



UNIVERSITI PUTRA MALAYSIA

**SHELF LIFE EXTENSION OF BANANA USING EDIBLE SURFACE
COATINGS CONJUGATED WITH SILVER NANOPARTICLES**

HODA JAFARIZADEH MALMIRI

FSTM 2012 3

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2012

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By

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

January 2012

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

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January 2012

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Banana is one of the most favoured specialty tropical fruits and is very popular world-wide. Short shelf life of banana limits the storage, handling and transport potentials of the fruit. 'Berangan' banana (*Musa sapientum* cv. Berangan) is one of the most popular dessert cultivars and very highly priced in Malaysia. In the present study, edible coatings incorporated with silver nanoparticles as an alternative packaging were used in combination with low temperature ($15\pm 1^{\circ}\text{C}$ and $65\pm 10\%$ RH) storage to extend the shelf life of banana.

Green mature 'Berangan' bananas were coated using eight different edible coating formulations based on polysaccharides and proteins and stored at ambient conditions ($26\pm 2^{\circ}\text{C}$ and $45\pm 5\%$ RH). Results of physico-chemical analysis of coated and control banana samples at day 10 of storage, indicated that edible coatings based on chitosan – glycerol – Tween 80 and sodium

carboxymethyl cellulose (Na-CMC) – sodium caseinate (Na-Cas) – glycerol were more effective in slowing ripening process of banana among all different edible coating formulations selected based on literature review. Optimum concentrations of edible components of these two selected coating formulations were obtained using response surface methodology (RSM). Optimum concentrations of chitosan, glycerol and Tween 80 were 2.02%, 0.18% and 0.1% (w/w), and for Na-CMC, Na- Cas and glycerol, the optimum concentrations were 1.32%, 0.40% and 0.86% (w/w), respectively.

Silver nanoparticles (SNPs), as a strong antimicrobial agent, was incorporated in the optimized edible coating formulations based on chitosan and Na-CMC. Due to high antimicrobial activity of edible coating based on chitosan, addition of small amount of SNPs (0 – 90 mg l⁻¹) to this coating formulation, did not show significant ($p > 0.05$) effect on antimicrobial properties of resulting coating. The minimum bactericidal concentration (MBC) of SNPs to be incorporated into the edible coating formulation based on Na-CMC was 60 mg l⁻¹.

Application of the optimized edible coatings based on chitosan – glycerol – Tween 80 and Na-CMC – Na-Cas – glycerol with and without SNPs, at a concentration of 60 mg l⁻¹, on green mature 'Berangan' banana followed by storage at both ambient (26±2°C and 70±10% RH) and low temperature (15±1°C and 65±10% RH) conditions, indicated that all these three coating formulations could increase the shelf life of bananas stored at ambient and low

temperatures by 3 days and 1 week, respectively. The maximum shelf life of control banana samples stored at ambient and low temperatures were 15 days and 5 weeks respectively.

Results of the present study revealed that there was no significant ($p > 0.05$) differences in the most of physico-chemical, physiological and sensory attributes between banana samples coated with coating formulations based on Na-CMC – Na-Cas – glycerol with and without SNPs. The coating formulations based on chitosan and Na-CMC conjugated with SNPs, significantly ($p < 0.05$) inhibited growth of bacteria, yeasts and moulds on the banana surface, while the coating formulation based on Na-CMC without SNPs did not show inhibition effect on microbial growth, during storage at ambient and low temperatures.

Evaluation of penetration of SNPs in both peel and pulp of coated banana samples with coating formulation based on Na-CMC – Na-Cas – glycerol – SNPs, indicated that during the ripening of coated banana samples, 92.5% and 90% of the SNPs which penetrated into the banana peel were detected in the outer layer of peel and the rest were detected in the inner layer of peel at both ambient and low temperature conditions, respectively. No SNPs were detected in the banana pulp, at both storage conditions. This could be due to the thickness and structure of banana peel. 'Berangan' banana is a thick-skinned banana and cell wall of its peel is composed of pectic, cellulose and hemicellulose components. These cell wall components of the peel can strongly

create ionic bonds with SNPs and decrease their penetration rate through the banana peel. Thus, no SNPs could penetrate the pulp.



