EFFECT OF KAPPA- AND IOTA-SEMI-REFINED CARRAGEENAN COATING ON OSMOTIC DEHYDRATION OF GUAVA

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ABSTRACT

The main objective of this study was to determine the effect of different kappa- and iota-semi-refined carrageenan (SRC) concentration and dipping time on the quality of osmotic dehydrated guava in terms of water loss, solid gain, total soluble solid, moisture content, water activity, and sensory properties. Two sets of 3 X 2 Factorial Design with three coating concentrations (1% w/v, 1.5% w/v and 2% w/v) and two dipping time (60 s and 120 s) were employed. Osmotic dehydration condition was fixed at 60°Brix sucrose solution and 32°C, where the ratio of guava sample to sucrose solution was fixed at 1:10 (w/w). During mass transfer, iota-SRC was found to be instable and experienced dissolution into osmotic medium, causing negative solid gain and increased water loss ($p<0.05$). However, increasing dipping time to 120 s led to reduced water loss ($p<0.05$) in iota-SRC coated sample. In contrast, kappa-SRC was found to lowered water loss ($p<0.05$) with increased coating concentration due to moisture barrier effect. Kappa-SRC was also found to be more brittle than iota-SRC that it caused detachment of coating upon long hour of immersion in osmotic medium. Although both kappa- and iota-SRC were found to demonstrate potential in lowering total soluble solid, kappa-SRC had no effect in controlling solid gain ($p>0.05$). The coating formed by 2% of kappa- and iota-SRC was found to inhibit moisture vapour evaporation during oven drying and resulted in higher moisture content and water activity ($p<0.05$) which subsequently reduced the firmness of the dried guava ($p<0.05$). However, iota-SRC was able to enhance firmness of dried guava ($p<0.05$) at 1% and 1.5% of coating concentration, which was not observed for kappa-SRC. In addition, SRC had no effect on the colour of dried guava and did not affect much on the sensory attributes being studied ($p>0.05$). Nonetheless, sensorial result showed that kappa-SRC coating was able to reduce the dryness of guava slice ($p<0.05$), indicating its ability to prevent excessive drying of fruit sample. In overall, it was found that concentration of SRC produced more pronounced and consistent effect than dipping time during osmotic dehydration as well as various quality aspects of final product. Increased coating concentration in iota-SRC was found to enhance mass transfer to a certain extent, but adversely affected the qualities of dried guava due to additional barrier to moisture evaporation during oven drying, particularly kappa-SRC. Generally, 1% of kappa-SRC was found to be a better coating considering its stability during osmotic dehydration and beneficial coating effect during oven-drying process, as well as higher acceptance by sensory panels.

