Application of Alginate and Agar-based Edible Coatings to Pre-cut Jackfruit and Evaluation of the Flavor Compounds of Coated Pre-cut Jackfruit during Refrigerated Storage.

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***Abstract*— Jackfruit (*Artocarpus heterophyllus* Lam) is in high demand by Asians. It is large and difficult to peel, therefore, consumers prefer to buy jackfruit as a ready to cook product. Jackfruit is highly perishable. It ripens faster during the shelf life, and soon become unfit for cooking. Development of volatile compounds which contribute to flavour and aroma takes place during the ripening process. The aim of this study was to investigate the effect of application of 1% alginate-based and agar-based edible coatings on retention of volatile compounds developed in pre-cut jackfruit during a shelf life of 5 days under refrigerated conditions (6 ± 1^0C). The alginate coating was developed by dissolving alginate and glycerol in distilled water. $CaCl_2$ was used as a cross-linking agent in the alginate-based coating. The agar coating was also developed by dissolving agar and glycerol in water. Jackfruit of initial brix 6.23 ± 0.39 were selected for the study. Volatile compounds were detected by SPME-GC-MS technique on a DB-225MS column in uncoated, alginate coated and agar coated jackfruit on the 2nd day and 5th day of the shelf life. Esters, benzenic derivatives, pyridine derivatives, volatile alkanes, volatile alkenes, terpenes, aldehydes, ketones and alcohols were detected during the analysis. Compounds which were detected only from alginate coated samples were 1,2-dichlorobenzene, dimethyl(4-bromo-phenoxy)pentadecyloxy silane, 1,4-dihydro-1,4-methanonaphthalene, 4-(1-methyl-2-pyrrolyl)-2,6-diphenylpyridine, vanillin, trans-octahydro-1H-inden-1-one, and dimethyl-silanediol. These can be attributed as volatile compounds related to alginate. Compounds like 2,5-bis(1,1-dimethylethyl)phenol, tetradecanal, hexadecanal and trans-dodec-5-enal were only detected from agar coated samples. These can be attributed as volatile compounds related to agar. Volatile compounds like 6-methyl-2-heptanone, naphthalene, tridecane, tetradecane, pentadecane and hexadecane were lost from the uncoated jackfruit sample during the shelf life and these compounds could be preserved in pre-cut jackfruit by the applied alginate and agar coatings.**

Keywords*— *Jackfruit, alginate coating, agar coating, flavour profile

I. INTRODUCTION

Jackfruit (*Artocarpus heterophyllus* Lam), can be introduced as a tropical tree that is native to India and common in Asia, Africa and South America [1]. It belongs to the Genus Artocarpus and Moraceae (Mulberry) family. Jackfruit trees produce a heavier yield than any other tree species, and it is also mentioned that it bears the largest known edible fruit which can be up to 35 kg [2]. Jack can be consumed as a vegetable in the unripened stage and as a fruit in the ripen stage. Jackfruit pulp can be used in various ways. It can be processed into cans, jams and chutneys or dried [3]. At present, edible coatings are becoming popular among consumers to preserve the quality parameters of foods. It is also becoming popular in the fruit and vegetable sector too. There are previous studies that have applied alginate-based coatings to maintain the quality of apple slices without causing anaerobic respiration. Those results have revealed that the application of an alginate-based coating can reduce the water loss, textural loss, and browning of apple slices. It was also observed a higher concentration of volatiles in coated apple slices than uncoated apple slices during storage [4]. Tabassum and Khan [5] have studied the quality parameters and shelf life of freshly cut papaya with an application of alginate-based edible coating containing thyme and oregano essential oils in various concentrations as the lipid component of the alginate-based coatings. Senturk et al. [6] have developed a uniform alginate-based edible coating for freshly cut cantaloupe pieces. These research studies have obtained positive results for quality parameters and shelf life of coated pre-cut samples over uncoated samples. In this study, alginate-based and agar-based edible coatings were applied on pre-cut jackfruit and determined the flavour compounds in pre-cut jackfruit samples which were stored in refrigerated conditions for 5 days.

