CHAPTER 7

Application of multi-core encapsulated *Michelia alba* D.C. flavor powder in Thai steamed dessert (Nam Dok Mai), and its release profile

Abstract

This research aimed to investigate the suitable content of flavor encapsulated powder for controlled release and its flavor release model. The *Nam Dok Mai* (NDM) dessert was selected for this experiment due to the high moisture content and high temperature during its steaming process. The controlled release of the aroma and flavor of the multi-core encapsulated *Michelia alba* D.C. (MAD) flavor powder was used in this experiment. The variations of the multi-core encapsulated MAD flavor powder used in this research were 0, 0.5, 1, 3, and 5% w/w. The color and texture profiles were analyzed, together with sensory evaluation. The pandan aroma release was examined from the outer shell of the multi-core encapsulated MAD flavor powder, whereas the MAD aroma release was examined from the inner core. The results revealed that the NDM dessert containing 1% w/w of the multi-core encapsulated MAD flavor powder demonstrated the most preferable of the sensory acceptance. The consumer acceptance of the NDM dessert with 1% w/w of the MEFP showed that the NDM dessert provided a sensory rating score in the range of 6.0–6.3. The acceptance and purchase intention were also revealed high amount as 98.0% and 98.3%, respectively. The controlled release model for the NDM dessert using the time intensity method showed the maximum intensity of the pandan aroma and the white champaca flavor at 48.79 and 50.80, respectively within 9th second. This indicated that the white champaca flavor provided higher intensity than the pandan flavor in the NDM dessert.

Keywords: multi-core flavor powder, controlled release, *Michelia alba* D.C., pandan, Nam Dok Mai dessert, time intensity

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7.1 Introduction

Food and beverages were consumed through mouth and transferred into throat before those passed through esophagus toward stomach and then adsorbed at intestines. The consumed foods through these parts of the digestive system are supposedly predigested. It is happened in oral cavity which mechanical and enzymatic degradation were taken place. The food fragments were then mixed with saliva and created consistent bolus to make it safe to swallow through digestive track. The quantity of consumed food in oral cavity each time (munching size) and other property like viscosity affected toward consumer preferences, also highly changeable among consumers (Prinz & De Wijk, 2007; De Wijk, Zijlstra, Mars, De Graaf, & Prinz, 2008). There is mandatory for breaking down a solid food in oral cavity to create smaller bite sizes than semisolid foods. The smaller bite sized is recognized to provide weaker food sensations, also lower aroma and flavor release which reduced preferable sensation toward consumers (De Wijk Polet, Boek, Coenraad, & Bult,2012).

The exposure aroma and flavor during consuming are affected toward consumers as following two reasons. Firstly, the perception of flavor intensity regulated adaptively from its bite size to maintain temperate intensity as increasing flavor intensity decreased when the bite size become smaller. Secondly, the aroma and flavor perceptions are going to be increased due to increase of fat-containing in product such as creamy or dairy product which created creaminess and thickness toward product properties (Bult, De Wijk, & Hummel, 2007). The increasing of those factors lead to increasing aroma and flavor from food during consuming. The perception of aroma and flavor from food are affected from its different bite size and fat-containing property (De Wijk *et al*., 2012). It is suggested that aroma and flavor are important parts that determined food quality and acceptability. The different content of aroma and flavor in food provided particularly improve consumers' perception and satisfaction of finished product. However, aroma and flavor are difficult to handle because of high volatility, vulnerability to oxidation and chemical reactions in applied system. Those are considerable sensitivity to expose in environment as heat, light and moisture (Wang, Yuan, & Yue, 2015).

Encapsulation techniques have been explored and applied to resolve those difficulties. The entrapments of volatile compounds are used to protect active materials from evaporation, to create resistance protective wall against undesired reactions during food processing, consuming and storage condition (Wang *et al*., 2015). There are major structures of aroma and flavor encapsulation which are single core and multiple cores. The latter is the formation of different active compounds to create controlled release property. Multi-core encapsulation entraps those core materials using complexation coacervation method. Complexation of aroma can improve food flavoring using reduction of evaporation and control their release during storage and application (Ades, Kesselman, Ungar, & Shimoni, 2012). Microcapsules produced from coacervation are water-insoluble, heat-resistant, and possessed excellent controlled release characteristics based on mechanical stress, temperature and sustained release (Dong *et al*., 2011). The complex coacervation is applied to create different intensity and delayed-time of flavor release in many products for instance, beverages, bakery products, chewing gum and desserts (Wang *et al*., 2015).

Interestingly, the development of Thai dessert was rarely approached. Most of the developed dessert premixes and provided in the market were western bakery and desserts. There were two developments involving instant and shelf-life extension of Thai desserts. Chaysirichote (2000) studied and developed Khanom Tubtim was developed into instant form. The shelf-life extension of Khanom Tubtim was extended to 3 months. Chamchan (2001) developed instant fluffy rice flour cake (Khanom Tauy-Fu) for consumers that prefer conveniently and easy to prepare Thai dessert. The result showed that consumers preferred the instant fluffy rice flour cake product moderately. The product can be stored at temperature $\leq$ 35°C for 3 months with slightly changes under accelerated condition. Hence, Thai desserts are considered to have unique flavor and aroma was which came from Thai herbs and flowers. Therefore, there is a need for flavor releasing during process time and from which the flavor preferably slowly becomes available over an increased period of time and not at a burst of flavor at the start of the processing time. Variation in ingredients concentration or characteristics can modify the rheological and sensory properties of semisolid dessert which influenced consumer responses. The effects are more complexed and there are shown that volatile compounds are engaged important role as lypophillic components in solvent and some aroma and flavor carriers are also influenced on product texture (Arancibia, Castro, Jublot, Costell, & Bayarri, 2015).

The development of NDM dessert from Jueyjareon (2003) was studied to set specification of Thai dessert. The study showed that the optimum of formula of NDM dessert consisted of rice flour (17.39%), sugar (26.09%), water (56.32%), and flavor (0.2%) which provided the maximized preference on product. NDM dessert was composed of 51.07% moisture content. The hardness, springiness and gumminess of the product were 10.28 N (1048.27 g.Force), 5.99 mm and 4.16 N (424.20 g.Force), respectively. Consumer testing of NDM dessert showed that overall liking was like moderately. The product acceptance test showed that the product acceptance was 100%. Therefore, the characteristics of interest related to the sensory quality that identified and properly studied using sensory descriptive analysis (Cadena & Bolini, 2011). The time-intensity technique is used to evaluate perception of a specific attribute's intensity and allow the observing on perceptual intensity variation during evaluation. Recently, the time-intensity has been widely used in studies to determine aroma and flavor perception from many food products, including beverages, chewing gum, meat product, salad dressing, olive oil, gelatin candies, dairy products and desserts (Cadena & Bolini, 2011).

In previous work, the multi-core encapsulated MAD flavor powder (MEFP) was prepared to create controlled release properties. The MAD flavor powder was used as inner core whereas the pandan flavor was used for outer shell. The pandan flavor was released in high temperature and high moisture condition while MAD flavor was release in simulated saliva fluid (SSF). In this research, the MEFP was applied the NDM dessert due to the high moisture and high temperature during production to investigate the suitable content. The aroma and flavor from NDM dessert were examined as the outer aroma release during dessert production while inner flavor release in oral cavity.

7.2 Materials and Methods

7.2.1 NDM dessert ingredients

The NDM dessert ingredients consisted of rice flour (Hand Brand, Chiang Mai, Thailand), tapioca flour (Flying Rabbit, Bangkok, Thailand), pure refined sugar (Lin, Bangkok, Thailand), and egg yellow color (Best Odour Brand, Best Odour Co., Ltd., Bangkok, Thailand) were purchased from Yok Intertrade Co., Ltd. (Chiang Mai, Thailand). Gelatin and gum arabic were purchased from Union Science Co., Ltd. (Chiang Mai, Thailand).

7.2.2 Aroma: References and standards

Dried parsley, dried oregano, dried rosemary, ground cinnamon, and dried thyme (McCormick & Co., Inc, MD, USA) were purchased from Rimping Supermarket (Chiang Mai, Thailand). Fresh lemon was purchased from Rimping Supermarket (Chiang Mai, Thailand). Pandan aroma was also purchased (Winner Brand, Greathill, Co., Ltd., Bangkok, Thailand). All the standard chemicals (2-methyl butyric acid, (-)-linalool, and (1s)-verbenone) were purchased from Sigma-Aldrich Co., LLC. (MO, USA). The analyzed organic chemicals were of analytical grade.

