ผลของไฮโดรคอลลอยด์และลิพิดต่อสมบัติทางเคมีกายภาพและการยอมรับของผู้บริโภคของเค้กสปันจ์

นายนราธิป ปุณเกษม

วิทยานิพนธ์นี้เป็นส่วนหนึ่งของการศึกษาตามหลักสูตรปริญญาวิทยาศาสตรดุษฎีบัณฑิต
สาขาวิชาเทคโนโลยีทางอาหาร ภาควิชาเทคโนโลยีทางอาหาร
คณะวิทยาศาสตร์ จุฬาลงกรณ์มหาวิทยาลัย
ปีการศึกษา 2557

EFFECT OF HYDROCOLLOIDS AND LIPIDS ON PHYSICOCHEMICAL PROPERTIES AND CONSUMER ACCEPTANCE OF SPONGE CAKE

Mr. Naratip Poonnakasem

A Dissertation Submitted in Partial Fulfillment of the Requirements
for the Degree of Doctor of Philosophy Program in Food Technology
Department of Food Technology
Faculty of Science
Chulalongkorn University
Academic Year 2014

Thesis Title	EFFECT OF HYDROCOLLOIDS AND LIPIDS ON PHYSICOCHEMICAL PROPERTIES AND CONSUMER ACCEPTANCE OF SPONGE CAKE
By	Mr. Naratip Poonnakasem
Field of Study	Food Technology
Thesis Advisor	Associate Professor Saiwarun Chaiwanichsiri, Ph.D.
Thesis Co-Advisor	Associate Professor Kalaya Laohasongkram, Ph.D. Professor Witoon Prinyawiwatkul, Ph.D.

Accepted by the Faculty of Science, Chulalongkorn University in Partial Fulfillment of the Requirements for the Doctoral Degree

---Dean of the Faculty of Science

(Professor Supot Hannongbua, Dr.rer.nat.)

THESIS COMMITTEE

---Chairman

(Assistant Professor Chidphong Pradistsuwana, Ph.D.)

---Thesis Advisor

(Associate Professor Saiwarun Chaiwanichsiri, Ph.D.)

---Thesis Co-Advisor

(Associate Professor Kalaya Laohasongkram, Ph.D.)

---Thesis Co-Advisor

(Professor Witoon Prinyawiwatkul, Ph.D.)

---Examiner

(Associate Professor Kanitha Tananuwong, Ph.D.)

---Examiner

(Sasikan Kupongsak, Ph.D.)

---External Examiner

(Professor Vanna Tulyathan, Ph.D.)

นราธิป ปุณเกษม : ผลของไฮโดรคอลลอยด์และลิพิดต่อสมบัติทางเคมีกายภาพและการยอมรับของผู้บริโภคของเค้กสปันจ์ (EFFECT OF HYDROCOLLOIDS AND LIPIDS ON PHYSICOCHEMICAL PROPERTIES AND CONSUMER ACCEPTANCE OF SPONGE CAKE) อ.ที่ปรึกษาวิทยานิพนธ์หลัก: รศ. ดร.สายวรุฬ ชัยวานิชศิริ, อ.ที่ปรึกษาวิทยานิพนธ์ร่วม: รศ. ดร.กัลยา เลาหสงคราม, ศ. ดร.วิฑูรย์ ปริญญาวิวัฒน์กุล, หน้า.

สเตลิงเป็นสาเหตุหลักประการหนึ่งของการเปลี่ยนแปลงทางเคมีกายภาพสำหรับเค้กสปันจ์ ซึ่งอาจเกิดเนื่องจากสตาร์ชรีโทรเกรเดชัน และการถ่ายเทความชื้น โดยงานวิจัยนี้ศึกษาผลของไฮโดรคอลลอยด์และลิพิดต่อการเปลี่ยนแปลงทางเคมีกายภาพของเค้กสปันจ์ ขั้นแรกศึกษาผลของไฮโดรคอลลอยด์ (ไฮดรอกซีโพรพิลเมทิลเซลลูโลส, HPMC; แซนแทนกัม, XG, อัลจิเนต, AG) ที่ระดับร้อยละ 0.5 และ 1.0 ต่อจลนพลศาสตร์การเปลี่ยนแปลงเนื้อสัมผัสของเค้กสปันจ์ระหว่างการเก็บรักษาที่อุณหภูมิ 15, 25, 35 และ 45 องศาเซลเซียส จากการทดลองพบว่าการเปลี่ยนแปลงความแน่นเนื้อของเค้กสปันจ์ที่แต่ละระดับอุณหภูมิการเก็บรักษา อธิบายได้ด้วยปฏิกิริยาอันดับหนึ่ง โดยพลังงานกระตุ้น (*Ea*) เรียงลำดับจากมากไปน้อยคือ HPMC > AG > XG ซึ่งเป็นไปในทิศทางตรงข้ามกับอัตราการเปลี่ยนแปลงความแน่นเนื้อ (*k*) การเติม HPMC ที่ร้อยละ 0.5 มีค่า *k* น้อยที่สุด และค่า *Ea* สูงที่สุด แสดงว่ามีสมบัติในการชะลอความแน่นเนื้อมากกว่าไฮโดรคอลลอยด์ชนิดอื่นๆ จากนั้นศึกษาผลของลิพิดชนิดต่างๆ (น้ำมันมะพร้าวชนิดบริสุทธิ์พิเศษ, EVCO; น้ำมันมะกอกชนิดบริสุทธิ์พิเศษ, EVOO; น้ำมันรำข้าว, RBO) ในปริมาณร้อยละ 20 ต่อสมบัติทางเคมีกายภาพ การยอมรับ และอารมณ์ความรู้สึกของผู้บริโภค โดยใช้น้ำมันเพื่อสุขภาพ เปรียบเทียบกับสูตรควบคุม (เนย) จากการทดลองพบว่า เค้กสปันจ์ผลิตด้วย EVCO มีคะแนนความชอบโดยรวม และอารมณ์ความรู้สึกเชิงบวกมากกว่าสูตรอื่นๆ ส่วนปริมาตรจำเพาะ อัตราการขยายตัว และความชื้นของเค้กสปันจ์สูตรควบคุม EVCO และ EVOO ไม่แตกต่างกันอย่างมีนัยสำคัญ แต่สูงกว่าสูตร RBO และขั้นสุดท้าย ศึกษาผลของการเติม HPMC ร้อยละ 0.5 หรือ EVCO ร้อยละ 20 เพียงอย่างเดียว และใช้ร่วมกัน (combination) ต่อสมบัติทางเคมีกายภาพ และโครงสร้างจุลภาคของเค้กสปันจ์ระหว่างการเก็บรักษา จากการทดลองพบว่าการเติม HMPC และ/หรือ EVCO สามารถชะลออัตราการเปลี่ยนแปลงความแน่นเนื้อได้ เรียงลำดับจาก combination < EVCO < HPMC < control โดยสอดคล้องกับข้อมูลจากเทคนิคการเลี้ยวเบนของรังสีเอ็กซ์คือ ระดับความเป็นผลึก และอัตราการเกิดผลึก (โดยใช้สมการ Avrami) เมื่อหาความสัมพันธ์ระหว่างความแน่นเนื้อกับค่าคุณภาพต่างๆพบว่า ความแน่นเนื้อแปรผันตรงกับระดับความเป็นผลึกแต่แปรผกผันกับความชื้น และเวลาของการผ่อนคลายแบบสปิน-แลกทิซ (T_1) จากเทคนิคนิวเคลียร์แมกเนติก เรโซแนนซ์

ภาควิชา	เทคโนโลยีทางอาหาร	ลายมือชื่อนิสิต	....
สาขาวิชา	เทคโนโลยีทางอาหาร	ลายมือชื่อ อ.ที่ปรึกษาหลัก	....
ปีการศึกษา	2557	ลายมือชื่อ อ.ที่ปรึกษาร่วม	....
		ลายมือชื่อ อ.ที่ปรึกษาร่วม	....

5472895023 : MAJOR FOOD TECHNOLOGY
KEYWORDS: HYDROCOLLOID / LIPID / PHYSICOCHEMICAL PROPERTIES / SPONGE CAKE / KINETICS MODELING / TEXTURE / STALING / CONSUMER ACCEPTANCE

NARATIP POONNAKASEM: EFFECT OF HYDROCOLLOIDS AND LIPIDS ON PHYSICOCHEMICAL PROPERTIES AND CONSUMER ACCEPTANCE OF SPONGE CAKE. ADVISOR: ASSOC. PROF. SAIWARUN CHAIWANICHSIRI, Ph.D., CO-ADVISOR: ASSOC. PROF. KALAYA LAOHASONGKRAM, Ph.D., PROF. WITOON PRINYAWIWATKUL, Ph.D., pp.

One of the important physicochemical property changes of sponge cake is staling which is presumed to be due to starch retrogradation and moisture migration. In this study, the effect of various hydrocolloids and lipids was determined. First, influence of hydrocolloids (hydroxy-propyl-methylcellulose, HPMC; xanthan gum, XG; alginate, AG) at 0.5 and 1.0% on textural kinetics of sponge cake during storage at 15, 25, 35 and 45 ^{O}C was studied. The firmness change of sponge cake at different storage temperatures followed a 1st-order kinetic reaction, where the activation energy (*Ea*) decreased in the following order: HPMC > AG > XG, which was in contrast to the firmness change rate constant (*k*). Addition of 0.5% HPMC gave the lowest *k* and highest *Ea* values, reflecting its better firmness retarding property. Moreover, effect of different lipids on physicochemical properties and consumer acceptance and emotion of sponge cake was evaluated. Healthy oils (extra virgin coconut oil, EVCO; extra virgin olive oil, EVOO; rice bran oil, RBO) vs. butter (control), were used at 20% in sponge cake. Overall liking and positive emotion scores of sponge cake made with EVCO were higher than others. Specific volume, expansion ratio, and moisture content of control, EVCO and EVOO were not significantly different, but higher than RBO sponge cake. Finally, influence of individual 0.5% HPMC or 20% EVCO and combination on physicochemical properties and microstructure of sponge cake during storage was studied. The use of HPMC and/or EVCO in sponge cake could retard the firmness rate in the following order: combination < EVCO < HPMC < control. The results were in line with X-ray diffraction data of crystallization degree and rate of crystallization, using Avrami equation. From correlation, it was found that firmness of sponge cake directly related to crystallization degree but inversely related to moisture content and spin-lattice relaxation time (T_1) from nuclear magnetic resonance technique.

Department:	Food Technology	Student's Signature	....
Field of Study:	Food Technology	Advisor's Signature	....
Academic Year:	2014	Co-Advisor's Signature	....
		Co-Advisor's Signature	....

ACKNOWLEDGEMENTS

I would like to express my gratitude and appreciation to my advisor, Assoc. Prof. Saiwarun Chaiwanichsiri, and my co-advisor, Assoc Prof. Kalaya Laohasongkram, for their guidance, support and encouragement all the time of research and writing of this Ph.D. thesis. I wish to specially thank my co-advisor, Prof. Witoon Prinyawiwatkul for all experience at Louisiana State University, Baton Rouge, LA, USA. I also wish to thank my Ph.D. thesis examiners, Prof. Vanna Tulyathan, Asst. Prof. Chidphong Pradistsuwana, Dr. Sasikan Kupongsak and Assoc Prof. Kanitha Tananuwong, for their valuable suggestions.

I am grateful to Suan Dusit Rajabhat University for allowing me to pursue my Ph.D. study in Food Technology, Faculty of Science, Chulalongkorn University. The financial supports from Chulalongkorn University Graduate School including (1) 60/40 Support for Tuition Fee, (2) The 90th anniversary of Chulalongkorn university fund (Ratchadaphiseksomphot Endowment Fund) (3) Overseas research experience scholarship for graduate student and (4) Overseas academic presentation scholarship for graduate student are particularly acknowledged.

I would like to thank all staffs and friends at Food Technology Department, Chulalongkorn University, all colleagues and Thai community at Baton Rouge, LA, USA for their help and encouragement and also my best friends at Assumption College for cheerfulness.

Especially, I would like to forward my thanks to my father, mother, brothers and all relatives for their care and moral support.

CONTENTS

Page

Page

LIST OF TABLES

LIST OF FIGURES

CHAPTER I

INTRODUCTION

Bakery products are one of the most consumed foods in the world. Among them, cakes are particularly popular as a tasteful product. The quality of the ingredients and the nature of their interactions strongly influence the quality of the finished product. In the bakery industry, sponge cake is air leavened product with a spongy texture that contain little lipid. Nevertheless, sponge cake is processed food with a short shelf life. During storage at room temperature, the quality of the cake, such as the moisture, flavor, aroma and firmness, changes in a detrimental manner. Freshly prepared sponge cake is soft, pliable and elastic, but when it is kept at room temperature it stales within a few days. Generally, this short shelf life of sponge cake is a major problem and can be costly to the producer, distributor and consumer.

One of the important physical property changes of sponge cake is staling which is presumed to be due to starch retrogradation and moisture transfer. Studies on the kinetics of the staling rate provide critical data in predicting and optimizing the quality of bakery products during storage. There have been reports that hydrocolloids can be used to decrease the staling rate of bread, due to their good functional attributes such as water binding, viscosity, foaming, emulsifying, gelling, solubility and textural improvement. Hydrocolloid selection is determined by the functional characteristics required for the end products.

Anti-staling agent used in bread includes lipids which affect loaf volume and produce a firmness retarding effect. They tenderize the bread crumb by coating structure builders, gluten proteins, egg proteins, and starch granules. However, lipids in baked product affect many qualities including consumer acceptance, so sensory techniques, e.g. sensory liking, product information, food-elicited emotion and purchase intention, are necessary.

During storage of sponge cake, the crystalline structure of the starch is slowly recovered at the short range scale. The studies of microstructure are the key to monitor the changes. Even though, the characterization of starch in bread and its role during bread staling have been extensively studied, for sponge cake, little attention has been devoted to determine effect of hydrocolloids and lipid on physicochemical properties and microstructure of sponge cake.

The objectives of this work were to investigate (1) the influence of the addition of different hydrocolloids individually at different concentrations on the batter quality and the kinetics of change in the textural properties of the resulting sponge cake during storage, (2) the effect of different lipids on physicochemical properties, consumer perception and purchase intent of sponge cake and (3) the effect of chosen hydrocolloid and lipid on physicochemical properties and microstructure of sponge cake during storage.

CHAPTER II

LITERATURE REVIEW

2.1 SPONGE CAKE

Bakery products are staple foods, provide nutrients, and vary widely in theirs formulation. Sponge cake is one of well-known cakes in the world. It is a cake made of flour (usually wheat flour), sugar, egg, baking powder and little lipid. Its structure is firm and similar to a sea sponge. The structure of the sponge cake was found to be porous (Figure 1) due to the presence of very large pores, around 0.1 – 2.0 mm (Roca et al., 2008).

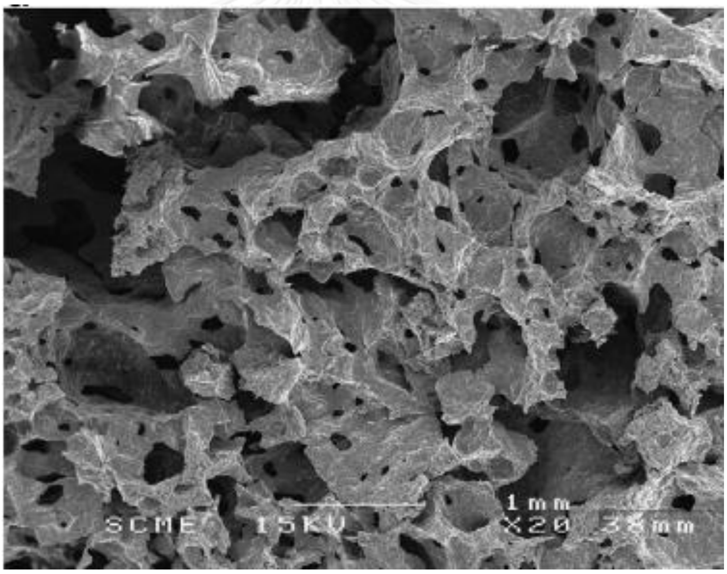


Figure 1 Observation of the surface of sponge cake by scanning electron microscopy (magnification 20x).

Source: Roca et al. (2008)

2.1.1 Sponge cake mixing

For sponge cake, mixing batter is a complex process. It involves more than just blending the ingredients. Basically, it provides air cells that finally form the crumb of sponge cake. The air cells are surrounded by cell walls, which consist of a continuous network of egg and gluten proteins embedded with starch and other particles. During the mixing process, the friction of the mixer on the batter breaks up the large particles, allowing them to dissolve or to hydrate in water. Due to particles hydration, water becomes less able to move freely, and the batter becomes thicker. For egg-foam cakes, the air cells are formed by whipping egg and sugar. For the optimum of foaming process, the egg and sugar mixture should be slightly warm. Whipping may be operated at high speed at first, but the final stage of whipping should be at medium speed in order to retain air cells (Gisslen, 2013).

During mixing of sponge cake, egg is whipped and air bubbles are beaten into the liquid while egg proteins unfold (Figure 2). The unfolded proteins quickly move through the liquid to the surface of the bubbles. Once there, nearby proteins bind or aggregate around the bubbles and form a filmy network (Figoni, 2008).

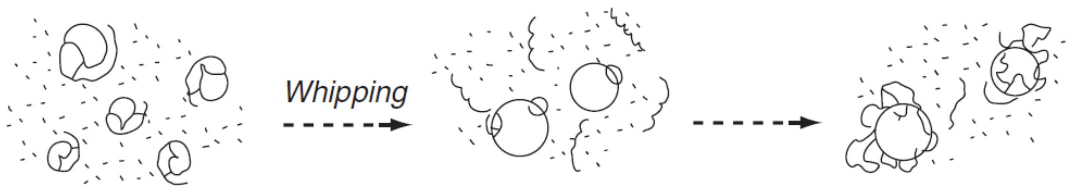


Figure 2 The process of egg foam formation

Source: Figoni (2008)

2.1.2 Sponge cake baking

Sponge cake batter is generally baked at high temperature (about 180 to 200 ^{O}C). Baking is a complex process in which chemical and physical changes take place simultaneously. Some of the actions occur during baking, such as starch gelatinization, expansion of gases, coagulation of proteins and browning reaction.