ABSTRAK

KESAN SALUTAN KARAGINAN SEPARA TULEN KAPPA DAN IOTA KE ATAS PENYAHHIDRATAN OSMOTIK JAMBU BATU

Objektif utama untuk kajian ini adalah untuk menentukan kesan kepekatan dan masa pencelupan salutan karaginan separa tulen kappa dan iota ke atas kualiti jambu batu terhidrat secara osmotik dari segi kehilangan air, pengambilan pepejal, jumlah pepejal terlarut, kandungan kelembapan, aktiviti air dan ciri-ciri sensori. Dua set Reka Bentuk Faktorial 3 x 2 yang terdiri daripada tiga kepekatan salutan (1% w/v, 1.5% w/v dan 2% w/v) dan dua masa pencelupan (60 s dan 120 s) telah digunakan. Keadaan penyahhidratan osmotik telah ditetapkan pada larutan sukrosa 60°Briks dan 32°C, manakala nisbah sampel jambu batu kepada larutan sukrosa ditetapkan pada 1:10 (w/w). Semasa pemindahan jisim, karaginan separa tulen iota diperhatikan tidak stabil dan melarut ke dalam media osmotik yang mengakibatkan pengambilan pepejal negatif serta peningkatan dalam kehilangan air ($p<0.05$). Namun, peningkatan dalam masa pencelupan kepada 120 s telah mengurangkan kehilangan air ($p<0.05$) bagi sampel disalut dengan karaginan separa tulen iota. Sebaliknya, karaginan separa tulen kappa didapati mengurangkan kehilangan air ($p<0.05$) dengan peningkatan kepekatan akibat kesan rintangan terhadap kehilangan lembapan. Karaginan separa tulen kappa juga didapati lebih rapuh daripada karaginan separa tulen iota di mana ia tertanggal dari permukaan buah apabila direndam dalam media osmotik untuk tempoh masa yang panjang. Walaupun kedua-dua karaginan separa tulen kappa dan iota menunjukkan potensi dalam mengurangkan jumlah pepejal terlarut, karaginan separa tulen kappa didapati tidak berkesan dalam mengawal pengambilan pepejal ($p>0.05$). Salutan yang terhasil daripada 2% karaginan separa tulen kappa dan iota didapati menghambat penyejatan wap kelembapan semasa pengeringan dalam ketuhar, justeru meningkatkan kandungan kelembapan dan aktiviti air ($p<0.05$) yang seterusnya mengurangkan kepadatan jambu batu kering ($p<0.05$). Walau bagaimanapun, karaginan separa tulen iota berupaya meningkatkan kepadatan jambu batu kering ($p<0.05$) dengan kepekatan salutan sebanyak 1% dan 1.5%, di mana ciri ini tidak dijumpai bagi karaginan separa tulen kappa. Selain itu, salutan karaginan separa tulen tidak menjejaskan warna jambu batu kering serta kurang mempengaruhi ciri-ciri sensori yang dikaji ($p>0.05$). Namun, hasil kajian sensori menunjukkan karaginan separa tulen kappa dapat mengurangkan kekeringan kepingan jambu batu ($p<0.05$), di mana ia berupaya mencegah pengeringan melampau ke atas sampel buah. Secara keseluruhannya, kepekatan karaginan separa tulen mempamerkan kesan yang lebih ketara dan konsisten ke atas penyahhidratan osmotik serta pelbagai aspek kualiti bagi produk akhir berbanding dengan masa pencelupan. Peningkatan dalam kepekatan karaginan separa tulen iota meningkatkan pemindahan jisim hingga suatu tahap tertentu, tetapi menurunkan kualiti jambu batu kering akibat kesan rintangan terhadap kehilangan lembapan semasa proses pengeringan, terutamanya salutan karaginan separa tulen kappa. Secara umum, 1% karaginan separa tulen kappa didapati merupakan salutan yang lebih baik memandangkan ia adalah lebih stabil semasa penyahhidratan osmotik dan bermanfaat ke atas proses pengeringan serta mempunyai tahap penerimaan yang tinggi oleh panel sensori.

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CHAPTER 1

INTRODUCTION

1.1 Background

Guava, or *Psidium guajaya* L. is an important fruit native to the American tropics, probably from Peru to Mexico and is botanically belongs to the Myrtaceae family. Nowadays, guava can be found growing abundantly in many other countries throughout the tropics and subtropics area. In Southeast Asia, guavas are planted in Myanmar, Thailand, Cambodia, Vietnam, Philippines, Malaysia, Singapore and also Indonesia (Lim and Khoo, 1990). The guava fruit is commercially important because of its flavor and aroma. It is used in the production of juice, jams, marmalade, ice cream, cookies, and several bakery products. Besides that, dried guava slice is also available in commercial markets in Southeast Asia (Fernandes *et al.*, 2011).