7.2.3 Preparation of MEFP

The mixtures were prepared according to methods described by Alvim & Grosso. (2010); Butstraen & Salaün. (2014) with modifications. The aqueous phase was prepared by dissolving gelatin and gum arabic separately in deionized water at 50°C while stirring for 30 min until the solution dissolved into homogenous mixture, then the pandan flavor was infused into gelatin mixture. The MAD flavor powder was dispersed into gelatin mixture at 2.5% w/w under magnetic stirring condition (1000 rpm). The solution of gum arabic was then added into gelatin mixture to create gelatin-gum arabic system (GGA). The pH of GGA mixture was adjusted to 4.0±0.2 using 10% v/v acetic acid and then slowly cooled to 0°C to create complexes of multi-core complexed in GGA system. The mixture was stirred for another 15 min to allow a complete formation of multi-core complexes. The precipitated microspheres were washed twice by decanting with distilled water and collected by centrifugation at 5000 rpm for 5 min. (Universal 320R, Hettich, Germany). The microspheres were dehydrated using freeze dryer (Model 494830, Labconco, USA). The microcapsules obtained from freeze drying were directly weighed and stored in desiccator for further analysis.

7.2.4 Preparation and experiment on formulations of NDM dessert

The NDM dessert was modified from previously described in Juyjaroen (2003). The modified formula of NDM dessert was consisted of rice flour (18% w/w), tapioca flour (2% w/w), sugar (23% w/w), and water (57% w/w). The preparation of NDM was done in a steam boiler which was preheated to 98±2°C. Rice flour and tapioca starch were mixed, and sugar was melt separately in water. The obtained syrup was poured into mixture of rice flour and tapioca starch then kneaded until it became homogeneous. The fixed 12.5 g of mixture was poured into preheated cups (98±2°C) inside a steam boiler and then closed the steam boiler lid for 15 min. The experiment was designed using completely randomized design (CRD). The variation of the MEFP was varied from 0.5, 1.0, 3.0, and 5% w/w with non-MEFP as a control (Samakradhamrongthai, 2011; Juyjaroen, 2003).

7.2.5 Physical properties of NDM dessert

Color measurement. The NDM dessert color was analyzed using Spectrophotometer (Hunter LAB, Colorquest XE, USA). The light source was

Illuminant D65. The CIELab color values were used with L^* (Lightness), a^* (negative value means green and positive value means red), b^* (negative value means blue and positive value means yellow). All samples were measured in triplicate.

Texture Profile Analysis (TPA) of NDM Dessert. The TPA of NDM desert was performed on a TA-XT plus texture analyzer (TA-XT plus, Stable Microsystems, UK) using an aluminum probe P/45C (diameter 45 mm). The TPA method was conducted under condition as the following: pre-test speed, 2 mm/s; post-test speed, 1 mm/s; rupture test distance, 1%; measurement distance, 40% deformation; force, 0.10 kg; and auto trigger force, 0.020 kg. The distance from the platform was 30.0 mm, with double compression performed in intervals of 10 s between two compressions (Phimolsiripol, Siripatrawan, Tulyathan, & Cleland 2008; Santos *et al.*, 2014). The textural parameters calculated were hardness (g.Force), adhesiveness (g.Force), cohesiveness (dimensionless), springiness (cm), gumminess (g.Force), and chewiness (g.Force). Ten measurements were performed on each sample to obtained mean measurement for that sample at room temperature.

7.2.6 Quantification of aroma and flavor using gas chromatography flame ionization detector (GC-FID)

7.2.6.1 Determination of pandan flavor from outer shell

The NDM dessert was analyzed for the pandan flavor release profile during steam process. Two millimeters of dessert slurry mixture was added into simulated steam condition in capped 20 ml vial. The heated water bath (WB22, Memmert GmbH+Co.KG, Germany) was used as a simulated condition of the preparation of NMD with controlled temperature of 98±2°C. The evaporated volatile compound from static head space was taken for analysis at 0, 5, 7.5, 12.5, and 15 min which the considering time for NDM to be finished was 15 min (Dong *et al.*, 2011). The finished NDM dessert at 15 min was also taken to compare the difference of contained pandan flavor in NDM dessert. All samples were analyzed in triplicate.

7.2.6.2 Determination of MAD aroma from inner encapsulated powder in SSF

The MAD aroma release of the finished NDM dessert from 7.2.5 was analyzed in SSF (Ades *et al*., 2012). The incubation was carried out in a 2 ml glass vial sealed by a screw cap covered with an aluminum foil. The pH of SSF was adjusted to 7.2 by potassium hydroxide. The α-amylase activity used was 100 units/ml, as the average activity found while chewing (Watanabe & Dawes, 1988; Yamaguchi *et al*., 2004; Ades *et al*., 2012). The chopped NDM dessert (20 mg) was then incubated in 2 ml of SSF at 37±2°C in controlled temperature water bath (WB22, Memmert GmbH+Co.KG, Germany) under continues stirring with shaker at 12 rpm (SV 1422, Memmert GmbH + Co.KG, Germany). The evaporated volatile compound from static head space was taken for analysis at 0, 1, 2, 3, 4, and 5 min. which considered time for maximum release in oral cavity of the NDM dessert. The main aromas of MAD were analyzed as 2-methyl butanoic acid and linalool following identification aroma from Pensuk *et al.* (2007) investigation. In addition, verbenone also analyzed as other main aroma following identification aroma from the study from Samakradhamrongthai Thakeow, Kopermsub, Chansakoaw, & Utama-ang (2012). The MAD aromas content from finished NDM at 5 min in SSF was also taken to compare the difference between treatments. All samples were analyzed in triplicate.

7.2.6.3 Gas chromatograph flame ionization detector analysis (GC-FID)

The extent of released aromas following the incubation from 7.2.6.1 and 7.2.6.2 were measured the released aromas of static head space from the reaction medium and quantifying by GC-FID. The gas chromatograph analysis was performed on gas chromatography (GC-2010, Shimadzu Corp., Japan). The column and carrier gas for released aroma analysis were DB-1column (30x0.25 mm ID and 0.25 μm film thickness) (Model 122-1032, Agilent Technologies, Inc., USA) and 1.0 ml/min. The oven temperature was held at 40°C for 3 min and increased to 250°C at 4°C/min and held for 5 min at 250°C (Samakradhamrongthai, 2011). Standards calibration curve of aroma were in order to calculate amount of each aroma from NDM dessert.

7.2.7 Sensory acceptance of NDM desserts

The NDM dessert was prepared with different concentration of MEFP were tested for sensory acceptance. Samples were put in disposable closed lid plastic cups coded with three-digit number. Test was performed in individual air-conditioned booths (25°C) in the Sensory Evaluation Laboratory (Division of product development technology, Faculty of Agro-Industry, Chiang Mai University, Chiang Mai, Thailand) and evaluated under white light, thus ensuring comfort and privacy. A complete block design was used (ASTM, 1992). NDM dessert was evaluated by untrained consumers (n=50) using as 9-point hedonic scale (Resurreccion, 1998) with NDM dessert attributes (appearance, color, aroma, flavor, taste, texture, overall liking) as followed from Jueyjareon (2003). The tested samples were also evaluated for product acceptance. The most preferable formulation in sensory attributes with high product acceptance was selected for further experiment.

7.2.8 Characteristics and consumer acceptance test for optimum NDM dessert

The selected NDM dessert from 7.2.7 was analyzed and validated for its characteristics and quantification of aroma release profile following method from 7.2.6.1 and 7.2.6.2. The consumer test was conducted at Chiang Mai University Central Cafeteria (Chiang Mai, Thailand). The untrained consumers (n=400) were recruited from Chiang Mai University students and officers. The selected formulation of NDM dessert was evaluated following method described by Resurreccion. (1998) using 9-point hedonic scale with specific attributes (appearance, color, aroma, flavor, taste, texture and overall liking). The consumer acceptance and purchased intention was added to this evaluation as well.

7.2.9 Sensory descriptive analysis of optimum NDM

A sensory evaluation was conducted for aroma and flavor profile of NMD dessert from 7.2.7. The NDM dessert was used as a warm up sample and to describe the term of aroma characteristic and determined level of intensity of each characteristic. Prepared standard references were used for intensity analysis of trained panels. All trained panels were research official and graduate students from Division of product development technology, Faculty of Agro-Industry, Chiang Mai University, which were five males and five females. The subjects were selected by screening questionnaire and odor matching test (ASTM, 2013). The references and standards aroma for odor matching on NDM dessert were prepared using dried parsley (3.75 g), dried oregano (1.00 g), pandan flavor (4.00 g), 2-methyl butanoic acid (0.50 g), linalool (1.50 g), dried rosemary (3.00 g), cinnamon (5.00 g), verbenone (1.00 g), dried MAD flower (10.00 g), lemon zest (7.50 g), and dried thyme (1.00 g).

