PHYSICOCHEMICAL AND RHEOLOGICAL PROPERTIES OF FOAM MAT DRIED PINEAPPLE Ananas comosus POWDERS

NUR ATIQAH BINTI SHAARI

FSTM 2019 32

PHYSICOCHEMICAL AND RHEOLOGICAL PROPERTIES OF FOAM MAT DRIED PINEAPPLE *Ananas comosus* POWDERS

By

NUR ATIQAH BINTI SHAARI

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of the Requirements for the Degree of Master of Science

November 2018

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the degree of Master of Science

PHYSICOCHEMICAL AND RHEOLOGICAL PROPERTIES OF FOAM MAT DRIED PINEAPPLE *Ananas comosus* POWDERS

By

NUR ATIQAH BINTI SHAARI

November 2018

Chair : Rabiha Binti Sulaiman, PhD
Faculty : Food Science and Technology

Pineapple fruit (*Ananas comosus*) has a high moisture content and highly perishable. Pineapple fruit has a high sugar content, fibre, sticky, viscous and sensitive to heat which is quite unsuitable for drying methods such as spray drying and drum drying. Foam mat drying is a suitable method for dehydration of any heat sensitive, sticky and viscous materials. The aim of this study was to evaluate the foam properties using different foaming agents at different concentration and whipping time and compare the physicochemical properties of foam mat dried and spray dried pineapple powders. Pineapple juice was foamed using two different protein bases; egg albumen (5, 10, 20% w/w) and fish gelatin (5, 10, 20% w/w) and carbohydrate base; methylcellulose (0.5, 1.0, 1.5% w/w). Then, 5% w/w maltodextrin was added as a foam stabilizer. The mixtures were blended at different whipping time (10, 20 and 30 min) and foam pineapple juice was hot air-dried using cabinet dryer at 50 ^{o}C until reached moisture content less than 8% w.b. The dried foam mat was scratched, grinded and analyzed. The results showed that an increase in foaming agent (egg albumen and fish gelatin) concentration significantly increased the foam expansion and significantly decreased foam density ($p \leq 0.05$). Analysis of physicochemical properties (pH, total soluble solid, acidity, water activity, moisture content, total phenolic content, color, water solubility index, water absorption index, bulk density and hygroscopicity) and rheological properties (steady shear and dynamic shear) were done on the reconstituted foam mat dried pineapple powder samples. The effect of temperature and concentration on rheological behavior of spray dried and foam mat dried pineapple juice concentrates were investigated using a rheometer over a wide range of temperatures (25-75 ^{o}C) and concentrations (10-50 ^{o}Brix). The pineapple juice concentrates fitted to the Power law model and exhibited shear thinning behavior within the range $0.01 < n < 0.86$. Consistency coefficient (K) and apparent viscosity of all samples increased as the concentration increased and temperature decreased. The activation energy of spray dried and foam mat dried pineapple juice concentrates treated with egg albumen and fish gelatin were found in the range of 19.96–49.56 kJ/mol, 11.67-36.30 kJ/mol and 12.36-23.66 kJ/mol, respectively. Foam mat dried pineapple juice treated with methylcellulose showed the highest G' (solid

like) and G" (liquid like) values at all concentration (10-50 ^{o}Brix), followed by samples treated with egg albumen and fish gelatin. Foam mat dried pineapple juices treated with methylcellulose showed lower tan δ which represent concentrated samples followed by foam mat dried pineapple juices treated with egg albumen and fish gelatin. Foam mat dried pineapple powder is suitable for instant beverages and confectionery products like pie filling while spray dried pineapple powder recommended for instant beverages. The obtained data are useful in the food product development and the use of fish gelatin in this study could help in halal product development by replacing the use of mammalian gelatin since it has similar properties.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Sarjana Sains

SIFAT FIZIKOKIMIA DAN REOLOGI SERBUK BUAH NENAS *Ananas comosus* DARI KAEDAH PENGERINGAN DENGAN BUIH

Oleh

NUR ATIQAH BITI SHAARI

November 2018

Pengerusi : Rabiha Binti Sulaiman, PhD
Fakulti : Sains dan Teknologi Makanan

Nenas (*Ananas comosus*) adalah sejenis buah yang mempunyai kandungan kelembapan yang tinggi dan mudah mengalami kerosakan. Nenas juga mempunyai kandungan gula yang tinggi, kandungan serat yang tinggi, melekit, likat dan sensitif terhadap haba yang mana sifat-sifat ini menjadikan nenas tidak stabil untuk kaedah pengeringan seperti pengeringan sembur dan pengeringan drum. Pengeringan buih adalah kaedah pengeringan yang paling sesuai untuk dehidrasi mana-mana bahan yang sensitif haba, melekit dan likat. Tujuan kajian ini dijalankan adalah untuk menilai sifat-sifat buih menggunakan agen pembuih yang berbeza dan masa kisaran yang berbeza dan kemudian membandingkan sifat-sifat fizikokimia serbuk nenas menggunakan kaedah pengeringan buih dan pengeringan sembur. Jus nenas dibuihkan dengan agen pembuih yang berbeza; putih telur (5, 10, 20% w/w), gelatin ikan (5, 10, 20% w/w) dan metilselulosa (0.5, 1.0, 1.5% w/w) dan 5% w/w maltodekstrin ditambah sebagai agen penstabil. Campuran tersebut kemudian dikisar dengan menggunakan masa kisaran yang berbeza (10, 20 and 30 minit) dan buih jus nenas dikeringkan dalam kabinet pengering pada suhu 50 ^{o}C sehingga kandungan kelembapan mencecah kurang daripada 8% w.b. Produk kering kemudian dikisar dan seterusnya dianalisis. Hasil keputusan menunjukkan semakin meningkat kepekatan agen pembuih (putih telur dan gelatin ikan), semakin berkembang buih dan semakin berkurang ketumpatan buih ($p \leq 0.05$). Analisis sifat fizik dan kimia (pH, jumlah pepejal larut, keasidan, aktiviti air, kandungan kelembapan, kandungan jumlah fenolik, warna, indek kelarutan air, indek penyerapan air, ketumpatan pukal dan higroskopisiti) dan sifat reologi (steady shear dan dinamik shear) dijalankan ke atas sampel serbuk nenas. Kesan suhu dan kepekatan ke atas sifat reologi serbuk nenas secara pengeringan sembur dan buih dijalankan mengunakan reometer pada suhu (25-75 ^{o}C) and kepekatan (10-50 ^{o}Brix). Jus nenas pekat disesuaikan dengan model hukum Power dan menunjukkan shear thinning dengan $0.01 < n < 0.86$. Konsisten koefisien (K) dan apparent viskositi untuk semua sampel meningkat dengan peningkatan kepekatan dan pengurangan suhu. Tenaga pengaktifan serbuk nenas secara sembur dan buih menggunakan putih telur dan gelatin ikan adalah pada kadar 19.96–49.56 kJ/mol, 11.67-

36.30 kJ/mol dan 12.36-23.66 kJ/mol, masing-masing. Serbuk nenas secara buih menggunakan agen pembuih metilselulosa menunjukkan nilai G' dan G" yang paling tinggi pada setiap kepekatan (10-50 ^{o}Brix) diikuti sampel putih telur dan gelatin ikan. Serbuk nenas secara buih yang dilarutkan menggunakan agen pembuih metilselulosa menunjukan tan δ yang lebih rendah (lebih pekat) diikuti oleh jus nenas yang dibuih menggunakan putih telur dan gelatin ikan. Serbuk nenas secara buih boleh digunakan untuk minuman segera dan produk konfeksi seperti inti pai manakala serbuk nanas secara sembur lebih sesuai untuk membuat jus minuman. Data yang diperolehi berpotensi untuk digunakan pada kajian yang akan datang dan penggunaan gelatin ikan dalam kajian ini dapat membantu dalam penghasilan dan pembangunan produk halal dengan menggantikan penggunaan gelatin mamalia.

ACKNOWLEDGEMENTS

First and foremost, my gratitude is to Allah Al-Mighty that gives me all this strength and courage to complete this thesis writing. Deepest gratitude and appreciation to my supervisor Dr. Rabiha Sulaiman. Thank you for all her valuable ideas and suggestions that help to conduct the experimental lab works as well as comment of improvement to complete this thesis. Special thanks to my co-supervisors Prof Russly Abdul Rahman and Prof Jamilah Bakar for the guidance and constructive suggestion throughout the process.