In terms of nutrients, this fruit is important due to its excellent source of vitamin C, niacin, riboflavin and vitamin A (Soares *et al.*, 2007). Depending on its ripening stage, guava may contain vitamin C up to 5 times more than oranges (240 mg/100 g) (Dembitsky *et al.*, 2011). Present study shows that tropical fruits such as guava have primary antioxidant potential in comparison to orange where antioxidants can helps in lowering incidence of degenerative diseases such as cancer, arthritis, arteriosclerosis, heart disease, inflammation, brain dysfunction and acceleration of the ageing process (Lim *et al.*, 2007). In Malaysia, guava is one of non-seasonal fruits due to its high yield which can be found all year round. However, guava fruit, as other tropical fruits, is highly perishable which needs preservation methods to increase its shelf-life (Ganjloo *et al.*, 2011).

In recent years, there is an increase in consumer demand for processed foods that maintain more of their original characteristics. In industrial term, this would indicate a need of development of operations that are able to minimize the adverse effects of processing on food ingredient (Torreggiani and Bertolo, 2001).

Hence, osmotic dehydration as a pre-treatment has gained much attention as this process is able to partially remove water from food material where water can affects food stability, microbial as well as chemical, which is responsible for the consumer perception of many organoleptic attributes (Lewicki and Lenart, 2006). From the industrial standpoint, osmotic dehydration has a potential advantage in producing food product of high quality as water removal can be achieved without a phase change that reduces the physical, chemical and biological changes (Azoubel *et al.*, 2009). This is largely due to the relatively low process temperature employed in osmotic dehydration (up to 50 °C), in which such temperatures do not affect the semi-permeable characteristics of cell membranes as well as favour the colour and flavour retention (Lazarides, 2001).

Basically, osmotic dehydration involves the partial water removal of water-rich solid foodstuffs, through immersion in hypertonic aqueous solutions of various edible solutes (Mavroudis *et al.*, 2001). In general, sugar solutions are used for fruits, while sodium chloride solution is used for vegetables (Ispir and Togrul, 2009). The driving force for water removal is the difference in concentration gradient between the solution and the intracellular fluid (Shi and Xue, 2009). With this, osmotic dehydration creates three types of counter-current mass transfer. The first one being an important water outflow, from the product to the solution. Second, a solute transfer from the solution to the product. While the third one refers to a leaching out of the product's own solutes such as sugars, organic acid, minerals and vitamins. However, the third mass transfer is considered quantitatively negligible in comparison to the first two types of transfer, but crucial with regard to the composition of the final product (Raoult-Wack, 1994). According to Ade-Omowaye *et al.* (2001), rapid and effective water removal as well as solute infusion during osmotic dehydration can be influenced by several factors such as temperature and concentration of the osmotic solution, the size and geometry of material, and also pretreatment prior to osmotic dehydration.

Osmotic dehydration is not used to produce food product with low moisture content that can be considered shelf stable. Instead, the osmotically treated product will undergo further processing either by air, freeze-, or vacuum-drying methods in order to obtain a shelf stable product, or the dehydration process could be used as a pretreatment prior to canning, freezing, and minimal processing (Rahman, 2007). Torreggiani and Bertolo (2001) stated that a partial dehydration step is useful to set the ingredients in the required moisture range, whereas a finer adjustment of water activity, consistency, sensory properties, and other functional properties is better achieved by an "osmotic step".

Despite the viability of osmotic dehydration process to produce food products with better organoleptic quality and to achieve energy savings in complementary drying process, there are some disadvantages that result in limitation of its application to foods. One of the major disadvantages associated with osmotic dehydration is the penetration of osmotic solute inside the food material (Dabrowska and Lenart, 2001). Most of the time, extensive solute uptake is undesirable as it can affect the taste and the nutritional profile of the product, which can no longer be marketed as "natural". Leaching of natural acids during osmotic dehydration also affects taste because it changes the natural sugar to acid ratio (Lazarides, 2001). Hawkes and Flink (1978) stated that solute uptake results in the development of a concentrated solids layer under the surface of the fruit, upsetting the osmotic pressure gradient across the fruit-medium interface and decreasing the driving force for water flow. Besides its adverse effect on water removal, solid uptake also blocks the surface layers of the product, posing an additional resistance to mass transfer and lowering the rates of complementary dehydration. In addition, solute uptake was found to affect the product rehydration in which longer osmosis time results in lower rehydration rate and subsequently the extent of complementary drying (Lazarides, 2001).