Egg proteins are the most important structure builders in sponge cake. The egg turns from liquid to solid and from clear to opaque. This process normally begins around 60 to 70 ^{O}C and continues as temperatures rise. Raw egg proteins occur as relatively large, coiled molecules, surrounded by water. As they are heated and begin to coagulate, the molecules unfold and bind with one another. They stretch from the pressure of expanded leavening gases. Finally, the bonding proteins become rigid and lose their ability to stretch. This rigid structure sets the final size and shape of sponge cake as showed in Figure 3 (Figoni, 2008).

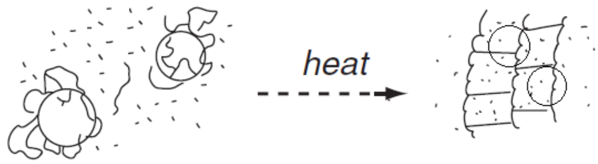


Figure 3 The process of egg protein coagulated
Source: modified from Figoni (2008)

Two baking periods and the corresponding main transfer mechanisms are reported by Lostie et al. (2002), namely (1) heating up period and (2) crust and crumb period. During the heating up period, water migrates from the core to the surface by diffusion in liquid phase and heat is transferred from the surface to the core by conduction. During the crust and crumb period, the main resistances for heat and mass transfer are located in the dried crust where heat is transferred by conduction.

The cross-sectional images of the sponge cake (Figure 4) show the black zones representing the pores while the white zones being the dry matter. The presence of two zones inside the sponge cake can be separated by their mean pore sizes as a zone with fine pores for crust and zone with large pores for crumb.

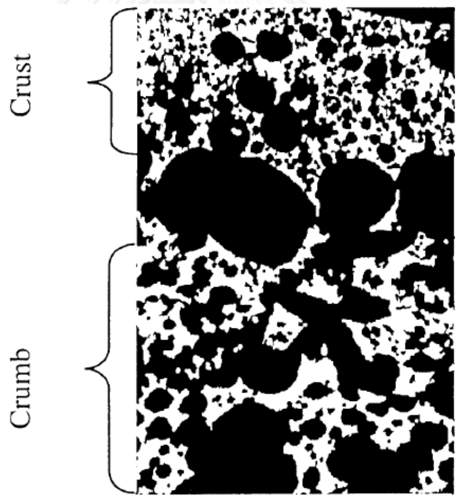


Figure 4 Image of the sponge cake cross-section

Source: Lostie et al. (2002)

2.2 STALING MECHANISM

Staling is the change in texture and aroma of baked goods due to a change of structure and a loss of moisture of the starch granules. For sponge cake, stale product has lost its fresh-baked aroma and is firmer, drier, and more crumbly than fresh. Prevention of staling is a major concern of the producer because it loses quality rapidly. It is presumed to be due to starch retrogradation and moisture transfer.

2.2.1 Starch retrogradation

Starch is significantly involved in the staling process. Its main transformation upon aging, retrogradation, is the aggregation of polysaccharide chains which may form crystal phases within and outside the contours of the native starch granules. Figure 5 shows a schematic representation of the phase transition of starch during gelatinization and retrogradation. The crystalline structure of the starch granules is destroyed during heating in water (Figure 5a and b). Gelatinized amylopectin initially remains in an amorphous state, even though there is still a small amount of ungelatinized amylopectin. Although the double-helical crystalline structure formed by the short-branched chains in amylopectin is torn apart during gelatinization, the chains remain in a regular pattern. It has been considered that these short-branched chains form gel-balls, which mainly contain chains from the same sub-main chain (Figure 5b). V-type single helix crystals (Figure 5c) have been found to form directly after heat processing, which initially results in higher modulus and yield stress for amylose-rich materials. The crystallinity of the B-type crystals increases with time (Figure 5d) (Yu and Christie, 2005).

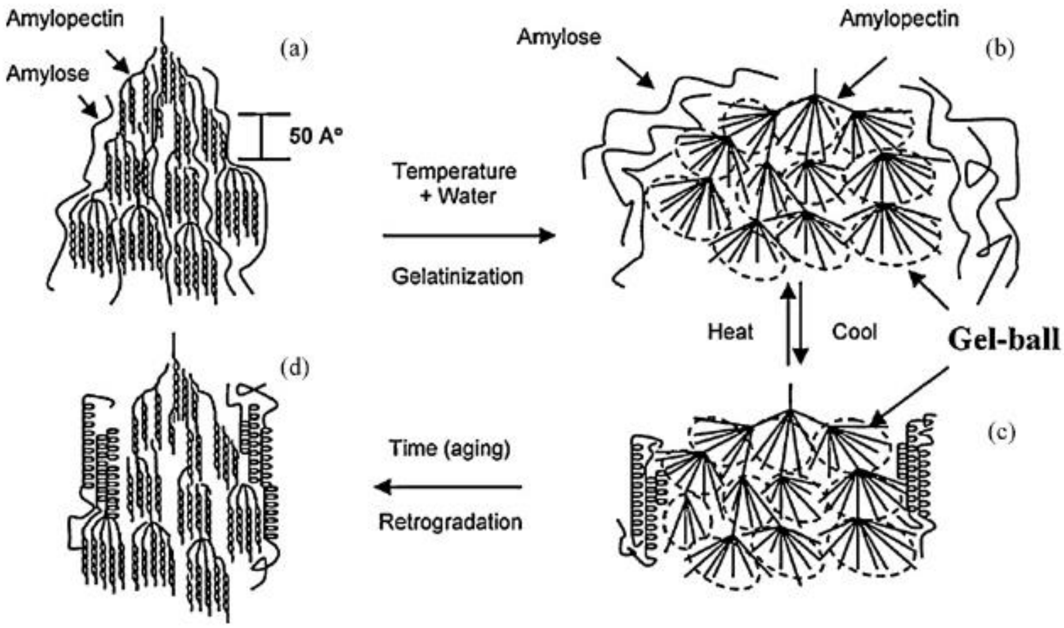


Figure 5 Schematic representation of the phase transitions of starch during thermal processing and aging

Source: Yu and Christie (2005)

Starch retrogradation is known to be the main reason for firming of bread and describes the aging process of starch after baking. However, retrogradation in cake was not detected by DSC measurement during storage time. The reason may be referred to the method, which was developed for bread not cakes. Cake contains additional ingredients which may interfere with starch gelatinization. These results indicated that cake firming was driven not only by starch retrogradation, as in the case of bread, but also by other ingredients in cake including eggs, lipids and sugar (Döring et al., 2013).

2.2.2 Moisture transfer

Water plays a critical role in the firming process, either by enhancing the molecular mobility of polymer chains or by acting as a coordination agent between them. It is involved in the following changes in the baked goods system including drying out, moisture equilibration between crumb and crust, and moisture redistribution between and among components (Gray and Bemiller, 2003).

Schiraldi and Fessas (2001) reviewed water content, water activity, water migration between phases, and the air cell crumb structure of bread. The water was rather mobile and could facilitate mutual displacement of the incompatible gel phases, so behaving as a plasticizer, and could enhance the crumb to crust migration of moisture. This local drying made the walls of the crumb air cell more rigid, while the concurrent moisture increased within the crust region was accompanied by a reduction of crispness even when overall moisture loss was prevented by packing bread in sealed bags (Piazza and Masi, 1995).

For sponge cake structure, liquid water diffusion occurs in the continuous, solid matrix and that water vapor diffusion occurs in the gas phase, corresponding to gas bubbles of various sizes and shapes embedded in the solid matrix and sometimes connected. Since liquid water diffusivity is 10^{-4} orders of magnitude lower than water vapor diffusivity, the overall effective moisture diffusivity may vary in large orders of magnitude depending on the ratio of open pores to solid matter (Figure 6). Decreasing the porosity of the sponge cake compartment (from 86 to 52 %) reduced significantly the internal moisture diffusivity (Guillard et al., 2013).

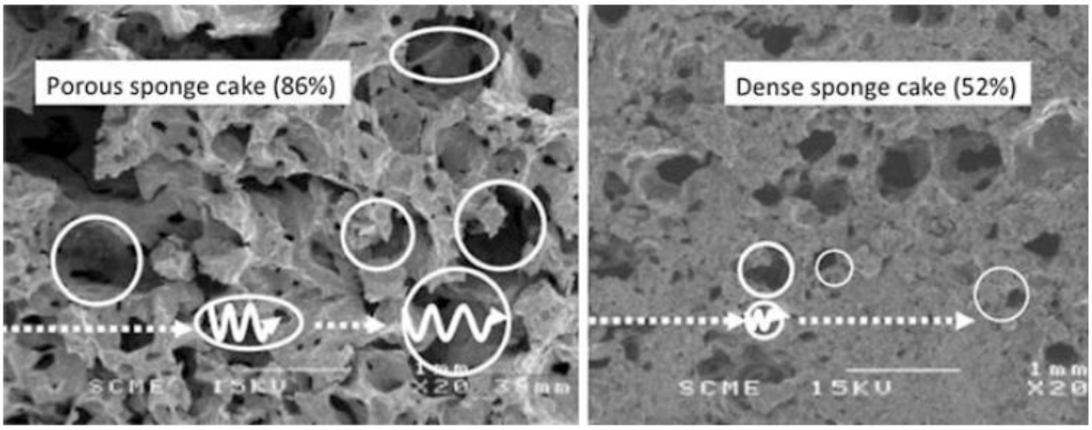


Figure 6 Schematic representation of moisture transport mechanisms in sponge cake as a function of percentage of porosity (continuous lines water vapor diffusion; dotted lines liquid water diffusion; circles pore walls)

Source: Guillard et al. (2013)

During baked cake begins to cool, moisture gradient forms in the loaf. Differences in vapor pressures between the crust and the internal region of the loaf result in moisture migration from the crumb to the crust (Luyts et al., 2013). Over time, the moisture content in the center of the loaf decreases, while that in the external region increases.

Baik and Chinachoti (2000) found that bread stored with its crust became significantly firmer than bread stored without its crust and contained more recrystallized amylopectin, indicating that moisture redistribution from crumb to crust plays a significant role in firming. Moreover, transfer of moisture from one constituent of the crumb to another is generally accepted as a contributing factor in staling, possibly being responsible for the perceived dryness of stale product. Chen et al. (1997) reported that the decrease in water mobility was due to incorporation of water molecules released from protein into crystalline structure of starch that developed upon staling.

2.3 STALING MEASUREMENT TECHNIQUES

Since staling is a complex process, various techniques have been employed to measure staling and to investigate the changes that accompany it.

2.3.1 Kinetic modeling of texture

Kinetic modeling of the transient changes in the quality parameters gives an important tool for predicting and optimizing the quality of food during storage (VanBoekel, 1996). It has been applied to study the texture change in many food systems, including meat product: beef (Olivera et al., 2013), vegetable products: green asparagus (Lau et al., 2000), carrot (Peng et al., 2014), potato (Nourian et al., 2003), dairy product: Gulabjamun (Kumar et al., 2006) and rice starch gel (Baik et al., 1997). Peng et al. (2014) investigated the degradation of food using general form of the reaction equation that can be expressed as

$$\frac{dC}{dt} = \pm kC^n \qquad \text{--- (1)}$$

where

C is the quality index,

t is the reaction time,

k is the rate constant, and

n is the order of reaction.

The quality property, presented as the fraction of the quality change (*C*), provides an accurate way to know the extent of the quality change at any given time (t) (Rizvi and Tong, 1997) and can be expressed by

$$C = \frac{(Q_t - Q_\infty)}{(Q_0 - Q_\infty)} \qquad \text{--- (2)}$$

where

Q_0 is the initial quality,

Q_t is the quality at time t, and

Q_∞ is the quality at equilibrium.

For textural change, the reaction order had been determined graphically and the best fitting line was decided by examining the coefficient of determination (R^2) (Lau et al., 2000; Swinburne, 1971). The rate constant (*k*) is temperature dependent and often follows the Arrhenius equation (Taoukis et al., 1997)

$$\ln k = \ln k_0 - \frac{Ea}{RT} \qquad \text{--- (3)}$$

where

k_0 is the pre-exponential factor,

Ea is in J/mol,

R is the universal gas constant (8.314 J/K mol), and

T is the temperature (K).

Determination of the kinetic parameters, such as the *k* and *Ea*, are necessary in order to predict the changes in the food. A plot of ln k against 1/T should result in a straight line, and *Ea* can be calculated from the slope of the line. When the *Ea* is high, the reaction is slower (Armstrong, 2011). In this study, *Ea* are applied to extrapolate the effect of hydrocolloids on the texture of sponge cake during storage.

2.3.2 X-ray diffraction

Starch granule commonly consists of coordinated layers that contain crystalline micelles arranged perpendicularly to the plane of the layer. Starch granules, partially crystallized polymer, give distinct X-ray diffraction (XRD) patterns (Karim et al., 2000). The starch chains can be assumed single and double helix conformations. In crystalline phases, these helices are regularly displaced around a hexagonal axis. A molecule of amylose or amylopectin can exist in segments arranged in a helical conformation as well as in unordered segments, contributing to the amorphous fraction of the starch. The crystalline phases as identified from X-ray diffraction are usually classified as A, B, C, and V patterns (Chinachoti and Vodovotz, 2001).

The A-type pattern is presented by cereal starches while B-type pattern is observed for tubers, fruit, high amylose corn (> 40%) starches, and retrograded starch. The C-type pattern, which is intermediate between A and B types, is showed by for legume seed starch. The B phase is caused by double-helix amylose chains and amylopectin side chains and mostly includes 27% water. The A and C phases, which tend to contain less than 27% water, are formed at higher temperatures. The V phase is formed by amylose and amylopectin single helices trapping or interacting with a lipid molecule. The hydrophobic tail of the lipid is extended along the internal cavity of the helix, while its hydrophilic head protrudes from the end of the coil.

At the first stage, upon baking the crystalline structure of the granule is disrupted by gelatinization (melting). When non-crystalline gels are cooled and aged, amylopectin molecules reassociate to generate a new crystalline order which has a typical X-ray diffraction pattern. The gel network is maintained by local crystalline regions, and the strength of the net depends both on the degree of molecular association and on the molecular component undergoing crystallization (Zobel, 1988). Starch retrogradation does not only involve changes in the amylopectin fraction, but also in the amylose fraction. Amylose recrystallization is fast and occurs about 1 hour after baking, during cooling, while amylopectin recrystallization is slower. Amylose forms complexes with naturally occurring fatty acids and phospholipids of the granule, giving "V"-structures (peak at 20^{O}) (Koksel et al., 1993). The peak at 20^{O} is attributed to a well formed "V"-structure, which apparently decreased during storage. The degree of crystallinity during storage may be followed by the intensity increase of the X-ray diffraction peaks (mainly that at 17^{O}).

Aguirre et al. (2011) studied XRD patterns for both wheat flour and bread crumb at day 0 (Figure 7). The four peaks at the diffraction angles of 15.2^{O}, 17.4^{O}, 18.3^{O} and 23.1^{O} represent the crystalline portion on A-pattern starch in wheat flour, as described by Zobel (1988). An area below the line that joins the valleys of these peaks shows the amorphous portion (Koksel et al., 1993). The X-ray diffractogram of bread crumb at day 0 represents that the peaks have disappeared at diffracted angles of 15.2^{O}, 17.4^{O}, 18.3^{O} and 23.1^{O} this fact reflecting a substantial loss of A-type crystallinity. An additional peak, attributed to a well formed V-structure (Ribotta et al., 2004), appears at the angle of 20^{O}.

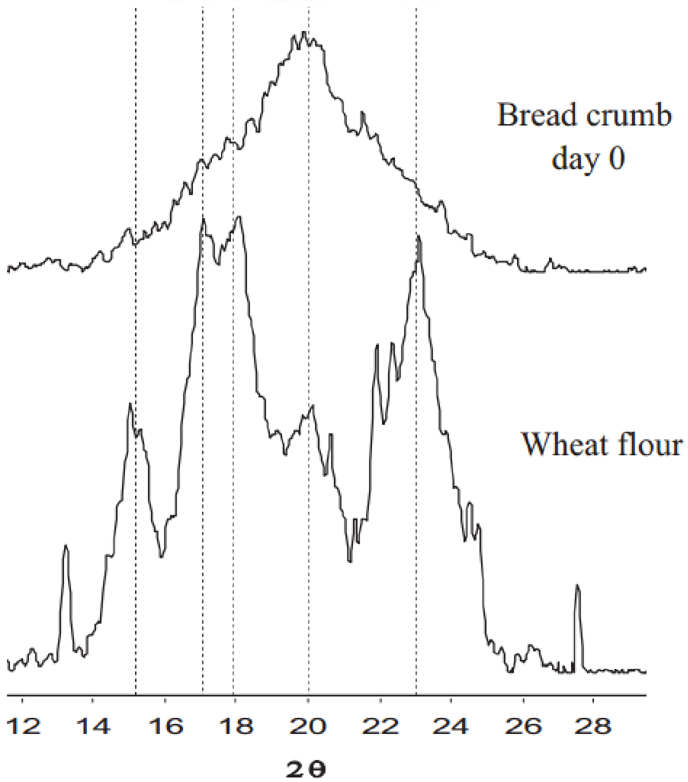


Figure 7 XRD patterns for wheat flour and fresh bread

Source: Aguirre et al. (2011)

2.3.3 Starch retrogradation kinetics

Crystallization kinetics of synthetic polymers are often described using the Avrami equation. This equation was originally derived to explain polymer crystallization from melt.

The crystallinity (Φ) was calculated as the ratio of area under the crystalline peaks to the entire area of under the diffractogram as given by

$$\Phi(t) = \frac{A(t)}{A(t) + B} \quad \text{--- (4)}$$

where, A(t) is the area of crystalline region and *B* is the area of amorphous region. By subtracting *A(t)* from the area under the diffractogram the non-crystalline fraction was calculated.