I would like to give my special appreciation to my beloved parents, Shaari Awang and Wan Kamilah Wan Yaccob for the motivation, guidance and moral support especially during my difficult time. Big thanks to my family and all my friends for loyal stand by me throughout this time.

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

Rabiha Sulaiman, PhD
Senior Lecturer
Faculty of Food Science and Technology
Universiti Putra Malaysia
(Chairman)

Russly Abdul Rahman, PhD
Professor
Faculty of Food Science and Technology
Universiti Putra Malaysia
(Member)

Jamilah Bakar, PhD
Professor
Faculty of Food Science and Technology
Universiti Putra Malay

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

Date:

Declaration by graduate student

I hereby confirm that:

- this thesis is my original work;
- quotations, illustrations and citations have been duly referenced;
- this thesis has not been submitted previously or concurrently for any other degree at any other institutions;
- intellectual property from the thesis and copyright of thesis are fully-owned by Universiti Putra Malaysia, as according to the Universiti Putra Malaysia (Research) Rules 2012;
- written permission must be obtained from supervisor and the office of Deputy Vice-Chancellor (Research and Innovation) before thesis is published (in the form of written, printed or in electronic form) including books, journals, modules, proceedings, popular writings, seminar papers, manuscripts, posters, reports, lecture notes, learning modules or any other materials as stated in the Universiti Putra Malaysia (Research) Rules 2012;
- there is no plagiarism or data falsification/fabrication in the thesis, and scholarly integrity is upheld as according to the Universiti Putra Malaysia (Graduate Studies) Rules 2003 (Revision 2012-2013) and the Universiti Putra Malaysia (Research) Rules 2012. The thesis has undergone plagiarism detection software.

Signature: _____ Date: _____

Name and Matric No.: Nur Atiqah Binti Shaari (GS42602)

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) are adhered to.

Signature: _____
Name of Chairman of Supervisory Committee: Dr. Hjh Rabiha Hj Sulaiman

Signature: _____
Name of Member of Supervisory Committee: Prof. Dr. Russly Abdul Rahman

Signature: _____
Name of Member of Supervisory Committee: Prof. Dr. Jamilah binti Bakar

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

%	Percentage
^{o}C	Degree Celsius
^{o}	Degree
µl	Microliter
µm	Micrometer
Cp	Centipoise
$\dot{y}$	Shear rate
ANOVA	Analysis of variance
AOAC	Association of Official Analytical Chemists
Ea	Activation energy
FAO	Food Agriculture Organizations
GME	Good Manufacturing Europe
G	Gram
G’	Storage modulus
G”	Loss modulus
H	Hour
kJ	Kilojoule
K	Consistency coefficient
Mg	Miligram
Ml	Mililitre
Mm	Milimetre
Min	Minutes
Mol	Mole
N	Flow behavior index

η_{100}	Apparent viscosity at shear rate of $100s^{-1}$
Pa	Pascal
Pa.s	Pascal second
R^2	Coefficient of determination
RH	Relative humidity
Rad	Radian
Rpm	Revolutions per minute
S	Seconds
TSS	Total soluble solid
w/w	Weight per weight
w/v	Weight per volume

CHAPTER 1

INTRODUCTION

1.1. Research Background

Pineapple (*Ananas comosus*) is one of the most popular tropical fruits after banana and citrus (Jaji, Man & Nawi, 2018) and it is known for its attractive aroma, flavor and refreshing sugar-acid balance (Noranizan et al., 2011). In Malaysia, pineapple became the first crop grown as a commodity crop with high export potential and raised the position of Malaysia as one of the top three pineapple producers in the world during the late 60s and early 70s (Jaji et al., 2018). Food Agricultural Organizations (FAO) reported that for the year 2013, Malaysia produced 315.977 metric tons of pineapple for the globe and it ranked nineteenth in the pineapple producing countries in the world (FAO, 2013; Agrofood Statistics, 2013).

Pineapple provides essential micronutrients in the human diet especially vitamins and minerals. The nutritional compounds in pineapple are generally identified as phytochemicals such as phenolic compounds which contribute to its antioxidant activity (Heim, Tagliaferro, & Bobilya, 2002; Hossain & Rahman, 2010). These components not only reduce the risk of oxidative damage related in the presence of free radicals but also effective agents against degenerative diseases of humans such as cancer, inflammation, atherosclerosis, aging and neurological diseases (Chang, Hasanah, Olga Martín, & Mohd, 2014).

However, pineapple faces a major challenge which is post-harvest losses. Pineapple has high moisture content and highly perishable. The shelf life of ripe pineapple is short and limited to 4-6 days (Hajare et al., 2006). Pineapple undergoes rapid deterioration in quality due to the short shelf life such as flavor degradation, color changes, excessive softening, reducing in sugar content and also increases the risk in susceptibility of microorganism. In addition, fresh pineapple contains thick, thorny inedible peel and a large crown, which occupies storage space and also results in higher transportation costs (Saxena, Mishra, Chander, & Sharma, 2009). To overcome the post-harvest losses during storage, pineapple should be processed into shelf stable products to make it durable for a longer time.

Drying is one of the common methods for preservation of fruits and extends the food shelf life by the reduction of the moisture content to a certain level. Drying process also brings about substantial reduction in weight and volume, minimizing packaging, storage and transportation costs (Kadam, Samuel, Chandra, & Sikarwar, 2008). In the food industry, many drying techniques have been applied such as sun drying, spray drying, freeze drying, drum drying and foam mat drying. Freeze and spray drying methods give excellent product quality with good rehydration and color. However, high operation and maintenance cost make it limited only for premium quality products (Sangamithra,

Sivakumar, Swamy, & Kannan, 2015). Among the other drying methods, foam mat drying is relatively simple, cost effective, rapid drying rate and enhances the quality of product.

Foam mat drying is a process that involves air incorporated into the liquid with the addition of foaming and stabilizing agents to produce stable foam and subsequently dried by thermal to form a thin porous honeycomb mat which is disintegrated to free-flowing powder. According to Lewicki (2006), the more porous structure of the foam, the larger the liquid surface area which enhances the heat transfer, resulting in a shorter drying time. The dried product obtained from this process is of better quality, porous and can be easily reconstituted (Kadam et al., 2012). Foam mat drying also allows the dehydration of any heat sensitive, high sugar content, and sticky and viscous materials which cannot be dried by other drying method and thus foam mat drying is a suitable drying method to preserve the fruit in powder form. Other drying methods such as the spray drying needs to remove the pineapple pulp during the drying process. However, the overall part of the fruit can be used in foam mat drying and make it possible in producing powder with high nutritional contents and a valuable product in the market.

In foam mat drying method, choosing a suitable foaming agent are very important. There are many types of foaming agents in the market and gelatin is one of common foaming agent that used in food industry. However, in the food industry, gelatin-based products became one of the most controversial issues especially in the Muslim world regarding the source of gelatin (Asher, 1999). Hayatudin (2005) reported that 41% of the gelatin produced in the world is sourced from pig skin, 28.5% from bovine hides and 29.5% from bovine bones. While in Europe, 80% of edible gelatin is produced from pig skin, 15% is from cattle hide split and 5% is from pig, cattle bones and fish (GME, 2013). This issue arises because of religious sentiment. For instance, both Judaism and Islam consider all any pork-related products prohibited to be consumed, while Hindus do not consume any cow-related products (Karim & Bhat, 2009). In addition, there is increasing concern among researchers about bovine gelatin having a potential risk of spreading bovine spongiform encephalopathy (BSE) or widely known as mad cow disease and food mouth disease (FMD) (Gudmundsson, 2002). According to an estimation by Kettani (2010), the Muslim community represents 1.65 billion of the world population and this number is expected to increase to 2.2 billion by 2030. Therefore, it is becoming increasingly difficult to ignore that the demand for halal products on the market place will also be increasing and fish gelatin can be considered as a possible alternative due to its similar characteristics to mammalian gelatin (Elgadir, Mirghani, & Adam, 2013).