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

**LANJUTAN JANGKA HAYAT PISANG MENGGUNAKAN SALUTAN YANG
BOLEH DIMAKAN DAN BERKONJUGASI DENGAN ZARAH
PERAK NANO**

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Pisang adalah salah satu buah-buahan tropika yang paling disukai dan sangat popular di seluruh dunia. Jangka hayat simpanan pisang yang pendek menghadkan potensi simpanan, pengendalian dan pengangkutan buah ini. Pisang 'Berangan' (*Musa sapientum* cv. Berangan) merupakan salah satu kultivar buah pisang pencuci mulut yang paling popular dan berharga tinggi di Malaysia. Dalam kajian ini, salutan boleh dimakan digunakan sebagai pembungkusan alternatif dengan kombinasi simpanan pada suhu rendah ($15\pm 1^{\circ}\text{C}$ dan $65\pm 10\%$ RH) untuk memanjangkan jangka hayat simpanan pisang.

Pisang 'Berangan' yang hijau matang disalut dengan lapan formulasi salutan boleh dimakan yang berbeza berasaskan polisakarida dan protein dan disimpan dalam keadaan ambien. Keputusan analisis fiziko-kimia dilakukan

keatas sampel pisang yang disalut dan pisang kawalan pada hari penyimpanan ke -10, menunjukkan bahawa salutan boleh dimakan berasaskan chitosan - gliserol - Tween 80 dan natrium karboksimetil selulosa (Na-CMC) – natrium kaseinate (Na-Cas) – gliserol didapati lebih berkesan untuk melambatkan proses peranakan pisang berbanding dengan formulasi salutan boleh dimakan yang lain yang dipilih berasaskan kajian literatur. Kepekatan optimum komponen boleh dimakan dari kedua-dua formulasi salutan yang dipilih telah diperolehi dengan menggunakan kaedah respon permukaan (RSM). Kepekatan optimum chitosan, gliserol dan Tween 80 adalah masing-masing 2.02%, 0.18% dan 0.1% (b/ b), dan untuk Na-CMC, Na-Cas dan gliserol kepekatan optimum pula adalah masing-masing 1.32%, 0.40% dan 0.86% (b/b).

Zarah perak nano (ZPN), sebagai agen antimikrob yang kuat, dipilih untuk ditambah kedalam formulasi optimum salutan boleh dimakan berasaskan chitosan dan Na-CMC. Oleh kerana, salutan boleh dimakan berasaskan chitosan mempunyai aktiviti antimikrob yang tinggi, penambahan sedikit ZPN (0 - 90 mg l⁻¹) kedalam formulasi salutan ini, tidak memberikan kesan yang signifikan ($p > 0.05$) pada sifat antimikrob salutan yang dihasilkan. Sementara itu, kepekatan bakterisida minimum (KBM) ZPN untuk dicampurkan kedalam formulasi salutan boleh dimakan berasaskan Na-CMC adalah 60 mg l⁻¹.

Aplikasi salutan boleh dimakan yang dioptimumkan berasaskan chitosan - gliserol - Tween 80 dan Na-CMC - Na-Cas - gliserol dengan dan tanpa ZPN,

pada kepekatan 60 mg l^{-1} , keatas pisang 'Berangan' yang hijau matang diikuti penyimpanan pada kedua-dua keadaan suhu ambien ($26 \pm 2^\circ \text{ C}$ dan $70 \pm 10\%$ RH) dan suhu rendah ($15 \pm 1^\circ \text{ C}$ dan $65 \pm 10\%$ RH), menunjukkan bahawa kesemua tiga formulasi salutan dapat meningkatkan jangka hayat simpanan pisang yang disimpan pada suhu ambien dan rendah masing-masing sehingga 3 hari dan 1 minggu. Jangka hayat simpanan maksimum sampel pisang kawalan yang disimpan pada suhu bilik adalah 15 hari, manakala, sampel pisang kawalan pada suhu rendah boleh meningkatkan jangka hayat simpanan sehingga 5 minggu.