The retrogradation of partially gelatinized starch was in part due to the growth of remainder crystals ($\Phi_1(t)$) in starch granules and in part due to nucleation and growth of new crystals ($\Phi_2(t)$) (Del-Nobile et al., 2003). The starch crystals volume fraction at a given storage time can be expressed as

$$\Phi(t) = \Phi_1(t) + \Phi_2(t) \quad \text{--- (5)}$$

Using the Avrami equation (Sharpless, 1966) to describe both $\Phi_1(t)$ and $\Phi_2(t)$, the following expression is obtained for $\Phi(t)$

$$\Phi(t) = \{\Phi_1^{\max}[1 - \exp(-k_1 t)] + \Phi^{in}\exp(-k_1 t)\} + \{k_2 t^2\} \quad \text{--- (6)}$$

The starch crystallinity level can be normalized as given by Equation (7)

$$\Gamma(t) = \frac{\Phi(t) - \Phi^{in}}{\Phi^{last} - \Phi^{in}} \qquad \text{--- (7)}$$

Substituting Equation (6) in Equation (7) and rearranging the normalized starch crystallinity value was obtained

$$\Gamma(t) = \frac{1 - \exp(-k_1 t) + \dfrac{k_2}{\Phi_1^{\max} - \Phi^{in}} t^2}{\dfrac{\Phi^{last} - \Phi^{in}}{\Phi^{\max} - \Phi^{in}}} \qquad \text{--- (8)}$$

The above equation can be rewritten as follows

$$\Gamma(t) = \frac{1 - \exp(-P_1 t) + P_2 t^2}{P_3} \qquad \text{--- (9)}$$

$\Gamma(t)$ is the normalized starch crystallinity level at time t (%), k_1 is the growth rate constant of the remainder crystals in starch granules (day^{-1}), k_2 is the growth rate constant of newly formed crystals (day^{-1}), $\Phi(t)$ is the volume fraction of the starch crystals at time t, Φ^{in} is the initial value of $\Phi(t)$ at storage time t = 0, Φ^{last} is the finally measured value of $\Phi(t)$ and $\Phi^{\max}$ is the value of $\Phi(t)$ at very long storage time (t =∞). $P_1 = k_1$; $P_2 = \dfrac{k_2}{\Phi_1^{\max} - \Phi^{in}}$; $P_3 = \dfrac{\Phi^{last} - \Phi^{in}}{\Phi^{\max} - \Phi^{in}}$

2.3.4 Nuclear magnetic resonance

Nuclear magnetic resonance (NMR) spectroscopy has been successfully used to study water mobility in various systems. There are two kinds of relaxation processes including spin-lattice (longitudinal) relaxation and spin-spin (transverse) relaxation. The time constants that illustrate these exponential relaxation processes are described as relaxation times. The spin-lattice relaxation time is denoted by T_1 and the spin-spin relaxation time by T_2 (Chinachoti and Vodovotz, 2001). The measurement of the T_1 and T_2 of a proton allows one to monitor the degree of water binding to other chemical components.

For starch retrogradation, Nakazawa et al. (1983) detected little change in ^1H NMR T_1, T_2, and the fraction of bound water during storage of non-glutinous rice starch gel (1:1 starch-water ratio) at $3^{O}C$. However, correlation time of water molecules and the fraction of bound water in glutinous rice starch gel increased noticeably during aging.

Bread firming will involve changes in molecular mobility of the bread system, which can be assessed by NMR techniques. NMR has been the choice for study of staling because of its ability to rapidly determine the mobility of protons associated with different molecules (Chinachoti and Vodovotz, 2001). Chen et al. (1997) revealed a complex and dynamic relationship between staling and properties of water in bread. The three-component model was found to well represent the states of water in the bread crumb samples used in this study. The results showed that T_1 decreased with increasing time, indicating an overall decrease in water mobility. Changes in T_{2s} and the corresponding intensities of protons were more complicated, suggesting a dynamic structural transform of macromolecules and microscopic migration of moisture in the staling bread. T_1, T_{23} and proton intensity at T_{21} were highly correlated with the firming process.

Bosmans et al. (2013) used ^1H NMR relaxometry to better elucidate the relationship between biopolymer interactions, water dynamics, and crumb texture evolution during storage of bread. The NMR analysis allowed finding 6 proton populations in bread crumb. From the NMR profiles of bread crumb, they were able to deduce the extent of formation of both amylopectin crystals and of crumb firmness.

On the basis of data obtained, it was concluded that the increase in crumb firmness of stored bread was caused by a combination of different events that were amylopectin retrogradation and the formation of a continuous, rigid, crystalline starch network that included water in its structure.

2.4 ANTI-STALING COMPOUND

2.4.1 Hydrocolloid

Hydrocolloids are a diverse group of long chain polymers characterized by their property of forming viscous dispersions and/or gels when dispersed in water. These materials were found in exudates from trees, extracts from plants or seaweeds, flours from seeds or grains, gummy slimes from fermentation processes and many other natural products. Occurrence of a large number of hydroxyl groups noticeably increases their affinity for binding water molecules rendering them as the hydrophilic compounds (Saha and Bhattacharyya, 2010). Moreover, they produce a dispersion, which is intermediate between a true solution and a suspension, and exhibits the properties of a colloid. Considering these two properties, they are appropriately termed as hydrophilic colloids or hydrocolloids. Hydrocolloids have a variety of functional properties in foods such as thickening, gelling, emulsifying, stabilization, coating, etc. The primary reason behind the broad use of hydrocolloids in foods is their ability to modify the rheology of food systems. This includes two basic properties of food systems that is, flow behavior (viscosity) and mechanical solid property (texture) (Imeson, 2010).

In baked goods, hydrocolloids have been used for improving the quality of the fresh products and for retarding the staling. Four different hydrocolloids, including carageenan, carboxymethyl cellulose, guar gum and xanthan gum, were used as texture improver in bread. For physical properties, loaf weight was mostly unchanged, while addition of hydrocolloid seemed to have a positive effect on loaf volume. Crumb firming kinetics of the bread during storage using the Avrami model showed that application of hydrocolloids at lower levels retarded the firming kinetics (Das et al., 2013).

The use of three hydrocolloids, including hydroxy-propyl-methylcellulose (HPMC), xanthan gum (XG) and sodium alginate (AG), had previously been evaluated in bread. A better bread volume (Rosell et al., 2001) and an improved volume of fresh bread and reduced crumb hardening rate during storage (Guarda et al., 2004) were obtained when 0.5% (w/w) HPMC was added to wheat flour. Likewise, the inclusion of XG or AG was found to give a softening effect to the bread due to the hindering of the gluten–starch interactions (Davidou et al., 1996).

Unlike the bread staling mechanism, hardening in sponge cake has not been so extensively studied. Gomez et al. (2007) studied the use of several hydrocolloids in yellow layered cakes and found that the addition of 1.0% (w/w) hydrocolloid improved the panelist's overall sensory score, especially for the cases of the inclusion of HPMC, XG or AG. Chaiya et al. (2015) studied the optimum formulation for wheat flour-based sponge cakes containing tapioca starch and xanthan gum using the central composite design with two factors and response surface methodology. Based on the contour plots, sponge cake formulation, containing 16% butter with desired physical properties and sensory quality, was found to be 11.09 – 11.88% tapioca starch and 0.10 – 0.11% xanthan gum.

2.4.1.1 Hydroxy-propyl-methylcellulose

The cellulose derivatives are obtained by chemical modification of cellulose, which ensures their uniform properties, in opposition to the hydrocolloids from natural sources that have a high variability (Guarda et al., 2004).

Hydroxypropylmethylcellulose (HPMC) is obtained by the addition of methyl and hydroxypropyl groups to the cellulose chain (Figure 8), leading to a polymer with a high surface activity and unique properties regarding its hydration–dehydration characteristics in the solution state and during temperature changes.

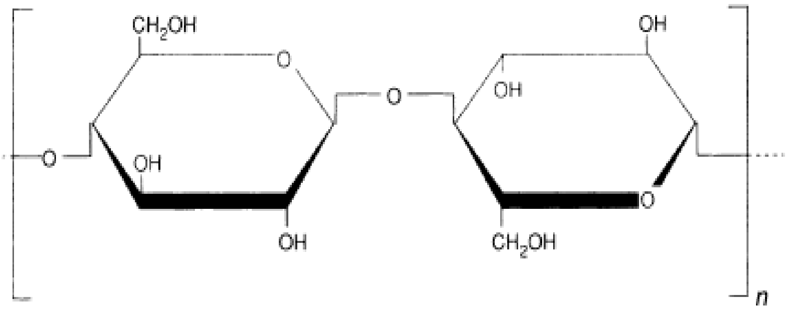


Figure 8 Cellulose structure

Source: Phillips and Williams (2000)

In addition, despite the presence of hydrophobic groups in the HPMC chain, this polymer partially maintains the hydrophilic properties of the cellulose. Those properties allow the HPMC acting as emulsifier, strengthener of the crumb grain and increase the moisture content of the crumb.

2.4.1.2 Xanthan gum

Xanthan gum (XG) is an anionic polysaccharide, derived from the bacterial coat of *Xanthomonas campestris*, used as a food additive and rheology modifier, commonly used as a food thickening agent and a stabilizer. It is produced by the fermentation of glucose, sucrose, or lactose by the *Xanthomonas campestris* bacterium. After a fermentation period, the polysaccharide is precipitated from a growth medium with isopropyl alcohol, dried, and ground into a fine powder. XG is often used along with starch, often rice starch, to replace wheat flour in gluten-free baked cakes. The structure of XG showed in Figure 9 (Phillips and Williams, 2000).

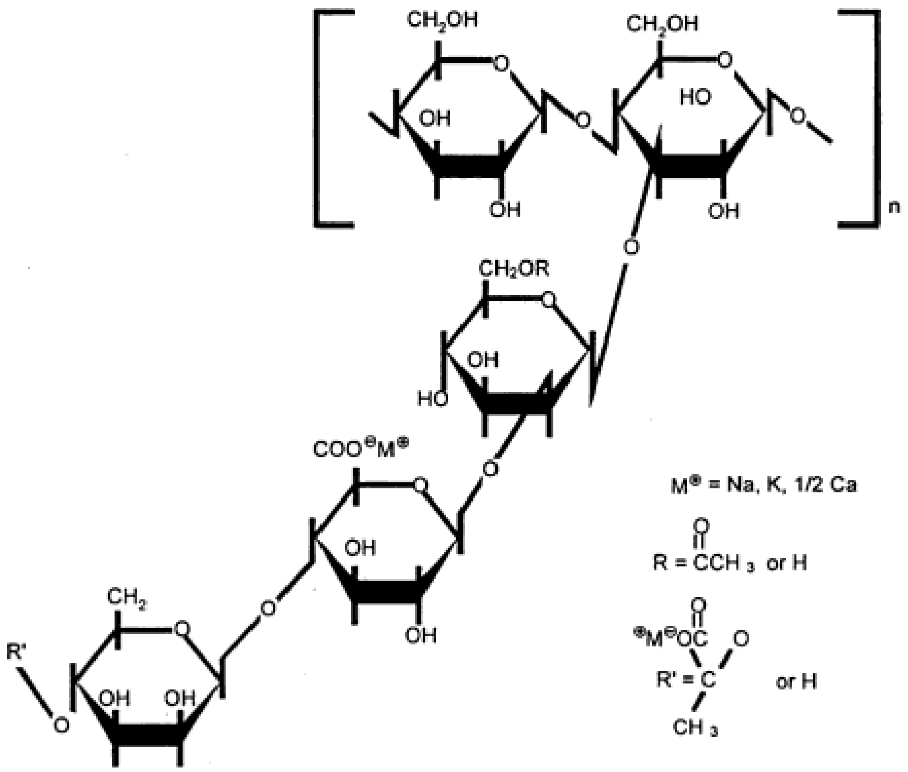
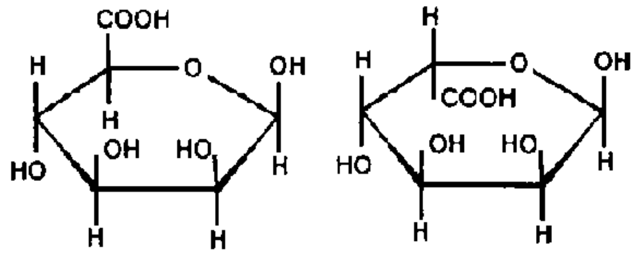


Figure 9 Xanthan gum structure

Source: Phillips and Williams (2000)

2.4.1.3 Alginate

Alginate (AG) is an anionic polysaccharide, colour ranging from white to yellowish-brown, distributed widely in the cell walls of brown algae and forms a viscous gum when binding with water. In extracted form, it can absorb water quickly and its capacity is around 200-300 times of its own weight in water. It is a linear copolymer with homopolymeric blocks of (1-4)-linked β-D-mannuronate (M) and its C-5 epimer α-L-guluronate (G) residues (Figure 10), respectively, covalently linked together in different sequences or blocks. The monomers can appear in homopolymeric blocks of consecutive G-residues (G-blocks), consecutive M-residues (M-blocks) or alternating M and G-residues (MG-blocks). AG absorbs water quickly, which makes it useful as an additive in dehydrated products such as slimming aids. It is also used for thickening drinks, ice cream and cosmetics (Phillips and Williams, 2000).



(a) (b)

Figure 10 Alginate monomer structure: β-D-Mannuronic acid (a), and α-L-Guluronic acid (b)

Source: Phillips and Williams (2000)

2.4.2 Lipid

For sponge cake, lipid tenderizes by coating structure builders, gluten proteins, egg proteins, and starch granules, and preventing them from hydrating and forming structure (Figoni, 2008). Lipid assists proteins in batter in trapping and holding air as they are mixed. Moreover, lipid affects volume and produces a significant anti-staling effect. A number of mechanisms of their action have been suggested. It has been established that fatty acids, monoglycerides, and diglycerides can be included within the central cavity of amylose and, to a lesser extent, amylopectin single helices, thus enhancing the formation of the V-type crystals (Chinachoti and Vodovotz, 2001). Beside anti-staling effect, lipid affects many sensory qualities of baked products (Laitinen et al., 1993).

Butter is normally used in sponge cake as it gives unique flavor. However, consumers have been advised to eat healthier foods. This trend is leading to increasing interest in foods that are healthy and nutritious. The consumption of health-promoting products may improve human health and prevent certain diseases. Other healthier lipid sources have been investigated such as olive oil for Madeira cakes (Matsakidou et al., 2010). In this study, three types of healthy oils are used to study the qualities of sponge cake, following extra virgin olive oil, extra virgin coconut oil and rice bran oil.

Among vegetable oils, extra virgin olive oil (EVOO), fatty acid profile; saturated fatty acid (SFA) : monounsaturated fatty acid (MUFA) : polyunsaturated fatty acid (PUFA) = 17.0 : 70.2 : 12.8, is well known for its heart healthy effects. It is very high in mono-unsaturated fatty acids and has been linked with a reduced incidence of coronary heart disease and low blood pressure levels. The absence of refining processes helps extra virgin olive oil to preserve its delicate aroma and nutritional properties (Boskou et al., 2006). Extra virgin coconut oil (EVCO), fatty acid profile; SFA : MUFA : PUFA = 92.5 : 6.2 : 1.3, which is growing in popularity as functional food oil, is rich in medium chain fatty acids (MCFA) (Marina et al., 2009). The process to extract for EVCO is also known as the wet extraction method which is due to the fact that the oil retains more biologically active components (Nevin and Rajamohan, 2006). It may exhibit good digestibility, improve HDL cholesterol, slightly boost metabolism, and increase feeling of fullness (Assunção et al., 2009). Rice bran oil (RBO), fatty acid profile; SFA : MUFA : PUFA = 25.0 : 38.4 : 36.6, is one of the healthiest oil due to its nutrition including protein, vitamin B complex, vitamin E, vitamin K and γ-oryzanol (Tomita et al., 2014). It has been suggested to show biological and physiological abilities such as serum cholesterol lowering and anti-oxidation (Zigoneanu et al., 2008).

2.5 SENSORY EVALUATION TECHNIQUES

In this study, sensory evaluation techniques are used including food-elicited emotion, product information and purchase intention.

Food-elicited emotion is increasingly becoming critical for product differentiation as many products are produced with similar characteristics. The food related questionnaire that has attracted wide interest in the emotion is the EsSense Profile™, which contains a task for evaluating 39 emotion terms (King and Meiselman, 2010). Recent studies have investigated relationships between food sensory characteristics and emotion responses, such as dark chocolate (Thomson et al., 2010), chocolate and potato chips (Cardello et al., 2012), blackcurrant squashes (Ng et al., 2013) and hamburger (Olsen et al., 2014). It is questionable whether sensory acceptability or liking alone is a sufficient criterion for sale prediction (Jiang et al., 2014). Overall acceptability has limited predictive value, because emotions influence consumer preferences and choices depending on situation (Koster, 2003). It has been widely known that emotion elicited by products, services, and store atmosphere positively impact subsequent purchase intention (Kang et al., 2010).

Product information given to consumers can be used to improve food choices (Di-Monaco et al., 2005); however, consumers may respond differently depending on the given information (Tuorila et al., 1998). Nutritional information can serve as an instrument to positively influence healthier food choices (Barreiro-Hurlé et al., 2010). For spread products, nutritional benefit of oil had a significant effect on purchase intent (Bower et al., 2003; Garcia et al., 2009). Purchase intent for spread formulations increased significantly after consumers had been informed of the potential health benefits associated with product consumption with an average increase of up to 20% (Garcia et al., 2009). However, in some products such as soy bean oil, nutritional information did not influence purchase intent. Carneiro et al. (2005) noted that most consumers (classified as concerned with the environment and their health) were not affected by nutritional information when evaluating intention to purchase soybean oil.

CHAPTER III

MATERIALS AND METHODS

3.1 INFLUENCE OF HYDROCOLLOIDS ON THE BATTER PROPERTIES AND TEXTURAL KINETICS OF SPONGE CAKE DURING STORAGE

3.1.1 Sponge cake making procedure

The basic ingredients for sponge cake making were purchased from local market in Bangkok, Thailand as follows: cake wheat flour [8% protein] and emulsifier monoglycerides (UFM Food Centre Co., Ltd., Bangkok, Thailand), refined sugar (Thai Roong Ruang Energy Co., Ltd., Phetchaboon, Thailand), grade A large eggs (Charoen Pokphand Foods Public Co., Ltd., Bangkok, Thailand) and double acting baking powder (KCG Corporation Co., Ltd., Bangkok, Thailand). The HPMC, XG, AG and calcium propionate were supplied by Union Chemical 1986 Co., Ltd., Bangkok, Thailand.

Sponge cakes were prepared according to the recipe described by Zhang et al. (2012) with some modifications. The formula, based as the weight ratio with respect to the wheat flour weight, was: 200% fresh whole egg, 120% refined sugar, 4% baking powder, 4% emulsifier, and 0.2% calcium propionate. Sponge cake batter was supplemented with 0.0 (control), 0.5 or 1.0% (w/w wheat flour basis) of the respective hydrocolloid. A mixer (KPM5, Kitchen Aid, Benton Harbor, MI, USA) attached with wire whip was used to beat the whole egg, refined sugar and emulsifier at high speed (level 8) for 4 min to obtain foamy and formed stiff peaks. Then, the sifted flour and hydrocolloid were added and gently folded into the whipped batter at a low speed (level 2) for 2 min. The batter was measured for its density, apparent viscosity and subject to microscopic analysis of the air bubble size, shape and density.

