The relationship between concentration of oil absorbed by the fruitcake (Y) and concentration of oil in the headspace (X) can be expressed by

$$Y = -0.580308 + 0.108933X - 0.000000254X^2 \quad \text{.....(2)}$$

with R-adjust = 0.9996. This equation was used to calculate the concentration of oil absorbed in fruitcake in Table 33.

Table 33 Predicted and experimental concentration of cinnamaldehyde in fruitcake

No.	Optimum conditions	Time storage (Wk)	Predicted concentration (ppm)*	Experimental concentration (ppm)
1	Temp (40 °C)	1	193	167±51
	Time (10 min)	2	171	148±49
	Volume of oil (50 μl)	3	156	141±58
	Volume of jar (700 ml)	4	145	125±47
2	Temp (40 °C)	1	167	143±57
	Time (10 min)	2	149	124±53
	Volume of oil (100 μl)	3	130	103±28
	Volume of jar (700 ml)	4	101	85±15

* = Mean ± standard deviation of sixth replicates determinations

Table 33 shows the predicted concentration of cinnamaldehyde in the fruitcake together with the experimental values. It is clear that all the predicted values lie within the range of the experimental results. The proposed equation 4 was then verified. The amount of cinnamaldehyde in fruitcake required to inhibit growth of fungi can be calculated as a function of the activation temperature and time, volume of oil and volume of package used. This should be very useful in determining process conditions suitable for a particular product and packaging size.

The temperature and %RH of room temperature storage condition were recorded as shown in Figures 45 to 46. The experiments were carried out at the sensory laboratory, Walailak University, situated in the South of Thailand in January 2006. There were rain and sunshine within the same week. The temperature at daytime (28 °C to 33°C) was about 5 °C higher than that in the nighttime. However, the cinnamaldehyde in the headspace of rice butter cake kept at room temperature was not significantly different from that kept at 30 °C.

The storage of rice butter cake under normal air condition using volume of jar at 700 ml, volume of oil at 50 µl and 100 µl which were activated at temperature of 40 °C for 10 minutes demonstrated it is possible to extend shelf life of rice butter cake up to 21 days and ≥ 1month, respectively. Moreover, the hedonic scores were between "like slightly" to "like moderately.

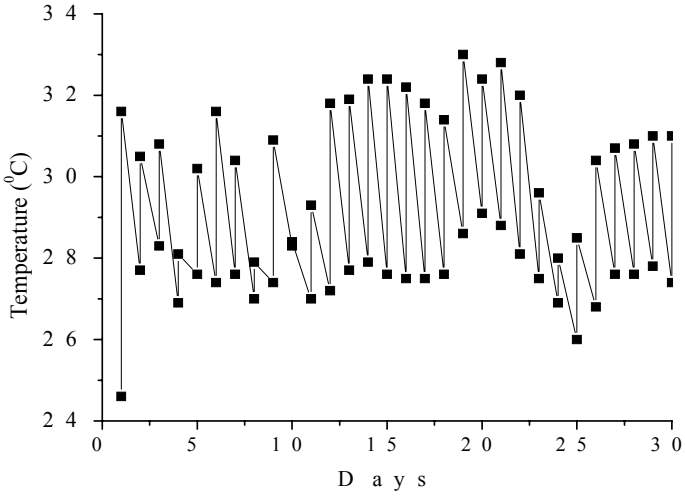

Figure 45 Temperature at the sensory laboratory, Walailak University in January 2006