Jackfruit is highly perishable. Minimally processed pre-cut jackfruit ripe faster and become unfit for consumption as a vegetable. During ripening, volatile flavour and aroma compounds develop in jackfruit. Therefore, the amount of volatile compounds in jackfruit increase during ripening. Jackfruit flavour is described with strong peculiar fruit notes, which depend on the content of several volatile compounds present in the fruit. These compounds play an important role in determining the effect on the overall flavour of the jackfruit [7]. Therefore, to sell good quality pre-cut jackfruit, loss of volatile compounds should be minimized in jackfruit during the shelf life.

II. METHODOLOGY

A. Sample Preparation

Jackfruits of optimum ripening stage were selected, washed and allowed to dry. After that, they were opened by manually cutting along the main axis using stainless steel

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knives, and the whole bulbs with seed were separated from the central axis of the fruit. Then, seeds were removed from the bulbs. After that, bulbs were cut into pieces, immersed in a 0.045% sodium benzoate solution for 30 minutes and got coated.

B. Extraction of Alginate

Alginate was extracted from *Sargassum sp*. according to the hot extraction method described by Chee et al. [8] with slight modifications.

C. Extraction of Agar

Extraction was done without treating with NaOH according to the method described by Praiboon et al. [9] with slight modifications.

D. Preparation and Application of Alginate-based and Agar-based Coatings

The alginate coating formulation was developed by dissolving 1g of alginate in 100 ml of distilled water at 70 ^{0}C and continued dissolving at 70 ^{0}C until alginate was completely dissolved in distilled water. Subsequently, cooled to 40 ^{0}C to dissolve 5g of glycerol.

Agar coating formulation was developed by dissolving 1g of agar in 100 ml of distilled water at 70 ^{0}C. Subsequently, cooled to 40 ^{0}C to dissolve 0.5g of glycerol.

Pre-cut jackfruit pieces were dipped in the alginate solution for 2 minutes. Subsequently, transferred into a 4% (w/v) $CaCl_2$ solution, dipped for 2 minutes and transferred into plates to air dry for 2 hours. Jackfruit pieces were dipped in the agar solution at 35 ^{0}C for 2 minutes and transferred into plates to air dry for 2 hours. Both alginate and agar coated samples were then transferred into salad plates made from natural sugar cane bagasse, wrapped with a cling wrapper and stored in refrigerated conditions.

E. Flavour Profile Analysis of Jackfruit

Volatile flavour compounds were detected by SPME-GC-MS technique on DB-225MS column in uncoated jackfruit, alginate coated jackfruit and agar coated jackfruit by the method described by Maduwanthi and Marapana [10] with slight modifications.

III. Results and Discussion

Alginate and agar can be introduced as marine polysaccharides which are extracted from brown algae and red algae respectively. When proper conditions are given, both alginate and agar can form gels. This gel-forming ability of alginate and agar can be used to develop edible coatings which can be applied to preserve the quality of food products. In this study, glycerol was used as the plasticizer of coating formulations. Plasticizers can improve the flexibility and reduce the brittleness of films and coatings. Alginate forms gels with the presence of divalent cations such as calcium, magnesium, manganese, aluminium, and iron in the medium. Calcium is the most common divalent cation used in gel formation.

Edible coatings are thin layers of edible components that are generally consumed with the food itself. Most commonly, it is used as a primary packaging of food. Edible coatings enable the maintenance of proper quality parameters during the shelf life of the product. In this study, alginate and agar-based coatings were used to preserve volatile flavour compounds in jackfruit to maintain the characteristic flavour of jackfruit within the shelf life. Jackfruit of optimum maturity with a Brix value of 6.23 $\pm$ 0.390 was selected for the analysis. Those samples were coated with 1% agar and 1% alginate-based coatings and stored under 6$\pm$1 ^{0}C temperature for analyzing the volatile flavour compounds. Ripening of Jackfruit takes place within the shelf life. The development of volatile compounds which contribute to its distinct flavour and aroma takes place during the ripening process. During this ripening period, metabolism changes to catabolism and the development of volatile compounds takes place from major plant constituents through various biochemical pathways [7]. Volatile compounds play a vital role in determining the overall flavour of Jackfruit. Authors have also pointed out that, a high proportion of esters is important for Jackfruit flavour. At the same time, this characteristic flavour will change among different Jackfruit cultivars and can also be altered by applying different pre-harvest and post-harvest conditions [7].