After that, a portion of the batter (22.0 ± 2.0 g) was placed into a paper baking cup (5.5 cm diameter and 5 cm height) and baked at 200 ^{O}C for 25 min using electric oven (Modular electrical ovens, Salva, Lezo, Spain). The cakes were then left for 1 hour at room temperature to cool, removed from the cup and packed in a polyvinylidene chloride (PVDC) bag (13 cm width and 17 cm length) (Janjaras Chem Supply Co., Ltd., Bangkok, Thailand). The specific volume and moisture content of the fresh cakes were measured immediately, whilst the others were stored in incubator (ICP600, Memmert, Schwabach, Germany) at 15, 25, 35 or 45 ^{O}C with 35 ± 5% relative humidity (RH) for 0, 1, 4, 7, 14, 21 and 28 days before being measured for their texture.

3.1.2 Batter Quality Measurement

3.1.2.1 Density

An aliquot of the batter was filled into an aluminum cup (25 mL) immediately after removal from the mixer, leveled off using a rubber spatula and weighed. The batter density was calculated as the ratio of the batter weight (W1) to the distilled water weight (W2) filled in the same cup (Gomez et al., 2007). The density of the water (D2) was taken to be 0.997 g cm^{-3} at 25 ^{O}C (Venard and Street, 1975). The density was then calculated as (W1/W2) x D2. Measurements were made by triplicate.

3.1.2.2 Apparent viscosity

About 500 mL of batter was used for the viscosity measurement, monitored at 25 ^{O}C using a rotational viscometer (DV-II+, Brookfield-RVT, Middleboro, MA, USA) equipped with a LV No. 6 spindle head at the spindle rotational speed of 60 rpm. The reading of the viscometer output started 2 min after the experiment onset (Shyu and Sung, 2010). Results were the mean of 3 measurements.

3.1.2.3 Microscopic analysis

Digital image analysis of the air bubble was performed using the ImageJ software (ImageJ 1.47v, National Institutes of Health, Bethesda, MD, USA). A thin layer of freshly prepared batter was prepared immediately by placing a drop of the batter on a microscope slide and covering with a cover slip. The sample was observed under an optical microscope (ICS KF2, Zeiss, Oberkochen, Germany) using 10x magnification. A digital camera was mounted on the microscope for taking photographs (Chaiya and Pongsawatmanit, 2011). The bubble structure was recorded in terms of the number of bubbles per unit area (bubble density), mean bubble area (average bubble size) and bubble to total area ratio (bubble area fraction). A bubble was defined to be any resolved shape larger than 0.1 mm that could be approximately determined by human eyes (Pongjaruvat et al., 2014).

3.1.3 Cake Quality Measurement

3.1.3.1 Specific volume

The cake volume was measured using the sesame seed displacement method (Ereifej and Shibli, 1993). The cake sample was cut into 25 mm cubes and then one cube was weighed (Wo), placed in a container and the rest of the container volume was filled with sesame seed (V2). The volume of the empty container (V1) was measured by filling with sesame seed. Both V1 and V2 were later determined by a graduated cylinder and the difference between V1 and V2 was defined as the cake volume (Vo). The specific volume was then calculated as the ratio of the volume to weight (Vo/Wo). Measurements were made by triplicate.

3.1.3.2 Texture

Texture of sponge cake crumb was determined using a compression test according to AACC standard 74-09 method (AACC, 2000) and reported as firmness (N). A 5 cm diameter and 2 cm thick slice of cake was measured using texture analyzer (TA-XT2i Plus, Texture Technologies, Hamilton, MA, USA) with a cylinder probe of 100 mm diameter. The test speed was 2 mm s^{-1} and the strain was 40%. Results were the mean of 6 measurements.

3.1.3.3 Moisture

The crust was cut over the whole surface of the cake to a 10 mm depth, in order to separate the crumbs. The water content of the crumb was determined using a moisture analyzer (MB200, Ohaus, Parsippany, NJ, USA). Results were the mean of 3 measurements.

3.1.4 Kinetics Modeling of Texture

A general form of the reaction rate equation can be expressed as showed in Equation (1). The texture property, presented as the fraction of the firmness change (C), provides an accurate way to determine the extent of quality change at any given time (t) and can be expressed by Equation (2). In the current study, the Q_{∞} value was obtained by measuring the texture of the sponge cake after 28 day storage period.

The reaction order of the texture was determined graphically as described in Swinburne (1971). The best fitting line was decided by examining the coefficient of determination (R^2) (Lau et al., 2000). The rate constant *(k)* as temperature dependent was assumed to follow the Arrhenius equation as showed in Equation (3). For verification, all sponge cakes, except the control, were supplemented with one of the respective hydrocolloids at either 0.5 or 1.0% (w/w flour basis) as described above. Cakes were stored in incubator at 30 ^{O}C with 35 ± 5% RH for 1, 7, 14 and 21 days before textural analysis, and the results were compared to the theoretical values obtained from the respective kinetic rate model.

3.1.5 Optimization of hydrocolloid level

Sponge cakes were supplemented with the chosen hydrocolloid at 0, 0.25, 0.50, 0.75 and 1.00% (w/w flour basis) as described above. Cakes were stored at 15, 25, 35 or 45 ^{O}C with 35 ± 5% RH for 0, 1, 4, 7, 14, 21 and 28 days before textural analysis. The hydrocolloid level was optimized using Arrhenius equation.

3.1.6 Statistical analyses

A completely randomized design (CRD) was used in this study and the experiment was performed in three independent replications. Analysis of variance was performed to assess hydrocolloid effects on batter properties, cake properties and texture change of cake during storage and the means of results were compared by Duncan's multiple range tests (DMRT). The relationship between measured parameters was assessed by Pearson’s correlation test. The analyses were done using SPSS 11.5 software (SPSS Inc., Chicago, IL). Statistically significant difference was established at $P \leq 0.05$.

3.2 EFFECT OF DIFFERENT LIPIDS ON PHYSICOCHEMICAL PROPERTIES, CONSUMER PERCEPTION AND PURCHASE INTENT OF SPONGE CAKE

3.2.1 Sponge cake making procedure

The basic ingredients for sponge cake making were purchased from local market in Baton Rouge, LA, USA as follows: all-purpose wheat flour [10% protein], refined sugar, unsalted butter, virgin olive oil (Wal-Mart Stores, Inc., Bentonville, AR, USA), grade A large eggs (Cal-Maine Foods Inc., Jackson, MS, USA), double acting baking powder (Ach Food Companies, Inc., Memphis, TN, USA), virgin coconut oil (Better Body Foods, Lindon, UT, USA) and rice bran oil (Riceland Foods, Stuttgart, AR, USA). Emulsifier monoglycerides was provided by UFM Food Centre Co., Ltd., Bangkok, Thailand, and hydroxypropyl methyl cellulose (HPMC) and calcium propionate were provided by Union Chemical 1986 Co., Ltd., Bangkok, Thailand.

Sponge cakes were prepared according to the recipe described by Zhang et al. (2012) with some modifications. The formula, based as the weight ratio with respect to the wheat flour weight, was: 160% whole egg, 120% refined sugar, 40% water, 4% baking powder, 2% emulsifier, 0.5% HPMC and 0.2% calcium propionate. Sponge cake batter was added with 20% (w/w wheat flour basis) of the respective lipid, including liquid butter (control), virgin coconut oil, virgin olive oil and rice bran oil.

A mixer (SP5-MIXER5QT, Globe, Dayton, OH, USA) attached with wire whip was used to beat the whole egg, refined sugar and emulsifier at medium speed (level 6) for 2 min and high speed (level 8) for 2 min to obtain foamy and formed stiff peaks. The mixed flour was added and gently folded into the whipped batter at low speed (level 3) for 2 min and then lipid was added at low speed (level 3) for 2 min. After that, a portion of the batter (20 ± 2 g) was placed into a paper baking cup (5.5 cm diameter and 3 cm height) and baked at 200 ^{O}C for 15 min using electric oven (Pro-style, Jenn-air, Benton Harbor, MI, USA).

After that the cake was left for 1 hour at room temperature for cooling, packed in polyethylene bags (14.9 cm width and 16.5 cm length) (Wal-Mart Stores, Inc., Bentonville, AR, USA) and stored at room temperature (25 ± 5 ^{O}C). All cakes were prepared 1 day before the consumer test.

3.2.2 Measurement of physicochemical properties

Volume of sponge cake was determined by sesame seed displacement method (Ereifej and Shibli, 1993), and specific volume was calculated as [volume/weight, cm^3 g^{-1}]. Expansion ratio was calculated as [(final height - initial height)/ initial height] (Mohamed and Abdul-Hamid, 1998). Moisture content and water activity (a_w) of sponge cake crumb were evaluated using the AOAC method 945.14 (AOAC, 1990) and a_w meter (Hygrolab, Rotronic, Hauppauge, NY, USA), respectively. Crumb color was determined using a colorimeter (BC-10, Konica Minolta, Inc., Osaka, Japan) and reported as L*, a*, b*, Chroma, Hue angle and ΔE (using a sponge cake made with butter as a reference). Measurements were made by triplicate. The texture profile analysis (TPA) method was performed using a compression test according to the AACC standard 74-09 method (AACC, 2000) and reported as firmness (N), cohesiveness and springiness (%). Texture analyzer (TA-XT Plus Texture Analyzer, Texture Technologies, Hamilton, MA, USA) was equipped with a cylinder probe of 50.4 mm (2 inch) diameter, and the test speed was 2 mm s^{-1} and the strain was 40%. Results were the mean of 6 measurements. All physicochemical measurements were performed in two independent replications.

3.2.3 Consumer acceptance, emotion responses and purchase intent evaluation

The research protocol for use of human subjects for this study was approved (IRB# HE15-9) by the Louisiana State University Agricultural Center Institutional Review Board. Food-elicited emotion terms from the EsSense Profile® (King and Meiselman 2010) were screened for relevance to the sponge cake products using check-all-that-apply (CATA) questionnaire (n = 234; consumers who have consumed sponge cake products; 26.9% male and 73.1% female; between 18 and 64 year of age). Questionnaire was administered via a web link using an internet survey tool (Toluna QuickSurveys™; Toluna SAS, Levallois-Perret, France), and typically took 5-10 min to complete. Emotion terms selected by ≥ 20% of participants with some exceptions were chosen for the consumer study.

For a consumer test, consumers (n = 148; consumers who have consumed sponge cake products; 44.5% male and 55.5% female; 47.9% with 18-24 year, 49.4% with 25-54 year and 2.8% with 55 year or over) were recruited from a pool of faculty, staff, and students, Louisiana State University, Baton Rouge, LA. All sample evaluations were performed in partitioned sensory booths illuminated with cool, natural, fluorescent lights. The Compusense® *five* (Compusense Inc., Guelph, Canada) software was used for questionnaire development, and to collect the data. Prior to sample taste testing, all consumers were briefed on the questionnaire, particularly the sensory attributes and their meanings. They thoroughly read and electronically signed a consent form (Appendix A1) [screening criteria including (1) consume sponge cakes or similar products, (2) not allergic to cake ingredients and (3) over 18 years old]. Following the randomized complete block design (RCBD), each consumer was presented with 4 sponge cakes (cup shape; 5.5 cm diameter and 3 cm height) in a counterbalanced protocol. All samples were coded with 3-digit random numbers.

The consumers were instructed to evaluate acceptability of 9 attributes including appearance, crumb color, visual volume/smoothness, overall aroma, moistness, softness, overall texture, overall taste, and overall liking, all on a 9-point hedonic scale (1 = dislike extremely, 5 = neither like nor dislike, and 9 = like extremely). The Just-About-Right (JAR) scale (1 = not enough, 2 = just about right, JAR, and 3 = too much) was also used to evaluate moistness and softness (Stone and Sidel, 1993). Subsequently, they evaluated 8 emotion responses (presented in an alphabetical order) including *calm, good, guilty, happy, pleased, satisfied, unsafe* and *worried*, all on a 5-point scale (1 = not at all, 2 = slightly, 3 = moderately, 4 = very, and 5 = extremely) (King and Meiselman, 2010) and then evaluate purchase intent using a binomial (yes/ no) scale (Sae-Ew et al., 2007) (Appendix A2). Then, consumers were informed of the oil used and oil health benefit statement corresponding to each sample as follows: Extra virgin coconut oil may provide health benefit. It may improve good (HDL) cholesterol, slightly boost metabolism, increase feeling of fullness and serve as a safe source of energy. This sponge cake was made with Extra virgin coconut oil.; Extra virgin olive oil has been scientifically proven to have heart healthy effects. It may help increase good (HDL) cholesterol and lower bad (LDL) cholesterol. Thus, it may reduce the risk of cardiovascular diseases. This sponge cake was made with Extra virgin olive oil.; Rice bran oil is rich in vitamin E and some phytonutrients. It may help reduce bad cholesterol, and combat cancer and chronic diseases. This sponge cake was made with Rice bran oil. For the sponge cake made with butter, the statement “This product was made with butter” was provided to consumers. Subsequently, they were instructed to again evaluate overall liking, emotion responses and purchase intent of each sample. Unsalted plain crackers and water were provided to cleanse the palate between samples (Appendix A3). To avoid biases, consumers did not receive any monetary incentive.

3.2.4 Statistical analyses

The study used a completely randomized design (CRD) and analysis of variance was performed to determine whether differences existed among the 4 sponge cakes in terms of physicochemical properties, sensory acceptability and emotion responses. The Duncan's multiple range test (DMRT) was performed for posthoc multiple comparisons. Multivariate analysis of variance (MANOVA), principal component analysis (PCA), and descriptive discriminant analysis (DDA) were applied to identify attributes largely accounted for overall product differences among sponge cakes when all attributes were considered simultaneously. The JAR data were analyzed using the Stuart-Maxwell and McNemar's test (Fleiss and Everitt, 1971; Sae-Ew et al., 2007; Stone and Sidel, 1993). The two-related sample dependent t-test was used to determine significant differences in overall liking as well as emotion responses comparing before and after consumers had been given oil health benefit statement; likewise, the McNemar's test was applied to determine significance differences in purchase intent. Logistic regression was performed to identify sensory liking attributes and emotion terms that influenced purchase intent. The above mentioned analyses were done using SPSS 11.5 software (SPSS Inc., Chicago, IL, USA). The PCA biplot (sponge cakes, physicochemical properties, sensory acceptability and emotion responses) was carried out using XLstat2007 software (Addinsoft, Paris, France). Statistically significant difference was established at $P \leq 0.05$.

To simplify the text from this section onward, sponge cake made with butter, EVCO, EVOO and RBO will be referred to as Butter sponge cake, EVCO sponge cake, EVOO sponge cake and RBO sponge cake, respectively, where appropriate.

3.3 INFLUENCE OF HPMC AND EXTRA VIRGIN COCONUT OIL ON PHYSICOCHEMICAL PROPERTIES AND MICROSTRUCTURE OF SPONGE CAKE DURING STORAGE

3.3.1 Sponge cake making and storage

The basic ingredients for sponge cake making were purchased from local market in Bangkok, Thailand as follows: cake wheat flour [8% protein] and emulsifier monoglycerides (UFM Food Centre Co., Ltd., Bangkok, Thailand), refined sugar (Thai Roong Ruang Energy Co., Ltd., Phetchaboon, Thailand), grade A large eggs (Charoen Pokphand Foods Public Co., Ltd., Bangkok, Thailand), and double acting baking powder (KCG Corporation Co., Ltd., Bangkok, Thailand). Calcium propionate and HPMC were supplied by Union Chemical 1986 Co., Ltd., Bangkok, Thailand, and EVCO was supplied by Ampol Food Processing Ltd., Bangkok, Thailand.

Sponge cakes were prepared according to the recipe described by Zhang et al. (2012) with some modifications. The formula, based as the weight ratio with respect to the wheat flour weight, was: 200% fresh whole egg, 120% refined sugar, 20% water, 4% baking powder, 4% emulsifier, and 0.2% calcium propionate This study used a 2 x 2 factorial design, manipulating the absence/presence of 0.5% HPMC and the absence/presence of 20% EVCO.

A mixer (KPM5, Kitchen Aid, Benton Harbor, MI, USA) attached with wire whip was used to beat the whole egg, refined sugar and emulsifier at high speed (level 8) for 4 min to obtain foamy and formed stiff peaks. The mixed flour-HPMC (in case of HPMC treatment) was added and gently folded into the whipped batter at low speed (level 2) for 2 min and then EVCO (in case of EVCO treatment) was added at low speed (level 2) for 2 min. After that, a portion of the batter (22.0 ± 2.0 g) was placed into a paper baking cup (5.5 cm diameter and 5 cm height) and baked at 200 ^{O}C for 20 min using electric oven (EB-20, Kluaynamthai Tow Op, Bangkok, Thailand). The cakes were then left for 1 hour at room temperature to cool and packed in a polyvinylidene chloride (PVDC) bag (13 cm width and 17 cm length) (Janjaras Chem Supply Co., Ltd., Bangkok, Thailand). The specific volume, expansion ratio and crumb color of the fresh cakes were measured immediately, whilst the others were stored at 30 ^{O}C with 60 ± 5% relative humidity (RH) for 0, 1, 4, 7, 14, 21 and 28 day before being measured for their properties.

3.3.2 Physicochemical properties measurement of fresh cakes

Volume of sponge cake was determined by sesame seed displacement method (Ereifej and Shibli, 1993), specific volume was calculated as volume/ weight (cm^3 g^{-1}). Expansion ratio was calculated by (final height - initial height)/ initial height (Mohamed and Abdul-Hamid, 1998). Crumb color was determined in triplicate using a spectrophotometer (CR-400, Konica Minolta, Inc., Osaka, Japan) and reported as L*, a*, b*. Water activity (a_w) was measured by an instrument using the chilled-mirror dew point technique (Series 3 TE, AquaLab, Pullman, WA, USA). All determinations were performed in triplicate.

3.3.3 Measurement of cakes during storage

3.3.3.1 Firmness

Texture of sponge cake crumb was determined using a compression test according to AACC standard 74-09 method (AACC, 2000) and reported as firmness (N). A 5 cm diameter and 2 cm thick slice of cake was measured using texture analyzer (TA-XT2i, Texture Technologies, Hamilton, MA, USA) with a cylinder probe of 100 mm diameter. The test speed was 2 mm s^{-1} and the strain was 40%. Results were the mean of 6 measurements.