Along with the undesirable effects of solute uptake due to osmotic dehydration, an increase in consumer awareness of high sugar content in the product has led to high demand for lower solute uptake (Chaiwong and Pongsawatmanit, 2011). Previous study has shown that solute penetration largely depends on solute molecular size and process parameters, such as solution concentration and process temperature (Matuska *et al.*, 2006). Therefore, it would be of high interest to explore the potential of edible coating as the solution to the problem of extensive solute uptake. Based on Falguera *et al.* (2011), an edible coating (EC) is a thin layer of edible material formed as a coating on a food product. It is usually applied in liquid form on the food by immersing the product in a solution-generating substance formed by the structural matrix composed of carbohydrate, protein, lipid or multi-component mixture. Pre-coating the food to be dehydrated with an artificial barrier on the surface may efficiently hinder the penetration of solute inside the food without affecting much of the rate of water removal (Dabrowska and Lenart, 2001). Camirand *et al.* (1992) found that near equilibrium the weight loss and the ratio [water loss (g)]:[solute gained (g)] (WL/SG) were greater with the coated food than with the same non-coated food.

For the purposes of the OSMEMB (osmotic membrane) process, edible coatings should have the following properties: good mechanical strength (gel strength), satisfactory sensory properties, easy and rapid film formation with simple techniques, high water diffusivity, low solute diffusivity and maintenance of the coatings in an intact state without dissolving into the osmotic agent (Camirand *et al.*, 1992). Hydrocolloids such as polysaccharides and proteins are the most widely investigated biopolymers in the field of edible coating. These edible coating are found to provide good mechanical properties and are effective barriers to gases and aroma compounds but have low water barrier efficiency (Fabra *et al.*, 2009). Potential of different types of edible film or coating have been studied. Examples of coating material include aqueous solution of potato and corn starches, gelatin, amylopectin, pectin, maltodextrin, wheat gluten, sodium alginate, methycellulose, chitosan and others (Dabrowska and Lenart, 2001).

In this experiment, kappa and iota semi-refined carrageenan have been chosen as the edible coating material. Carrageenan is a type of hydrocolloids that are water-soluble polymers with a linear chain of partially sulphated galactans extracted from the cell walls of various red seaweeds (Rhodophyceae). In Malaysia, the production of semi-refined carrageenan is a relatively new industry (Normah *et al.*, 2005) and its usage is yet to be optimized. The main advantage of semi-refined carrageenan is the low cost although it has been claimed that semi refined products are actually superior to refined one.

The use of carrageenan as an edible coating or film was found to be appropriate in a aroma encapsulation study due to the high affinity for polar volatile compounds where it can gradually releasing aroma compounds and thereby maintain the sensory characteristics such as aroma and taste for certain periods of time (Marcuzzo *et al.*, 2010). Besides that, properties of carrageenan edible coating as polysaccharides such as poor barrier capacity against moisture transfer (Falguera *et al.* 2011) and relatively low oxygen permeability with excellent mechanical and structural strength (Ribeiro *et al.*, 2007) has fulfill the criteria for OSMEMB process. Carrageenan has also been used as a coating material in few studies (Ribeiro *et al.*, 2007; Matuska *et al.*, 2006; Chaiwong and Pongsawatmanit, 2011) where it has been reported that 0.5% of kappa carrageenan as coating material in papaya cubes can lower sugar uptake and lower total soluble solid in the product during osmotic dehydration process and in final dried product (Chaiwong and Pongsawatmanit, 2011).