The training for the aroma and flavor intensity was performed by direct approach to individual trained panels with the reference of the NDM dessert for each attribute (pandan flavor, white champaca aroma, pandan flavor, and white champaca flavor). Selected panels were trained in 10 hr training session to perform the Time-intensity analysis (TI) (Lawless & Heymann, 1998). The attribute intensity level was demonstrated on line scale (150 mm) with weak intensity at 12.5 mm. and strong intensity at 137.5 mm. (ASTM, 2013). The trained panels were also trained for chewing at the rate of one chew per s. The chewing rate was adjusted during training session to be at least 29 chew within 30 s and at most 32 chew within 30 s (Lawless & Heymann, 1998). The time-intensity parameters of NDM dessert were pandan and white champaca flavor. Those were assessed as I_{max} (maximum intensity recorded by trained panels), T_{max} (time at which the maximum intensity was recorded) and area (area of time x intensity curve; area under curve) (Lawless & Heymann, 1998). The trained panels assessed release profile of NDM given flavor while chewing.

7.2.10 Statistical analysis

All data were carried out in triplicate and reported as mean±standard deviation of mean (SEM). Analysis of variance (ANOVA) was performed using the Duncan's multiple range test (DMRT) with significant level at 95% ($p < 0.05$). Statistic analysis was conducted using SPSS 11.0 (SPSS Inc., IBM Corp., Chicago, IL, USA) with significant level determined at 95% confident limit ($p < 0.05$).

7.3 Results and discussion

7.3.1 Color Values and TPA of NDM Dessert

The MEFP was applied in the NDM dessert at different concentrations ranging from 0.5–5%w/w. The results showed that color value *a** and *b** of NDM desserts was significantly different in range of 0.21–0.24 and 7.01–7.03, respectively. The increasing of color value *a** and *b** showed that the MAD flavor powder inside MEFP released into dessert matrix. The redness and yellowness from MAD flavor powder distributed into the matrix to increase color value *a** and *b**. The increasing of MEFP also affected the NDM dessert TPA in all treatments with significantly different (Table 7.1). The TPA results indicated that increasing multi-core flavor powder decreased hardness, cohesiveness, springiness, gumminess and chewiness. The NDM desert with the 5% w/w MEFP demonstrated lowest hardness, cohesiveness, springiness, gumminess and chewiness. This suggested that the NDM contained the multi-core flavor powder was softer than the NDM without the flavor powder. It indicated that hardness was decreased because of the volume of the samples were occupied by the microcapsules consisted of gelatin and gum arabic as reported in Meulleneti, Lyon, Carpenter, & Lyon (1998) and Santos *et al*. (2014) studies. The same results were observed for the cohesiveness, springiness, gumminess and chewiness, where samples containing the microcapsules showed decreasing values of those parameters as suggested in Szczesniak (2002) and Santos *et al*. (2014) investigations. In contrast, the texture profile on adhesiveness was increased when applied more the multi-core flavor powder which suggested that the sample had less adhesive and less sticky (Santos *et al*., 2014). The sample with more than 3% w/w of the multi-core flavor powder showed the adhesive to be decreased which implied that the product repossessed highly adhesive and stickier again as suggested in research of Santos *et al*. (2014), both of which were unacceptable characteristics of NDM dessert.

7.3.2 Determination on Aroma Content of NDM Dessert

The aroma content in the NDM dessert was analyzed using the static head space GC-FID. The results of all aroma content from the NDM dessert were significantly different as shown in Table 7.2. The pandan flavor was in range of 7.86–283.67 µg/ml. All MAD flavor content of 2-methyl butanoic acid, linalool and verbenone were in range of 23.29–242.24 µg/ml, 41.25–414.17 µg/ml, and 22.78–251.23 µg/ml, respectively. The increased amount of the multi-core MAD flavor powder affected increasing content of the pandan and the MAD aroma. The NDM desserts were analyzed for retaining pandan flavor and MAD aroma. The results showed that pandan flavor and MAD aroma content increased while added more MEFP as shown in Table 7.2. These results showed that the content of aroma compound blended in GGA system (pandan flavor) and dessert matrix (pandan and MAD aroma) with increased amount of aroma as increasing MEFP. This can be explained by the conformation of dessert matrix and aroma compounds (Arvisenet, Le Bail, Voilley, & Cayot, 2002a). The higher amount MEFP can be introduced higher amount of aroma into dessert complexes better than lower amount of MEFP, then this was affected toward increasing of aroma content in NDM dessert when increasing MEFP. Seuvre, Philippe, Rochard, & Voilley (2007) also pointed out those aromas were representing different in polarities, volatilities and other physicochemical properties. These characteristics changed when microcapsules differently applied in specific content. The phenomenon of volatiles release and retention is mostly depended on variation of its own amount. Moreover, it is extremely

Table 7.1 Color value and textural profile of NDM dessert prepared with different concentrations of MEFP

Multi-core flavor powder (% w/w)	Color value			Hardness (g.Force)	Adhesiveness (g.Force)	Cohesiveness	Springiness (cm)	Gumminess (g.Force)	Chewiness (g.Force)
	L*^{ns}	***a****	***b****						
0.0	36.54±0.05	0.22±0.01c	7.01±0.03b	4426.41±304.60a	-180.80±29.98c	0.75±0.03a	0.75±0.08a	3310.81±276.70a	2481.98±230.60a
0.5	36.59±0.04	0.21±0.01c	7.01±0.01b	4427.35±281.91a	-181.54±31.85c	0.75±0.03a	0.75±0.08a	3390.29±336.90a	2506.59±237.20a
1.0	36.60±0.01	0.22±0.01bc	7.01±0.01ab	4495.82±319.15a	-175.53±25.91b	0.77±0.10a	0.75±0.12a	3482.02±612.93a	2621.65±636.98a
3.0	36.59±0.04	0.23±0.02ab	7.02±0.01a	3376.55±269.86b	-145.43±9.38a	0.74±0.13a	0.74±0.12b	2514.72±0.549.59b	1860.39±485.56b
5.0	36.60±0.03	0.24±0.02a	7.03±0.02a	2714.63±261.79c	-188.10±13.47d	0.69±0.09b	0.61±0.12c	1873.93±355.63c	1119.29±172.83c
***p*-value**	<0.876	<0.001	<0.014	<0.001	<0.001	0.007	<0.001	<0.001	<0.001

Note: The different letters in the same column mean significant difference (p ≤ 0.05)
^{ns} means non-significant difference (p ≤ 0.05)

Table 7.2 Aroma and flavor content of NDM dessert using gas chromatograph flame ionization detector (GC-FID)

Multi-core flavor powder (% w/w)	Pandan flavor (μg/ml)	MAD flavor content (μg/ml)		
		2-methyl butanoic acid	**linalool**	**verbenone**
0.0	Not detect	Not detect	Not detect	Not detect
0.5	7.86±0.87d	23.29±0.01d	41.25±0.69d	22.78±0.30d
1.0	122.39±1.08c	62.20±0.50c	84.94±0.51c	42.16±0.22c
3.0	225.89±0.86b	146.03±0.52b	247.48±0.27b	127.99±0.24b
5.0	283.67±1.02a	242.24±0.33a	414.17±0.50a	251.23±0.30a
***p*-value**	<0.001	<0.001	<0.001	<0.001

Note: The different letters in the same column mean significant difference (p ≤ 0.05)
^{ns} means non-significant difference (p ≤ 0.05)

complex and therefore, there is a need to elucidate the main factors affecting these processes (Friel & Taylor, 2001; Seuvre *et al*., 2007).

7.3.3 Release profile of aroma and flavor from NDM dessert

7.3.3.1 Determination of pandan flavor release profile during steaming

The pandan flavor release profile during the NDM steaming showed level of aroma content related to amount of the multi-core encapsulated powder. The NDM with 5% w/w multi-core encapsulated powder provided highest aroma content (2387.59±9.58 μg/ml), follow by 1, 3, and, 0.5% w/w, respectively. However, pandan flavor profile was not demonstrated as suggested in Dong *et al.* (2011) study which indicated that peppermint aroma from coacervate microcapsules was increased in hot-water condition (80°C). The result revealed, in contrary, that the pandan flavor was deceasing over time of steaming condition (98±2°C) (Fig. 7.1).