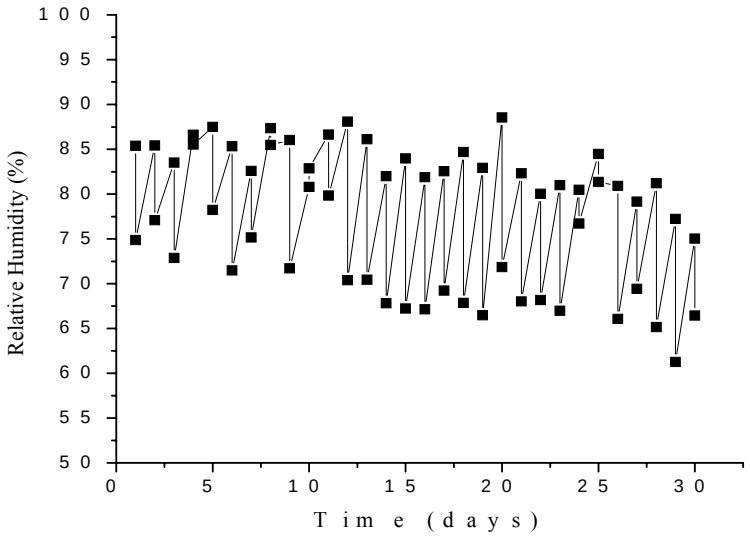

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Figure 46 Relative humidity at the sensory laboratory, Walailak University in January 2006

CONCLUSION

The major findings of this research can be categorized into four groups, which are described in turn.

1. A survey on the IMF products available in the modern market in Thailand was carried out in order to search for a product suitable for preservation with a combined active packaging technique of modified atmosphere and volatile essential oils. From 136 items of the IMF products surveyed, five products (cake, ham, bacon, bread and cheese) were screened as high potential products by using the pass-fail screening technique. Fruitcake, the premium market product, was selected to be the product for this research study because essential oils such as cinnamon oil and clove oil are already part of the product recipe.

2. The following conclusions may be drawn from the study of effectiveness of using cinnamon and clove oil as antifungi in IMF product by using active packaging technique:

2.1 The combination between cinnamon oil and clove oil with MA conditions showed stronger inhibition than essential oil alone into agar containing those microorganisms frequently causing spoilage of IMF products.

2.2 The combination of cinnamon oil and clove oil at the ratio 5:1 of 4,000 μL was considered to best prevent the growth of *A. flavus* on agar.

2.3 Variety fruitcake mix (PMC_5), rice fruitcake (RF) and rice butter cake (RBC) were selected as products to be tested using the combined effect of cinnamon oil and clove oil because their water activities and their moisture contents were similar to those of the commercial fruitcake available in the market.

2.4 To prevent the growth of *A. flavus* on the surface of fruitcake, 300 μL of cinnamon oil and clove oil at ratio 5:1 under high concentration of CO_2 or 700 μL of cinnamon oil and clove oil at ratio 5:1 under normal air at 30 °C were required.

2.5 Western consumers tend to accept odour and taste of cinnamon and clove oil better than Thai consumers do.

3 The following conclusions may be drawn from the development of active packaging product for preservation of the selected IMF products with modified atmosphere condition:

3.1 Polypropylene film, filter paper and calcium silicate type 1 (CaSE-1) were found to release volatile oil into the headspace more effectively than thyvex, LLDPE, LDPE35 and LDPE 70 with silica gel and calcium silicate type 2 (CaSE-2). The results from the volatile headspace showed that major volatiles in the headspace above an inhibitory mixture of these oils were identified as *p*-cymene, linalool, cinnamaldehyde and eugenol. Furthermore it was found that the surface concentration of oil on the surface of the fruitcake was approximately 10%of the headspace concentration.

3.2 Storage of premix fruitcake and rice fruitcake were investigated under the active packing condition. High concentration of CO_2 (40%) and low concentration of O_2 (< 0.05%) could help to extent the shelf life of fruitcake from 3 days to 14 days. In addition, the combined effect of volatile compound of cinnamon oil and clove oil at 300 μl under high concentration of CO_2 could extend shelf life of fruitcake at 20 °C, 68% RH and 30 °C, 75%RH to up to 21 days.

3.3 The RSM model was successfully employed to describe the growth rate of *Aspergillus flavus*. It was found that water activity, volume of oil and time were the most significant parameters influencing growth of *Aspergillus flavus*. The rice

fruitcake was used to verify the growth model. The predicted growth rate of *A. flavus* was in agreement with the experimental microbial value.

