



UNIVERSITI PUTRA MALAYSIA

***DEVELOPMENT AND CHARACTERISTICS OF STACKABLE CASSAVA
(Manihot esculanta Crantz) CHIPS***

NUR `AINI BINTI ISMAIL

FSTM 2015 15



**DEVELOPMENT AND CHARACTERISTICS OF STACKABLE CASSAVA
(*Manihot esculanta* Crantz) CHIPS**

By

NUR AINI BINTI ISMAIL

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

September 2015

COPYRIGHT

All material contained within the thesis, including without limitation text, logos, icons, photographs and all other artwork, is copyright materials of Universiti Putra Malaysia unless otherwise stated. Use may be made of any material contained within the thesis for non-commercial purposes from the copyright holder. Commercial use of material may only be made with the express, prior, written permission of Universiti Putra Malaysia.

Copyright© Universiti Putra Malaysia



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

**DEVELOPMENT AND CHARACTERISTICS OF STACKABLE CASSAVA
(*Manihot esculanta* Crantz) CHIPS**

By

NUR `AINI BINTI ISMAIL

September 2015

Chairman: Noranizan Mohd Adzahan, PhD
Faculty: Food Science and Technology

The shortcoming of cassava chips products in the market which are; uneven shape and cannot be stacked have hindered the process of fitting cassava chips into cylindrical containers. These conditions have caused reduction in the attractiveness of the final product. In this study, the effects of process variables which are; the thickness and numbers of cassava slice, on the final shape of fried cassava chips were determined in order to develop cassava chips with stackable properties and acceptable quality as close as those displayed by fabricated potato chips. Moreover, the strength of cassava chips were evaluated through simulation test to imitate transportation and handling. A bigger frying setup was used to determine whether it could produce cassava chips with the intended stackable properties. Frying condition for mass production of cassava chips for SME industries was also studied. The shape of sliced cassava is ellipse with 5.0 cm major diameter and 4.8 cm minor diameters. Four different thickness measurements were used including 1.0 mm, 1.5 mm, 1.75 mm and 2.0 mm. Commercial potato chips with 1.27 mm thickness were used as control sample. Then, the sliced cassava was fried in the deep fat fryer with the temperature of 170°C until no bubbles could be observed on the oil surface. For each thickness studied, different numbers of slices (10, 20, 30 and 40 slices) were fried simultaneously which resulted in different shapes of the fried cassava chips produced and the stacking ability of the chips was also recorded. The results show that there are 6 shapes of fried chips produced after frying in which curvy shape was chosen by the panelists as the best shape as it delivered the same characteristics as the control. High ratio of the numbers of cassava slices to frying area resulted in less curvy shape of the fried cassava chips due to the limited space between the sliced cassava. Cassava chips with thickness of 2.0 mm have higher strength and absorb less oil during frying compared to other thickness. To conclude, cassava chips thickness and numbers of slice during frying affect the final shape of cassava chips. Thirty cassava slices with the thickness of 2.0 mm yield the highest number of curvy shape when fried using frying temperature of 170°C, 594 cm² of frying area and frying time of 120 seconds.

Abstrak tesis yang dikemukakan kepada senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk Ijazah Master Sains

PEMBANGUNAN DAN CIRI-CIRI KEREPEK UBI KAYU (*Manihot esculanta* Crantz) YANG BOLEH DISUSUN BERTINDAN