The decreased retention of pandan flavor in NDM dessert over time-course production occurred because of amylose-aroma (Arvisenet, Le Bail, Voilley, & Cayot 2002b) and amylopectin-aroma (Van Ruth & King, 2003) interactions. As Van Ruth & King (2003) stated that the binding of volatile compounds to starch has been categorized into two forms. It had been shown that amylose formed inclusion complexes with many volatile compounds which encapsulated in amylose helix through hydrophobic bonding. Particularly, linear molecules have been suggested to be included in the hydrophobic cavity of the amylose helix. On the other hand, volatile compounds also formed complexes with amylopectin called helical complex which bond amylopectin and volatile compounds through hydrogen bonds and also favored the hydrophobic effect (Jouquand, Ducruet, & Giampaoli., 2004). The explained interactions from amylose/amylopectin and volatile compound suggested that released pandan flavor from MEFP were able to form complexes in NDM dessert matrix over again in dessert matrices. The retrapped pandan flavor happened through thermal transition of the starch called gelatinization. The temperature of this forming usually starts at 50°C (Phimolsiripol, Siripatrawan, & Henry, 2011) In this experiment, the dessert steaming temperature was 98±2°C which allowed the rice flour to recreate gelling effect between released pandan flavor and starch mixture within 15 min as suggested in Pozo-Bayon, Biais, Rampon, Cayot, & Le Bail (2010).

The decreasing of released pandan flavor amount from the inside to the outer surface MEFP during the steaming can also be sustained in high temperature for 15–20 min through cooking time as suggested in the research from Yahya (2011), who explained that the pandan flavor formed three-dimensional networks on the surface of the starch mixture. As the hydrophilic characteristics of pandan flavor, the interaction between the amylose and pandan flavor occurred through the hydrogen bond and created the interaction of the starch-water molecules in the steaming process (Porrarud & Pranee, 2010). The starch mixture of the NDM dessert changed its semi-crystalline phase to an amorphous phase with exceeded water. The hydrogen bonds were broken allowing water be associated with the free hydroxyl hydrogen and oxygen (Evans & Haisman, 1982) in starch mixture while amylose and amylopectin bonded with volatile compounds. Sequentially, these changes facilitated starch molecular mobility in the amorphous regions and allowing the swelling of the mixture to create gel-type dessert product, resulting the retention of pandan flavor to deceased because of complexes recreation (Jouquand *et al.*, 2004).

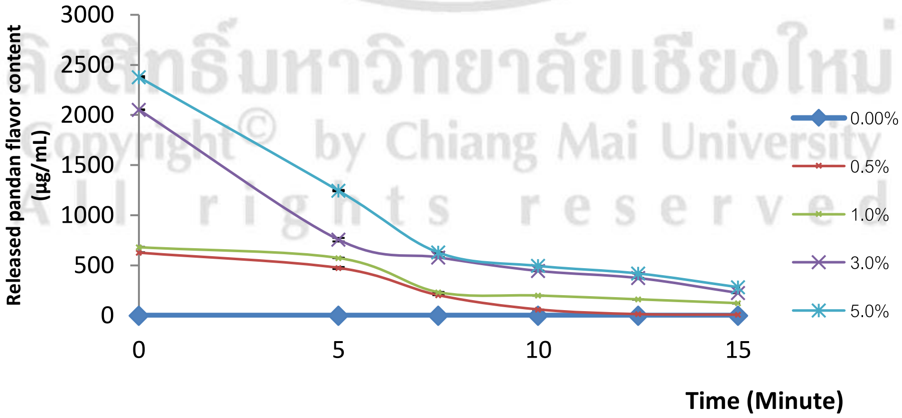


Fig. 7.1 Released pandan flavor content from NDM dessert during 15 min steaming.

The release rate constant of the pandan flavor from Avrami's equation showed in Eq. (7.1). Avrami's equation was chosen to employ in this experiment because of the fitted model that was applied to describe the shelf-life failure and was suitable to describe the release time-course of the encapsulated flavor powder (Yoshii *et al*, 2001; Soottitantawat *et al*, 2004; Szente and Sejtli, 2004). Where R is the release amount of aroma, t is the time that incubating in artificial saliva, k is the release rate of constant and n is a parameter representing the release mechanism. The parameters were calculated as n from slope from plotting ln(-ln R) and ln t, and the release rate constant k from the interception at ln t = 0.

$$R = 1\text{-}\exp[-kt]^{n} \qquad (7.1)$$

The result revealed that release profile of pandan flavor were significantly different and divided into three groups. In addition, the increased MEFP affected the pandan flavor as the higher *k* value demonstrated slower release rate (Table 7.3). This was affected from increased gelatin and gum arabic from flavor powder releases pandan flavor into starch molecules in water. Those were regrouped to create a hydrophobic medium and organized the pandan flavor and water over again. Consequently, the pandan flavor interacted with starch because of lacking of strong complimentary interactions with water molecules. All of the results above explained the greater ability of gelatinization to re-entrap the pandan flavor release from the multi-core flavor powder into starch matrices of the NDM dessert. Therefore, the gelatinization of the NDM dessert was affected in the positive way toward the retaining of pandan flavor.

After the NDM desserts were analyzed for the pandan flavor, those were analyzed for the MAD aroma release in SSF. The release rate constant of aroma of 2-methyl butanoic acid, linalool and verbenone was increased over time-course condition. The MAD main aromas content from the NDM dessert were varied. The increasing MEFP increased aroma content of the MAD main aroma through time in SSF as shown in Fig. 7.2. The three main aromas were released through enzymatic mechanism from interaction between α-amylase and α-1,4-glycosidic bond/1,6-glycosidic bond (Berg, Tymoczko, & Stryer, 2002).

Since, the SSF was able to hydrolyzed aroma-starch complex and release aroma via inclusion complex hydrolysis reaction which release aroma and its increasing amount was followed in time (Ades *et al.*, 2012). The hydrolysis rate found to be reduced compare to uncomplex the MEFP as reported in researches from Heinemann, Zinsli, Renggli, Escher, & Conde-Petit (2005) and Ades *et al*. (2012).

Table 7.3 The release rate constant and the kinetics parameters of NDM dessert using the Weibull model under steaming

MEFP (% w/w)	k (min^{-1})	R-square
0.5	5.211±0.001c	0.9680
1.0	5.352±0.011c	0.7813
3.0	7.280±0.055b	0.9604
5.0	8.320±0.005a	0.9829
***p*-value**	<0.001	

Note: The different letters in the same column mean significant difference ($p \leq 0.05$)

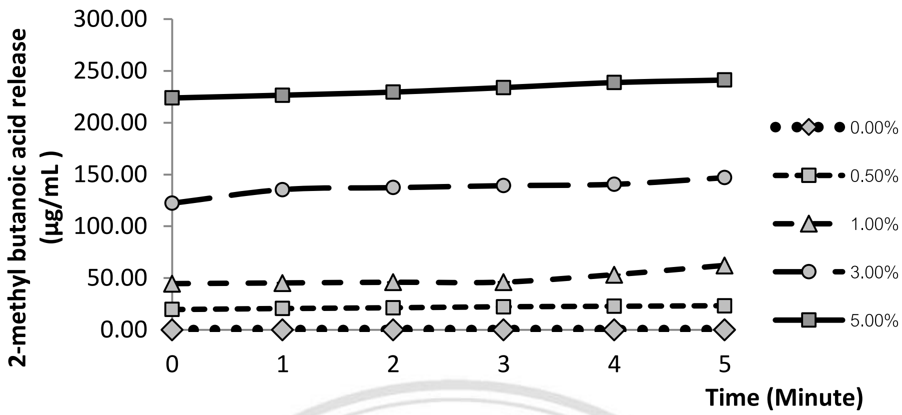
7.3.2.2 Determination of MAD flavor release profile in SSF

As for NDM dessert release aroma, the results showed that MAD aromas content were released at different amount. The release of linalool was the highest amount (41.24–414.17 μg/ml), followed by verbenone (22.79–251.23 μg/ml) and 2-methyl butanoic acid (23.29–241.24 μg/ml). According to the results, the release of 2-methyl butanoic acid was the fastest from aroma-starch complex, followed by verbenone and linalool. Therefore, the result was not agreed on many studies (Kim & Maga, 1994; Anantha & Milford, 1997; Jouquand *et al*., 2006) that suggested volatile compounds higher molecular weight comprised lower release rate. Since, molecular weight of 2-methyl butanoic acid, verbenone and linalool were shown as 102.13, 150.22 and 154.25, respectively. On the other hand, this result demonstrated the same direction as Naknean & Meenune (2010) reviews. The higher molecular weight also showed higher hydrophobicity, resulting greater retaining of aroma compound within amylose/amylopectin cavity (Jouquand *et al*., 2004). This behavior also applied to linear carbon chain like linalool to be trapped inside starch cavity better than verbenone and 2-methyl butanoic acid which showed that linalool and verbenone were retained longer in the encapsulated matrix than 2-methyl butanoic acid. This suggested that the enzymatic reaction, molecular weight, compound formation, and hydrophobicity were involved in the release of MAD and it is can be applied to product that required releasing active ingredients in consumer oral cavity.