There is growing scientific background for the role of foaming agent in the production of foam mat dried fruit powder. Type of foaming agents play an important role in determining the quality of the products since it comes from different characteristic. Thus, it is important to study the properties of powder with different foaming agents. Attributes of foam properties such as foam density and expansion also play a main role because they provide an essential part in the migration of the moisture during drying (Bag, Srivastav, & Mishra, 2011; Thuwapanichayanan, Prachayawarakorn, Kunwisawa, & Soponronnarit, 2011).

1.2 Problem Statement

Pineapple fruit has a high sugar content, fibre, sticky, viscous and sensitive to heat which is quite unstable for drying method such as spray drying and drum drying. Foam mat drying is a suitable method for dehydration of any heat sensitive, sticky and viscous foods. In addition, choosing a suitable foaming agent are very important in foam mat drying method since it can affect the the quality of final products. There are many types of foaming agents in the market and gelatin is one of common foaming agent that used in food industry. However, gelatin-based products became one of the most controversial issues in food industry especially in the Muslim world regarding the source of gelatin. Moreover, no previous work has been done on foam mat drying of pineapple using fish gelatin. Therefore, in this study, the use of fish gelatin could help in developing halal product by substitute the use of mammalian gelatin to fish gelatin.

1.3 Research Hypothesis

To address the objectives, several hypothsis were stated as follows:

a) Different type of foaming agents and concentration will affect the physicochemical properties of foam mat dried pineapple powder
b) Different concentration of foaming agent and temperature will affect the rheological behavior of reconstituted foam mat dried pineapple powder

1.4 Research Aims And Objective

The research aims to develop produce pineapple powder using foam mat drying method with different type of halal base foaming agents. To achieve the aim, several objectives were set, as listed below:

a) To evaluate the foam properties using different foaming agents at different concentration and whipping time
b) To compare the physicochemical properties of foam mat dried and spray dried pineapple powders
c) To determine the effect of concentration and temperature on steady and dynamic shear rheological properties of rehydrated foam mat dried pineapple powder.

1.5 Scope, Novelty And Limitation Of Research

This study was conducted to produce foam mat dried pineapple powder using three different foaming agents; protein base (egg albumen and fish gelatin) and carbohydrate base (methylcellulose) at different concentration and whipping time. In foam mat drying method, understanding the behavior of foaming agents on the properties of foam mat dried pineapple powders is important in producing a good quality of final products. Also, understanding the rheological properties of the reconstituted powder is important for food engineer during the process design calculations and aids food producer choose the suitable formulation and conditions for specific processing conditions. The originality of this study is no previous work have been done on foam mat drying of pineapple using fish gelatin and methycellulose as foaming agent and the limitation of this study is the finding from this research is specific for Josephine variety pineapple.

REFERENCES

Abadio, F. D. B., Domingues, A. M., Borges, S. V., & Oliveira, V. M. (2004). Physical properties of powdered pineapple (*Ananas comosus*) juice-effect of maltodextrin concentration and atomization speed, *Journal of Food Engineering*, 64: 285–287.

Abbas, E., & Azizpour, M. (2016). Evaluation of physicochemical properties of foam mat dried sour cherry powder. *LWT - Food Science and Technology*, 68: 105-110.

Abeyrathne, E. D., Lee, H. Y., & Ahn, D. U. (2013). Egg white proteins and their potential use in food processing or as nutraceutical and pharmaceutical agents. - A review. *Poultry Science*, 92(12): 3292–3299.

Adhikari, B., Howes, T., Bhandari, B. R., & Truong, V. (2003). Characterization of the surface stickiness of fructose–maltodextrin solutions during drying. *Drying Technology*, 21(1): 17-34.

Agrofood Statistics (2013). Pineapple production. In Selected Agricultural Indicator Malaysia, p.16. Department of Statistics, Malaysia. ISSN 2289-2257.

Ahmed, J., & Ramaswamy, H. S. (2006). Viscoelastic and thermal characteristics of vegetable puree-based baby foods. *Journal of Food Process Engineering*, 29: 219–233.

Akbulut, M., Coklar, H., & Zen, G. (2008). Rheological characteristics of *Juniperus drupacea* fruit juice (pekmez) concentrated by boiling. *Food Science and Technology International*, 14: 321-328.

Akintoye, O., & Oguntunde, A. (1991). Preliminary investigation on the effect of foam stabilizers on the physical characteristics and reconstitution properties of foam-mat dried soymilk. *Drying Technology*. 9: 245–262.

Alleoni, A. C. C. (2006). Albumen protein and functional properties of gelation and foaming. *Scientia Agricola*, 63(3): 291-298.

Ali, M. S., Ghazaleh, H., & Akram, A. (2014). Effect of temperature and concentration on density and rheological properties of melon (*Cucumis melo* L. var. *Inodorus*) juice. *Nutrition & Food Science*, 44(2): 168-178.

Altan, A., & Maskan, M. (2005). Rheological behavior of pomegranate (*Punica granatum*
L.) juice and concentrate. *Journal of Texture Studies*, 36(1): 68–77.

Alvarez, M. D., Fernández, C., & Canet, W. (2004). Rheological behavior of fresh and frozen potato puree in steady and dynamic shear at different temperatures. *European Food Research Technology*, 218: 544–553.

Ambekar, S., Gokhale, S., & Lele, S. (2013). Process optimization for foam mat-tray drying of *Passiflora edulis flavicarpa* pulp and characterization of the dried powder. *International Journal of Food Engineering*, 9: 1–11

Angkananon, W., & Anantawat, V. (2015). Effects of spray drying conditions on characteristics, nutritional value and antioxidant activity of gac fruit aril powder. *Review of Integrative Business & Economic Research*, 4: 1-11.

Antonio, G. C., Faria, F. R., Takeiti, C. Y., Park, K. J. (2009). Rheological behavior of blueberry. *Ciência e Tecnologia de Alimentos Campinas*, 29(4): 732-737.

Arzhavitina, A., & Steckel, H. (2010). Foams for pharmaceutical and cosmetic application. *International Journal of Pharmaceutics*, 394, 1-17.

Asher, D. M. (1999). The transmissible spongiform encephalopathy agents: concerns and responses of United States regulatory agencies in maintaining the safety of biologics. *Development in Biological Standard*, 100: 103–118.

Assis, M. M. M., Tadini, C. C., Lannes, S. C. & Da., S. (2005). Influence of temperature and concentration on rheological properties of caja juice (*Spondia mombin*, L). Eurotherm Seminar 77 – Heat and Mass Transfer in Food Processing June 20-22, 2005 Parma, Italy.

Auisakchaiyoung, T., & Rojanakorn, T. (2015). Effect of foam-mat drying conditions on quality of dried Gac fruit (*Momordica cochinchinensis*) aril. *International Food Research Journal*, 22(5): 2025-2031.

Augusto, P. E. D., Ibarz, A., & Cristianini, M. (2012). Effect of high pressure homogenization (HPH) on the rheological properties of a fruit juice serum model. *Journal of Food Engineering*, 111: 474–477.

Augusto, P. E. D., Falguera, V., Cristianini, M., & Ibarz, A. (2011). Influence of fiber addition on the rheological properties of peach juice. *International Journal of Food Science and Technology*, 46: 1086–1092.

Augusto, P. E. D., Falguera, V., Cristianini, M., & Ibarz, A. (2011). Viscoelastic properties of tomato juice. *Procedia Food Science*, 1: 589–593.

Avila, E. L., Rodríguez, M. C., & Velásquez, H. J. C. (2015). Influence of maltodextrin and spray drying process conditions on sugarcane juice powder quality. *Revista Facultad Nacional de Agronomía Medellín*, 68(1): 7509-7520.

Azizpour, M., Mohebbi, M., & Haddad Khodaparast, M. H., (2016). Effects of foam-mat drying temperature on physico-chemical and microstructural properties of shrimp powder. *Innovative Food Science and Emerging Technologies*, 34: 122–126.

Azizpour, M., Mohebbi, M., Haddad Khodaparast, M. H., & Varidi, M. (2013). Foam-mat drying of shrimp: Characterization and drying kinetics of foam. *Agricultural Engineering International: The CIGR Journal*, 15(3): 159–165.