Oleh

NUR `AINI BINTI ISMAIL

September 2015

Pengerusi: Noranizan Mohd Adzahan, PhD
Fakulti: Sains dan Teknologi Makanan

Terdapat dua kelemahan produk kerepek ubi kayu di pasaran iaitu; bentuk yang tidak sekata dan tidak boleh disusun dengan cantik telah menghalang proses pengisian kerepek ubi kayu ke dalam balang silinder. Keadaan ini menyebabkan kurangnya daya tarikan terhadap produk. Dalam kajian ini, kesan proses pembolehubah iaitu ketebalan dan bilangan keping kerepek ubi kayu terhadap bentuknya setelah digoreng telah dinilai untuk mendapatkan kerepek ubi kayu yang boleh di susun dengan sekata dan kualiti yang boleh diterima seperti yang terdapat dalam kerepek ubi kentang yang telah di fabrikasi. Selain itu, kekuatan kerepek ubi kayu juga telah di nilai melalui ujian simulasi untuk menyerupai situasi sebenar pengangkutan dan pengendalian. Sebuah kualiti yang lebih besar telah digunakan untuk menentukan sama ada ia boleh menghasilkan bentuk kerepek ubi kayu yang di mahukan. Bentuk kepingan ubi kayu sebelum digoreng adalah bujur dengan major diameter 5.0 cm dan minor diameter ialah 4.8 cm. Empat ketebalan ubi kayu yang berbeza telah digunakan iaitu 1.0 mm, 1.5 mm, 1.75 mm dan 2.0 mm. Kerepek ubi kentang komersil dengan ketebalan 1.27 mm telah digunakan sebagai sampel kawalan. Ubi kayu yang telah dihiris di goreng di dalam kualiti dengan suhu 170 °C sehingga masak iaitu tiada lagi buih dapat dilihat di permukaan minyak. Untuk setiap ketebalan ubi kayu, jumlah bilangan kepingan ubi kayu yang berbeza (10, 20, 30 dan 40 keping) telah goreng secara serentak dan ini telah menyebabkan terhasilnya bentuk yang berbeza dan kebolehan kerepek disusun secara bertingkat juga telah direkod. Hasil kajian menunjukkan bahawa terdapat 6 bentuk akhir kerepek ubi kayu telah terbentuk, di mana bentuk melengkung telah dipilih oleh ahli panel sebagai bentuk yang terbaik kerana ia mempunyai ciri yang sama dengan bentuk kerepek kawalan. Nisbah jumlah kepingan ubi kayu dengan kawasan menggoreng akan menyebabkan berlaku pengurangan dalam jumlah bentuk melengkung kerana terdapat ruang yang terhad antara ubi kayu di dalam kualiti. Kerepek ubi kayu dengan ketebalan 2.0 mm lebih keras dan kurang menyerap minyak semasa di goreng berbanding ketebalan lain. Sebagai kesimpulan, ketebalan dan bilangan keping ubi kayu ketika proses pengorengan akan mempengaruhi bentuk akhir kerepek ubi kayu. 30 keping ubi kayu dengan ketebalan 2.0 mm akan menghasilkan bilangan bentuk melengkung yang paling tinggi apabila digoreng dengan suhu 170 °C, kawasan pengorengan 594 cm² dan di goreng selama 120 saat.

ACKNOWLEDGEMENTS

To the Almighty, from whom all mercies flow, I thank Him for the strength and wisdom he has bestowed upon me in the course of my studies and through all the days of my life.

After years of struggling and hardworking, I could not say more than Alhamdulillah. I would like to express my deepest appreciation to Prof Madya Dr. Noranizan Mohd Adzahan, the chairman of my supervisory committee, for taking me under her wings and giving me the benefit of her knowledge, wisdom and expertise over the years, and enabling me to successfully complete my thesis. She has been my pillar of strength throughout the entire period of my study here at UPM and I will always be grateful for her patience for me.

My sincere appreciation also goes to Prof Madya Dr Roselina Karim and Prof Madya Dr. Rosnah Shamsudin, members of my supervisory committee, who have been extremely helpful and supportive, providing me guidance, answering my question and showing me the way. To the most important person in my life; Ismail bin Muhammad and Akmal binti Ismail, you are my everything. Thank you for your love, your passion, your advice, your thought and your guide for me. To the many others who have come into my life in my years at UPM, I thank you for your friendship.