Generally, during fruit ripening, volatile compounds belonging to esters, alcohols, aldehydes, ketones, and terpenes will develop. Volatiles in Table 1 shows flavour compounds detected by SPME-GC-MS technique on DB-225MS column in uncoated jackfruit, alginate coated jackfruit and agar coated jackfruit on the 2nd day and the 5th day of the shelf life respectively. Previous research has extracted 37 volatile compounds from five different Jackfruit cultivars using the SPME method. There, 20 esters, five alcohols, nine aldehydes, two ketones, and one ether was detected [11]. In those Jackfruit cultivars, high concentrations of ethyl isovalerate, 3-methyl butyl acetate, 1-butanol, propyl isovalerate, isobutyl isovalerate, 2-methyl-1-butanol, and butyl isovalerate were detected. These compounds are responsible for the sweet and fruity note of jackfruit [11]. According to the results of the study, different kinds of ester compounds were detected from uncoated and coated samples on the 2nd day and the 5th day. On the 5th day, uncoated samples were observed with a dried appearance than the coated samples. During drying, case hardening of the surface takes place. Hence, some volatile compounds which were detected on the 2nd day may not be detected on the 5th day in the uncoated sample than the coated samples. Methyl 3-methylbutanoate was detected in the uncoated sample and agar coated sample on the 2nd day while Methyl 3-methylbutanoate was detected from uncoated, alginate coated and agar coated samples on the 5th day. Except for Methyl 3-methylbutanoate, there is no similarity in ester compounds detected from the 2nd day and 5th day of uncoated, alginate coated and agar coated samples. New ester compounds known as 2-Methyl-1-(1,1-dimethylethyl)-2-methylpropanoic acid, 1,3-propanediyl ester, Butanoic acid, 2-butoxy-1-methyl-2-oxoethyl ester and Pentanoic acid,2,2,4-trimethyl-3-carboxyisopropyl, isobutyl ester have developed in uncoated, alginate coated and agar coated jackfruit samples on the 5th day while losing the initial ester compounds. Except for naphthalene, other benzene derivatives which were detected on the 2nd day of uncoated and coated samples were not detected on the 5th day. Azulene was the only benzene derivative detected on the 5th day in the uncoated sample. Benzene derivatives such as 1,2-dichlorobenzene, dimethyl(4-bromo-phenoxy)pentadecyloxy silane , 1,4-Dihydro-1,4-methanonaphthalene and -(1-methyl-2-pyrrolyl)-2,6-diphenylpyridine were only detected from alginate coated samples. These compounds may be due to the alginate coating applied to jackfruit. Benzene derivative which is Phenol,2,5-bis(1,1-dimethylethyl) was only detected from agar coated samples. That compound may be due to the agar coating applied to jackfruit. 1,6,10-Dodecatriene,7,11-dimethyl-3-methylene-,(E) is a terpene that was detected only on the 2nd day of the uncoated sample. It was not detected on the 5th day in any of the samples. Caryophyllene was detected in all the 3 samples on the 2nd day. However, it was only detected in uncoated and alginate coated samples on the 5th day. Aldehyde also plays an important part when determining the flavour profile of jackfruit. Decanal was detected on the 2nd and 5th day of all the samples. Aldehydes such as Tetradecanal, Hexadecanal and Trans-dodec-5-enal were only detected on the 2nd day of agar coated sample. These aldehyde compounds can be due to the agar coating applied to jackfruit. Compounds like Vanillin, trans-octahydro-1H-inden-1-one and dimethyl-silanediolwere only observed in the alginate coated sample. They may be due to the application of an alginate coating on jackfruit. Cyclopropanecarboxamidine was only detected on the 2nd day and 5th day of agar coated sample. This compound may also be due to the application of an agar coating on jackfruit. Volatile alkanes and alkenes were also detected during the analysis. Tridecane and Tetradecane were detected in all the samples on the 2nd day and they were absent in the uncoated sample on the 5th day. Naphthalene was detected on the 2nd day of uncoated and agar coated samples. 6-Methyl-2-heptanone, Tridecane and Tetradecane were detected in all three samples on the 2nd day. Pentadecane and Hexadecane were detected only in uncoated samples during the 2nd day. On the 5th day naphthalene, 6-Methyl-2-heptanone, Tridecane, Tetradecane, Pentadecane and Hexadecane were absent in the uncoated sample but present in alginate coated and agar coated samples. This shows that the application of alginate or agar coating has an impact on minimizing volatile compound lost or has delayed the generation of certain volatile compounds by delaying ripening.