Barbosa-Canovas, G. V., & Juliano, P. (2005). Physical and chemical properties of food powders. In C. Onwulata (Ed.), *Encapsulated and powdered foods* (pp. 39–71). Boca Raton: Taylor and Francis.

Bag, S. K., Srivastav, P. P., & Mishra, H. N. (2011). Optimization of process parameters for foaming of bael (*Aegle marmelos* L.) fruit pulp. *Food Bioprocess Technology*. 4: 1450–1458.

Bartolome, A. P., Ruperez, P., & Fuster, C. (1995). Pineapple fruit: morphological characteristics, chemical composition and sensory analysis of Red Spanish and Smooth Cayenne cultivars. *Food Chemistry*, 53: 75–79.

Bayindirli, L., Ozilgen, M., & Ungan, S. (1993). Mathematical analysis of freeze concentration of apple juice. *Journal of Food Engineering*, 19: 95-107.

Bayod, E., Willers, E. P., & Tornberg, E. (2008). Rheological and structural characterization of tomato paste and its influence on the quality of ketchup. *LWT-Food Science and Technology*, 41: 1289–1300.

Belibağli, K. B., & Dalgic, A. C. (2007). Rheological properties of sour-cherry juice and concentrate. *International Journal of Food Science and Technology*, 42: 773–776.

Belitz, H. D., Grosch, W., & Schieberle, P. (2004). Food Chemistry (3rd rev. ed.). Berlin Springer.

Belitz, H. D., Grosch, W., & Schieberle, P. (2009). Food chemistry (4th ed.). Berlin: Springer.

Berk, Z. (2009). Food process engineering and technology (1st ed.). NewYork: Academic Press.

Betts, G., Cook, S., McLean, B., Betts, R., Sharpe, T., & Walker, S. (2006). Scientific review of the microbiological risks associated with reductions in fat and added sugar in foods. *Food Standards Agency*: 1-55.

Bhandari, B., & Howes, T. (2005). Relating the stickiness property of foods undergoing drying and dried products to their surface energetics. *Drying Technology*, 23(4): 781-797.

Binsi, P. K., Shamasundara, B. A., Dileepa, A. O., Badiib, F., & Howell, N. K. (2009). Rheological and functional properties of gelatin from the skin of Bigeye snapper (*Priacanthus hamrur*) fish: Influence of gelatin on the gel-forming ability of fish mince. *Food hydrocolloids*, 23: 132-145.

Boger, D. V., & Tiu, C. (1974). Rheological properties of food products and their use in the design of flow systems. *Food Technology*, 26: 325–335.

Cabral, R. A. F., Gut, J. A. W., Telis, V. R. N., & Telis Romero, J. (2010). Non-newtonian flow and pressure drop of pineapple juice in a plate heat exchanger. *Brazilian Journal of Chemical Engineering*, 27 (4): 563-571.

Cano-Chauca, M., Stringheta, P. C., Ramos, A. M., & Cad-Vidal, J. (2005). Effect of the carriers on the microstructure of mango powder obtained by spray drying and its functional characterization. *Innovative Food Science and Emerging Technologies*, 6: 420–428.

Caparino, O. A., Tang, J., Nindo, C. I., Sabiani, S. S., Powers, J. R., & Fellman, J. K. (2012). Effect of drying methods on the physical properties and microstructures of mango (Philippine 'Carabao' var.) powder. *Journal of Food Engineering*, 111: 135-148.

Carp, D., Baeza, R., Bartholomai, G., & Pilosof, A. (2004). Impact of proteins- κ-carrageenan interactions on foam properties. *LWT- Food Science and Technology*, 37: 573-580.

Chaikham, P., & Apichartsrangkoon, A. (2012). Comparison of dynamic viscoelastic and physicochemical properties of pressurized and pasteurized longan juices with xanthan addition. *Food Chemistry*, 134: 2194–2200.

Chandak, A. J. & Chivate, M. R. (1974). Studies in foam-mat drying of coffee extract. *Indian Food Packer*, 28(2): 17-27.

Chang, C. S., Hasanah, M. G., Olga Martín, B., & Mohd, A. N. (2014). Effects of combining ultraviolet and mild heat treatments on enzymatic activities and total phenolic contents in pineapple juice. *Innovative Food Science ad Emerging Technologies*, 26: 511-516.

Chang, Y. H., & Cui, S. W. (2011). Steady and dynamic shear rheological properties of extrusion modified fenugreek gum solutions. *Food Science and Biotechnology*, 20(6): 1663–1668.

Chegini, G. R., & Ghobadian, B. (2007). Spray dryer parameters for fruit juice drying. *World Journal of Agricultural Sciences*, 3(2): 230-236.

Chegini, G., & Ghobadian, B. (2005). Effect of spray-drying conditions on physical properties of orange juice powder. *Drying Technology*, 23: 657–668.

Chin, N. L., Chan, S. M., Yusof, Y. A., Chuah, T. G., & Talib, R. A. (2009). Modelling of rheological behaviour of pummelo juice concentrates using master-curve. *Journal of Food Engineering* 93(2): 134–140.

Cole, C. G. B. (2000). Gelatin. In F. J. Francis (Ed.), *Encyclopedia of food science and technology* (pp. 1183-1188). New York: John Wiley & Sons.

Dak, M., Verma, R. C., & Jaaffrey, S. N. A. (2007). Effect of temperature and concentration on rheological properties of ''Kesar'' mango juice. *Journal of Food Engineering*, 80(4): 1011–1015.

Dak, M., Verma, R. C., & Sharma, G. P. (2006). Flow characteristics of juice of ''Totapuri'' mangoes. *Journal of Food Engineering*, 76: 557–561.

Damodaran, S., Parkin, K. L., & Fennema, O. R. (2010). Fennema's food chemistry (4th ed.). London: CRC Press.

De Wolf, F. A. (2003). Collagen and gelatin. In: Progress in biotechnology, vol. 23. Elsevier Science B.V., pp 133-218.

Elgadir, M. A., Mirghani, M. E. S., & Adam. A. (2013). Fish gelatin and its applications in selected pharmaceutical aspects as alternative source to pork gelatin. Journal of Food, Agriculture & Environment, 11(1): 73-79.

Ersus, S., & Yurdagel, U. (2007). Microencapsulation of anthocyanin pigments of black carrot (*Daucus carota* L.) by spray drier. *Journal of Food Engineering*, 80(3): 805–812.

Falade, K. O., & Okocha, J. O. (2012) Foam-mat drying of plantain and cooking banana (*Musa* spp.). *Food and Bioprocess Technology*, 5(4):1173–1180.

Falade, K., Adeyanju, K., & Uzo-peters, P. (2003). Foam-mat drying of cowpea (*Vigna unguiculata*) using glyceryl monostearate and egg albumin as foaming agents. *European Food Research Technology*, 217: 486–491.

Fazaeli, M., Emam-Djomeh, Z., Ashtari, A. K., & Omid, M. (2012a). Effect of process conditions and carrier concentration for improving drying yield and other quality attributes of spray dried black mulberry (*Morus nigra*) juice. *International Journal of Food Engineering*, 8(1): 1–20.

Febrianto, A., Kumalaningsih, S., & Aswari, A.W. (2012). Process engineering of drying milk powder with foam-mat drying method. A study on the effect of the concentration and types of filler Process. *Journal of Basic and Applied Scientific Research*, 2(4): 3588-3591.

Fennema, O. R. (1996). The biochemistry of the carotenoids. In O. R. Fennema (Ed.), *Food chemistry* (2nd ed.). New York: Marcel Dekker Inc.

Fernandez R. V. B., Queiroz, F., Botrel, D. A., Rocha, V.V., de Lima C. F., & de Souza V. R. (2013). Foam mat drying of tomato pulp. *Bioscience Journal Uberlândia*, 29(4): 816-825.

Food and Agriculture Organization of the United Nations (FAO). (2013). Pineapple fresh production. Retrieved on September 25, 2018 from http://faostat3.fao.org/home/index.html.

Franco, T. S., Perussello, C. A., Ellendersen, L. N., & Masson, M. L. (2016). Effects of foam mat drying on physicochemical and microstructural properties of yacon juice powder. *LWT- Food Science and Technology*, 66: 503–513.