3.3.3.2 Moisture

The crust was cut over the whole surface of sponge cake, at 10 mm deep, in order to separate the crumb. Water contents of crust and crumb were determined by moisture analyzer (HB43-S, Mettler Toledo International, Inc., Greifensee, Switzerland). Measurements were made by triplicate.

3.3.3.3 NMR Relaxation Time

A nuclear magnetic resonance spectrophotometer (Fourier 300, Bruker, Madison, WI, USA), operating at 300 MHz, was used for the measurement of the longitudinal relaxation time (T_1, ms) of a proton via a multinuclear 5 mm probe. A piece of sponge cake (5 mm diameter, 40 mm height) was fitted into a 5 mm NMR tube and all measurements were performed at a constant temperature (25 ^{O}C). The T_1 value was measured using the inversion-recovery method (Sritongtae et al., 2011).

3.3.3.4 X-ray diffraction pattern

Sponge cake crumb was dried in a convection forced air oven at 35 ^{O}C, up to 12–14% of moisture content. The drying temperature was selected so as to avoid annealing effects (Aguirre et al., 2011). The XRD patterns of sponge cake crumb during storage were obtained through X-ray diffractometer (D8, Bruker, Madison, WI, USA) equipped with a monochromator that selects the K_{α} radiation from a copper target generated under 40 kV and 40 mA, by using Diffrac plus XRD Commander software (Bruker, Madison, WI, USA). Patterns were recorded from a diffraction angle (2θ) of 10 to 30^{O} at 0.02^{O} intervals with a rate of 0.5^{O}/min. The crumb samples were then passed through a 0.85 mm sieve. The crystallinity of each peak, mainly at 17^{O} and 20^{O}, was measured following the whole diffractogram using Graph 4.4.2 software (GNU General Public, Copenhagen, Denmark). The Avrami equation was used in the modelling of the crystallization data as showed in Equation (9).

3.3.4 Statistical analyses

A 2 x 2 factorial design was used and the experiment was performed in three independent replications. Analysis of variance was performed to assess the effect of HPMC and EVCO on cake properties and texture and moisture change of cake during storage. The means of results were compared by Duncan's multiple range tests (DMRT). The analyses were done using SPSS 11.5 software (SPSS Inc., Chicago, IL, USA). Statistically significant difference was established at $P \leq 0.05$.

CHAPTER IV
RESULTS AND DISCUSSION

4.1 INFLUENCE OF HYDROCOLLOIDS ON THE BATTER PROPERTIES AND TEXTURAL KINETICS OF SPONGE CAKE DURING STORAGE

4.1.1 Quality of batter and sponge cake with different hydrocolloids

The addition of XG and AG at either 0.5 or 1.0 (w/w) significantly increased the batter density ($P \leq 0.05$) with XG causing a higher density (1.33- and 1.16-fold greater at 1% (w/w) XG than the control and 1% (w/w) AG containing samples, respectively), whilst the slight numerical increase with the addition of HPMC at either concentration was not significant (Table 1).

Table 1 Effect of hydrocolloids on characteristics of batter and sponge cake

Sample	Batter		Cake		
	Density ($g\ cm^{-3}$)	Viscosity (Pa s)	Specific volume ($cm^3\ g^{-1}$)	Crumb moisture (%)	Firmness (N)
Control	0.49 ± 0.02 c	8.71 ± 0.10 e	5.84 ± 0.06 a	29.76 ± 1.58 c	1.90 ± 0.17 b
0.5 HPMC	0.50 ± 0.01 c	10.54 ± 0.09 d	5.76 ± 0.11 ab	33.89 ± 1.73 b	1.64 ± 0.09 c
1.0 HPMC	0.51 ± 0.01 c	12.59 ± 0.57 c	5.65 ± 0.12 ab	37.41 ± 1.14 a	1.74 ± 0.12 c
0.5 XG	0.63 ± 0.02 a	15.27 ± 0.18 b	4.66 ± 0.12 c	35.72 ± 1.06 ab	3.88 ± 0.33 a
1.0 XG	0.65 ± 0.01 a	18.49 ± 0.09 a	4.34 ± 0.11 d	37.88 ± 0.95 a	3.86 ± 0.73 a
0.5 AG	0.56 ± 0.04 b	10.49 ± 0.84 d	5.78 ± 0.11 a	33.46 ± 1.51 b	1.77 ± 0.30 c
1.0 AG	0.57 ± 0.02 b	12.52 ± 0.13 c	5.54 ± 0.17 b	36.56 ± 1.74 a	2.15 ± 0.45 b

Data are showed as the mean ± 1 SD, derived from three replicates. Means within a column followed by different letters are significantly different ($P \leq 0.05$).

The batter viscosity was also increased with a dose and type of hydrocolloid, the latter being in the order of XG > HPMC ≈ AG. The water absorption property of the hydrocolloids has been attributed to their hydroxyl groups that allows more water interactions through hydrogen bonding (Guarda et al., 2004). Thus, the increased water absorption of the batter may be due to the hydrophilic nature of the added hydrocolloids. Note that XG is a very high molecular weight with the rigidity of polysaccharide side chains (Chen and Sheppard, 1980).

The effect of hydrocolloid addition on the bubble features of the batter are summarized in Table 2. The addition of HPMC and especially AG at either 0.5 or 1.0% (w/w) significantly (~1.3- and 1.5- to 1.6-fold for HPMC and AG, respectively) increased the bubble density ($P \leq 0.05$) while XG caused an insignificant decrease ($P > 0.05$) in the bubble density. The addition of any of the three hydrocolloids significantly decreased the mean bubble size in the batter, particularly the addition of XG or AG (~2.2- to 2.4-fold). A high proportion of medium sized bubbles were observed in the control and 0.5% (w/w) HPMC containing samples (Figure 11 a and b) due to the low batter viscosity, whereas the batters with a higher viscosity showed a large number of smaller sized bubbles with a nonuniform appearance. The nonuniform appearance was expected to represent evidence of coalescence where two or more bubbles had merged to form a larger bubble during the aeration stage before baking (Irene et al., 2006) and might affect the appearance of the baked cake. Moreover, the addition of the hydrocolloids decreased the bubble area fraction (Table 2), especially those of the inclusion of XG (3.0- to 3.4-fold). The increase in the batter density and viscosity could be directly related to the decreased bubble area fraction. A higher viscosity of the batter would cause less air incorporation during the batter mixing (Gomez et al., 2007).

Table 2 Effect of hydrocolloids on the bubble features in the cake batter

Sample	Bubble density (# bubble cm^{-2})	Mean bubble size (mm^2)	Bubble area fraction (%)
Control	67 ± 19 c	0.22 ± 0.05 a	14.47 ± 1.54 a
0.5 HPMC	85 ± 2 b	0.13 ± 0.01 b	10.99 ± 0.79 b
1.0 HPMC	87 ± 3 b	0.11 ± 0.02 bc	9.49 ± 1.89 b
0.5 XG	56 ± 6 c	0.09 ± 0.01 bc	4.82 ± 0.65 c
1.0 XG	57 ± 11 c	0.08 ± 0.02 c	4.25 ± 0.74 c
0.5 AG	110 ± 7 a	0.08 ± 0.01 c	8.97 ± 0.82 b
1.0 AG	100 ± 1 a	0.10 ± 0.02 bc	9.68 ± 2.02 b

Data are showed as the mean ± 1 SD, derived from three replicates. Means within a column followed by different letters are significantly different ($P \leq 0.05$).

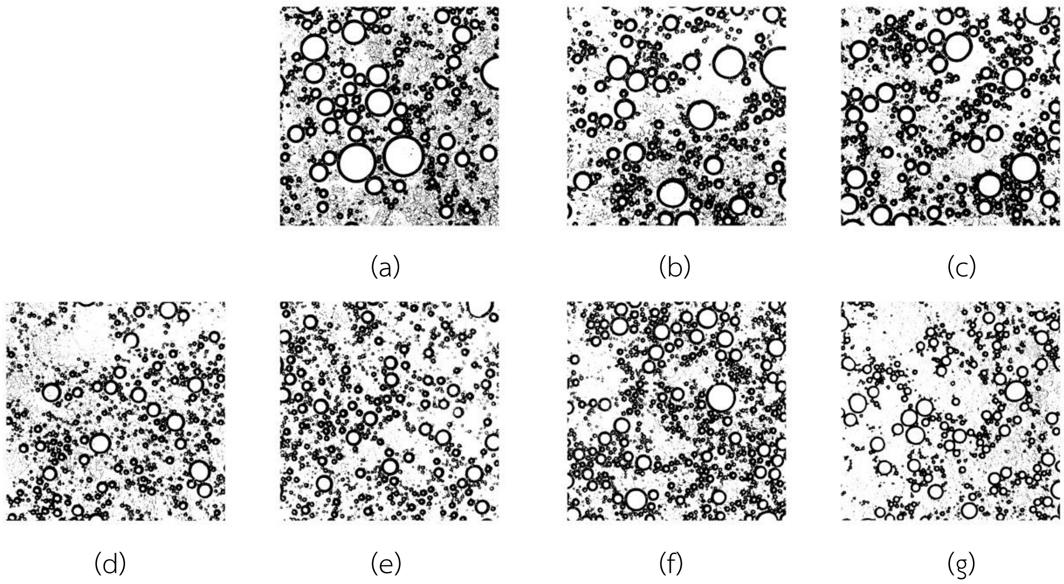


Figure 11 Microscopy images of aerated sponge cake batters (10x magnification) with different hydrocolloids: (a) control, (b) 0.5% (w/w) HPMC, (c) 1.0% (w/w) HPMC, (d) 0.5% (w/w) XG, (e) 1.0% (w/w) XG, (f) 0.5% (w/w) AG and (g) 1.0% (w/w) AG. Images showed are representative of those seen from at least 5 such fields of view per sample and 2 independent samples.

The baked sponge cake was analyzed for its specific volume, crumb moisture content and initial firmness (Table 1). The sponge cakes without any hydrocolloid addition had the highest specific volume (5.84 cm^3 g^{-1}), while those with 0.5 and 1.0% (w/w) XG had a significantly lower value than other conditions. The addition of 1.0% but not 0.5% (w/w) AG also caused a significantly lower cake specific volume, but to a lesser magnitude (1.05-fold less than the control). The hydrocolloid addition led to a lower cake volume than that in the control agrees with that previously reported by Young and Bayfield (1963). The influence of hydrocolloids on cake volumes can be explained by the increase in observed batter viscosity that slows down the rate of gas diffusion and allows its retention during the early stage of baking (Shi and BeMiller, 2002). As already mentioned, the sponge cake with 1.0% (w/w) XG had the lowest specific volume, with a decrease of 25.7% compared to the control, which reflects the lower amount of air that remained in the final product (Chaiya and Pongsawatmanit, 2011).

Furthermore, the addition of 0.5% or 1.0% (w/w) HPMC significantly decreased the initial firmness of the sponge cake ($P \leq 0.05$), whereas XG at both 0.5 and 1.0% (w/w) significantly increased the initial firmness of the sponge cake ($P \leq 0.05$), and AG had no significant effect. This could be directly related to the batter density and viscosity. The crumb moisture content of the sponge cakes was significantly and dose-dependently increased with the addition of the hydrocolloids ($P \leq 0.05$). The greatest effect was found in the samples added with 1 % (w/w) AG. The increased crumb moisture content might reflect the ability of hydrocolloids to retain more water (Barcenas and Rosell, 2006), depending on their chemical structure and their interaction with the other ingredients (Gomez et al., 2007).

The quality attributes of sponge cakes affected by the addition of hydrocolloids exhibited definite Pearson's correlation (Table 3). A high correlation between batter density and viscosity was observed. The correlation matrix shows that both density and viscosity were negatively correlated with bubble size, bubble area and specific volume ($P \leq 0.01$) and directly correlated with moisture and firmness. These relationships were already demonstrated by Gomez et al. (2010). It was also observed that as the bubble area fraction increased, specific volume increased. This could be explained by higher air retention in batter led to a higher specific volume of the cake product (Gomez et al., 2008).

Table 3 Coefficients of Pearson's correlation between quality attributes of batter and sponge cake

	Viscosity	Bubble density	Bubble size	Bubble area	Specific volume	Moisture	Firmness
Batter							
Density	0.84**	-	-0.59**	-0.84**	-0.86**	0.46*	0.86**
Viscosity		-0.49*	-0.60**	-0.86**	-0.94**	0.73**	0.80**
Bubble density				-	0.64**	-	-0.69**
Bubble size				0.73**	0.46*	-0.70**	-
Bubble area					0.81**	-0.67**	-0.79**
Cake							
Specific volume						-0.51*	-0.89**
Moisture							-

* Correlation is significant at the 0.05 level, ** Correlation is significant at the 0.01 level.

- Correlation is not significant at the 0.05 level

4.1.2 Textural kinetics of sponge cake with different hydrocolloids

From the zero, first and second order plots of the firmness change over time of the sponge cakes at various temperatures (Figure 12 for the first order), the coefficients of determination are summarized in Table 4 (firmness data were showed in the appendix B1). Considering each type and level of hydrocolloid and storage temperature, the first order reaction model had the highest R^2 value in all cases. Thus, the firmness change of sponge cakes over time could best be described by a first order reaction model. The textural change of the cakes could be affected by many factors such as water transfer and solubility of colloids (Gomez et al., 2010).

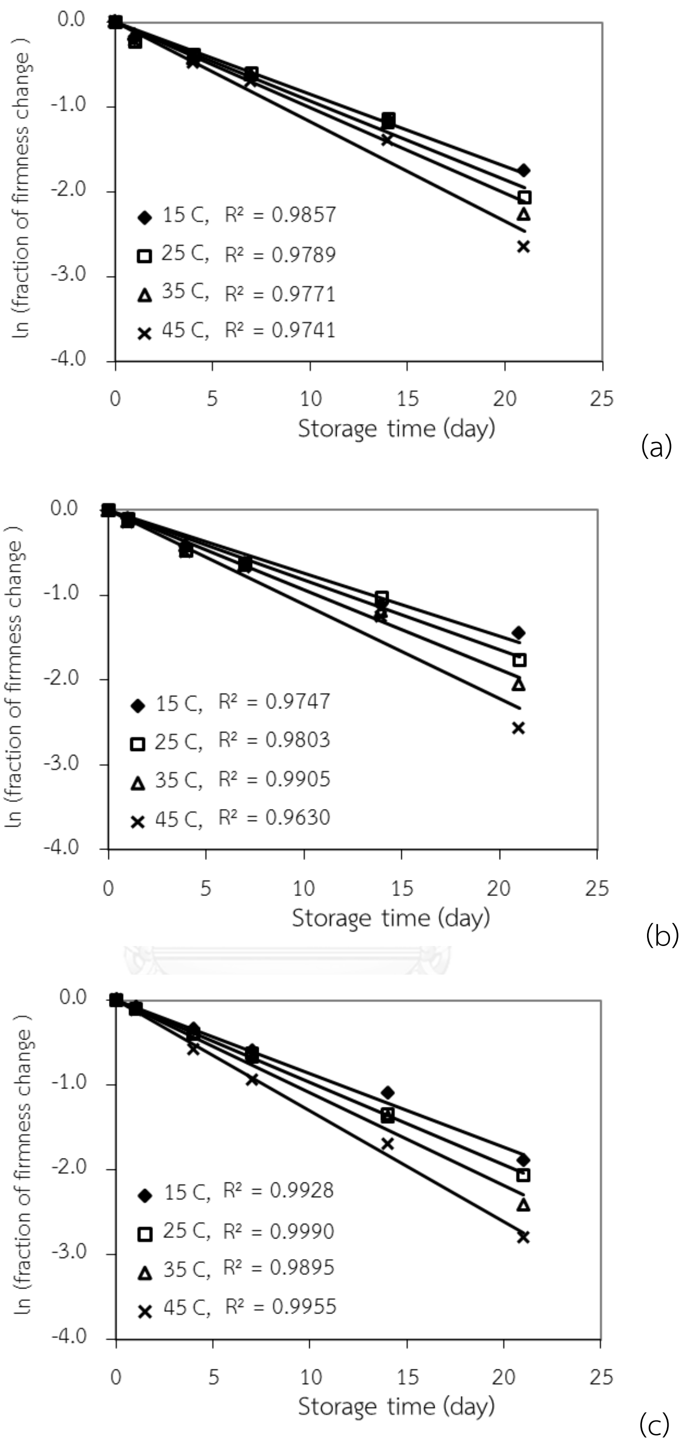
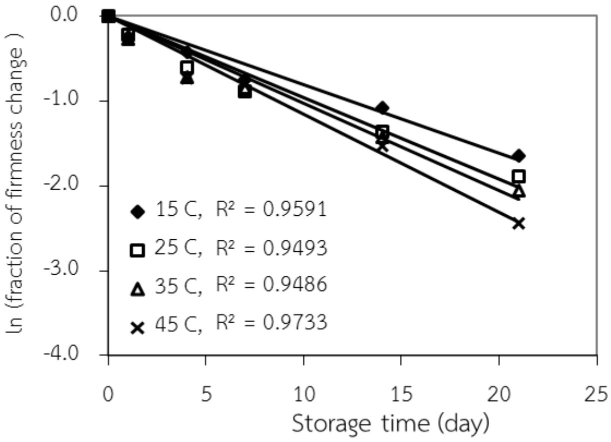
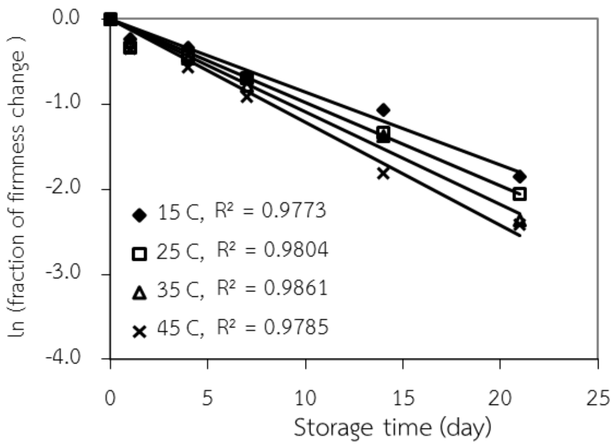