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

Noranizan Mohd Adzahan, PhD

Associate Professor
Faculty of Food Science and Technology
Universiti Putra Malaysia
(Chairman)

Roselina Karim, PhD

Associate Professor
Faculty of Food Science and Technology
Universiti Putra Malaysia
(Member)

Rosnah Shamsudin, PhD

Associate Professor
Faculty of Engineering
Universiti Putra Malaysia
(Member)

BUJANG KIM HUAT, 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, lecturer notes, learning modules or any others 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`Aini binti Ismail (GS32010)

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 (Reversion 2012-2013) are adhered to.

Signature: _____

Name of
chairman of

supervisory committee: Noranizan Mohd Adzahan, PhD

Signature: _____

Name of
member of

supervisory committee: Rosnah Shamsudin, PhD

Signature: _____

Name of
member of

supervisory committee: Roselina Karim, PhD

TABLE OF CONTENTS

	Page
ABSTRACT	i
ABSTRAK	ii
ACKNOWLEDGEMENTS	iii
APPROVAL	iv
DECLARATION	vi
LIST OF TABLES	xi
LIST OF FIGURES	xii
LIST OF ABBREVIATIONS	xv

CHAPTER

1	INTRODUCTION	1
2	LITERATURE REVIEW	3
2.1	Cassava	3
2.1.1	Origin and Distribution of Cassava Tree	3
2.1.2	Characteristic of Cassava	3
2.1.3	Nutrient Composition of Cassava Tuber	5
2.1.4	World Production of Cassava	6
2.1.5	Cultivation of Cassava in Malaysia	8
2.2	Postharvest Handling and Storage	8
2.3	Cassava Chips	9
2.3.1	Cassava Chips Processing	9
2.3.2	Comparison of Cassava Chips and Potato Chips	10
2.3.3	Cassava Chips in Malaysia	11
2.3.4	Storage of Chips	14
2.4	Deep Fat Frying	14
2.4.1	Frying Process of Chips	14
2.4.2	Shrinkage Process During Frying	14
2.4.3	Cassava Chips Processing in Industry	16
2.4.4	Oil Absorption and Water Uptake During Frying	16
2.5	Effect of Process Variables on Fried Chips Quality	17
2.5.1	Colour Changes During Deep Fat Frying	17
2.5.2	Changes in Texture During Deep Fat Frying	17
2.5.3	Consumer Acceptance for Fried Chips	18
2.6	Food Packaging	18
2.6.1	Metal Food Packaging	19
2.6.2	Plastic Food Packaging	19
2.6.3	Paper and Paperboard Food Packaging	19
2.7	Transportation of Food Products	20

3	MATERIALS AND METHODS	21
3.1	Scope of Study	21
3.2	Stacking Properties	21
3.3	Characteristics of Potato Chips and Cassava Chips in the Market	22
3.4	Sample Preparation	23
3.5	Frying Procedure	24
3.5.1	Household Deep Fryer	24
3.5.2	Mass Production with Bigger Fryer	25
3.6	Sensory Evaluation	26
3.6.1	Hedonic Scale Test	26
3.6.2	Ranking Test	27
3.7	Analysis of Chips	27
3.7.1	Moisture Content	27
3.7.2	Fat Content	27
3.7.3	Determination of Chips Hardness	28
3.7.4	Determination of Colour	28
3.8	Stackability Test	28
3.9	Strength of Cassava Chips	29
3.9.1	Drop Test	31
3.9.2	Vibration Test	31
3.10	Statistical Analysis	32
4	RESULTS AND DISCUSSION	33
4.1	Characteristics of Cassava Chips in the Market	33
4.2	Characteristics of Potato Chips (Fabricated) in the Market	34
4.3	Different Thickness of Sliced Cassava Tubers	36
4.4	Frying Condition for Slice Cassava	37
4.4.1	Frying Cassava Chips Using Household Fryer	37
4.4.2	Frying Process	40
4.5	Effect of Mass Production on Shape of Cassava Chips	43
4.5.1	Curvy Shape	43
4.5.2	'U' Shape	44
4.5.3	'D' Shape	45
4.5.4	'I' Shape	46
4.5.5	Flower Shape	47
4.5.6	'O' Shape	48
4.6	Percentage of Chips Shape	49
4.7	Sensory Evaluation (Ranking Test)	52
4.8	Colour of Cassava Chips	52
4.8.1	Lightness Value	52
4.8.2	Parameter a*	53
4.8.3	Parameter b*	54
4.9	Hardness of Cassava Chips	55
4.10	Cassava Chips Stackability (Curvy Shape)	56
4.11	Proximate Analysis of Cassava Chips	57
4.11.1	Fat Content in Cassava Chips	57
4.11.2	Moisture Content in Cassava Chips	58