Gabas, A. L., Telis, V. R. N., Sobral, P. J. A., & Telis-Romero, J. (2007). Effect of maltodextrin and arabic gum in water vapor sorption thermodynamic properties of vacuum dried pineapple pulp powder. *Journal of Food Engineering*, 82(2): 246-252.

Giner, J., Ibarz, A., Garza, S., & Xhian-Quan, S. (1996). Rheology of clarified cherry juices. *Journal of Food Engineering*, 30: 147-154.

GME (2013). Gelatin Manufacturers of Europe.

Gelatin Manufacturers Institute of America (GMIA). 2012. Gelatin Handbook. America: GMIA.

Goula, A. M., & Adamopoulos, K. G. (2010). A new technique for spray drying orange juice concentrate. *Innovative Food Science and Emerging Technologies*, 11: 342–351.

Grabowski, J. A., Truong, V. D., & Daubert, C. R. (2006). Spray drying of amylase hydrolyzed sweet potato puree and physicochemical properties of powder. *Journal of Food Science*, 71(E2): 09–17.

Gratão, A. C. A., Silveira, V., & Telis-Romero, J. (2007). Laminar flow of soursop juice through concentric annuli: Friction factors and rheology. *Journal of Food Engineering*, 78: 1343–1354.

Gratão, A. C. A., Silveira Jr., V., & Telis-Romero, J. (2006). Laminar forced convection to a pseudoplastic fluid food in circular and annular ducts. *International Communications in Heat and Mass Transfer*, 33: 451–457.

Grover, J. A. (1984). In M. Glicksman (Ed.), *Food hydrocolloids* (pp. 121). Florida: CRC Press.

Gudmundsson, M. (2002). Rheological properties of fish gelatins. *Journal of Food Science*, 67: 2172–2176.

Gunko, S., Verbych, S., Bryk, M., & Hilal, N. (2006), Concentration of apple juice using direct contact membrane distillation. *Disalination*, 190: 117-124.

Hajare, S., Dhokane, V., Shashidhar, R., Saroj, S. D., Sharma, A., & Bandekar, J. R. (2006). Radiation processing of minimally processed pineapple (*Ananas comosus* Merr.): Effect on nutritional and sensory quality. *Journal of Food Science*, 71: 501–505.

Hardy, Z., & Jideani, V. A. (2015). Foam-mat Drying Technology: A Review, Critical Reviews in Food Science and Nutrition, DOI: 10.1080/10408398.2015.1020359

Harmayani, E., Winarti, S., & Nurismanto, R. (2011). Preparation of inulin powder from Dioscorea Esculenta tuber with foam mat drying method. Proceedings of the 12th Asian Food Conference (pp. 16–18), Bangkok.

Hassan, M., & Ahmed, J. (1998). Sensory quality of foam-mat dried pineapple juice powder. *Indian Food Packer*, 52(7): 31–33.

Hayatudin, H. (2005). More Effort Needed to Produce Halal Medicinal Products. The Halal Journal – the online journal of the global halal market. Website: www.halaljournal.com. Retrieved January 2, 2006.

Heim, K. E., Tagliaferro, A. R., & Bobilya, D. J. (2002). Flavonoid antioxidants: Chemistry, metabolism and structure–activity relationships. *The Journal of Nutritional Biochemistry*, 13: 572–584.

Hogekamp, S., & Schubert, H. (2003). Rehydration of food powders. *Food Science & Technology Internship*, 9(3): 223–235.

Hossain, M. F., Akhtar, S., & Anwar, M. (2015). Nutritional value and medicinal benefits of pineapple**.** *International Journal of Nutrition and Food Sciences,* 4(1): 84-88.

Hossain, A., & Rahman, S. M. (2010). Total phenolic, flavonoids and antioxidant activity of tropical fruit pineapple. *Food Research International*, 44: 672–676.

Hui, Y. H., & Al-Holy, M. A. (Eds.). (2007). Food chemistry: Principles and Applications (2nd ed.). West Sacramento, CA: Science Technology System.

Ibarz, R., Falguera, V., Garvin, A., Garza, S., Pagan, J., & Ibraz, A. (2009). Flow behavior of clarified orange juice at low temperatures. *Journal of Texture Studies*, 40: 445-456.

Jaji, K., Man, N. & Nawi, N.M. (2018). Factors affecting pineapple market supply in Johor, Malaysia. *International Food Research Journal*, 25(1): 366-375.

Jakubczyka, E., Gondeka, E., & Tamborb, K. (2011). Characteristics of selected functional properties of apple powders obtained by the foam-mat drying method. In Food Process Engineering in a Changing World. Proceedings of the 11th International Congress on Engineering and Food, pp. 1385–1386.

Jayasundera, M., Adhikari, B., Adhikari, R., & Aldred, P. (2010). The effects of proteins and low molecular weight surfactants on spray drying of model sugar rich foods: Powder production and characterization. *Journal of Food Engineering*, 104: 259-271.

Jaya, S., & Das, H. (2004). Effect of maltodextrin, glycerol monostearate and tricalcium phosphate on vacuum dried mango powder properties. *Journal of Food Engineering*, 63: 125–134.

Jinapong, N., Suphantharika, M., Jamnong, P., 2008. Production of instant soymilk powders by ultrafiltration, spray drying and fluidized bed agglomeration. *Journal of Food Engineering*, 84(2): 194-205.

Jittanit, W., Niti-Att, S., & Techanuntachaikul, O. (2010). Study of spray drying of pineapple juice using maltodextrin as an adjunct. *Chiang Mai Journal of Science*, 37(3): 498-506.

Johnson, T. M., & Zabik, M. E. (1981). Response surface methodology for analysis of protein interactions in angel food cakes. Journal of Food Science, 46: 1226–1230.

Juszczak, L., Witczak, M., Fortuna, T., & Solarz, B. (2010). Effect of temperature and soluble solids content on the viscosity of beetroot (*Beta vulgaris*) juice concentrate. *International Journal of Food Properties*, 13: 1364–1372.

Juszczak, L., & Fortuna, T. (2004). Effect of temperature and soluble solids content on the viscosity of cherry juice concentrate. *International Agrophysics*, 18: 17–21.

Juszczak, L., & Fortuna, T. (2003). Viscosity of concentrated strawberry juice Effect of temperature and soluble solids content. *Electronic Journal of Polish Agricultural Universities, Food Science and Technology*, 6(2): 1-8.

Kadam, D. M., Wilson, R. A., Kaur, V., Chadha, S., Kaushik, P., Kaur, S., Patil, R. T., & Rai, D. R. (2012). Physicochemical and microbial quality evaluation of foam-mat dried pineapple powder. *International Journal of Food Science & Technology*, 47: 1654–1659.

Kadam, D. M., Wilson, R. A., Kaur, V., Chadha, S., Kaushik, P., Kaur, S., Patil, R. T., & Rai, D. R. (2012b). Physicochemical and microbial quality evaluation of foam-mat-dried pineapple powder. *International Journal Food Science and Technology*, 47: 1654–1659.

Kadam, D. M., Rai, D. R., Patil, R. T., Wilson, R. A., Kaur, S., & Kumar, R. (2011). Quality of fresh and stored foam-mat dried mandarin powder. *Food Science and Technology*, 46: 793–799.

Kadam, D. M., & Balasubramanuan, S. (2011). Foam-mat drying of tomato juice. *Food Processing and Preservation*, 35: 488–495.

Kadam, D. M., Wilson, R. A., & Kaur, S. (2010). Determination of biochemical properties of foam-mat dried mango powder. *International Journal of Food Science and Technology*, 45: 1626–1632.

Kadam, D. M., Patil, R. T., & Kaushik, P. (2010a). Foam mat drying of fruit and vegetable products. In Drying of foods, vegetables and fruits - Volume 1 (S.V. Jangam, C.L. Law and A.S. Mujumdar, eds) pp. 113-124, ISBN: 978-981-08-6759-1, Published in Singapore.

Kadam, D. M., Samuel, D. V. K., Chandra, P., & Sikarwar, H. S. (2008). Impact of processing treatment and packaging material on some proteins of stored dehydrated cauliflower. *International Journal of Food Science & Technology*, 43(1): 1–14.

Kandasamy, P., & Varadharaju, N. (2014). Assessment of biochemical characteristics of foam-mat dried papaya powder. *International Journal Agriculture and Food Science*, 4: 54–58.