Figure 12 The first order plot (ln c *vs*. time) for cakes with the inclusion of different hydrocolloids: (a) control, (b) 0.5% HPMC, and (c) 1.0% HPMC. Data are showed as the means with the best fit regression line and corresponding correlation coefficient

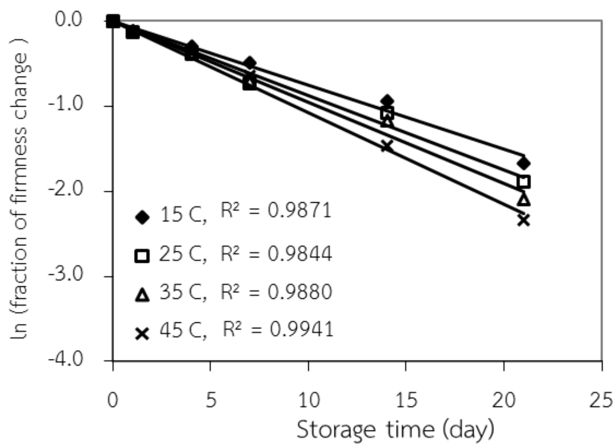


(d)

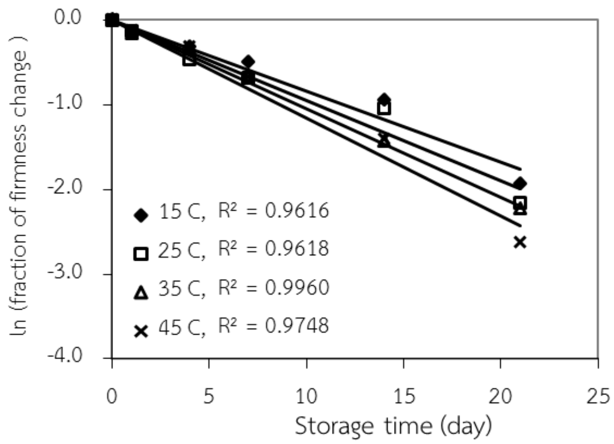


(e)

Figure 12 (cont'd) The first order plot (ln c *vs*. time) for cakes with the inclusion of different hydrocolloids: (d) 0.5% XG, and (e) 1.0% XG. Data are showed as the means with the best fit regression line and corresponding correlation coefficient



(f)



(g)

Figure 12 (cont'd) The first order plot (ln c *vs*. time) for cakes with the inclusion of different hydrocolloids: (f) 0.5% AG and (g) 1.0% AG. Data are showed as the means with the best fit regression line and corresponding correlation coefficient

Table 4 Coefficient of determination of the zero, first and second order rate constant of the change in sponge cake texture

Sample	Storage temperature (^{O}C)	zero order, C *vs.* time	first order ln C *vs.* time	second order 1/C *vs.* time
Control	15	0.7993	0.9857	0.9628
	25	0.8620	0.9789	0.8234
	35	0.8845	0.9771	0.7508
	45	0.8301	0.9741	0.7416
0.5 HPMC	15	0.8316	0.9747	0.9628
	25	0.8382	0.9803	0.8234
	35	0.8822	0.9905	0.7508
	45	0.8755	0.9630	0.7416
1.0 HPMC	15	0.9191	0.9928	0.8732
	25	0.8961	0.9990	0.8968
	35	0.9085	0.9895	0.8157
	45	0.7816	0.9955	0.8157
0.5 XG	15	0.7279	0.9591	0.9628
	25	0.6513	0.9493	0.8234
	35	0.5941	0.9486	0.7508
	45	0.6497	0.9733	0.7416
1.0 XG	15	0.8235	0.9773	0.8838
	25	0.7399	0.9804	0.9014
	35	0.7789	0.9861	0.8376
	45	0.6444	0.9785	0.9306
0.5 AG	15	0.9456	0.9871	0.9628
	25	0.8600	0.9844	0.8234
	35	0.8810	0.9880	0.7508
	45	0.9072	0.9941	0.7416
1.0 AG	15	0.9351	0.9616	0.8019
	25	0.8593	0.9618	0.7923
	35	0.8931	0.9960	0.8743
	45	0.9286	0.9748	0.7685

The firmness change rate constant at various storage temperatures and the *Ea* of the sponge cakes are summarized in Table 5. The *k* values of all samples increased with increasing storage temperature, in agreement with that reported before that the rate of change in the sponge cake firmness was limited at lower temperatures (Guinot and Mathlouthi, 1991). The kinetics data of each hydrocolloid was then analyzed separately, and revealed that the inclusion of XG, which gave the highest initial firmness, did not show any significant effect on the *k* and *Ea* values. This may be due to the higher level of XG in baked product. Chaiya et al. (2015) reported that the sponge cake formulation with desired physical properties and sensory quality was found to be only 0.10–0.11% XG. In contrast, the *k* values of sponge cakes with 0.5% (w/w) HPMC or AG was lower than the control at lower temperature (15 and 25 ^{O}C) (Table 5), while *k* values at 35 and 45 ^{O}C were not significantly different ($P > 0.05$). These results are similar to Baik et al. (1997), showing that the greatest firmness rate are followed by faster propagation recrystallization of starch gel at 40 °C.

The Arrhenius equation accurately described the temperature dependence of the reaction rate constants, and could be used to correlate the reaction rate constant in these cakes over the typical temperature ranges associated with preservation and storage of food products. The Arrhenius plot (ln *k* vs. 1/T) of the firmness change with time (Figure 13) shows that the *Ea* ranged from 8.32 to11.23 kJ mol^{-1} (Table 4), with the *Ea* of the cakes without any hydrocolloid (control) being lower than the sponge cakes with the inclusion of a hydrocolloid, indicating a lower temperature dependence of the firmness indices.

Table 5 Kinetics information for the change in texture of sponge cakes at different storage temperatures

Sample†	k_{15C} (day^{-1})	k_{25C} (day^{-1})	k_{35C} (day^{-1})	k_{45C} (day^{-1})	Ea (kJ mol^{-1})
HPMC					
0	0.0853 ±0.0089 a	0.0935 ±0.0098 a	0.1013 ±0.0102 b	0.1204 ±0.0031 ab	8.45
0.5	0.0748 ±0.0048 b	0.0829 ±0.0059 b	0.0986 ±0.0214 b	0.1156 ±0.0212 b	11.23
1.0	0.0876 ±0.0027 a	0.0971 ±0.0035 a	0.1115 ±0.0078 a	0.1340 ±0.0207 a	10.71
XG					
0	0.0853 ±0.0089	0.0935 ±0.0098	0.1013 ±0.0102	0.1204 ±0.0031	8.45
0.5	0.0831 ±0.0157	0.1016 ±0.0235	0.1041 ±0.0159	0.1203 ±0.0150	8.65
1.0	0.0883 ±0.0210	0.0992 ±0.0177	0.1106 ±0.0218	0.1265 ±0.0288	9.01
AG					
0	0.0853 ±0.0089 a	0.0935 ±0.0098 a	0.1013 ±0.0102	0.1204 ±0.0031	8.45
0.5	0.0757 ±0.0061 b	0.0878 ±0.0060 b	0.0975 ±0.0109	0.1087 ±0.0059	9.08
1.0	0.0850 ±0.0109 a	0.0952 ±0.0079 a	0.1057 ±0.0191	0.1182 ±0.0215	8.32

k_{XC} is the rate constant (k) at the indicated temperature in ^{O}C (subscript 15, 25, 35 or 45 ^{O}C) Data are showed as the mean ± 1 SD, derived from three replicates. Means within a column of each hydrocolloid followed by different letters are significantly different (P ≤ 0.05). † Means within a row at various temperatures of each hydrocolloid and levels are significantly different (P ≤ 0.05).

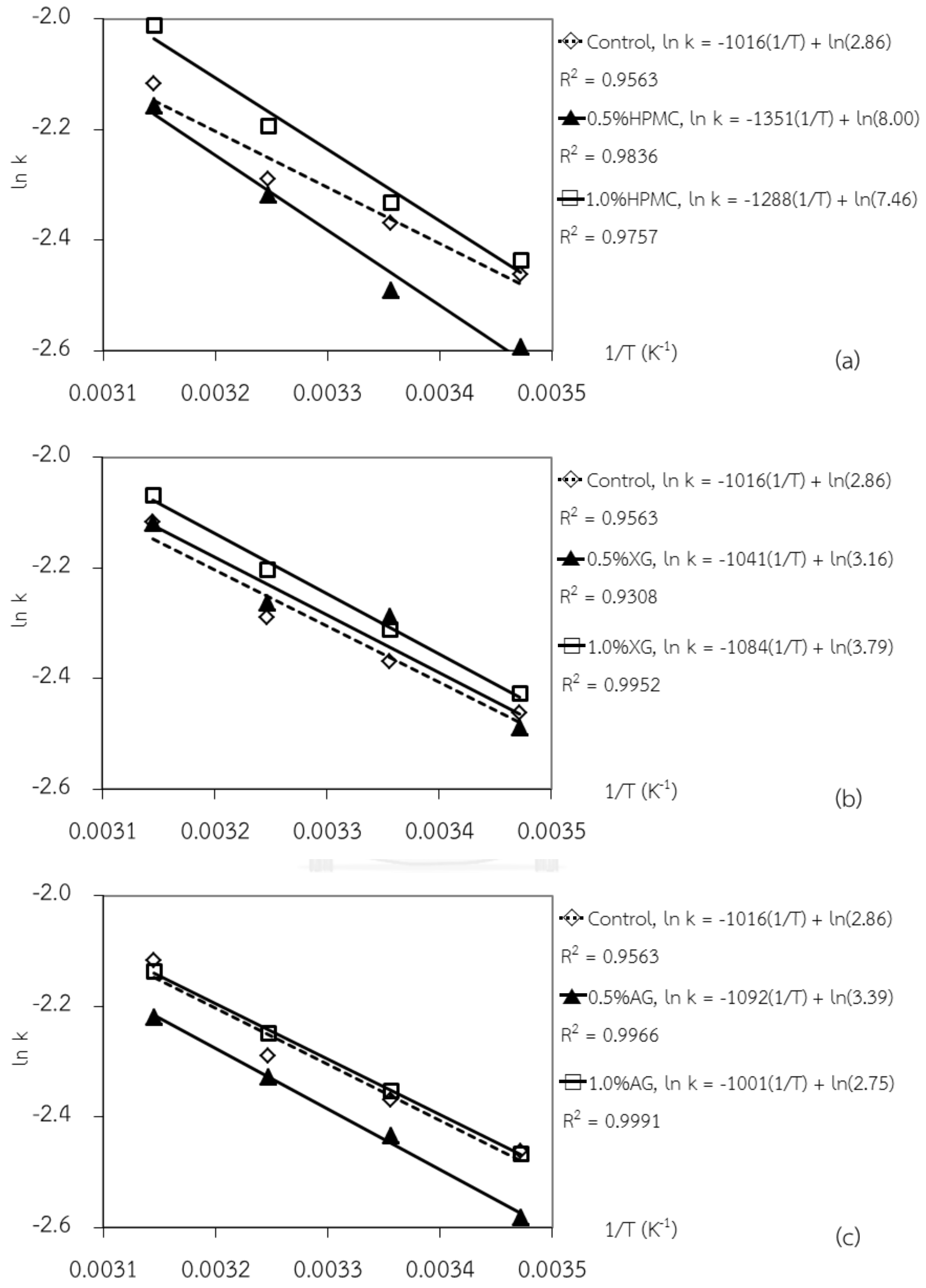


Figure 13 Arrhenius plot of the rate of change in the firmness of sponge cakes with different hydrocolloids: (a) HPMC, (b) XG and (c) AG.
Data are showed as the means with the best fit regression line, equation and corresponding correlation coefficient

From the *Ea* data, it was found that the inclusion of 1.0% (w/w) HPMC or 0.5% (w/w) AG could moderately retard the rate of firmness change whilst 0.5% (w/w) HPMC gave the best antistaling effect (highest *Ea* value of 11.23 kJ mol^{-1}). The different effect of the respective hydrocolloids on the sponge cake firmness change might be explained by the interactions between the respective hydrocolloid and the starch that affect its retrogradation. In the case of the inclusion of HPMC, the highest *Ea* value obtained was potentially due to the inhibition of amylopectin retrogradation, since HPMC preferably bound to starch (Collar et al., 2001).

The improving effect of 0.5% (w/w) HPMC inclusion on the cake texture has been reported previously by other researchers (Gomez et al., 2008). The HPMC network formed during baking could act as barrier to gas diffusion, decreasing the water vapor loss, and so increasing the softness of the bread (Rosell et al., 2001). However, the addition of HPMC at 1.0% (w/w) affected the viscosity of batter, which played an important role during the mixing step. A higher batter viscosity led to an inadequate aeration resulting in poorer appearance and higher moisture of the resultant sponge cake. Moreover, Heflich (1996) stated that hydrocolloids can make the baked crumb rubbery and elastic. The crumb may be perceived as softer or fresher at sufficiently low levels of gums, and also as tough at elevated levels of hydrocolloids.

From the experimental verification of the theoretical results using the order kinetic model, the difference between the experimental firmness values and those predicted using the first order were found to be less than 5% (Table 6).

Table 6 Verification of the first order rate model for the change in cake firmness during storage at 30 ^{O}C

Sample	Storage time (day)	Predicted firmness (N)	Experiment firmness (N)	Difference (%)
Control	1	2.77	3.00 ± 0.20	2.02
	7	6.51	6.32 ± 0.26	0.73
	14	8.80	8.86 ± 0.07	0.17
	21	9.94	9.61 ± 0.13	0.84
0.5 HPMC	1	2.28	2.31 ± 0.26	0.36
	7	5.10	5.72 ± 0.23	2.85
	14	6.91	6.44 ± 0.26	1.77
	21	7.86	7.88 ± 0.20	0.07
1.0 HPMC	1	2.50	2.96 ± 0.32	4.21
	7	5.72	5.78 ± 0.42	0.25
	14	7.61	7.81 ± 0.25	0.65
	21	8.50	8.44 ± 0.19	0.17
0.5 XG	1	5.02	5.21 ± 0.41	0.94
	7	9.89	9.27 ± 0.31	1.62
	14	12.83	12.31 ± 0.22	1.03
	21	14.27	14.42 ± 0.25	0.27
1.0 XG	1	5.16	5.64 ± 0.31	2.21
	7	10.62	10.27 ± 0.34	0.83
	14	13.84	13.65 ± 0.49	0.35
	21	15.38	15.45 ± 0.31	0.12
0.5 AG	1	2.48	2.64 ± 0.12	1.56
	7	5.61	5.84 ± 0.12	1.02
	14	7.62	7.71 ± 0.39	0.28
	21	8.68	8.94 ± 0.37	0.75
1.0 AG	1	2.99	3.40 ± 0.32	3.23
	7	6.59	6.71 ± 0.48	0.46
	14	8.78	8.69 ± 0.50	0.25
	21	9.86	9.71 ± 0.33	0.37

Data are showed as the mean ± 1 SD, derived from three replicates.

4.1.3 Optimization of HPMC level

From the results, HPMC was chosen as a hydrocolloid for this part according to the better effect to retard the firmness change of sponge cake during storage. As mentioned above, the firmness change of sponge cakes over time could best be described by a first-order reaction model. The firmness change rate constant at different storage temperatures and the *Ea* of the sponge cakes supplemented with various levels of HPMC are summarized in Table 7. The *k* value of all samples increased with increasing storage temperature, in agreement with Guinot and Mathlouthi (1991), as previous described.

Table 7 The first rate order kinetics reaction rate constants of firmness change of sponge cakes with various levels of HPMC at different storage temperatures

HPMC (%) †	k_{15C} (day^{-1})	k_{25C} (day^{-1})	k_{35C} (day^{-1})	k_{45C} (day^{-1})	*Ea* (kJ mol^{-1})
0	0.0853 ±0.0089 ab	0.0935 ±0.0098 ab	0.1013 ±0.0102	0.1204 ±0.0031	8.45
0.25	0.0786 ±0.0028 ab	0.0937 ±0.0086 ab	0.1050 ±0.0063	0.1194 ±0.0078	10.43
0.50	0.0748 ±0.0048 b	0.0829 ±0.0059 b	0.0986 ±0.0214	0.1156 ±0.0212	11.23
0.75	0.0783 ±0.0066 ab	0.0878 ±0.0058 ab	0.0999 ±0.0121	0.1171 ±0.0216	10.15
1.00	0.0876 ±0.0027 a	0.0971 ±0.0035 a	0.1115 ±0.0078	0.1340 ±0.0207	10.71

k_{XC} is the rate constant *(k)* at the indicated temperature in ^{O}C (subscript 15, 25, 35 or 45 ^{O}C) Data are showed as the mean ± 1 SD, derived from three replicates. Means within a column followed by different letters are significantly different (P ≤ 0.05). † Means within a row at various temperatures of each level are significantly different (P ≤ 0.05).

HPMC level affected *k* value of samples at lower temperature (15 and 25 ^{O}C), while *k* value at 35^{O}C and 45^{O}C were not significantly different (P > 0.05), ranging from 0.0986 to 0.1115 day^{-1} and from 0.1156 to 0.1340 day^{-1} (Table 7), respectively. For sponge cakes stored at 15 ^{O}C and 25 ^{O}C, it was found that *k* values decreased with increasing the level of HPMC from 0 to 0.5% (w/w), inversely when level of HPMC over than 0.5%, *k* value increased with increasing the level of HPMC. The rates of change in the firmness of sponge cakes with various level of HPMC were plotted, according to the Arrhenius equation (Figure 14) with high R^2 (0.95 - 0.99). However, for HPMC level ranging from 0 - 1.0% (w/w), it was showed that 0.5% (w/w) HPMC gave the highest *Ea* value of 11.23 kJ mol^{-1}. Therefore, it can be conclude that 0.5% HPMC is a practical level to add in sponge cake to retard the firmness change during storage.