4.12	Sensory Evaluation (Hedonic Scale Test) for Cassava Chips	59
4.13	Strength of Cassava Chips	60
4.13.1	Drop Test	60
4.13.2	Vibration Test	63
4.14	Acceptable Thickness and Numbers of Slice Cassava for Mass Production of Cassava Chips	63
4.15	Application of Cassava Chips in Bigger Fryer	65
5	CONCLUSION AND RECOMMENDATION	66
5.1	Conclusion	66
5.2	Recommendation	67
	REFERENCES	68
	APPENDICES	73
	BIODATA OF STUDENT	77
	LIST OF PUBLICATIONS	78

LIST OF TABLES

Table	Page
2.1 Proximate analysis of cassava roots	6
2.2 World's cassava production	7
2.3 Agri-Food Retail Sales in Malaysia (Notable in US\$ Millions)	13
2.4 Sales of sweet and savoury snacks by category in Malaysia (tonnes)	13
3.1 Stacking properties of cassava chips	22
4.1 Different thickness and length of cassava chips place in cylindrical container	33
4.2 Thickness, minor and major diameter of potato chips in market	35
4.3 Thickness of cassava slices in different condition	36
4.4 Different thickness of slices cassava and its frying conditions	39
4.5 Characteristic of cassava chips after frying (Curvy shape)	43
4.6 Characteristic of cassava chips after frying ('U' shape)	44
4.7 Characteristic of cassava chips after frying ('D' shape)	45
4.8 Characteristic of cassava chips after frying ('I' shape)	46
4.9 Characteristic of cassava chips after frying (Flower shape)	47
4.10 Characteristic of cassava chips after frying ('O' shape)	48
4.11 Rank score for six cassava chips shape	52
4.12 Numbers of chips that can be placed in 4.5 cm cylindrical container	57
4.13 Sensory evaluation of cassava chips for different thickness and the commercial prepared cassava chips	60
4.14 Packaging weight requirement for drop test	60
4.15 Percentage of chips breakage after drop test	62
4.16 Overall characteristics of cassava chips with different thickness and mummurs of slice	64
4.17 Bigger fryer to produce curvy shape of cassava chips	65

LIST OF FIGURES

Figure		Page
2.1	Cassava tuber cross-section containing different components	4
2.2	Cassava tubers shape before peeling with (A) Cassava roots with conical, conical-cylindrical, cylindrical and fusiform shapes; (B) cross-section of cassava roots	5
2.3	Global cassava harvested area	6
2.4	Hectarage of cassava cultivation in Malaysia	8
2.5	General process flow of cassava chips production	10
2.6	Sweet and savoury snack sales in Asia Pacific and Australasia	11
2.7	Percentage of consumers who said they ate these snacks in the last 30 days	12
2.8	Heat and mass transfer in deep fat frying	15
2.9	Batch fryers of tortilla chips	16
3.1	Major and minor diameter of potato chips	22
3.2	Curved yellow flesh cassava tuber	23
3.3	Straight line yellow flesh cassava tuber	23
3.4	Trimmed cassava tubers with 5cm major diameter and 4.8cm minor diameter	24
3.5	Physical appearance of sliced cassava chips in different thickness	24
3.6	Measurement for household deep fat fryers	25
3.7	Deep fryer for mass production	25
3.8	Measurement for mass deep fat fryers. A = Front view and B = Side view	26
3.9	Stackability of cassava chips	29
3.10	Hard card (Chips' holder)	29
3.11	Cylindrical container of cassava chips with 5.0 cm length and 7.0 cm height	30
3.12	Chips in cylindrical container before the experiment	30
3.13	Wrapped box as a chips cover	30