Keputusan dari kajian ini menunjukkan bahawa tiada ($p > 0.05$) perbezaan yang signifikan pada kebanyakan ciri-ciri fiziko-kimia, fisiologi dan atribut sensori di antara sampel pisang disalut dengan kedua-dua formulasi salutan berasaskan Na-CMC - Na-Cas - gliserol dengan ZPN dan tanpa ZPN. Formulasi salutan berasaskan chitosan dan Na-CMC berkonjugasi dengan ZPN, menghalang pertumbuhan bakteria, yis dan kulat pada permukaan pisang secara signifikan ($p < 0.05$). Manakala, formulasi salutan berasaskan Na-CMC tanpa ZPN memberikan kesan negatif terhadap pertumbuhan mikroorganisma, semasa penyimpanan pada suhu ambien dan rendah.

Penilaian penetrasi ZPN ke dalam kedua-dua kulit dan isi sampel pisang yang disalut dengan salutan berasaskan Na-CMC - Na-Cas - gliserol - ZPN, menunjukkan bahawa pada sepanjang proses peranakan sampel pisang yang

disalut, 92.5% dan 90% ZPN yang menembusi ke dalam kulit pisang, dapat dikesan dalam lapisan kulit luar dan yang selebihnya dikesan dalam lapisan kulit di bahagian dalam pada kedua-dua keadaan suhu ambien dan rendah, masing-masing. Tiada ZPN yang dikesan dalam isi pisang pada kedua-dua keadaan penyimpanan. Ini mungkin disebabkan oleh ketebalan dan struktur kulit pisang. Pisang Berangan adalah pisang berkulit tebal dan dinding sel kulitnya terdiri daripada komponen pektik, selulosa dan hemiselulosa. Komponen dinding sel ini boleh dengan kuatnya membentuk ikatan ionik dengan ZPN dan mengurangkan kadar penembusannya melalui kulit pisang. Dengan ini, tidak ZPN yang dapat menembusi isi pisang.

ACKNOWLEDGEMENT

First of all, I thank God for allowing me to complete my PhD thesis. I am honored and grateful to have the full support from a number of persons in my life for their commitment during my PhD's degree.

This work would not have been possible without the support and encouragement of my supervisor, Professor Dr. Azizah Osman. I would like to express my sincere appreciation and gratitude to her for her kindness, support and guidance shown throughout my PhD program. I am extremely thankful that she genuinely cared not only about my academic and professional success, but also about my well-being as a person.

Special thanks are expressed to Associate Professor Dr. Tan Chin Ping, a member of my supervisory committee. He took his time to make helpful suggestions and to guide in the right direction. I really appreciate everything that he has done for me and I wish him health, prosperity and generosity.

I am also grateful to Professor Dr. Russly Abdul Rahman, my co-supervisor, for giving his critical comments and suggestions regarding my research.

I am thankful to all the staff of the Department of Food Science, Faculty of Food Science and Technology, Universiti Putra Malaysia (UPM), providing me with the most pleasant and convenient working environment.

Finally, my warmest thanks go to my parents, Hassan and Alamtaj, and wife, Navideh. I cannot express how much I would like to say thank you to them for their love and support from day one. They have always been there for me no matter what the situation and I am forever indebted to them.



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

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TABLE OF CONTENTS

DEDICATION	Page
ABSTRACT	ii
ABSTRAK	vi
ACKNOWLEDGEMENTS	x
APPROVAL	xii
DECLARATION	xiv
LIST OF TABLES	xix
LIST OF FIGURES	xxi
LIST OF ABBRIVIATIONS	xxvii

CHAPTER

1	INTRODUCTION	1
2	LITERATURE REVIEW	8
2.1	Banana	8
2.2	Postharvest changes in banana	11
2.2.1	Physiological changes	12
2.2.2	Physico-chemical changes	23
2.3	Postharvest deterioration of banana	31
2.4	Techniques of shelf life extension of banana	32
2.4.1	Low temperature and high relative humidity	32
2.4.2	Controlled atmosphere storage	33
2.4.3	Modified atmosphere storage	34
2.4.4	Ethylene absorbent packaging	34
2.4.5	Irradiation	35
2.4.6	Hot water treatment	36
2.4.7	Other techniques	36
2.5	Edible coatings and edible films	37
2.6	Potential uses of edible coatings on the fruits	38
2.7	Requirements for edible coatings to be used on the fruits	40
2.8	Composition of edible coatings for fruits	41
2.8.1	Polysaccharides	42
2.8.2	Proteins	49
2.8.3	Lipids	53
2.8.4	Additives	54
2.9	Commercial edible coatings	57
2.10	Methods of formation of edible coatings	60
2.11	Silver nanoparticles	62
2.11.1	Physical and antimicrobial properties	63
2.11.2	Common applications	64
2.11.3	Applications in food industry	65