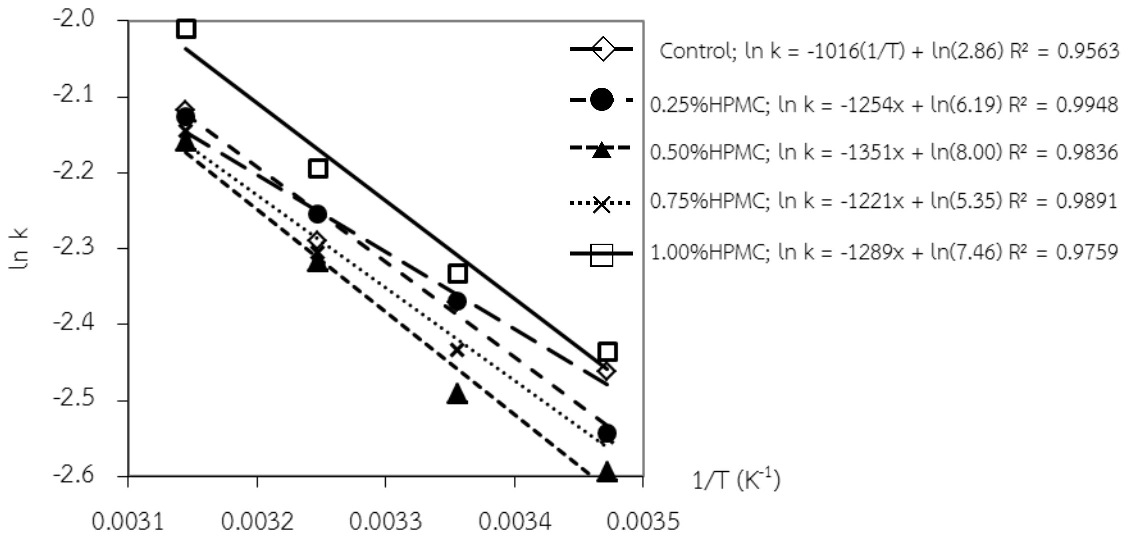


Figure 14 Arrhenius plot of the rate of change in the firmness of sponge cakes with various level of HPMC

4.2 EFFECT OF DIFFERENT LIPIDS ON PHYSICOCHEMICAL PROPERTIES, CONSUMER PERCEPTION AND PURCHASE INTENT OF SPONGE CAKE

4.2.1 Online selection of consumer emotion terms

A total of 26 out of 39 emotion terms which were selected by ≥ 5% of participants (n = 234) are showed in Figure 15. Eight emotion (7 positive and 1 negative) terms with frequency > 20% were *satisfied, happy, good, pleased, pleasant, joyful, calm* and *guilty*. Only 5 positive terms: *satisfied, happy, good, pleased* and *calm* were chosen; *pleasant* and *joyful* may be perceived as similarly as *pleased* and *happy*, respectively, so they were omitted. *Guilty* was chosen and it was the only negative emotion term with frequency >20%. *Unsafe* (7.1%) and *worried* (5.3%), which might be related to consumption of cake (Kuijer and Boyce, 2014), were also chosen as negative emotion terms for subsequent consumer testing.

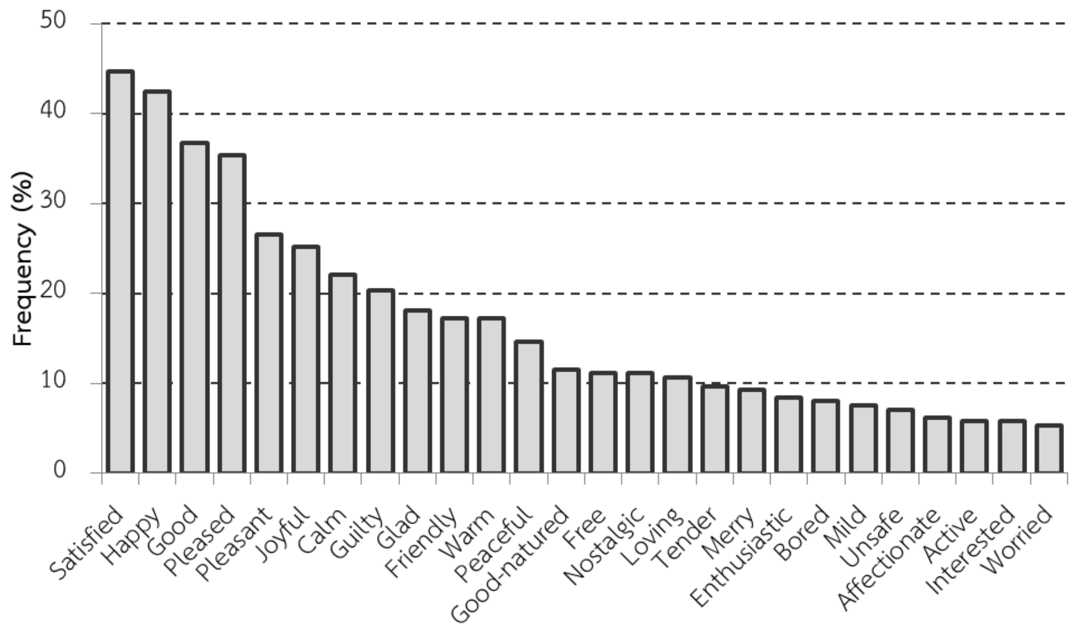


Figure 15 Emotion terms elicited by sponge cake obtained from N = 234 consumer responses. Terms with < 5% frequency count were not showed.

4.2.2 Effects of oil type on sensory liking and some physicochemical properties

Overall, EVCO sponge cake had liking scores ≥ 5.7 for all sensory attributes. It was most liked with an overall liking score of 6.0 compared with Butter, EVOO and/or RBO sponge cakes (scores 4.9 - 5.4; Table 8). Appearance and crumb color liking scores had a similar pattern. EVCO or Butter sponge cakes had slightly higher scores than EVOO or RBO sponge cakes (6.3 - 6.7 vs 6.0 - 6.4). Compared with EVCO sponge cake, the lower crumb color liking scores for EVOO or RBO sponge cakes were likely due to slightly darker color (L* 82.0 vs. 77.18 - 80.28; Table 9). A total color difference (ΔE) value of 2.3 implies "just noticeable difference" by human eyes (Sharma, 2003). The ΔE values for EVOO or RBO sponge cakes (2.90 - 5.87) were higher than 2.3, which may have also contributed to the observed lower color liking scores. Visual volume/smoothness liking scores of all sponge cakes ranged from 5.9 to 6.5. Compared with EVCO sponge cake, the RBO sponge cake had significantly lower specific volume (3.55 vs. 2.94 cm^3/g) and expansion ratio (0.67 vs. 0.49) (Table 9), which may partially contributed to a lower liking score for visual volume /smoothness (6.5 vs. 6.1; Table 8). The influence of appearance on acceptance is variable, may not be relevant for some consumers (Moskowitz and Krieger, 1995), and ultimately may not be a primary driver of liking (Li et al., 2015). In this study, the type of oils used in the sponge cake formulation affected liking scores of appearance, crumb color and visual volume/smoothness but did not make these attribute unacceptable (all scores ≥ 5.9).

Regarding overall aroma and taste, liking scores ranged from 5.4 to 6.4 for Butter or EVCO sponge cakes and from 4.9 to 5.5 for EVOO and RBO sponge cakes. The green-fruity notes contribute significantly to EVOO aroma (Matsakidou et al., 2010; Olias et al., 1993), while RBO imparts off-flavor when used at high temperatures (Nanua et al., 2000); this likely led to the observed lower liking scores of overall aroma and taste. The texture-related (moistness, softness and overall texture) liking scores for sponge cakes showed a similar pattern, in which lower scores were observed with those made with EVOO or RBO (4.9 - 5.1) compared with those made with EVCO or Butter (5.4 - 6.1; Table 8). This observation could be explained by physical texture measurements (Table 9) and JAR data (Figure 16). RBO vs. EVCO sponge cakes had the highest (12.76 N) vs. the lowest (6.61 N) firmness values from the TPA test (Table 9).

For softness JAR analysis (Figure 16), consumers indicated that EVCO sponge cake was softer than RBO sponge cake, which substantiated the finding from the TPA firmness values (Table 9). Consumers also indicated that moistness of EVCO sponge cake was not different from that of Butter sponge cake (a critical χ^2 value = 5.99, df = 2 at α = 0.05), but both Butter and EVCO sponge cakes were softer than EVOO and RBO sponge cakes (Figure 16). The lower liking scores for texture related attributes likely contributed to the lower overall liking score of RBO sponge cake (Table 8), which was in agreement with that previously reported by Sae-Ew et al. (2007). Based on Tables 8 and 9 and Figure 16, it was obvious that the type of oils affected sensory liking and physicochemical properties of sponge cakes. EVOO and RBO tended to decrease liking scores, and this negative effect was more pronounced for aroma, taste and texture-related attributes than for appearance-related attributes.

Table 8 Mean consumer acceptability scores and purchase intent of sponge cakes made with different lipids

Attribute	Butter	EVCO	EVOO	RBO
Appearance	6.3 ± 1.8 ab	6.6 ± 1.6 a	6.0 ± 1.7 b	6.2 ± 1.7 b
Crumb color	6.6 ± 1.6 a	6.7 ± 1.4 a	6.2 ± 1.6 b	6.4 ± 1.6 ab
Visual volume/smoothness	6.4 ± 1.9 ab	6.5 ± 1.6 a	5.9 ± 1.6 c	6.1 ± 1.7 bc
Overall aroma	6.0 ± 1.9 a	6.4 ± 1.8 a	5.5 ± 1.9 b	5.3 ± 1.9 b
Moistness	5.8 ± 2.1 a	6.1 ± 1.9 a	5.1 ± 2.1 b	5.1 ± 2.1 b
Softness	5.4 ± 2.1 a	5.7 ± 1.8 a	5.1 ± 1.9 ab	4.9 ± 1.9 b
Overall texture	5.5 ± 1.9 ab	5.7 ± 1.9 a	5.1 ± 1.8 bc	5.0 ± 1.8 c
Overall taste	5.4 ± 2.0 b	5.8 ± 2.0 a	5.0 ± 1.9 bc	4.9 ± 2.1 c
Overall liking				
Before	5.4 ± 2.0 b	6.0 ± 1.9 a	5.0 ± 2.1 bc	4.9 ± 2.1 c
After	5.5 ± 1.9 b	6.6 ± 1.9 a*	5.5 ± 1.9 b*	5.3 ± 2.1 b*
Purchase intent (%)				
Before	57.4	66.0	43.2	40.5
After	53.7	74.0 *	59.2 *	49.0 *

Data are showed as the mean ± 1 SD from 148 responses based on a 9-point hedonic scale, derived from two replicates. Means within a row followed by different letters are significantly different ($P \leq 0.05$).

Overall liking and purchase intent were obtained from both before and after consumers had gained information about health benefits of lipids.

*Indicates significant differences of overall liking based on the dependent samples t-test and purchase intent based on the McNemar's test ($P \leq 0.05$) before and after.

Table 9 Physicochemical properties of sponge cakes made with different lipids

	Butter	EVCO	EVOO	RBO
Specific volume (cm^3/g)	3.35 ± 0.16 a	3.55 ± 0.16 a	3.37 ± 0.30 a	2.94 ± 0.10 b
Expansion ratio	0.63 ± 0.06 a	0.67 ± 0.04 a	0.62 ± 0.02 a	0.49 ± 0.09 b
Moisture (%)	28.30 ± 0.18 a	28.62 ± 0.19 a	29.26 ± 1.06 a	26.61 ± 0.51 b
Water activity	0.847 ± 0.002 b	0.853 ± 0.003 a	0.856 ± 0.002 a	0.846 ± 0.001 b
Crumb color				
L*	83.0 ± 2.41 a	82.0 ± 1.12 a	80.28 ± 3.95 ab	77.18 ± 0.53 b
a*	-0.40 ± 0.36	-0.60 ± 0.22	-0.50 ± 0.12	-0.73 ± 0.17
b*	18.98 ± 2.16	17.25 ± 1.57	18.07 ± 1.86	18.55 ± 0.41
Chroma	18.98 ± 2.15	17.26 ± 1.58	18.08 ± 1.86	18.56 ± 0.41
Hue (^{o})	91.30 ± 1.22	91.97 ± 0.65	91.60 ± 0.39	92.24 ± 0.55
ΔE	-	2.13 ± 0.65 b	2.90 ± 0.66 b	5.87 ± 0.08 a
Texture profiles				
Firmness (N)	9.69 ± 0.03 b	6.61 ± 0.08 d	8.01 ± 0.05 c	12.76 ± 0.05 a
Cohesiveness	0.79 ± 0.07	0.80 ± 0.08	0.80 ± 0.08	0.80 ± 0.08
Springiness (%)	94.98 ± 2.30	97.05 ± 2.75	96.44 ± 3.64	93.10 ± 4.93

Data are showed as the mean ± 1 SD, derived from two replicates. Means within a row followed by different letters are significantly different ($P \leq 0.05$).

Color difference (ΔE: CIE76) based on sponge cake made with butter; ΔE > 2.3 corresponds to just noticeable difference (Sharma, 2003) (-) indicates not determined

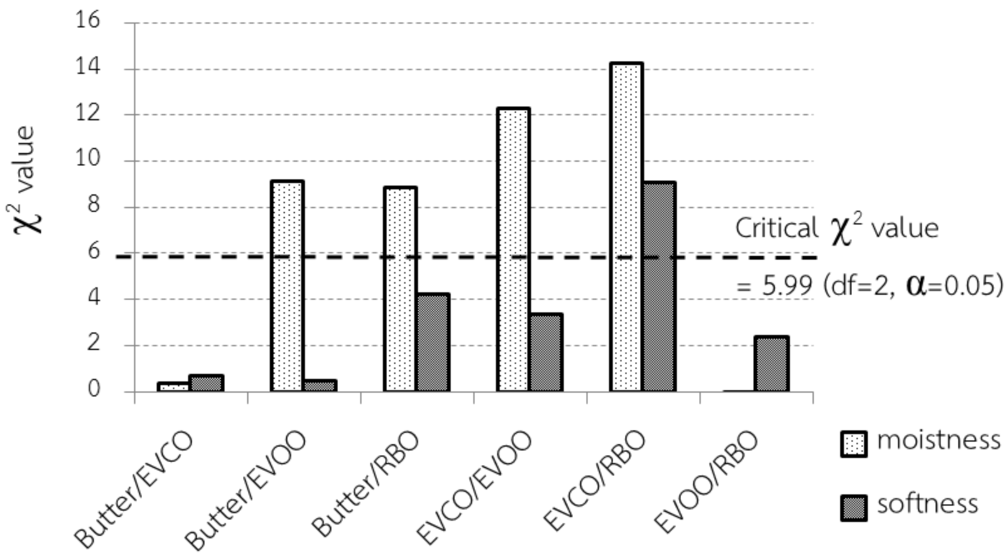


Figure 16 Pairwise comparisons of moistness and/or softness of sponge cakes using the McNemar's test. EVCO = extra virgin coconut oil; EVOO = extra virgin olive oil; RBO = rice bran oil.

Bars above the dash line indicate significant differences in moistness or softness between a pair of sponge cakes with the former product being more moist and/or softer than the former product.

4.2.3 Effects of oil type and oil health benefit statement on overall liking and purchase intent

The oil health benefit statement given to consumers significantly affected the overall liking scores; a significant increase was observed for EVCO (from 6.0 to 6.6), EVOO (5.0 to 5.5) and RBO (4.9 to 5.3) sponge cakes (Table 8). EVCO remained the most liked product. There were no differences in overall liking scores among Butter, EVOO and RBO sponge cakes (5.3 - 5.5). Positive purchase intent of EVCO sponge cake was highest and significantly increased (based on the McNemar's test; $P \leq 0.05$) from 66% to 74% after consumers had been informed of EVCO health benefits. The largest increase in positive purchase intent was observed (16%; from 43.2% to 59.2%) when the health benefit statement of EVOO was given to consumers. It is known that extrinsic factors such as packaging and product information are of importance for initial purchase intent (Li et al., 2015). Purchase intent significantly increased for mayonnaise-type spread made with RBO after consumers had been informed of the potential health benefits associated with product consumption (Garcia et al., 2009). Purchase intent of RBO sponge cake was lowest (40.5%) which was likely caused by undesirable taste, softness, and overall liking (all with scores of 4.9; Table 8); however, an increase by 8.5% (to 49%) was observed after RBO health benefits was given to consumers. After having been informed that butter was used in the formulation without stating any negative health effects, 53.7% of consumers indicated positive purchase intent (a slight decrease, but not significant, from 57.4%). More in-depth research is needed to evaluate consumer perception toward butter in food formulations.

4.2.4 Effects of oil type and oil health benefit statement on consumer emotional responses

Mean consumer emotion scores of sponge cakes made with difference oils are presented in Table 10. On a 5-point rating scale, the magnitude of positive emotion scores (2.5 - 3.3 and 2.7 - 3.5, respectively, before and after oil health benefit statements provided to consumers) were greater than the corresponding negative emotion scores (1.4 - 1.9 and 1.3 - 2.2) (Table 10). This pattern is of typical as also reported by several studies (Cardello et al., 2012; King and Meiselman, 2010; King et al., 2010, 2013; Wardy et al., 2015). To date, no research work has been done to evaluate effects of oil type and oil health benefit statement on emotional responses.

For positive emotion and before oil health benefit statements given to consumers, EVCO sponge cake had emotion scores comparable with those of Butter sponge cake (except *pleased;* a higher score for the former). However, a significantly higher score (0.5-0.7 units) for all positive emotion terms was observed for EVCO compared with Butter sponge cakes after oil health benefit statements given to consumers (Table 10 and Figure 17). Compared with EVOO and RBO sponge cakes, EVCO sponge cake had significantly higher positive emotion scores with the magnitude of the differences being 0.4 - 0.6 units, regardless of the oil health benefit statements (except *calm*). For Butter sponge cake, the positive emotion intensity scores decreased by 0.1 - 0.2 units after consumers were informed that butter was used in the formulation even without stating any negative health benefit. Contrarily, after health benefit statements of EVCO, EVOO and RBO were given to consumers, positive emotional intensity scores increased. However, while most of these observed increases were significant ($P \leq 0.05$), an increase of ≥ 0.3 units was observed for *happy* and *pleased* (both from 3.1 to 3.4) for EVCO and *pleased* (from 2.5 to 2.8) for EVOO, but none was observed for RBO sponge cakes. King et al. (2013) indicated that the mean emotional difference of ≤ 0.2 units (on a 5-pont intensity scale), while significantly different statistically, may be of less practical in value. Hence, the oil type and oil health benefit statements had a significant impact on consumer positive emotions elicited by sponge cakes.