3.14	Cassava chips in box	30
3.15	Drop test; a) before operation, and b) after operation	31
3.16	Box of cassava chips during test	32
4.1	Cassava chips in canister	33
4.2	Potato chips in canister	34
4.3	Different dimension angle for measuring fabricated potato chips	34
4.4	Stacking ability of fabricated potato chips.	35
4.5	Different numbers of sliced cassava during frying in deep fryer [(A) 10 pieces (B) 20 pieces (C) 30 pieces (D) 40 pieces]	38
4.6	Effect of oil temperature on frying time when various number of cassava chips were fried simultaneously with thickness 1.0 mm and 1.5 mm	41
4.7	Effect of oil temperature on frying time when various number of cassava chips were fried simultaneously with thickness 1.75 mm and 2.0 mm	42
4.8	Curvy shape of cassava chips from mass production	43
4.9	'U' Shape of cassava chips in mass production	44
4.10	'D' Shape of cassava chips in mass production	45
4.11	'I' Shape of cassava chips in mass production	46
4.12	Flower Shape of cassava chips in mass production	47
4.13	'O' Shape of cassava chips in mass production	48
4.14	Percentage of shapes produced after frying slice cassava tuber with different thickness and numbers of slice for thickness 1.0 mm and 1.5 mm	50
4.15	Percentage of shapes produced after frying slice cassava tuber with different thickness and numbers of slice for thickness 1.75 mm and 2.0 mm	51
4.16	L value for cassava chips	53
4.17	Parameter a* value for cassava chips	54
4.18	Parameter b value for cassava chips	54
4.19	Hardness value of different numbers of slice and thickness of cassava chips.	55
4.20	Stackability of cassava chips with different thickness and	56

	numbers of slice	
4.21	Numbers of curvy shape chips that can fill up in 45 cm distance in different thickness	57
4.22	Oil uptake before and after frying in different thickness and numbers of slice cassava chips	58
4.23	Water loss before and after frying in different thickness and numbers of slices cassava chips	59
4.24	Condition of chips after vibration test	63



LIST OF ABBREVIATIONS

cm	centimeter
cm ²	centimeter square
g	gram
h	hour
Ha	hectare
kg	kilogram
km	kilometer
L	litre
lbs	Pound
mg	milligram
mL	milliliter
mm	milimeter
N	Force
RH	Relative Humidity
rpm	Round per Minute
s	second
SME	Small and Medium Entrepreneur
V	volt
W	watt

CHAPTER 1

INTRODUCTION

Manihot esculanta Crantz is the scientific name for cassava plant. There are various cassava names used worldwide for example, Manioc (French), Yuca (Spanish), Lucca (Italian), Mandioca (Brazil) and Ubi kayu (Malaysia) (Anom, 2012). There are increases of 44% in cassava harvesting area around the world since 1980 to 2011 (FAO, 2013). In Asia, Thailand is the leading producer of cassava since 2012 followed by Indonesian and other Asian countries. The area of cassava cultivation in Malaysia increase gradually from 2011 to 2013 and it shows that the request for cassava increased significantly due to high demand from entrepreneur. There are many types of food can be produced from cassava roots such as fufu, mingao, farina, sago wafers, gatot, gari and fried chips. The growths of sales of sweet and savoury snacks in Malaysia are increased as much as 3.8% from 2009 until 2013.

Few studies have been conducted to find the parameters that can be attributed to the quality of cassava chips. Salvador et al. (2009) relates sensory attribute of the potato chips with the crispy texture of chips. Olivier et al. (2002) measured the different thickness of slices cassava roots fried at 160°C were affect the time for chips to be fried. As a result, there were different effects on the final quality of chips produced including colour, texture and oil uptake of the chips (Abong et al., 2011; Kita et al., 2007; Oliver et al., 2000; Romani et al., 2009; Vincent, 2004). This result can be related to the study from Vitrac et al. (2002), which has found that heat transfer process during frying contributed to the changes and development of final chips quality. According to Krokida et al. (2000), water loss and oil uptake in chips was a part of heat transfer process occurred during frying. According to Chung (2010), cassava chips fried individually can be stacked nicely into cylindrical container.

