. https://doi.org/10.1007/s13197-011-0323-2

Vishwanathan, K. H., Hebbar, H. U., & Raghavarao, K. S. M. (2010). Hot Air Assisted Infrared Drying of Vegetables and Its Quality. *Food Science and Technology Research*, *16*(5), 381–388. https://doi.org/10.3136/fstr.16.381

Walker, T., Thiele, G., Suarez, V., & Crissman, C. (2011). *Hindsight and foresight about potato production and consumption* (5 No. 5). Peru.

Wang, H., Zhang, M., & Mujumdar, A. S. (2014). Comparison of Three New Drying Methods for Drying Characteristics and Quality of Shiitake Mushroom (Lentinus edodes). *Drying Technology*, *32*(15), 1791–1802. https://doi.org/10.1080/07373937.2014.947426

Wang, J., Mu, W.-S., Fang, X.-M., Mujumdar, A. S., Yang, X.-H., Xue, L.-Y., … Zhang, Q. (2017). Pulsed vacuum drying of Thompson seedless grape: effects of berry ripeness on physicochemical properties and drying characteristic. *Food and Bioproducts Processing*, *106*, 117–126. https://doi.org/10.1016/j.fbp.2017.09.003

Wang, S., Nie, S., & Zhu, F. (2016). Chemical constituents and health effects of sweet potato. *Food Research International*, *89*, 90–116. https://doi.org/10.1016/j.foodres.2016.08.032

Wang, W., Hu, D., Pan, Y., Niu, L., & Chen, G. (2018). Multiphase transport modeling for freeze-drying of aqueous material frozen with prebuilt porosity. *International Journal of Heat and Mass Transfer*, *122*, 1353–1365. https://doi.org/10.1016/j.ijheatmasstransfer.2018.02.054

Wang, Y., Zhang, M., Mujumdar, A. S., & Chen, H. (2014). Drying and Quality Characteristics of Shredded Squid in an Infrared-Assisted Convective Dryer. *Drying Technology*, *32*(15), 1828–1839. https://doi.org/10.1080/07373937.2014.952379

Workneh, T. S., & Oke, M. O. (2013). Thin layer modelling of microwave-convective drying of tomato slices. *International Journal of Food Engineering*, *9*(1), 75–90. https://doi.org/10.1515/ijfe-2012-0205

Yadav, A. R., Guha, M., Tharanathan, R. N., & Ramteke, R. S. (2006). Influence of drying conditions on functional properties of potato flour. *European Food Research and Technology*, *223*(4), 553–560. https://doi.org/10.1007/s00217-005-0237-1

Yadav, B. S., Yadav, R. B., Kumari, M., & Khatkar, B. S. (2014). Studies on suitability of wheat flour blends with sweet potato, colocasia and water chestnut flours for noodle making. *LWT - Food Science and Technology*, *57*(1), 352–358. https://doi.org/10.1016/j.lwt.2013.12.042

Yadollahinia, A., & Jahangiri, M. (2009). Shrinkage of potato slice during drying. *Journal of Food Engineering*, *94*(1), 52–58. https://doi.org/10.1016/j.jfoodeng.2009.02.028

Yan, Z., Sousa-Gallagher, M. J., & Oliveira, F. A. R. (2008). Shrinkage and porosity of banana, pineapple and mango slices during air-drying. *Journal of Food Engineering*, *84*(3), 430–440. https://doi.org/10.1016/j.jfoodeng.2007.06.004

Yang, J., Chen, J. F., Zhao, Y. Y., & Mao, L. C. (2010). Effects of drying processes on the antioxidant properties in sweet potatoes. *Agricultural Sciences in China*, *9*(10), 1522–1529. https://doi.org/10.1016/S1671-2927(09)60246-7

Zainun, C. A., Salma, O., & Hamidah, H. (2005). Organoleptic acceptability and nutritional properties of the sweetpotato-based traditional cakes produced using sweetpotato flour. *Journal of Tropical Agriculture and Food Science*, *33*(2), 211–219.