2.11.4	Safety considerations	67
3	SCREENING OF EDIBLE COATING COMPONENTS AND OPTIMIZATION OF THEIR CONCENTRATIONS	69
3.1	Introduction	69
3.2	Materials and methods	72
3.2.1	Source of fruits	72
3.2.2	Edible coating components	73
3.2.3	Preparation of edible coating solutions	73
3.2.4	Coating and storage of bananas	76
3.2.5	Physico-chemical analysis	76
3.2.6	Experimental design and statistical analysis for screening	80
3.2.7	Experimental design and statistical analysis for optimization	81
3.3	Results and discussion	83
3.3.1	Screening	83
3.3.2	Optimization	96
3.3.3	Microstructure	119
3.4	Conclusions	122
4	OPTIMIZATION OF SILVER NANOPARTICLES CONCENTRATION TO CONJUGATE WITH OPTIMIZED EDIBLE COATING FORMULATIONS	125
4.1	Introduction	125
4.2	Materials and methods	128
4.2.1	Silver nanoparticles	128
4.2.2	Microorganisms and culture media	128
4.2.3	Edible coating components	128
4.2.4	Preparation of edible coating formulations incorporated with SNPs	129
4.2.5	Characterization of SNPs	129
4.2.6	Antibacterial assay of edible coating formulations incorporated with SNPs	130
4.2.7	Antifungal assay of edible coating formulations incorporated with SNPs	133
4.2.8	Statistical analysis	133
4.3	Results and discussion	134
4.3.1	Characterization of SNPs	134
4.3.2	Antibacterial activity of edible coating formulations incorporated with SNPs	138
4.3.3	Antifungal activity of edible coating formulations incorporated with SNPs	144
4.4	Conclusions	148

5	PHYSICO-CHEMICAL, PHYSIOLOGICAL AND MICROBIAL CHARACTERISTICS OF COATED BANANA WITH AND WITHOUT SILVER NANOPARTICLES INCORPORATED INTO THE OPTIMIZED EDIBLE COATING FORMULATIONS	
5.1	Introduction	150
5.2	Materials and methods	150
5.2.1	Source of fruits	153
5.2.2	Edible coating components and silver nanoparticles	153
5.2.3	Culture media	153
5.2.4	Preparation of edible coating formulations incorporated with and without SNPs	154
5.2.5	Coating and storage of bananas	154
5.2.6	Physico-chemical analysis	154
5.2.7	Physiological analysis	155
5.2.8	Microbial analysis	159
5.2.9	Statistical analysis	161
5.3	Results and discussions	162
5.3.1	Physico-chemical analysis	162
5.3.2	Physiological analysis	162
5.3.3	Microbial analysis	198
5.4	Conclusions	205
		211
6	PENETRATION PROFILES OF SILVER NANOPARTICLES IN PEEL AND PULP OF COATED 'BERANGAN' BANANA AND SENSORY ANALYSIS	
6.1	Introduction	214
6.2	Materials and methods	214
6.2.1	Source of fruits	217
6.2.2	Edible coating components and silver nanoparticles	217
6.2.3	Preparation of edible coating formulations incorporated with and whithout SNPs	217
6.2.4	Coating and storage of bananas	217
6.2.5	Microstructure of banana peel	218
6.2.6	Determination of penetration profile of SNPs in banana peel and pulp	218
6.2.7	Sensory analysis	219
6.2.8	Statistical analysis	221
6.3	Results and discussion	223
6.3.1	Microstructure of banana peel	223
6.3.2	Penetration profile of SNPs in banana peel and pulp	223
6.3.3	Sensory assessment	226
6.4	Conclusions	233

7	CONCLUSIONS AND RECOMMENDATIONS FOR FUTURE RESEARCH	239
	REFERENCES	240
	APPENDICES	
	BIODATA OF STUDENT	244
	LIST OF PUBLICATIONS AND AWARDS	268
		280
		281