Packaging is an important element in food industry. It does not only protect the food safety and appearance but it also can provide information about the product itself and at the same time can increase the commercial value of the products. If cassava chips can be developed to resemble fabricated chips, then it is likely can increase the commercial value of cassava chips. Besides that, Federal Agricultural and Marketing Authority Malaysia (FAMA) have requested to improve the quality of cassava chips in cylindrical container. Therefore, research in this sector is important which can help food industry since cassava products have a high and increasing demand especially during the festive seasons.

Cassava chips are usually prepared from sliced tubers and not fabricated such as those in the potato chips industry. Cassava chips in the current market are usually packed in plastic material. Although, there are cassava chips that have been packaged in cylindrical container, but it's does not have even shape, not stackable, fragile/breakable, burnt, uneven colour, less attractive and not attractive packaging. In the world, the most acceptable potato chips products from generation to generation are fabricated potato chips products for example Mister Potato™, Pringles®, Jacker, Lay's®, etc. Fabricated potato chips provides better chips colour, even size and shape, good packaging and stack nicely in canister. However the

process of fabricating chips will increase cost for production of chips since it's involve several ingredient and processing step. In addition, when cassava has been fabricated, the taste and texture of the fried chips were changed to the point that it is not acceptable the consumers. Thus, the objectives of this study are;

- i) To develop cassava chips with stackable properties and acceptable quality as close as those displayed by fabricated potato chips.
- ii) To evaluate the strength of the developed cassava chips during transportation and handling.
- iii) To determine whether a bigger frying setup could produce cassava chips with the intended stackable properties.



- Che Man, Y. B. & Tan, C. P. (1999). Effects of natural and synthetic antioxidants on changes in refined, bleached and deodorized palm olein during deep fat frying of potato chips. *JAOCS*, 76(3):331-339.
- Chen, Y. & Moreira, R. G. (1997). Modelling of a Batch Deep-Fat Frying Process for Tortilla Chips. *Trans IchemE.*, Vol 75, part C.
- Duizer, L. (2001). A review of acoustic research for studying the sensory perception of crisp, crunchy and crackly textures. *Trends in Food Science & Technology*, 12:17-24.
- Department of Agricultural (DOA). 2013. Vegetables and Cash Crops Statistic.
- Euromonitor International (2011). Sweet and Savoury Snacks in Malaysia.
- Euromonitor International (2014). Sweet and Savoury Snacks Asia Pacific and Australasia
- Edmund, W. L. & Llyod, W. R.. (2001). *Snack food processing*. Technomic Publishing Co., Inc.
- Enriquez-Fernandez, B. E., Yanez L. A. & Sosa-Morales, M. E. (2012). Influence of oil types and freshness on the sensory perception of fried foods. *Journal of Culinary Science and Technology*, 10(2): 145-153.
- FAO. (2014). Food Outlook: Biannual Report on Global Food Markets.
- FAO. (2013). Food Outlook: Biannual Report on Global Food Markets.
- FAO. (2013). Save and Grow Cassava: A Guide to Sustainable Production Intensification
- FAO. (2012). Food Outlook: Global market analysis.
- Grizotto, R. & Menezes, H. D. (2002). Effect of cooking on the crispiness of cassava chips. *Sensory and Nutritive Qualities of Food*, 67(3): 1219-1223.
- Gokmen, V. & Senyuva, H. Z. (2006). Study of colour and acrylamide formation in coffee, wheat flour and potato chips during heating. *Food Chemistry*, 99: 238-243.
- Hillocks, R. J., Tresh, J. M. & Belloti, A. C. (2002). *Cassava: Biology, production and utilization*. CABI publishing.
- Houhoula, D. P., Oreopoulou, V. & Tzia, C. (2003). Antioxidant efficiency of oregano during frying and storage of potato chips. *Journal of the Science of Food Agriculture*, 83:1499-1503.
- Kawas, M. L. & Moreira, R. G. (2001). Characterization of product quality attributes of tortilla chips during the frying process. *Journal of Food Engineering*, 47:97-107.