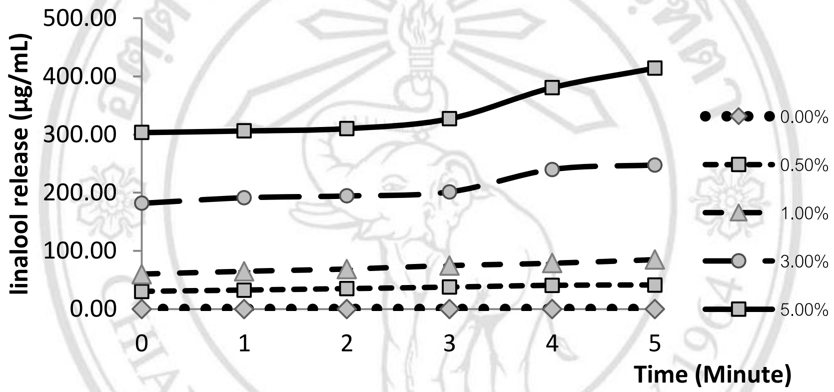
7.3.3 Sensory evaluation of NDM dessert with variation of MEFP

The sensory acceptance score of the NDM dessert five formulae showed that all attributes rating were in range of 5.5–6.3 which were significantly different. The appearance attribute rating was decreased when increasing the MEFP. This indicated that increasing MEFP impacted on appearance of the NDM dessert. Santos *et al*. (2014) also stated that increasing gelatin and gum arabic which in this case a wall material of the MEFP created more adhesiveness and stickiness on the NDM appearance and those were unacceptable characteristics of the NDM dessert.

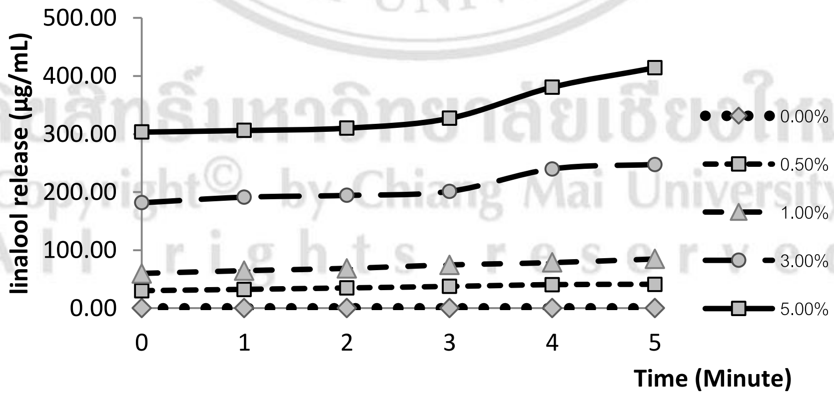
For other attributes, there were increasing rating score when applied the MEFP toward 1% w/w and the rating score was decreased when applied MEFP more than 1% w/w. The NDM dessert that contained more than 3% w/w of the MEFP revealed sensory rating score lower than 6.0 with significance (p<0.05) among the NDM formulations. This suggested that increasing of aroma intensity in the NDM dessert affected to decrease sensory rating score. Moreover, the product acceptance also showed that same trend that the NDM dessert with 1% w/w of the MEFP showed the highest acceptance percentage (100.0%) (Table 7.4).



(a)



(b)



(c)

Fig. 7.2 The release of main aroma compounds during incubation in SSF (pH 7.0±0.2, 37˚C). Aroma release was presented as the amount from static head space; (a) 2-methyl butanoic acid, (b) linalool, and (c) verbenone.

Table 7.4 Sensory evaluation of NDM dessert

Multi-core Flavor Powder (% w/w)	**Appearance**	**Color**	**Aroma**	**Flavor**	**Taste**	**Texture**	**Overall Liking**	**Acceptance (%)**
0.0	6.0±0.6a	6.1±0.5b	6.0±0.6b	6.0±0.6a	6.1±0.7b	5.9±0.7ab	6.0±0.7b	98.0
0.5	6.0±0.7a	6.3±0.5a	6.0±0.6b	6.0±0.7a	6.0±0.7b	5.9±0.7ab	6.1±0.7b	98.0
1.0	6.1±0.4a	6.2±0.5a	6.3±0.6a	6.1±0.5a	6.3±0.7a	6.0±0.6a	6.2±0.7a	100.0
3.0	5.7±0.5b	6.2±0.5ab	6.0±0.5b	6.0±0.6a	5.6±0.6c	5.8±0.6b	5.8±0.5c	90.0
5.0	5.5±0.5c	5.9±0.3c	5.7±0.5c	5.8±0.4b	5.6±0.5c	5.5±0.5c	5.6±0.5c	76.0
***p*-value**	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	

Note: Different letters in the same column means significant difference ($p \leq 0.05$).

The results from 7.3.1–7.3.3 showed that the NDM desserts with variation of the MEFP were significantly different. The increasing of MEFP showed increasing redness and yellowness also the NDM texture parameters and aroma release from the NDM dessert. However, those parameters of the NDM dessert were not the only parameters that can indicate the most suitable formulation of the NDM dessert. There were more parameters that taken to this investigation which was sensory evaluation. The rating score from sensory evaluation can support characteristics of the NDM dessert. Those can indicate that which one was the most suitable formulation of the NDM dessert.

As the results suggested that the NDM dessert with 1% w/w the MEFP provided higher rating score than others together with the highest rate of product acceptance at 100%. The relation of this selected formulation showed that sensory rating scores were in range of "slightly like" to "like moderately" also indicated that color value (a^* and b^*), hardness, adhesiveness, cohesiveness, springiness, gumminess, chewiness, pandan flavor content, 2-methylbutanoic acid content, linalool content, and verbenone content at the value of 0.22, 7.01, 4495.82 g.Force, (-175.53) g.Force, 0.77, 0.75 cm, 3482.02 g.Force, 2621.65 g.Force, 122.39 µg/ml, 62.20 µg/ml, 84.94 µg/ml, and 42.16 µg/ml can be the accepted value parameters for selected NDM dessert. NDM dessert with 1%w/w MEFP was then taken for further validation experiment.

7.3.4 Characteristics, consumer acceptance and aroma release profile of optimum NDM

7.3.4.1 Characteristics and consumer acceptance

The NDM desert with 1% w/w of the MEFP was selected from sensory acceptance with the highest sensory rating score and acceptance percentage at 100%. The result from consumer acceptance (n=400) showed that NDM dessert provided sensory rating score in range of 6.0–6.3; appearance (6.0±0.5), color (6.1±0.5), aroma (6.3±0.6), flavor (6.2±0.6), taste (6.0±0.4), texture (6.0±0.5), and overall liking (6.2±0.6). The consumer acceptance and purchase intention also evaluated and showed high percentage at 98.0% and 98.3%, respectively (Table 5).

The NDM dessert with 1% w/w the MEFP was analyzed for its characteristic as show in Table 7.5. The result showed that the NDM dessert provided higher hardness and gumminess than NDM from Jueyjareon (2003) research with hardness and gumminess at 1048.27 g.Force and 424.20 g.Force, respectively. This high value of hardness and gumminess were occurred because of gelatin and gum arabic from multi-core encapsulated powder which provided more gel strength toward the NDM dessert carried out from heat setting mechanism that unfold/expansion of native starch/protein and their subsequent rearrangement into a dessert matrix (Nishinari & Zhang, 2004). In addition, consumer acceptance of the NDM with 1% w/w the MEFP was in the same range from Jueyjareon (2003) investigation but the rating scores were slightly higher. This showed that the higher of sensory rating score can be affected from addition flavor into the NDM dessert also the product acceptance test was higher than 90% which showed that consumer accepted NDM from this experiment as well as NDM dessert from Jueyjareon (2003) experiment.