1.2 Objective

The objective of this study is to determine the effect of different concentration and dipping time of kappa- and iota-semi-refined carrageenan coating on the qualities of osmotic dehydrated guava in terms of water loss, solid gain, total soluble solid, moisture content, water activity, and organoleptic properties including colour, texture and sensory.

CHAPTER 2

LITERATURE REVIEW

2.1 Osmotic Dehydration

2.1.1 Current Status of Food Drying

Dehydration is a vital food processing procedure to preserve raw food material and products in the food industry. The most basic objective in food dehydration is the removal of water from the raw material to extend the shelf life or reduce the load for the following operations (Shi and Xue, 2009). Preservation methods such as hot air drying, canning, and freezing have been applied to prolong the shelf life of foods, but these methods produce food products that are low in quality compared to their original fresh state.

One of the most commonly and extensively used drying method is hot air drying. Typical quality defects of hot air-dried products is mainly due to the evaporation of water at elevated temperature which causes chemical, physical and biological changes in food (Lewicki, 2006). As concentration of solubles is increased during drying process, this can promote chemical and enzymatic reactions due to higher concentration of reagents and catalysts. Besides that, contact between food materials with oxygen is substantially increased during drying. All of these changes will eventually lead to quality impairment of dried product such as shrinkage and shape distortions, discolouration, decreased flavour as well as unappetizing texture. Moreover, poor rehydration ability and reduced nutritional quality are also evidence disadvantageous influence of drying on food (Lewicki, 2006).

Nowadays, consumers' expectation for better quality, safety and nutritional value drives research and improvement of drying technologies. It was said that fresh fruits and vegetables consumption have been increasing in popularity compared to canned and frozen fruits in the last two decades (Shewfelt, 1987).

Besides that, increasing attention has been paid to the role of natural active ingredients such as antioxidants in human health. The preservation of these compounds is important in the quality aspect of food preservation especially in drying (Fernandes *et al.*, 2011). Therefore, it is crucial that the denaturation or damage of the active ingredients is minimized during preservation (Santos and Silva, 2008). As such, proper selection of drying method for the preservation of fruits is of utmost importance.

Despite the fact that conventional drying can adversely affect product quality, food drying is indispensable in many food industry sectors because of the increased shelf-life, reduced packaging cost, lower shipping weights and environmental advantages (Lewicki, 2006). Therefore, researchers have looked for new ways to process foods to achieve better quality of dehydrated food products. One of which is the osmotic dehydration process. Osmotic dehydration has shown a potential advantage in producing food product of high quality as water removal can be achieved without a phase change that reduces the physical, chemical and biological changes (Azoubel *et al.*, 2009). This is largely due to the relatively low process temperature employed in osmotic dehydration (up to 50 °C), in which such temperatures do not affect the semi-permeable characteristics of cell membranes as well as favour the colour and flavour retention (Lazarides, 2001). Lazarides (2001) also pointed that there is a progressively greater pressure to reduce the negative impact and cost of processing, as well as the cost of shipping, handling, and storage of agricultural product. Thus, osmotic dehydration is particularly advantageous at this point where rapid and effective water removal can be achieved utilizing high osmotic rate by economical mean (Bolin *et al.*, 1983).

2.1.2 Principle of Osmotic Dehydration

Osmotic dehydration is the process of water removal by immersion of water-containing cellular solid in a concentrated aqueous solution of soluble solutes (Rahman, 2007). A driving force for the diffusion of water from the tissue into the solution is provided by the difference in osmotic pressure between the food and surrounding osmotic solution (Rastogi and Raghavarao, 2004). In an ideal osmotic situation, a semi-permeable membrane would be permeated by the solvent molecules only but not the solute molecules (Torreggiani, 1993). However, it is difficult to obtain a perfect semi-permeable membrane in food material because of their complex internal structure and possible damage during processing (Shi and Xue, 2009). Based on Torreggiani (1993), cellular membranes of fruit and vegetables, which are composed mainly of parenchyma cells, freely allow the solvent molecules to pass through but they also allow the passage of some of the solute molecules to a lesser degree. This type of membrane could be classified differentially permeable, rather than semi-permeable.