TABLE I. COMPOUNDS DETECTED BY SPME ANALYSIS

Compounds	**Initial readings**			**Readings obtained on the 5th day**		
	Uncoated	***Alginate coated***	***Agar coated***	***Uncoated***	***Alginate coated***	***Agar coated***
Esters						
3-Methyl-2-butenoic acid	ND	D	ND	ND	ND	ND
Ethyl 3-methylbutanoate	ND	D	ND	ND	ND	ND
Methyl 3-methylbutanoate	D	ND	D	D	D	D
3-Methylbutyl 2-methylbutanoate	ND	ND	D	ND	ND	ND
3-Methyl-1-butyl acetate	ND	ND	D	ND	ND	ND
Methyl 2-hydroxy-tricosanoate	D	ND	ND	ND	ND	ND
4-Methylpentyl 3-(trifluoromethyl)benzoate	D	ND	ND	ND	ND	ND
Dichloroacetic acid, 4-hexadecyl ester	ND	ND	D	ND	ND	ND
2-Methyl-1-(1,1-dimethylethyl)-2-methylpropanoic acid, 1,3-propanediyl ester	ND	ND	ND	D	ND	ND
Butanoic acid, 2-butoxy-1-methyl-2-oxoethyl ester	ND	ND	ND	ND	D	ND
Pentanoic acid,2,2,4-trimethyl-3-carboxyisopropyl, isobutyl ester	ND	ND	ND	ND	ND	D
Benzenic derivatives						
Benzaldehyde,2-5-bis[(trimethylsilyl)oxy]	D	ND	ND	ND	ND	ND
Benzaldehyde, 4-(methylthio)	ND	ND	D	ND	ND	ND
3-Allyl-6-methoxyphenol	D	D	ND	ND	ND	ND
Naphthalene	D	ND	D	ND	D	D
Benzene	ND	ND	D	ND	ND	ND
1H-Indene, 1-methylene	ND	D	ND	ND	ND	ND
Benzaldehyde	D	D	D	ND	ND	ND
1,2-dichlorobenzene	ND	ND	ND	ND	D	ND
Phenol,2,5-bis(1,1-dimethylethyl)	ND	ND	ND	ND	ND	D
dimethyl(4-bromo-phenoxy)pentadecyloxy silane	ND	ND	ND	ND	D	ND
Azulene	ND	ND	ND	D	ND	ND
1,4-Dihydro-1,4-methanonaphthalene	ND	ND	ND	ND	D	ND
Pyridine derivatives						
-(1-methyl-2-pyrrolyl)-2,6-diphenylpyridine	ND	ND	ND	ND	D	ND
Alkanes						
Tridecane	D	D	D	ND	D	D
Tetradecane	D	D	D	ND	D	D
Cyclododecane	ND	D	ND	ND	ND	ND
Pentadecane	D	ND	ND	ND	D	D
Hexadecane	D	ND	ND	ND	D	D
Dodecane	ND	ND	ND	ND	D	D
Cycloeicosane	ND	ND	ND	ND	ND	D
Alkene						
Cyclodecene	D	D	ND	ND	ND	ND
2-Pentene	D	ND	ND	ND	ND	ND
1-Octadecene	D	ND	ND	ND	ND	D
1-Nonadecene	D	ND	ND	ND	ND	ND
9-Tricosene, (Z)	ND	ND	ND	D	ND	ND
9-Eicosene, (E)	ND	ND	ND	ND	D	D