Table 7.5 The characteristics NDM dessert with 1% w/w MEFP

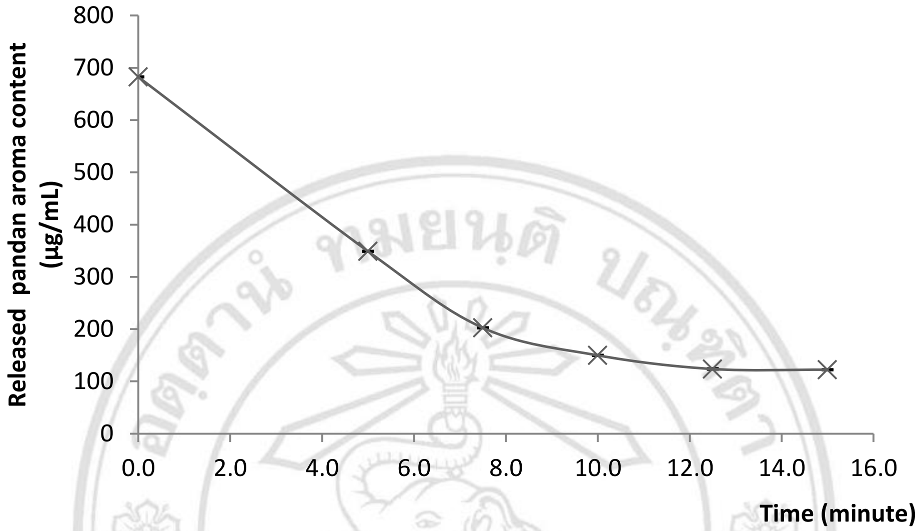
Product characteristics	Analyzed value
Color value L^*	44.64±0.02
Color value a^*	0.71±0.01
Color value b^*	9.74±0.01
Hardness (g.Force)	4522.24±344.74
Adhesiveness (g.Force)	(-177.02)±25.58
Cohesiveness	0.78±0.11
Springiness (cm)	0.74±0.12
Gumminess (g.Force)	3551.42±649.36
Chewiness (g.Force)	2639.69±654.52
Pandan flavor (µg/ml)	0.034±0.0004
2-methyl butanoic acid release (µg/ml)	61.92±0.50
linalool release (µg/ml)	84.73±0.54
verbenone release (µg/ml)	42.15±0.25

7.3.4.2 Release profile of aroma and flavor from NDM dessert with MEFP

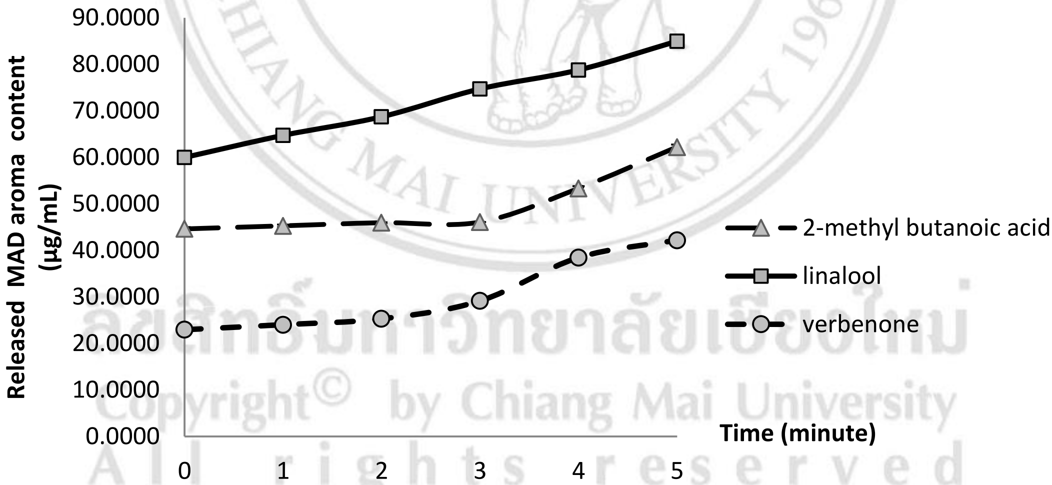
The NDM dessert with 1% w/w the MEFP was analyzed for the pandan flavor release during production. The pandan flavor release content was demonstrated as expect as it was decreasing in time-course steaming. The amount of release content was starting at 682.45–122.46 µg/ml. The MAD aroma release content also demonstrated to be increased. This is happened due to the reformation of pandan flavor with starch matrix as suggested in a review from Naknean & Meenune (2010) review about flavor carbohydrate interactions that polysaccharide mostly created matrix to entrap flavor due to its structure, particularly amylose molecule, which normally has ability to form v-amylose complex with flavor molecule. The release profile of 2-methyl butanoic acid, linalool, and verbenone were started at 44.608–62.198 µg/ml, 59.959–89.943 µg/ml, and 22.945–42.160 µg/ml, respectively. The result showed success of retaining aroma from MAD extract with controlled release property through enzymatic mechanism and partially degraded from SSF as suggested in Ades *et al*. (2012) (Fig. 7.3).

7.3.4.3 Evaluation and perception on aroma profiling of optimum NDM dessert using time intensity

The trained panels were asked to compare and match aroma to the referenced aroma samples. The aroma released from sample was similar with different intensity. The reference standards and materials were gathered for matching session and trained panels matched reference aromas from the NDM dessert with prepared reference standards and materials. The result from first and second sessions revealed that trained panels matched pandan flavor (strong intensity), white champaca extract (weak intensity) and dried white champaca petal (weak intensity) for NDM dessert aroma. In addition, the pandan flavor (medium intensity) and dried white champaca petal (strong intensity) were matched for the NDM dessert flavor (Table 7.6). The aroma and flavor from pandan and white champaca were agreed upon as reference this experiment. The order of aromas was perceived in order of pandan flavor and white champaca, respectively. The aromas were detected in similar perception but in different level of intensity that might occurred from differences of trained panels' aroma perception (Murugan, Thiyagarajan, & Ramesh, 2007).



(a)



(b)

Fig. 7.3 The release profile from optimum NDM dessert (a) released pandan flavor content from NDM dessert steaming (b) released of MAD main aroma compounds during incubation in SSF (pH 7.0±0.2, 37°C).

Table 7.6 Comparison of aroma between standard references and NDM dessert

Reference standards and materials	NDM dessert	
	Aroma	Flavor
dried parsley	-	-
dried oregano	-	-
pandan flavor	+++	++
2-methyl butanoic acid	-	-
linalool	-	-
dried rosemary	-	-
ground cinnamon	-	-
white champaca extract	+	-
mix standard (2-methyl butanoic acid, linalool, verbenone)	-	-
verbenone	-	-
dried white Champaca petal	+	+++
lemon zest	-	-
dried thyme	-	-

+++ = strong intensity, ++ = medium intensity and + = weak intensity

The characteristic aromas from the NDM dessert with 1% w/w the MEFP were investigated in this experiment. The conclusion of terms and definitions from NDM dessert were described pandan flavor and dried white champaca. The trained panels were asked to sniff all samples, and coffee bean were use to cleanse aroma between sniff. The order of aromas was pandan and white champaca, respectively.

The result from panelist's decision was compared to aroma and flavor lexicon (Civille & Lyon, 2001). The conclusion of terms and definitions from the NDM dessert were described and the two main aromas from the NDM which were pandan and white champaca were concurred from trained panels to be pandan flavor and dried white champaca (Table 7.7). From term and definition, the reference samples of pandan flavor and dried white champaca petal were selected. Standard aromas were prepared for evaluating and discussing for the intensity. Line scale was used to discuss intensity range from weak to strong. The rating score range were from 1 to 15 (Meilgaard, Civille, & Carr, 2007).

Table 7.7 Term and definition and reference sample of character aromas

Term	definition	reference sample
pandan	aromatic associated with materials that have a sweet aroma and related to flower scent	pandan flavor (Winner Brand, Greathill, Co., Ltd.,Bangkok, Thailand)
white champaca	aromatic associated with materials that related to spics and savory aroma	dried white champaca

The standard references were prepared in three levels of intensity. Those aromas were weighed differently as in low, medium and high. The pandan flavor was used for pandan characteristic. The dried white champaca petal was used for White Champaca characteristic. For the third session, trained panels were inquired to rate intensity of prepared standard references and adjusted intensity for all three levels. The intensity of standards was concluding for trained panels. The aroma intensity from the NDM dessert was rated using prepared standard aroma as references as shown in Table 7.8.

Table 7.8 The threshold intensity level of pandan flavor and dried white champaca petal

Standard reference	Aroma intensity (mm.)		
	Low (µl/ml)	Medium (µl/ml)	High (µl/ml)
pandan flavor	20.00 mm. (0.01 gram)	60.00 mm. (2.00 gram)	80.00 mm. (4.00 gram)
pried white champaca petal	10.00 mm. (0.08 gram)	30.00 mm. (0.24 gram)	60.00 mm. (0.48 gram)

*Aroma sample applied from Civille & Lyon (2001) with intensity level on scale 150 mm. Weak intensity = 12.5 and Strong intensity = 137.5

The third to fifth session was held for trained panels to adjust their perception to aromas intensity. The trained panels evaluated aroma intensity with raking of each aroma from weak to strong which the aroma intensity from this session showed the score similar to the prior session. This evaluation showed that the trained panels were mostly stable as the standard deviation was decreasing from previous session. The average intensity showed that trained panels have rated the intensity close to another. The pandan flavor had higher intensity than white champaca in the NDM dessert. The pandan flavor had lower intensity than white champaca in the NDM dessert. The trained panels were trained for chewing rate at one chew per second. The chewing rate was adjusted during training session to be at least 29 chew within 30 s and at most 32 chew within 30 s. The average of chewing was at 30 chew per 30 s (30±0.6). The intensity of flavor and aroma the NDM dessert were dictated and evaluated as pandan flavor, white champaca aroma, pandan aftertaste and white champaca aftertaste as shown in Table 7.9.