Kandasamy, P., Varadharaju, N., Kalemullah, S., & Maladhi, D. (2014). Optimization of process parameters for foam-mat drying of papaya pulp. *Journal of Food Science and Technology*, 51(10): 2526–2534.

Kandasamy, P., Varadharaju, N., Kalemullah, S., & Maladhi. (2012). Optimization of process parameters for foam-mat drying of papaya pulp. *Journal of Food Science and Technology*, 51(10): 2526-2534.

Karim, A. A., & Bhat, R. (2009) Fish gelatin: properties, challenges, and prospects as an alternative to mammalian gelatins. *Food Hydrocolloids*, 23: 563–576.

Karim, A. A., & Wai, C. C. (1999a). Foam-mat drying of star fruit (*Averrhoa carambola* L.) puree. Stability and air drying characteristics. *Food Chemistry*, 64: 337–343.

Karim, A. A., & Wai, C. C. (1999b). Characteristics of foam prepared from star fruit (*Averrhoa carambola* L.) puree by using methyl cellulose. *Food Hydrocolloids*, 13: 203–210.

Kaushal, M., Sharma, P. C., & Sharma, R. (2013). Formulation and acceptability of foam mat dried seabuckthorn (*Hippophae salicifolia*) leather. *Journal of Food Science and Technology*, 50(1): 78–85.

Kaya, A., & Belibagli, K. B. (2002). Rheology of solid Gazıantep Pekmez. *Journal of Food Engineering*, 54(3): 221–226.

Kaya, A., & Sozer, N. (2005), Rheological behavior of sour pomegranate juice concentrates (*Punica granatum* L.). *International Journal of Food Science and Technology*, 40: 223-227.

Kettani, H. (2010). 2010 World Muslim population. In Proceedings of the 8th Hawaii international conference on arts and humanities. Honolulu, Hawaii, January 2010. 8-62

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.

Khalil, K. E., Ramakrishna, P., Nanjundaswamy, A. M., & Patwardhan, M. V. (1989). Rheological behavior of clarified banana juice: effect of temperature and concentration. *Journal of Food Engineering*, 10(3): 231-240.

Keshani, S., Luqman Chuah, A., & Russly, A. R. (2012). Effect of temperature and concentration on rheological properties pomelo juice concentrates. *International Food Research Journal*, 19(2): 553-562.

Kettani, H. (2010). 2010 World Muslim Population . Proceedings of the 8th Hawaii International Conference on Arts and Humanities, Honolulu, Hawaii, January 2010.

Klitzing, R. V., & Müller, H. J. (2002). Film stability control. *Current Opinion in Colloid & Interface Science*, 7: 42–49

Kobus, Z., Nadulski, R., GuzJacek, T., Mazun, J., Panasiewicz, M., & Zawiślak, K. (2015). Effect of pasteurization on rheological properties of white carrot juice. *Agriculture and Agricultural Science Procedia*, 7: 99-102.

Krasaekoopt, W., & Bhatia, S. (2012). Production of yogurt powder using foam-mat drying. *AU Journal of Technology*, 15(3): 166-171.

Lau, C. K., & Dickinson, E. (2005). Instability and structural change in an aerated system containing egg albumen and invert sugar. *Food Hydrocolloids*, 19: 111-121.

Lau, K., & Dickinson, E. (2004). Structural and rheological properties of aerated high sugar systems containing egg albumen. Journal of Food Science, 69(5), E232-E239.

Lewicki, P. P. (2006). Design of hot air drying for better foods. *Trends in Food Science and Technology*, 17: 153–163.

Liu, X., Cui, C., Zhao, M., Wang, J., Luo, W., Yang, B., & Jiang, Y. (2008). Identification of phenolic in the fruit of emblica (*Phyllanthus emblica* L.) and their antioxidant activities. *Food Chemistry*, 109: 909–915.

Macherey, L., Conforti, F., Eigel Iii, W., & O'Keefe, S. (2011). Use of mucor miehei lipase to improve functional properties of yolk-contaminated egg whites. *Journal of Food Science*, 76(4), C651-C655.

Manjunatha, S. S., & Raju, P. S. (2015). Rheological characteristics of reconstituted spray dried beetroot (*Beta vulgaris* L.) juice powder at different solid content, temperatures and carrier materials. *International Food Research Journal*, 22(6): 2333-2345.

Marques, G. R., Borges, S. V., Mendonça, K. S., Fernandes, R. V. B., & Menezes, E. G. T. (2014). Application of maltodextrin in green corn extract powder production. *Powder Technology*, 263: 89-95.

Massa, A., González, C., Maestro, A., Labanda, J., & Ibarz, A. (2010). Rheological characterization of peach purees. *Journal of Texture Studies*, 41: 532–548.

Meher, J., Keshav, A., & Mazumdar, B. (2017). Rheology of Cassia Caronda: Effect of temperature and total soluble solid. *International Journal of Engineering Technology Science and Research*, 4(4): 90-98.

Memnune, S. M., Fatih, E., Mustafa, S., & Yavuz, Y. (2007). Rheological characteristics of carob pekmez. *International Journal of Food Properties*, 10: 39–46.

Mishra, P., Mishra, S., & Mahanta, C. L. (2014). Effect of maltodextrin concentration and inlet temperature during spray drying on physicochemical and antioxidant properties of amla (*Embica officinalis*) juice powder. *Food and Bioproducts Processing*, 92: 252–258.

Montero-Calderon, M., Rojas-Grau, M.A., & Martin-Belloso, O. (2008). Effect of packaging conditions on quality and shelf life of fresh–cut pineapple *Post harvest biology and technology*,50(2-3): 182-189.

Moraes, I. C. F., Fasolin, L. H., Cunha, R. L., & Menegalli, F. C. (2011). Dynamic and steady-shear rheological properties of xanthan and guar gums dispersed in yellow passion fruit pulp (*Passiflora edulis f. flavicarpa*). *Brazillian Journal of Chemical Engineering*, 28(3): 483-494.

Mounir, S. (2017). Foam mat drying. In Drying technologies for food, 169-191.

MPIB, Malaysian Pineapple Industry Board 2010. Report of pineapple production statistics according to variety 2009

Muthukumaran, A., Ratti, C., & Raghavan, V. G. S. (2008). Foam-mat freeze drying of egg white-mathematical modeling part II: freeze drying and modeling. *Drying Technology*, 26: 513–518.

Nasatto, P. L., Pignon, F., Silveira, J. L. M., Duarte, M. E. R., Noseda, M. D., & Rinaudo, M. (2015). Methylcellulose, a cellulose derivative with original physical properties and extended applications. *Polymers*, 7: 777-803.

Nelson, D. L., & Cox, M. M. (2004). Lehninger principles of biochemistry (4th ed.). New York: W. H. Freeman and Company.

Ng, M. L., & Sulaiman, R. (2018). Development of beetroot (*Beta vulgaris*) powder using foam mat drying. *LWT - Food Science and Technology*, 88: 80-86.

Nindo, C. I., Tang, J., Powers, J. R., & Singh, P. (2005). Viscosity of blueberry and raspberry juices for processing applications. *Journal of Food Engineering*, 69: 343–350.

Nindo, C., & Tang, J. (2007). Refractance window dehydration technology: a novel contact drying method. *Drying Technology*, 25: 37–48.

Noranizan, M. A., Lau, P.L., Narimah. H., Rosnah, S., Sew, C. C., & Babak, S. (2011) Pineapple juice production using ultraviolet pasteurisation: potential cost implications *Journal of agribusiness marketing*, 14: 38-50.

Nurhadi, B., Andoyo, R., Mahani, & Rossi, I. (2012). Study the properties of honey powder produced from spray drying and vacuum drying method. *International Food Research Journal*, 19(3): 907-912.

Ochoa-Martinez, L. A., Garza-Juarez, S. E., Rocha-Guzman, N. E., Morales-Castro, J., & Gonzalez-Herrera, S. M. (2015). Functional properties, color and betalain content in beetroot - orange juice powder obtained by spray drying. *Research & Reviews: Journal of Food and Dairy Technology*, 3(2): 30-36.

Oliveira, D. M., Clemente, E., & Costa, J. M. C. (2014). Hygroscopic behavior and degree of caking of grugru palm (*Acronomia aculeate*) powder. *Journal of Food Science and Technology*, 51(10): 2783–2789.