Hence, mass transport in osmotic dehydration is actually a combination of simultaneous water and solute transfer processes (Rahman, 2007), with two simultaneous, countercurrent solution flows and one gas flow (Shi and Xue, 2009). It was being pointed that the solution flow out of food material is water mixed with solutes such as organic acids, reducing sugars, minerals, and flavour compounds which subsequently affect the organoleptic and nutritional characteristics of the final products. Soluble solids present in the osmotic solution, on the other hand, are taken up by the food material while gas flow is out of intercellular space (Figure 2.1). However, in the natural food systems, there is also some leakage of solute (sugars, organic acids, minerals and salts) across the membrane, or known as the third mass transfer (Raoult-Wack, 1994). Though quantitatively negligible, it may be essential as far as organoleptic or nutritional qualities are concerned (Torreggiani, 1993).

During osmotic dehydration, water continues to pass through the cell wall membrane until the concentration of water molecules is in equilibrium on both sides. The osmotic pressure gradient is imposed by a concentrated external solution. Hence, the mass transfer behavior will appear in two different patterns: osmotic dehydration (dewatering) or impregnation soaking (swelling) (Shi and Xue, 2009). Based on Raoult-Wack (1994), osmotic dehydration generally involves significant water removal (40-70 g of water is lost per 100 g of initial product) with limited and controlled solute incorporation (5-25 g of solute is gained per 100 g of initial product). This is mainly achieved by the use of highly concentrated solutions (50-75 g of solute per 100g of solution). Under typical operating conditions used

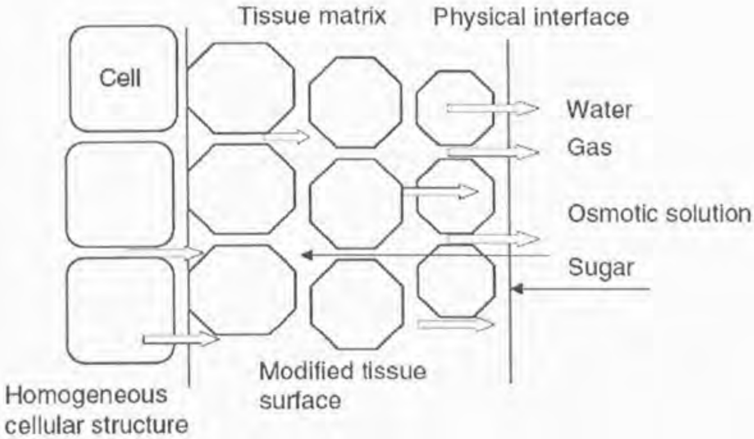

Figure 2.1: Schematic cellular material tissue representation and mass transfer pattern

Source: Shi and Xue (2009)

for fruit and vegetables, mass transfer mainly occurs during the first two hours and the mass transfer rates become progressively slower until water loss stops, whereas solute gain continues to increase steadily.

However, if the food product is immersed in a low concentration osmotic solution, the solute uptake is greater than water removal. Thus, the process is in an "impregnation soaking situation". Under this particular situation, the gradient of moisture concentration drives the osmotic solution into the product while the gradient of solutes transfers them into the osmotic solution. Therefore, some pigments, flavours, and nutrients are usually leaching out of the product during soaking and rehydration processes (Shi and Xue, 2009).

Therefore, compared to conventional drying processes, osmotic dehydration has two distinctive features. First, a dewatering and formulation effect (impregnation of solutes) which leads to weight reduction. Second, the process does not generally produce shelf-stable products and has to be used as a pre-processing step before complementary processing steps, such as drying, freezing, pasteurization, canning, frying and/or the addition of preservative agents (Raoult-Wack, 1994). As "impregnation" effect may be important, the term "dewatering-

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