Cycloheptene	ND	ND	ND	ND	ND	D
Terpenes						
Caryophyllene	D	D	D	D	D	ND
1,6,10-Dodecatriene,7,11-dimethyl-3-methylene-,(E)	D	ND	ND	ND	ND	ND
10-dodecatriene,7,11-dimethyl-3-methylene-,(Z)	ND	ND	ND	ND	ND	D
4,11,11-trimethyl-8-methylene-,[1R-(1R*,4Z,9S*)]	ND	ND	ND	ND	ND	D
Limonene	ND	ND	ND	D	ND	D
Cis-alpha-Bisabolene	ND	ND	ND	ND	D	ND
Aldehydes						
Dodecanal	D	D	ND	ND	ND	D
6-Octanal, 3,7-dimethyl	D	ND	D	ND	ND	ND
6-Octenal,3,7-dimethyl-, (R)	ND	ND	ND	D	D	D
Decanal	D	D	D	D	D	D
Tetradecanal	ND	ND	D	ND	ND	ND
Hexadecanal	ND	ND	D	ND	ND	ND
Trans-dodec-5-enal	ND	ND	D	ND	ND	ND
3-Methylbutanal	D	D	D	ND	ND	ND
2-butenal,3-methyl	ND	D	D	D	D	D
2-Butenal, 2-methyl	D	ND	ND	D	D	D
Vanillin	ND	D	ND	ND	D	ND
Hexanal	ND	ND	ND	ND	D	D
Octanal	ND	ND	ND	D	ND	D
E-15-Heptadecenal	ND	ND	ND	D	ND	ND
Ketones						
6-Methyl-2-heptanone	D	D	D	ND	D	D
Floro-3,5-bispentaflurophenoxy-2,5-cyclohexadienone	ND	ND	ND	D	ND	ND
5H-Inden-5-one,octahydro-,cis	ND	ND	ND	D	ND	ND
trans-octahydro-1H-inden-1-one	ND	ND	ND	ND	D	ND
Alcohols						
dimethyl-silanediol	ND	D	ND	ND	ND	ND
beta.-methoxy-.alpha.-phenylphenethyl alcohol	ND	ND	ND	D	ND	ND
Other						
3-(1,5-dimethyl-4-hexenyl)-6-methylene-,[S-(R,S)]	ND	ND	D	D	ND	ND
bicyclo[3,1,1]hept-2-ene,2,6-dimethyl-6-(4-methyl-3-pentenyl)	D	D	D	D	D	D
Cyclopropanecarboxamidine	ND	ND	D	ND	ND	D
Floro-3,5-bispentaflurophenoxy-2,5-cyclohexadienone	D	ND	ND	ND	ND	ND
2,2,6,6-tetramethyl-4-piperidone	ND	ND	ND	ND	ND	D
4-methoxybenzylamine,N,N-dibutyl	ND	ND	ND	D	ND	ND

III. Conclusion

Application of alginate or agar coating has minimized the loss of certain volatile compounds and has delayed the generation of certain volatile compounds in jackfruit. Generation of Methyl 3-methylbutanoate, Naphthalene Azulene, Pentadecane, hexadecane and 2-Butenal, 2-methyl were delayed in the alginate coated sample. Generation of Azulene, Pentadecane, hexadecane, 1-Octadecene and 2-Butenal, 2-methyl were delayed in the agar coated sample. Compounds like 6-Methyl-2-heptanone, Naphthalene, Tridecane, Tetradecane, Pentadecane and Hexadecane have lost from the uncoated jackfruit sample during the shelf life and these compounds were preserved by the application of alginate and an agar coating.

The authors would like to suggest determining the volatile flavour components of jackfruit by coating with a carrageenan based coating.

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