Oliveira, T. M., Pirozi, M. R., Borges, J. T. S., Germani, R., & Fontes, M. P. F. (2009). Caracterizaçao do amido de grao-de-bico. *Boletim do Centro de Pesquisa de Processamento de Alimentos*, 27(1), 27–42 (in Portuguese).

Orishagbemi, C. O., Egwu, T., Odoh, A., Okereke, R. E., Ekele, D., & Abuh, A. M. (2015). Foam–mat dehydration effect on the physical properties, micronutrient contents and sensory characteristics of pineapple and cashew apple juice powder. *British Journal of Applied Science & Technology*, 7(2): 205-212.

Orishagbemi, C. O., Falade, K. O., Akinoso, R., & Oshundahunsi, O. F. (2010). Assessment of the physico-chemical properties and flavor profiles of foam mat dehydrated banana powder. *Nigerian Food Journal*, 28(2): 323–335.

Osorio, C., Forero, D., & Carriazo, J. (2011. Characterisation and performance assessment of guava (*Psidium guajava* L.) microencapsulates obtained by spray-drying. *Food Research International*, 44(5): 1174–1181.

Patil, V., Chauhan, A. K., Singh, R. P. (2014). Optimization of the spray-drying process for developing guava powder using response surface methodology. *Powder Technology*, 253: 230–236.

Pedro, E. D. A., Marcelo, C., & Albert, I. (2012). Effect of temperature on dynamic and steady-state shear rheological properties of siriguela (*Spondias purpurea* L.) pulp. *Journal of Food Engineering*, 108: 283-289.

Pereira, E. A., Brandão, E. M., Borges, S. V., & Maia, M. C. A. (2008). Influence of concentration on the steady and oscillatory shear behavior of umbu pulp. *Revista Brasileira de Engenharia Agrícola e Ambienta*, 12(1): 87–90.

Pereira, E. A., Machado, M. T., Borges, S. V., Maia, M. C. A., & Augusta, I. M. (2008). Influence of osmotic agent on the physiochemical composition and drying kinetics of Gala apples. *Revista Ciencia Agronomica*, 39: 173–176.

Phisut, N. (2012). Spray drying technique of fruit juice powder: some factors influencing the properties of product. *International Food Research Journal*, 19(4): 1297-1306.

Phoungchandang, S., & Sertwasana, A. (2010). Spray-drying of ginger juice and physicochemical properties of ginger powders. *Science Asia*, 36: 40-45.

Prin, A. (1988). Principles of foam stability. In E. Dickinson., & G. Stainsby (Eds.), *Advances in Food Emulsions and Foam* (pp. 91–122). London: Elsevier Applied Science.

Punidadas, P., & McKellar, R. C. (1999). Selected physical properties of liquid egg products at pasteurization temperatures. *Journal of Food Processing and Preservation*, 23: 153–168.

Quek, M. C., Chin, N. L., & Yusof, Y. A. (2013). Modelling of rheological behavior of soursop juice concentrates using shear rate – temperature – concentration superposition. *Journal of Food Engineering*, 118: 380–386.

Quek, M. C., Chin, N. L., & Yusof, Y. A. (2012). Optimisation and comparative study on extraction methods of soursop juice. *Journal of Food, Agriculture and Environment*, 10(3&4): 245–251.

Quek, S.Y., Chok, N. K., & Swedlund, P. (2007). The physicochemical properties of spray dried watermelon powder. *Chemical Engineering and Processing*, 4(5): 386-392.

Radwan, H. M., & Lobna, A. M. H. (2002). Production of tomato powder and dried slices for use in some foodstuffs. *Egyptian Journal of Agricultural Research*, 80: 1751–1762.

Radványi, D., Juhász, R., Németh, C., Suhajd, A., Balla, C., & Barta J. (2012). Evaluation of the stability of whipped egg white. *Czech Journal of Food Sciences*, 30(5): 412–420.

Raharitsifa, N., Genovese, D. B., & Ratti, C. (2006). Characterization of apple juice foams for foam-mat drying prepared with egg white protein and methylcellulose. *Journal of Food Science*, 71: 142-151.

Rajkumar, P., Kailappan, R., Viswanathan, R., & Raghavan, G. (2007). Drying characteristics of foamed Alphonso mango pulp in a continuous type foam mat dryer. *Journal of Food Engineering*, 79: 1452–1459.

Rajkumar, P., Kailappan, R., Viswanathan, R., Raghavan, G. S. V., & Ratti, C. (2007). Foam mat drying of alphonso mango pulp. *Drying Technology*, 25(2): 357- 365.

Rajkumar, P., & Kailappan, R. (2006). Optimizing the process parameters for foam mat drying of totapuri mango pulp. *The Madras Agricultural Journal*, 93(1-6): 86-98.

Rao, D.G. Fundamentals of Food Engineering, Eastern Economy Edition, PHI Learning Private Limited, pp126-142, 2012

Rao, M. A. Rheology of fluid and semisolids foods: principles and application. Maryland, Aspen, p. 443 (1999).

Rao, M. A., Boume, M. C., & Cooley, H. J. (1981). Flow properties of tomato concentrates. *Journal of Texture Studies*, 12: 521.

Ratti, C., & Kudra, T. (2006). Drying of foamed biological materials: opportunities and challenges. *Drying Technology*, 24, 1101-1108.

Ratti, C. (2009). Advances in food dehydration (1st ed.). Boca Raton: CRC Press.

Sabahelkhier, K. M., Hussain, A. S., & Ishag, K. E. A. (2010). Effect of maturity stage on protein fractionation, in vitro protein digestibility and anti-nutrition factors in pineapple (*Ananas comosus*) fruit grown in southern Sudan. *African Journal of Food Science*. 4(8): 550-552.

Saikia, S., Mahnot, N. K., & Mahanta1, C. L. (2015). Effect of spray drying of four fruit juices on physicochemical, phytochemical and antioxidant properties. *Journal of Food Processing and Preservation*, 39: 1656–1664.

Samsonova, A. N., & Usheva, V. B. (1990), Fruit and Vegetable Juices, Engineering and Technology, Agropomizdat, Moscow.

Sangamithra, A., Sivakumar, V., Swamy, G. J., & Kannan, K. (2015). Foam mat drying of food materials: A review. *Journal of Food Processing and Preservation*, 39(6): 3165-3174.

Sangamithra, A., Sivakumar, V., Kannan, K., & Swamy, G. J. (2015) Optimization of foaming properties and foam mat drying of muskmelon using soy protein. *Journal of Food Process Engineering*, 39(6): 692-701

Sangamithra, A., Sivakumar, V., Kannan, K., & Swamy, G. J. (2015). Foam mat drying of muskmelon. *International Journal of Food Engineering*, 11(1): 127–137.

Sani, A. M., Hedayati, G., & Arianfar, A. (2014). Effect of temperature and concentration on density and rheological properties of melon (*Cucumis melo* L. var. *Inodorus*) juice. *Nutrition & Food Science*, 44(2): 168-178.

Sankat, C. K., & Castaigne, F. (2004). Foaming and drying behavior of ripe bananas. *Lebensmittel-Wissenshaft und-Technologie*, 37: 517-525.

Sato, A. C. K., & Cunha, R. L. (2009). Effect of particle size on rheological properties of jaboticaba pulp. *Journal of Food Engineering*, 91(4): 566-570.

Saxena, S., Mishra, B. B., Chander, R. & Sharma, A. (2009). Shelf stable intermediate moisture pineapple (*Ananas comosus*) slices using hurdle technology. *LWT–Food Science and Technology*, 42: 1681–1687.

Shamsudin, R., Wan Daud, W. R., Takrif, M. S., Hassan, O., Mustapha Kamal, S. M., & Abdullah, A. G. L. (2007). Influence of temperature and soluble solid contents on rheological properties of the josapine variety of pineapple fruit (*Ananas comosus* L.). *International Journal of Engineering and Technology*, 4(2): 213-220.

Sharma, A. P., Gujral, H. S., & Rosell, C. M. R. (2011). Effects of roasting on barley b-glucan, thermal, textural and pasting properties. *Journal of Cereal Science*, 53: 25–30.