- Kita, A., Lisinska, G. & Golubowska, G. (2007). The effects of oils and frying temperatures on the texture and fat content of potato crisps. *Food Chemistry*, 102: 1-5.
- Krokida, M. K., Oreopoulou, V. & Aroulis, Z. B. (2000). Water loss and oil uptake as a function of frying time. *Journal of Food Engineering*, 44(1):39-46.
- Krokida, M. K., Oreopoulou, V., Maroulis, Z. B. & Kouris, D. M. (2001). Colour changes during deep fat frying. *Journal of Food Engineering*, 48:219-225.
- Larmond, E. (1977). *Laboratory methods for sensory evaluation of food*. Canada Department of Agriculture. Ottawa.
- Lolos, M., Oreopoulou, V. & Tzia, C. (1999). Oxidative stability of potato chips: Effects of frying oil type, temperature and antioxidants. *Journal of the Science of Food and Agriculture*, 79:1524-1528.
- Malaysian Standard 1261. (1992). Specification for potato chips: Standard and industrial research institute of Malaysia.
- Malaysian Agricultural Research and Development Institute (MARDI). 2015. Industrial crops: Scope of research. Retrieved 7 June 2015 from <http://www.mardi.gov.my/en/skop-penyelidikan7>.
- Math, R. G., Velu, V., Nagender, A., & Rao, D. G. (2004). Effect of frying conditions on moisture, fat, and density of papad. *Journal of Food Engineering*, 64(4):429–434.
- Matthaus, B. (2007). Use of palm oil for frying in comparison with another high-stability oils. *Eur. J. Lipid Science Techn*, 109:400-409
- Mendoza, F., Dejmek, P. & Aguilera, J. M. (2007). Colour and image texture analysis in classification of commercial potato chips. *Food Research International*, 40:1146-1154.
- Ministry of Agriculture (MOA). 2015. Agro-based industry: Information. Retrieved 27 June 2015 from <http://www.moa.gov.my/informasi4>.
- Olivier, V., Dominique, D., Gilles, T. & Anne-Lucie, R. W. (2000), Deep-fat frying of cassava: Influence of raw material properties on chip quality. *Journal of the Science of Food and Agriculture*, 81:227-236.
- Olivier, V., Dominique, D., Gilles, T. & Anne-Lucie, R.W. (2002). Characterization of heat and mass transfer during deep-fat frying and its effect on cassava chip quality. *Journal of Food Engineering*, 53:161–176.
- Moreira, R. G., Sun, X. Z. & Chen, Y. H. (1997). Factors affecting oil uptake in tortilla chips in deep fat frying. *Journal of food engineering*, 30:485-498.

