UNIVERSITI PUTRA MALAYSIA

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By

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Chairman : Professor Azizah Osman, PhD

Faculty : Food Science and Technology

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±1°C and 65±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±2°C and 45±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 sebagi memenuhi keperluan untuk ijazah Doktor Falsafah

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

Oleh

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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±1°C dan 65±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. Keputusen 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 peranuman pisang berbanding dangan 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 penyinpanan pada kedua-dua keadaan suhu ambien (26±2° C dan 70±10% RH) dan suhu rendah (15±1°C dan 65±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 peranuman 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 subu 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 mengurunkan kadar penembusannya melalui kulit pisang. Dengan ini, tidak ZPN yang dapat menembusi isi pisang.

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