Table 7.9 The intensity aromas of pandan and white champaca from NDM dessert

Attributes	Intensity rating (mm.)
pandan aroma	13.80±0.92
white champaca aroma	9.24±0.22
pandan flavor	40.03±1.06
white champaca flavor	30.43±1.14
pandan aftertaste	11.5±0.25
white champaca aftertaste	36.1±0.83

*Aroma sample applied from Civille & Lyon (2001) with intensity level on scale 150 mm. Weak intensity = 12.5 and Strong intensity = 137.5

The controlled releases of flavor were investigated using time-intensity method (TI). The trained panels were inquired to consume the NDM dessert and rate the flavor intensity of pandan and white champaca flavor with 20 s. The Time initiate (T_i) and Time end (T_e) was at 0 s and 20 s, respectively. The flavor intensity of pandan and white champaca were plotted to create trend on flavor release in oral cavity. The result showed that intensity of pandan flavor and white champaca flavor were initiated at 35.83 and 30.96. This is because of the pandan flavor was release prior to production of NDM dessert and white champaca flavor from MAD flavor powder was still contained within NDM dessert matrix. Maximum intensity and time (I_{max} and T_{max}) of pandan and white champaca flavor were 48.79 at 50.80 at 9th second (Table 7.10). The area under curves showed that white champaca exhibited higher intensity than pandan at 822.98 and 763.03, respectively (Fig. 7.4). This suggested that the different of I_{max} and T_{max} were affected from the enzymatic reaction of α-amylase while chewing. The flavors were release through enzymatic reaction from saliva that break 1,4 and 1,6 linkage in OSA starch (Ades *et al*., 2012). Moreover, the mechanic shear force from chewing was another factor that assists the flavor release in oral cavity. This is suggested that overall flavor from the NDM showed higher intensity of white champaca than pandan as suggested in Cadena *et al*. (2011) that parameter area under curve showed that absolute value of attribute intensity. The higher area value provided more intense and more persistent than others. These results revealed that the MEFP that applied in the NDM dessert had a success in controlled release of pandan and white champaca flavor and it can be delayed in consumer oral cavity.

Table 7.10 The flavor intensity of pandan and white champaca in NDM dessert using Time-intensity method

Time (seconds)	**Intensity rating (mm.)**	
	Pandan flavor	**White champaca flavor**
0	35.83±2.21	30.96±0.69
3	39.87±0.70	35.25±0.89
6	44.83±0.82	41.24±0.89
9	48.79±1.08	50.80±0.72
12	47.73±0.95	49.88±0.81
15	25.45±1.19	37.96±0.64
20	25.53±1.23	37.43±0.71

*Aroma sample applied from Civille & Lyon (2001) with intensity level on scale 150 mm. Weak intensity = 12.5 and Strong intensity = 137.5

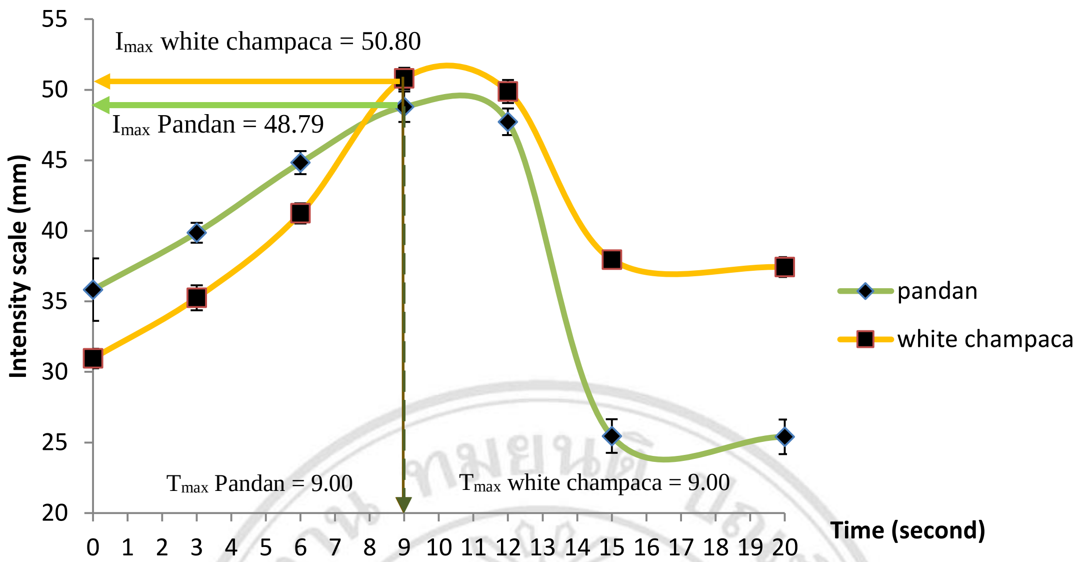


Fig. 7.4 Time intensity of pandan and White champaca flavor in NDM dessert

7.4 Conclusions

The NDM dessert containing 1% w/w of the MEFP proved to be the most preferable as regards sensory preference. The consumer acceptance analysis results of the NDM dessert with 1% w/w of the MEFP revealed that the NDM dessert provided sensory rating scores in the range of 6.0–6.3. Thus, the MEFP at 1% w/w was the most suitable for this formula of the NDM dessert. In addition, Product acceptance and purchased intention of the NDM dessert with 1% w/w MEFP were also showed high percentages at 98.0% and 98.3%, respectively. The controlled release model of the NDM dessert from the time intensity method revealed that the maximum intensity of the pandan flavor and the white champaca flavor were 48.79 and 50.80, respectively, at the 9th second. It was indicated that the white champaca showed higher intensity than the pandan because of the pandan aroma was released prior through the steaming of the NDM dessert while the white champaca flavor from the MAD flavor powder was contained within the NDM dessert matrix. Additionally, the mechanical shear force from chewing was another factor that assisted the flavor release in the oral cavity. This demonstrates that making use of MEFP in the NDM dessert for the controlled release of the flavors of the pandan and white champaca is a success and that the release can be delayed in the oral cavity of consumers.

7.5 References

Ades, H., Kesselman, E., Ungar, Y., & Shimoni, E. (2012). Complexation with starch for encapsulation and controlled release of menthone and menthol. *Food Science and Technology*, 45, 277-288.

Alvim, I.D., & Grosso C.R.F. (2010). Microparticles obtained by complex coacervation: influence of the type of reticulation and the drying process on the release of the core material, *Ciência e Technologia de Alimentos,* 30(4), 1069-1076; DOI: http://dx.doi.org/10.1590/S0101-20612010000400036.

Arancibia C., Castro, C., Jublot, L., Costell, E. & Bayarri, S. 2015. Colour, rheology, flavor release and sensory perception of dairy desserts. Influence of thickener and fat content. *LWT-Food Science and Technology,* 62, 408-416.

Arvisenet, G., Le Bail, P., Voilley, A., & Cayot, N. (2002a). Influence of physicochemical interactions between amylose and aroma compounds on the retention of aroma in food like matrices. *Journal of Agricultural and Food Chemistry,* 50 (24),7088-7093.

Arvisenet, G., Le Bail, P., Voilley, A., & Cayot, N. (2002b). Retention of aroma compounds in starch matrices: competitions between aroma compounds toward amylose and amylopectin. *Journal of Agricultural and Food Chemistry,* 52 (25), 7345–7349.

ASTM. (1992). Manual on descriptive analysis testing for sensory evaluation. In Hootman, R. C. ed., *ASTM Manual 13,* West Conshohocken. PA: ASTM International.

ASTM. (2013). *Standard guide for time-intensity evaluation of sensory attributes (E-1909-13) ASTM Books of standards 15.07*,: American Society for Testing and Materials, PA, Philadephia, USA.

Berg, J.M., Tymoczko, J.L., & Stryer, L. (2002). Biochemistry. Complex Carbohydrates Are Formed by Linkage of Monosaccharides. 5th ed., In ed. W. H. Freeman; Section 11.2, New York: Retrieved from http://www.ncbi.nlm.nih.gov/books/NBK22396/ (9 June 2014).

Bult, J.H.F., De Wijk, R.A., & Hummel, T. (2007). Investigation on multimodal sensory integration, texture, taste, and ortho- and retro nasal olfactory stimuli in concert. *Neuroscience Letters*, 411, 6-10.