Zare, D., Naderi, H., & Ranjbaran, M. (2015). Energy and Quality Attributes of Combined Hot-Air/Infrared Drying of Paddy. *Drying Technology*, *33*(5), 570–582. https://doi.org/10.1080/07373937.2014.962143

Zenoozian, M. S., Feng, H., Shahidi, F., & Pourreza, H. R. (2007). Image Analysis and Dynamic Modeling of Thin-Layer Drying of Osmotically Dehydrated Pumpkin. *Journal of Food Processing and Preservation*, *32*(2008), 88–102.

Zhang, B., Huang, W., Li, J., Zhao, C., Fan, S., Wu, J., & Liu, C. (2014). Principles, developments and applications of computer vision for external quality inspection of fruits and vegetables: A review. *Food Research International*, *62*, 326–343. https://doi.org/10.1016/j.foodres.2014.03.012

Zhang, H., & Li, D. (2014). Applications of computer vision techniques to cotton foreign matter inspection: A review. *Computers and Electronics in Agriculture*, *109*, 59–70. https://doi.org/10.1016/j.compag.2014.09.004

Zhang, J., & Datta, A. K. (2004). Some considerations in modeling of moisture transport in heating of hygroscopic materials. *Drying Technology*, *22*(8), 1983–2008. https://doi.org/10.1081/LDRT-200032740

Zhang, M., Chen, H., Mujumdar, A. S., Tang, J., Miao, S., & Wang, Y. (2017a). Recent Developments in High-quality Drying of Vegetables, Fruits and Aquatic Products. *Critical Reviews in Food Science and Nutrition*, *57*(6), 1239–1255. https://doi.org/10.1080/10408398.2014.979280

Zhang, M., Chen, H., Mujumdar, A. S., Tang, J., Miao, S., & Wang, Y. (2017b). *Recent developments in high-quality drying of vegetables, fruits, and aquatic products*. *Critical Reviews in Food Science and Nutrition* (Vol. 57). https://doi.org/10.1080/10408398.2014.979280

Zhang, M., Tang, J., Mujumdar, a. S., & Wang, S. (2006). Trends in microwave-related drying of fruits and vegetables. *Trends in Food Science & Technology*, *17*(10), 524–534. https://doi.org/10.1016/j.tifs.2006.04.011

Zhang, X., Liu, F., He, Y., Li, X., & Science, F. (2012). Application of Hyperspectral Imaging and Chemometric Calibrations for Variety Discrimination of Maize Seeds. *Sensors*, *12*, 17234–17246. https://doi.org/10.3390/s121217234

Zhao, D., An, K., Ding, S., Liu, L., Xu, Z., & Wang, Z. (2014). Two-Stage Intermittent Microwave Coupled with Hot-Air Drying of Carrot Slices: Drying Kinetics and Physical Quality. *Food and Bioprocess Technology*, *7*(8), 2308–2318. https://doi.org/10.1007/s11947-014-1274-1

Zheng, C., Sun, D.-W., & Zheng, L. (2006). Correlating colour to moisture content of large cooked beef joints by computer vision. *Journal of Food Engineering*, *77*(4), 858–863. https://doi.org/10.1016/j.jfoodeng.2005.08.013

Zhu, A., & Jiang, F. (2014). Modeling of mass transfer performance of hot-air drying of sweet potato (Ipomoea Batatas L.) slices. *Chemical Industry and Chemical Engineering Quarterly*, *20*(2), 171–181. https://doi.org/10.2298/CICEQ120509122Z

Zhu, H., Gulati, T., Datta, A. K., & Huang, K. (2015). Microwave drying of spheres: Coupled electromagnetics-multiphase transport modeling with experimentation. Part I: Model development and experimental methodology. *Food and Bioproducts Processing*, *96*, 314–325. https://doi.org/10.1016/j.fbp.2015.08.003