4 The following conclusions may be drawn from the application of the active packaging technique developed to preserve the IMF products under normal air condition:

4.1 The high temperature condition could be used to increase concentration of cinnamaldehyde in the headspace. The results indicated that the concentration of cinnamaldehyde could be increased to ≥ 1,000 ppm in the headspace by a combination of heating at 40 °C, 10 minutes.

4.2 The RSM model was successfully employed to describe the concentration of cinnamaldehyde in the headspace at high temperature. It was found that volume of desiccators simulating the packages volume and volume of oil were the most significant parameters influencing the amount of cinnamaldehyde in the headspace.

4.3 For storage of rice butter cake under a normal air condition using a jar of 700 ml, volume of oil of 50 µl or 100 µl, which were activated at temperature of 40 °C for 10 minutes to increase the amount of volatile oil in the head space, It was possible to extend the shelf life up to 21 days and ≥ 1 month, respectively. Moreover, the hedonic scores were between “like slightly” to “like moderately”.

The results of this work suggest that mixtures of oils can potentially be manipulated to achieve adequate microbial control and yet may also provide a more favourable flavour profile than the use of only a single active component. The findings may help the manufacturer in achieving the desired response, i.e., the desired product shelf life and may open new opportunities for optimisation of antimicrobial active packaging systems in the future.

RECOMMENDATION FOR FUTURE WORK

The volatile active packaging system could prevent growth of microorganisms on the surface of fruitcake and rice butter cake. The packaging concept should be able to be applied to preserve other IMF products. Sensory tests will also need to be conducted to find a suitable gas phase concentration of cinnamon oil and clove oil for each specific product. Furthermore, the composition of volatile compound from two or more essential oils can potentially be manipulated to achieve adequate microbial control and yet may also provide a more favourable flavour profile than the use of only a single active essential oil. To achieve this outcome will require a thorough understanding of the kinetics of release and uptake of the mixture's volatile components, and of their relative contributions to microbial inhibition and the product's sensory profile under those conditions prevailing through the product supply chain. Cinnamon oil and clove oil at 5:1 were shown to be strong inhibitors of the growth of yeasts and moulds. However, more clove oil should be evaluated to prevent the growth of bacteria on surface of some IMF products because the eugenol in clove oil has been show to be effective against many bacteria. As can be see from the research, the volatiles packaging may open new opportunities for optimisation of antimicrobial active packaging systems in the future.

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APPENDIX

APPENDIX I

Sensory Questionnaire

Massey University

Te Kunenga ki Pürehuroa

TITLE of Work:

Researcher(s) Introduction

Researchers Name:	Narumol Matan	Supervisors Name:	Associate Professor John Mawson Mr. Michael Parker
Contact Details:	Fresh Technologies IFNHH,Massey University n.matan@massey.ac.nz. Tel: 5985	Contact Details:	Fresh Technologies IFNHH,Massey University a.j.mawson@massey.ac.nz. m.e.parker@massey.ac.nz. Tel: 5963, 5232

You are invited to take part in a sensory evaluation of food product. The product is 'fruitcake', packaged inside the high gas barrier polymeric packages containing food grade essential oil.

Your participation in this activity will take approximately 10 minutes.

We are selecting people for this exercise who meet the following criteria:
From Western countries and Thailand.

Certain ingredients of fruitcake used in this experiment may be harmful or cause allergic reactions with certain groups of people. You are requested to refrain from our experiment if following ingredient can cause adverse effects to you:

Wheat Flour	Sugar	Vegetable oil	Emulsifiers
Flavours	Salt	Sultanas	Pineapple
Egg	Baking powder	Thickener (modified starch)	Essential oil

The information collected in this study will be used to complete an assignment in partial fulfilment of the Doctor of Philosophy (Agro-Industrial Product Development). No data linked to an individual's identity will be collected.

If you have any questions about this work, please contact one of the people indicated above.