- Pangloli, P., Melton, S. L., Collins, J. L., Penfield, M. P. & Saxton A. M. (2006). Flavor and storage stability of potato chips fried in cottonseed and sunflower oils and palm olein/sunflower oil blends. *JFS: Food Chemistry and Toxicology*, 67(1):97-103.
- Pedreschi, F., & Moyano, P. (2005). Oil uptake and texture development in fried potato slices. *Journal of Food Engineering*, 70(4):557–563.
- Malaysian standard. (1992). Specification for potato chips. Standards and industrial research institute of Malaysia (SIRIM).
- Pedreschi, F., Bungler, A., Skurtys, O., Allen, P. & Rojas, X. (2011). Grading of potato chips according to their sensory quality determined by color. *Food Bioprocess Technol*, DOI 10.1007/S11947-011-0559-X.
- Pedro, C. M., Vanessa, K., Rioseco, P. A., Gonzalez. (2002). Kinetics of crust color changes during deep-fat frying of impregnated french fries. *Journal of Food Engineering*, 54:249–255.
- Poste, L. M., Mackie, D. A., Butler, G. & Larmond, E. (1991). *Laboratory Methods for sensory analysis of food*. Agriculture Canada Publication. Pg1.
- Rajkumar, V., Moreira, R. & Barrufet, M. (2003). modelling the structural changes of tortilla chips during frying. *Journal of Food Engineering*, 60:167-175.
- Ravli, Y., Silva, P. D., Moreira, R. G. (2013). Two stage frying process for high-quality sweet potato chips. *Journal of Food Engineering*, 118:31-40.
- Reilly, K., Vasquez, R. G., Buschmann, H., Tohme, J. & Beeching, J.R. (2004). Oxidative stress responses during cassava post-harvest physiological deterioration. *Plant molecular Biology*, 56:625-641.
- Salvador, A., Varela, P., Sanz, T. & Fiszman, S. M. (2009). Understanding potato chips crispy texture by simultaneous fracture and acoustic measurements and sensory analysis. *LWT, Food Science and Technology*, 42:763-767
- Sahin, S., Sastry, S. K. & Bayindirli, L. (1999.) Heat transfer during frying of potato slices. *LWT- Food Science and Technology*, 32(1):19-24.
- Santini, R., Pietro, R., Fernando, M. & Marco, D. R. (2009). Image characterization of potato chips appearance during frying. *Journal of Food Engineering*, 93:487-494.
- Segini, S., Dejmek, P. & Oste, R. (1999). Reproducible texture analysis of potato chips. *Journal of Food Science*, 64(2):309-312.
- Segini, S. & Dejmek, P. (1999). Relationship between instrumental and sensory analysis of texture and colour of potato chips. *Journal of Texture Studie*, 30:677-690.

- Sobukola, O. P., Awonorin, S. O., Sanni, L. O., & Bamiro, F. O. (2008). Deep-fat frying of yam slices: Optimization of processing conditions using response surface methodology. *Journal of Food Processing and Preservation*, 32(3):343–360.
- Silvestre, P. (1989). *Cassava: The Tropical Agriculturalist*. London and Basingstoke: Macmillan Publisher Ltd.
- Taiwo, K. A. & Baik, O. D. (2007). Effects of pre-treatments on the shrinkage and textural properties of fried sweet potatoes, *LWT-Food Science and Technology*, 40(4):661–668.
- Vincent, J. F. W. (2004). Application of fracture mechanics to the texture of food. *Engineering Failure Analysis*, 11:695-704.
- Vitrac, O., Dufour, D., Trystram, G. & Roult-Wack, A. L. (2000). Deep fat frying of cassava: Influence of raw material properties on chips quality. *J Sci Agriculture*, 81:227-236.
- Vitrac, O., Dufour, D. & Trystram, G. (2001). Deep-fat frying of cassava: influence of raw material properties on chip quality. *Journal of the Science of Food and Agriculture*, 81(2):227–236.
- Vitrac, O., Dufour, D., & Trystram, G. (2002). Characterization of heat and mass transfer during deep-fat frying and its effect on cassava chip quality. *Journal of Food Engineerin*, 53(2):161–176.
- Yamsaengsung, R. & Moreira, R. G. (2002). Modeling the transport phenomena and structural changes during deep fat frying Part II: model solution & validation. *Journal of Food Engineering*, 53(1):11–25.
- Yusof, N. N. (2012). Quality of cassava (*Manihot esculanta* Crantz) chips in various storage conditions of the tuber. B. S. of Food Technology Thesis, Universiti Putra Malaysia, Serdang.
- Ziaifar, A. M., Achir, N., Courtois, F., Trezzani, I., & Trystram, G. (2008). Review of mechanisms , conditions , and factors involved in the oil uptake phenomenon during the deep-fat frying process. *International Journal of Food Science and Technology*, 43(8):1410–1423.