Butstraen, C., & Salaün, F. (2014). Preparation of microcapsules by complex coacervation of gum arabic and chitosan, *Carbohydrate. Polymers*, 99, 608-616; DOI: 10.1016/j.carbpol.2013.09.006.

Cadena, R.S., & Bolini H.M.A. (2011). Time-intensity analysis and acceptance test for traditional and light vanilla ice cream. *Food Research International*, 44, 677-683.

Chamchan, R. (2001). Development of Instant Ka-Nom Tuay-Fu, Masterof Science (Agro-Industrial Product Development), Major Field Agro-Industrial Product Development, Kasetsart University, Bangkok.

Chaysirichote, T. (2000). Production of Dried Khanom Tubtim (Thai dessert). Master of Home Economics, Major field: Home Economins, Department of Home Economics, Kasetsart University, Bangkok.

Civille, G.V., & Lyon, B.G. (2001). Aroma and flavor lexicon for sensory evaluation: terms,definitions, references, and examples. Ontario, American Society for Testing and Materials (ASTM).

De Wijk, R.A., Zijlstra, N., Mars, M., De Graaf, C., & Prinz, J.F. (2008). The effects of food viscosity on bite size, bite effort and food intake. *Physiological Behavoir*, 95, 527-532.

De Wijk R.A., Polet, I.A., Boek, W., Coenraad, S., & Bult, J.H.F. (2012). Food aroma affects bite size. *Flavour*, 1(3), 1-6.

Dong, Z., Ma, Y., Hayat, K., Jia, C., Xia, S., & Zhang, X. (2011). Morphology and release profile of microcapsules encapsulating peppermint oil by complex coacervation, *Journal of Food Engineering*, 104, 455-460. DOI: 10.1016/j.foodeng.2011.01.011.

Evans, I.D., & Haisman, D.R., (1982). The Effect of Solutes on the Gelatinization Temperature Range of Potato Starch. Starch, 34, 224-231.

Friel, E. N., & Taylor, A. J. (2001). Effect of Salivary Components on Volatile Partitioning from Solutions, *Journal of Agricultural and Food Chemistry*, 49(8), 3898-3905; DOI: 10.1021/jf010371e.

Heinemann, C., Zinsli, M., Renggli, A., Escher, F., & Conde-Petit, B. (2005). Influence of amylose-flavor complexation on bulid-up and break down of starch structures in aqueous food model systems. *LWT-Food Science and Technology*, 38(8), 885-894.

Jouquand, C., Ducruet, V., & Giampaoli, P. (2004). Partition coefficients of aroma compounds in polysaccharide solutions by the phase ratio variation method *Food Chemistry*, 85 (3), 467-474.

Juyjaroen, N. (2003). Development of Khanom Nam-dok-mai to set the specific of Thai Standard, Master of Science (Agro-Industrial Product Development), Kasetsart University, Bangkok.

Kim, C.H., & Maga, J.A. (1994). Chain length and functional group impact on retention during extrusion, In Parliament, T.H., Morello, M.J. and McGorrin, R.J. (Eds), Thermally generated flavors: Mailard, Microwave and extrusion processes, p.105-153. CS Symposium Series 543, American Chemical Society. Washington, DC. USA.

Lawless, H.T., & Heymann, H. (1998). *Sensory evaluation of food principles and practices*, New York, Chapman & Hall,

Meulleneti, J., Lyon, B.G., Carpenter, J.A., & Lyon, C.E. (1998). Relationship between sensory and instrumental texture profile attributes, *Journal of Sensory Studies*, 13: 77-93; DOI 10.111/j.1745-459x.1998.tb00076.x.

Meilgaard M., Civille, G.A., & Carr, B.T. (2007). *Sensory evaluation techniques*, 4th edition. CRC Press. Boca Raton, USA.

Murugan, P. A., Thiyagarajan, G., & Ramesh, K. (2007). Dry flower technology. Science Tech ENTREPRENEUR. Retrieved from http://www.techno-preneur.net/information-desk/sciencetech-magazine/2007/dec07/Dry-flower.pdf. (25 July 2008).

Naknean, P., & Meenune, M. (2010). Factors affecting retention and release of flavor compounds in food carbohydrates, *International Food Research Journal*, 17, 23-34.

Nishinari, K,. & Zhang, H. (2004). Recent advances in the understanding of heat set gelling polysaccharides. *Trends in Food Science and Technology*, 15, 305-312.

Pensuk, W., Padumanond, T., & Pichaensoonthon, C. (2007). Comparison of the chemoical constituents in *Michelia alba* D.C. flower oil extracted by steam distillation, hexane extraction and enfleurage method. *Journal of Thai Traditional & Alternative medicine*, 5(1), 30-39.

Phimolsiripol, Y., Siripatrawan, U., Tulyathan, V., & Cleland, D. J. (2008). Effect of freezing and temperature fluctuations during frozen storage on frozen dough and bread quality. *Journal of Food Engineering,* 84, 48-56.

Phimolsiripol, Y., Siripatrawan, U., & Henry, C.J.K. (2011). Pasting behavior, textural properties and freeze-thaw stability of wheat flour-crude malva nut (*Scaphium scaphigerum*) gum system. *Journal of Food Engineering,* doi: 10.1016/j.jfoodeng.2011.03022.

Porrarud, S. & Pranee, A. (2 010).Microencapsulation of Zn-chlorophyll pigment from Pandan leaf by spray drying and its characteristic. *International Food Research Journal,* 17,1031-1042.

Pozo-Bayon, M.-Á., Biais, B., Rampon, V., Cayot, N., & Le Bail, P. (2010) Influence of complexation between amylose and a flavored model sponge cake on the degree of aroma compound release. *Journal of Agricultural and Food Chemistry,* 56, 6640-6647.

Prinz, J.F., & De Wijk, R.A. (2007). Perceptual effects of ingested volume in semi-solid foods. *Journal of Sensory Studies,* 22, 273-280.

Resurreccion, A.V. A. (1998). Consumer sensory testing for Product Development. Maryland, An Aspen Publication,

Samakradhamrongthai, R. (2011). Extraction of Champaca (*Michelia champaca* L.) essential oil and its application in instant Champaca-flavored tea powder. Master of science (Agro-industrial product development), Chiang mai University, Chiang Mai, Thailand.

Samakradhamrongthai R., Thakeow, P., Kopermsub, P., Chansakoaw, S., & Utama-ang N. 2012. Sensory acceptance and antioxidant activity of selected Thai aromatic plants. The 4th international conference on Natural Products for Health and Beauty (NATPRO4), 28-30 November 2012, Chiang mai Orchid Hotel, Chiang mai, Thailand.

Santos, M.G., Carpinteiro, D.A., Thomazini, M. Rocha-Selmi, G.A., da Cruz, A.G., Rodrigues, C.E.C., & Favaro-Trindade, C.S. (2014). Coencapsulation of xylitol and mentol by double emulsion followed by complex coacervation and microcapsule application in chewing gum, *Food Research International,*66, 454-462. DOI: http//dx.doi.org/10.1016/j.foodres.2014.10.0100963-9969.

Sczesniak, A.S. (2002). Texture is a sensory property, *Food Quality and Preferences,* 13, 215-225. DOI: 10.1016/S0950-3293(01)00039-8**.**

Seuvre, A. Philippe, E, Rochard, S., & Voilley, A. (2007). A Kinetic study of the release of aroma compounds in different model food systems, *Food Research International*, 40, 480-492; DOI: 10.1016/j.foodres.2006.09.005.

Van Ruth, S.M., & King C. (2003). Effect of starch and amylopectin concentrations on volatile flavour release from aqueous model food systems. *Flavour and Fragrance Journal*, 18, 407-416.

Wang, X., Yuan, Y., & Yue, T. (2015). The application of starch-based ingredients in flavor encapsulation. *Starch/Stärke*, 67, 225-236.

Watanabe, S., & Dawes, C. (1988). A comparison of the effects of tasting and chewing foods on the flow rate of whole saliva in man. *Archives of Oral Biology*, 33(10), 761-764.

Yamaguchi, M., Kanemori, T., Kanemaru, M., Takai, N., Mizuno, Y., & Yoshida, H. 2004. Performance evaluation of salivary amylase activity monitor. *Biosensors and Bioelectronics*, 20(3), 491-497.

Yahya, F.B. (2011). Extraction of aroma compound from pandan leaf and use of compound to enhance rice flavor. School of Chemical Engineering, The University of Birmingham, Birmingham, United Kingdom.

Yoshii, H., Soottitantawat, A., Liu, X., Atarashi, T., Furuta, T., Aishima, S., Ohgawara, M., & Linko, P. 2001. Flavor release from spray-dried maltocextrin/gum arabic or soy matrices as a functional of storage relative humidity. *Innovative Food Science and Emerging Technologies*, 2, 55-61.