Shishir, M. R. I., Taip, F. S., Aziz, N. A., & Talib, R. A. (2014). Physical properties of spray dried pink guava (*Psidium guajava*) powder. *Agriculture and Agricultural Science Procedia*, 2: 74-81.

Shivhare, U. S., Gupta, M., Basu, S., & Raghavan, G. S. V. (2009). Optimization of blanching process for carrots. *Journal of Food Process Engineering*, 32(4): 587–605.

Shrestha, A. K., Ua-arak, T., Adhikari, B. R., Howes, T., & Bhandari, B. R. (2007). Glass transition behavior of spray dried orange juice powder measures by differential scanning calorimetry (dsc) and thermal mechanical compression test (TMCT). *International Journal of Food Properties*, 10: 661–673.

Silva, F. C., Guimaraes, D. H. P., & Gasparetto, C. A. (2005). Rheology of acerola juice: effects of concentration and temperature. *Ciência Tecnologia de Alimentos*, 25(1): 121–126.

Sinemobong, O. E., & Emediong, U. U. (2016). Effect of temperature on the rheological properties of pineapple juice (*Ananas comosus*). *International Journal of Latest Research in Science and Technology*, 5(2): 86-90.

Singh, I., Sandeep, K., Gaikwaad, S.T., Sharma, H. K. (2014). Influence of process conditions on the physicochemical& functional properties of litchi powder produced by spray drying. *GE - International Journal of Engineering Research*, 2(9): 23-38.

Singh, N. I., & Eipeson, W. E. (2000). Rheological behavior of clarified mango juice concentrates. *Journal of Texture Studies*, 31(3): 287–295.

Stanley, D. W., Goff, H. D., & Smith, A. K. (1996). Food Research International, 29(1): 1–13.

Steffe, J. F. (1996). Introduction o Rheology. In Rheological Methods in Food Process Engineering P.1-91. USA: Freeman Press.

Sudhanshu Saxena, B.B., Mishra, Ramesh, C, & Arun, S. (2009). *LWT - Food Science and Technology*, 42: 1681–1687

Swami Hulle, N. R., Patruni, K., & Rao. P. S. (2014). Rheological properties of aloe vera (*Aloe barbadensis Miller*) juice concentrates. *Journal of Food Processing Engineering.* 37: 375–386.

Thuwapanichayanan, R., Prachayawarakorn, S., & Soponronnarit, S. (2012). Effects of foaming agents and foam density on drying characteristics and textural property of banana foams. *LWT - Food Science and Technology*, 47: 348–357.

Thuwapanichayanan, R., Prachayawarakorn, S., Kunwisawa, J., & Soponronnarit, S. (2011). Determination of effective moisture diffusivity and assessment of quality attributes of banana slices during drying. *LWT - Food Science and Technology*, 44: 1502-1510.

Tonon, R. V., Alexandre, D., Hubinger, M. D., & Cunha, R. L. (2009). Steady and dynamic shear rheological properties of açai pulp (*Euterpe oleracea mart*.). *Journal of Food Engineering*, 92: 425–431.

Tonon, R. V., Baroni, A. F., Brabet, C., Gibert, O., Pallet, D., & Hubinger, M. D. (2009) Water sorption and glass transition temperature of spray dried açai (*Euterpe Oleracea* Mart.) juice. *Journal of Food Engineering*, 94: 215–221.

Tonon, R., Brabet, C., & Hubinger, M. (2008). Influence of process conditions on the physicochemical properties of acai (*Euterpe oleraceae* Mart.) powder produced by spray drying. *Journal of Food Engineering*, 88(3): 411–418.

Toralles, R. P., Vendruscolo, J. L., & Vendruscolo, C. T. (2006). Rheology of homogenized peach purée: effect of temperature and concentration. *Brazilian Journal of Food Technology*, 9(1): 1-8.

Tsai, S., Wu, T., Yang, K., Liu, H., & Liaw, C. (2007). Effects of cooking methods and rehydration on the chemical composition and texture of peanut. *Journal of Taiwan-Agricultural Research*, 56: 189–205.

Tze, N. L., Han, C. P., Yusof, Y.A., Ling, C.N., Talib, R.A., Taip, F. S., & Aziz, M. G. (2012). Physicochemical and nutritional properties of spray-dried pitaya fruit powder as natural colorant. *Food Science and Biotechnology*, 21(3): 675-682.

Uan-On, T., & Senge, B. (2008). Rheological behavior of pineapple puree mixed with different types of stabilizers (gum). *Annual Transactions of the Nordic Rheology Society*, 16: 1-8.

United Nations Conference on Trade and Development (2016). Retrieve from http://unctad.org/en/publicationslibrary/INFOCOMM_cp09_Pineapple_en.pdf . 1-2.

Vaclavik, V. A., & Christian, E. W. (2008). Proteins in Food: An Introduction. In: Essentials of Food Science, 4th ed., pp. 145-159. Springer New York, NY.

Valencia, C., Sánchez, M. C., Ciruelos, A., Latorre, A., Franco, J. M., & Gallegos, C. (2002). Linear viscoelasticity of tomato sauce products: influence of previous tomato paste processing. *European Food Research Technology*, 214(5): 394-399.

Vasconcelos, C. M., Minim, V. P. R., & Chaves, J. B. P. (2012). Low-calorie yogurt added with yacon flour: development and physicochemical evaluation. *Revista Chilena de Nutricion*, 39(3): 65-71.

Veerapandian, C., John, S. G., Kannan, K., & Sangamithra, A. (2015) Effect of foaming agent concentration and drying temperature o physicochemical and antimicrobial properties of foam mat dried powder. *Asian Journal of Dairy and Food Research*, 34(1): 39–43.

Viuda-Martos, M., Ruiz-Navajas, Y., Martin-Sanchez, A., Sanchez-Zapata, E., Fernandez Lopez, J., & Sendra, E. (2012). Chemical, physic-chemical and functional properties of pomegranate (*Punica granatum* L.) bagasses powder coproduct. *Journal of Food Engineering*, 110, 220–224.

Vitali, A. A. & Rao, M. A. (1982). Flow behavior of guava as a function of temperature and concentration. *Journal of Texture Studies*, 13: 275-289.

Walsh, D. J., Russell, K., & Fitzgerald, R. J. (2008). Stabilisation of sodium caseinate hydrolysate foams. Food Research International, 41: 43-52.

Walton, D. E. (2000). The morphology of spray-dried particles, a qualitative view. *Drying Technology*, 18: 1943-1986.

Wang, W., & Zhou, W. (2012). Characterization of spray-dried soy sauce powders using maltodextrins as carrier. *Journal of Food Engineering*, 109(3): 399–405.

Wang, J., & Chao, Y. (2002). Drying characteristics of irradiated apple slices. *Journal of Food Engineering*, 52: 83–88.

Wilson, R. A., Dattatreya, M. K., Chadha, S., Grewal, M. K., & Sharma, M. (2014). Evaluation of physical and chemical properties of foam-mat dried mango (*Mangifera indica*) powder during storage. *Journal of Food Processing and Preservation*, 38: 1866-1874.

Wilson, R. A, Kadam, D. M., Chadha, S., & Sharma, M. (2012). Foam mat drying characteristics of mango pulp. *International Journal of Food Science and Nutrition Engineering*, 2(4): 63–69.

Yoo, B. & Rao, M. A. (1996). Creep and dynamic rheological behavior of tomato concentrates: effect of concentration and finisher screen size. *Journal of Texture Studies*, 27: 451–459.

Yousefi, S., Emam-Djomeh, Z., & Mousavi, S. M. (2011). Effect of carrier type and spray drying on the physicochemical properties of powdered and reconstituted pomegranate juice (*Punica Granatum* L.). *Food Science and Technology*, 48(6): 677–684.

Zheng, X. Z., Liu, C. H., & Zhou, H. (2013). Optimization of parameters for microwave assisted foam-mat drying of blackcurrant pulp. *Drying Technology*, 29: 230–238

Zhou, L., Guan, Y., Bi, J., Liu, X., Yi, J., Chen, Q., Wu, X., & Zhou, M. (2017). Change of the rheological properties of mango juice by high pressure homogenization. *LWT - Food Science and Technology*, 82: 121-130.