CONSENT FORM

THIS CONSENT FORM WILL BE HELD UNTIL DECEMBER 2005

I have read and understood the Information Sheet and have had the details of the study explained to me. My questions have been answered to my satisfaction, and I understand that I may ask further questions at any time.

I agree to voluntarily participate in this study under the conditions set out in the Information Sheet.

I understand I have the right to withdraw from the study at any time and to decline to answer any particular questions.

I have advised and discussed the Researcher of any potentially relevant cultural, religious or ethical beliefs that may prevent me from consuming the Foods under consideration.

I agree /do not agree to be audio taped, but understand that I have the right to ask for the tape to be turned off at any time during the study *(if applicable include this statement)*

Participants **Date:**

Signature: ....

Full Name - printed .....

Age……Country……

Address:……

E-mail:……Tel……..…

Answer Sheet

Instructions

Open and taste the sample from left to right and note the intensity of the characteristic studied. Rate each sample on the following scale:

1 = Dislike extremely
2 = Dislike very much
3 = Dislike moderately
4 = Dislike slightly
5 = Neither like nor dislike it
6 = Like slightly
7 = Like moderately
8 = Like very much
9 = Like extremely

1. Sample Code ……..

- How do you feel about the odour after opening the package?

□ □ □ □ □ □ □ □ □
1 2 3 4 5 6 7 8 9

- How do you feel about the color of the sample?

□ □ □ □ □ □ □ □ □
1 2 3 4 5 6 7 8 9

- How do you feel about the texture of the sample?

□ □ □ □ □ □ □ □ □
1 2 3 4 5 6 7 8 9

- How do you feel about the taste of the sample?

□ □ □ □ □ □ □ □ □
1 2 3 4 5 6 7 8 9

- How do you feel about the flavor of the sample?

□ □ □ □ □ □ □ □ □

1 2 3 4 5 6 7 8 9

- Overall of sample

□ □ □ □ □ □ □ □ □

1 2 3 4 5 6 7 8 9

Comments:……

2. Sample Code ……..

- How do you feel about the odour after opening the package?

□ □ □ □ □ □ □ □ □

1 2 3 4 5 6 7 8 9

- How do you feel about the color of the sample?

□ □ □ □ □ □ □ □ □

1 2 3 4 5 6 7 8 9

- How do you feel about the texture of the sample?

□ □ □ □ □ □ □ □ □

1 2 3 4 5 6 7 8 9

- How do you feel about the taste of the sample?

□ □ □ □ □ □ □ □ □

1 2 3 4 5 6 7 8 9

- How do you feel about the flavor of the sample?

□ □ □ □ □ □ □ □ □

1 2 3 4 5 6 7 8 9

- Overall of sample

□ □ □ □ □ □ □ □ □

1 2 3 4 5 6 7 8 9

Comments:……

……

APPENDIX II

Key to *Aspergillus flavus*

Colonies on CYA at 25 ^{0}C and 37 ^{0}C both exceeding 35 mm diam

↓

Colonies coloured

↓

Colonies yellow, green or brown

↓

Conidia yellow, yellow green or brown; developing cleistothecia not present

↓

Conidia yellow green or yellow

↓

Conidia with relatively thin walls, smooth or finely roughened, spherical to broadly ellipsoidal; vesicles up to 50 µl diameter

CURRICULUM VITAE

NAME : Mrs.Narumol Matan

BIRTH DATE : February 1976

BIRTHPLACE : Kalasin, Thailand

EDUCATION :

YEAR	INSTITUTION	DEGREE
1997	King Mongkut University of Thonburi	B.Sc.(Microbiology)
1999	Kasetsart University	M.Sc.(Agro-Industrial Product Development)

POSITION : Lecturer

WORKPLACE : Institute of Agricultural Technology, Food Technology
Walailak University, Thailand

AWARDS : Award of Kasetsart Thesis, as the best overall thesis.
(Utilization of Cinnamon oil as Antifungi in Durian Paste)

SCHOLARSHIP : Agro-Industry Ph.D. Program Consortium,
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