For all negative emotion terms, there were no significant differences in emotion intensity scores across all sponge cakes before additional oil and health benefit information had been given to consumers. However, after consumers had been informed of such additional information, all negative emotion scores for Butter sponge cake were significantly higher than those of EVCO, EVOO and RBO sponge cakes, with the mean difference between 0.3-0.6 units (Table 10 and Figure 17). In addition, the *guilty* intensity score of Butter sponge cake was highest (2.2) among negative emotion terms across products. For Butter sponge cake, emotion intensity scores significantly increased for all negative emotion terms after consumers had been informed of butter in the formulation, but the mean differences ≥ 0.3 units were observed for *guilty* and *unsafe*, but not for *worried*. The oil health benefit information of EVCO, EVOO and RBO positively affected the negative emotion terms, i.e., decreased their intensity scores, but the magnitude of these decreases was ≤ 0.2 units (Table 10). Overall, it could be concluded that the oil type and oil health benefit statements affected positive emotion more than negative emotion.

Table 10 Mean consumer emotion scores of sponge cakes made with different lipids

Attribute		Butter	EVCO	EVOO	RBO
Calm	Before	3.0 ± 1.1	3.2 ± 1.2	3.0 ± 1.1	2.9 ± 1.0
	After	2.9 ± 1.1 b	3.4 ± 1.2 a*	3.0 ± 1.1 b	3.0 ± 1.1 b
Good	Before	3.1 ± 1.1 a	3.3 ± 1.1 a	2.8 ± 1.0 b	2.8 ± 1.1 b
	After	2.9 ± 1.1 b*	3.5 ± 1.2 a*	3.0 ± 1.1 b*	3.0 ± 1.2 b
Happy	Before	2.9 ± 1.2 ab	3.1 ± 1.2 a	2.6 ± 1.1 c	2.7 ± 1.1 bc
	After	2.8 ± 1.2 b	3.4 ± 1.1 a*	2.8 ± 1.2 b*	2.8 ± 1.1 b
Pleased	Before	2.8 ± 1.2 b	3.1 ± 1.2 a	2.5 ± 1.1 c	2.6 ± 1.2 bc
	After	2.7 ± 1.2 b*	3.4 ± 1.2 a*	2.8 ± 1.2 b*	2.8 ± 1.2 b*
Satisfied	Before	2.8 ± 1.2 a	3.0 ± 1.2 a	2.5 ± 1.1 b	2.5 ± 1.2 b
	After	2.7 ± 1.2 b*	3.2 ± 1.3 a*	2.7 ± 1.2 b*	2.7 ± 1.2 b*
Guilty	Before	1.8 ± 1.0	1.9 ± 1.1	1.7 ± 1.0	1.8 ± 1.0
	After	2.2 ± 1.2 a*	1.8 ± 1.1 b*	1.6 ± 0.9 b	1.6 ± 0.9 b*
Unsafe	Before	1.4 ± 0.8	1.5 ± 1.0	1.4 ± 0.8	1.5 ± 0.9
	After	1.7 ± 1.1 a*	1.3 ± 0.8 b*	1.3 ± 0.7 b*	1.3 ± 0.8 b*
Worried	Before	1.5 ± 0.9	1.5 ± 0.9	1.4 ± 0.8	1.5 ± 0.9
	After	1.7 ± 1.1 a*	1.4 ± 0.8 b	1.3 ± 0.7 b*	1.4 ± 0.8 b*

Data are showed as the mean ± 1 SD from 148 responses based on a 5-point emotion, derived from two replicates. Means within a row followed by different letters are significantly different (P ≤ 0.05).

Emotion score was obtained from both before and after consumers had gained information about health benefits of lipids.

*Indicates significant differences based on the dependent samples t-test (P ≤ 0.05).

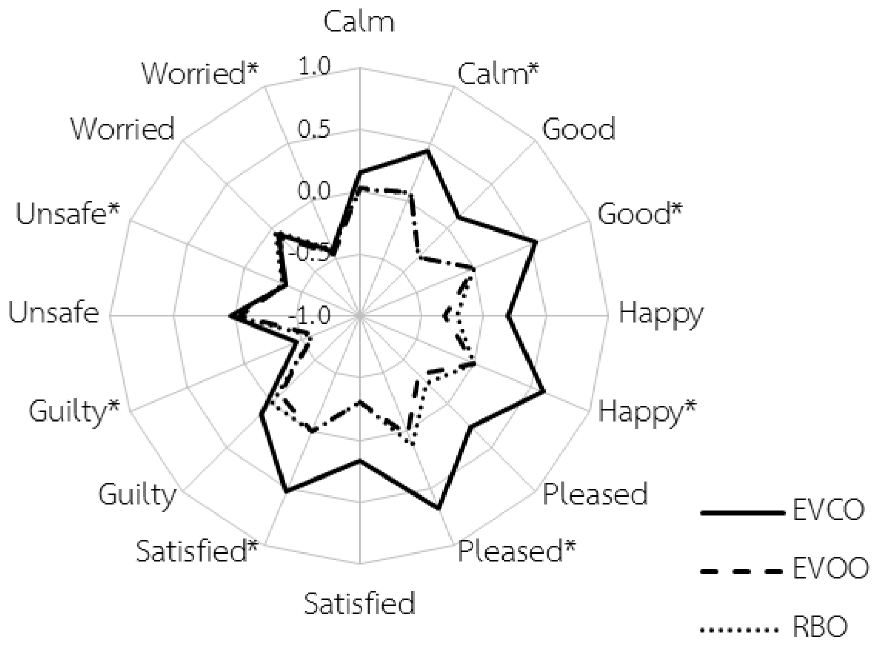


Figure 17 Comparison of mean emotion responses elicited by sponge cakes made with healthy oils. The emotional responses for sponge cake made with butter were used as a baseline.

* indicated emotion responses after consumers had been given information about oil type and oil health benefits. EVCO = extra virgin coconut oil; EVOO = extra virgin olive oil; RBO = rice bran oil.

4.2.5 Overall product differences and discriminating sensory and emotion attributes

To determine further which attributes were largely responsible for overall product differences, MANOVA and DDA were performed (Table 11). From the MANOVA Wilks' *P* values, all sponge cakes were overall different based on sensory acceptability attributes alone ($P < 0.0001$), emotional attributes alone ($P < 0.0001$), or all combined attributes ($P < 0.0001$). When considering only sensory acceptability attributes, overall liking (canonical correlation, cc = 0.68 - 0.79), overall aroma and taste (cc = 0.60 - 0.70), texture-related attributes (cc = 0.40 - 0.68) contributed more toward the overall differences among sponge cakes than appearance-related attributes (cc = 0.37 - 0.41) in the 1st canonical dimension (Can 1) with 64.1% variance explained. This substantiated the results from Table 8 in that the type of oils affected sensory liking of 4 sponge cakes, and the effect was more pronounced for overall liking, overall aroma and taste, and texture-related attributes [a range of the mean difference between the highest and the lowest scores for each attribute = 0.7 - 1.3] than appearance-related attributes [0.5 - 0.6]. Oil health benefit statements increased overall liking scores (before vs. after = 6.0 vs. 6.6, Table 8), and hence its increased contribution to overall product differences as reflected by an increased canonical correlation from 0.689 to 0.794 (Table 11).

When considering only emotion attributes, after oil health benefit statements were given to consumers, the magnitude (disregarding +/- sign) of canonical correlation increased for all emotion terms; however, the negative emotion terms (cc = 0.384 - 0.481) contributed more than positive emotion terms (cc = 0.194 - 0.273) to the overall product differences. DDA identified *guilty, worried* and *unsafe* terms as the 3 most discriminating attributes in the 1st canonical dimension (Can 1) with 72.7% variance explained (Table 11). Likewise, when considering all attributes simultaneously, DDA identified negative *guilty, worried* and *unsafe* terms as the 3 most discriminating attributes in the 1st canonical dimension (Can 1) with 56.8% variance explained (Table 11). Can 2, which was orthogonal to Can 1, added 34.2% more variance explained. Based on Can 2, the attributes that had canonical correlation ≥ 0.5 included overall liking, moistness, overall aroma, overall taste, *happy* (after), and *pleased*. Furthermore, appearance-related attributes generally contributed less to the overall product differences compared with other sensory attributes; likewise *calm* contributed less than other positive emotion terms.

The PCA biplot (Figure 18) revealed the relationship between 4 sponge cake products and physicochemical and sensory and emotion attributes. The first two components (PC1 and PC2) explained 83.16% of the cumulative variance. As can be seen, a group of positive emotions (*calm, good, happy, pleased* and *satisfied*) was positioned closely to overall liking with a positive correlation ($r > 0.8$; data not showed). Another group of negative emotions (*unsafe*, *worried and guilty,*) positioned farther away from the positive emotion group. From visual observation, 3 groups of sponge cakes were observed: I (EVCO), II (EVOO and RBO) and III (BUTTER). EVCO sponge cake located in the same quadrant (PC1) with the positive emotion term group and overall liking, and hence was characterized by these attributes. Butter sponge cake positioned closer to the negative emotion term group, which was coincided with results from Table 10. RBO sponge cake positioned farthest away from EVCO sponge cake mainly due to positive emotion scores (Table 10) and instrumental firmness values (Table 9). Implications of the results from Table 10 and Figure 18 must be made with caution because the purpose of DDA and PCA here was to identify sensory acceptability, emotion attributes, physicochemical properties that accounted for product differences, rather than to identify those attributes that influenced purchase intent as also pointed out by Prinyawiwatkul and Chompreeda (2007)

Table 11 Canonical structure r's describing group difference among sponge cakes made with different lipids

Attribute		Can 1		Can 2		Can 3	
Acceptability			Com		Com		Com
Appearance		0.414*	-0.022	0.188	0.367	-0.409	-0.182
Crumb color		0.378*	0.084	0.369	0.350	-0.078	-0.099
Visual volume/smoothness		0.387	0.069	0.391	0.382	-0.362	-0.190
Overall aroma		0.704*	0.006	0.218	0.601	0.201	0.227
Moistness		0.684*	0.078	0.446	0.624	-0.083	-0.026
Softness		0.502*	0.005	0.150	0.412	0.355	0.259
Overall texture		0.400*	0.025	0.156	0.346	0.284	0.189
Overall taste		0.600*	-0.036	0.122	0.500	0.150	0.175
Overall liking	Before	0.689*	-0.043	0.116	0.569	0.149	0.179
	After	0.794*	-0.244	-0.311	0.619	-0.046	0.276
Cumulative variance explained		64.1		91.7		100.0	
MANOVA Wilks'		<0.0001		0.036		0.531	
Emotion							
Calm	Before	-0.019	0.005	0.324	0.210	-0.208	0.201
	After	-0.220	-0.194	0.443	0.301	-0.252	0.220
Good	Before	0.053	0.032	0.635	0.439	-0.050	0.029
	After	-0.253	-0.279	0.642	0.435	-0.382	0.219
Happy	Before	0.020	-0.002	0.669	0.451	0.041	-0.003
	After	-0.218	-0.235	0.806	0.555	-0.168	0.054
Pleased	Before	0.007	-0.028	0.757	0.519	0.003	-0.067
	After	-0.273	-0.292	0.754	0.518	-0.148	0.037
Satisfied	Before	0.049	0.010	0.683	0.465	-0.047	0.041
	After	-0.194	-0.219	0.658	0.456	-0.281	0.126
Guilty	Before	-0.034	-0.044	0.166	0.155	0.154	-0.135
	After	0.481*	0.411*	0.310	0.286	-0.159	0.076
Unsafe	Before	-0.036	-0.092	0.128	0.101	0.215	-0.079
	After	0.384*	0.302*	0.099	0.096	0.162	-0.003
Worried	Before	0.052	0.019	0.031	0.054	0.241	-0.104
	After	0.429*	0.356*	0.150	0.133	0.199	-0.049
Cumulative variance explained		72.7	56.8	95.0	91.0	100.0	100.0
MANOVA Wilks'		<0.0001	<0.0001	0.023	0.001	0.844	0.763

Based on the pooled within group variances calculated separately using acceptability and/or emotion responses and Com column based on the pooled within group variances of all combined attributes. Can 1, 2, and 3 refer to the 1st, 2nd, and 3rd canonical discriminant functions, respectively.

* Indicated attributes that accounted for the group differences in 1st dimension.

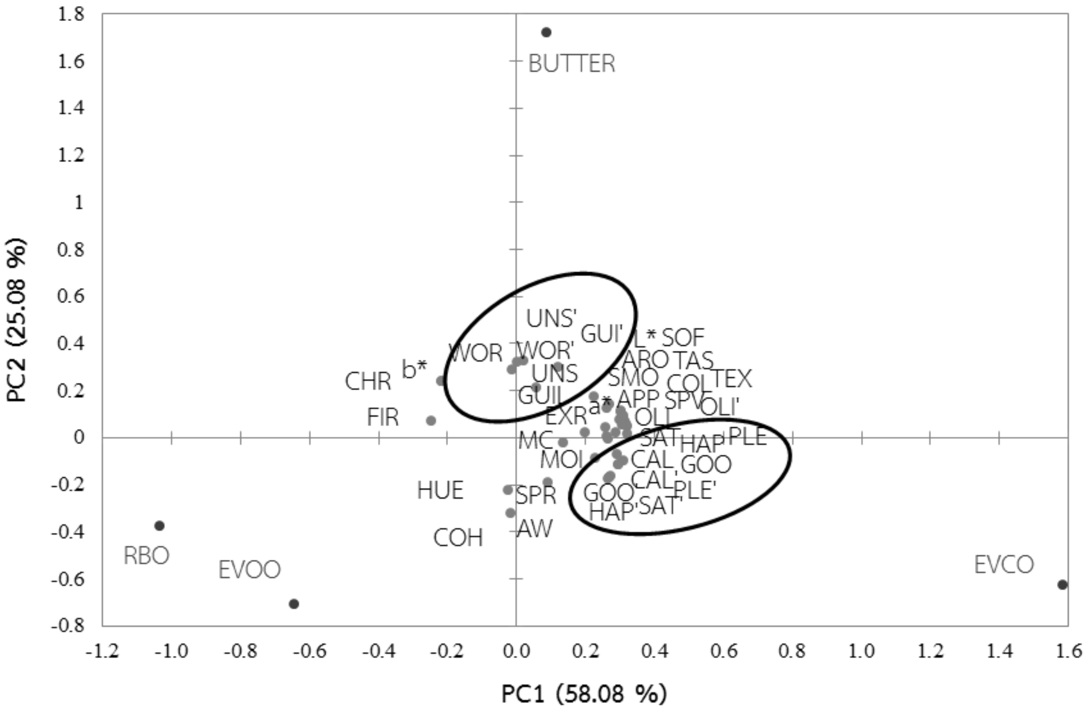


Figure 18 A biplot of the principle component (PC) 1 and 2 visualizing between sponge cakes made with different lipids and physicochemical properties, sensory attributes and emotion responses;

SPV = specific volume, EXR = expansion ratio, MC = moisture content, AW = water activity, L* a* b* CHR HUE = instrument color value, FIR = firmness, COH = cohesiveness, SPR = springiness, APP = appearance, COL = crumb color, SMO = visual volume/ smoothness, ARO = overall aroma, MOI = moistness, SOF = softness, TEX = overall texture, TAS = overall taste OLI = overall liking, CAL = calm, GOO = good, GUI = guilty, HAP = happy, PLE = pleased, SAT = satisfied, UNS = unsafe, WOR = worried. ’ indicated emotion responses after consumers had gained information about health benefits of lipids. EVCO = extra virgin coconut oil, EVOO = extra virgin olive oil and RBO = rice bran oil.

4.2.6 Predicting purchase intent using logistic regression analysis

In this study, the probability of the sponge cake products to be purchased was modeled using logistic regression analysis (LRA). For logical comparison, only those attributes, that were evaluated both before and after the oil type and oil health benefit statement had been given to consumers, were included in the LRA model (Table 12).

Overall, overall liking and only 3 positive emotion terms (*calm, happy* and *pleased*) were significant in the LRA models (Table 12). Both *calm* and *happy* became insignificant predictors after the type of oil used and oil health benefit statement had been given to consumers. However, *pleased* became a significant predictor after such additional information had been given to consumers, with the odds ratio values of 2.056 (when Butter, EVCO, EVOO and RBO sponge cakes were all included in the model) and 2.356 (when Butter sponge cake was excluded). This means that for every 1-unit increase of the *pleased* emotion score (based on a 5-point intensity scale) after consumers had been informed of such additional information, the probability of the product being purchased would be 2.056 - 2.356 times higher than not being purchased. When considering only sponge cakes made with EVCO, EVOO and RBO, the odds ratio for *pleased* increased from 1.043 to 2.356 after consumers had been given additional information. This clearly demonstrated positive effects of additional information of oil type and health benefit on purchase intent.

Without additional information about the oil type and health benefits, overall liking was a significant predictor for purchase intent. However, the additional information increased the odds ratios from 3.143 - 3.300 to 3.669 - 3.752, indicating that every 1-unit increase of the overall liking score on a 9-point hedonic scale will likely increase the purchase intent of the product up to 366.9 to 375.2%. Garcia et al. (2009) reported that an increased purchase intent of a spread made with RBO, and they attributed this increase to consumer willingness to sacrifice product liking for health benefits associated with RBO. The lower odds ratio of 3.669 (Butter sponge cake included) compared to 3.752 (Butter sponge cake excluded) was likely due to a slight decrease in purchase intent from 57.4% to 53.7% after consumers knew that butter was used in the formulation (Table 8). Based on the full logit model with overall liking and 8 emotions as predictors, purchase intent of sponge cakes after additional information about oil type and its health benefits (Butter sponge cake excluded) given to consumers could be predicted with 88.7% accuracy (data not showed in Table).

Table 12 Odds ratio estimates for predicting purchase intent of sponge cakes made with different lipids

	Overall				Healthy oil			
	Before		After		Before		After	
Variables	Pr>χ^2	Odds ratio	Pr>χ^2	Odds ratio	Pr>χ^2	Odds ratio	Pr>χ^2	Odds ratio
Overall liking	**0.000**	**3.143**	**0.000**	**3.669**	**0.000**	**3.300**	**0.000**	**3.752**
Calm	**0.002**	**0.486**	0.498	0.846	**0.003**	**0.437**	0.762	0.912
Good	0.095	1.643	0.123	1.530	0.122	1.684	0.257	1.490
Happy	**0.003**	**2.416**	0.602	0.837	**0.029**	**2.185**	0.202	0.593
Pleased	0.749	0.904	**0.037**	**2.056**	0.908	1.043	**0.049**	**2.356**
Satisfied	0.118	1.543	0.860	1.051	0.329	1.381	0.817	1.082
Guilty	0.220	0.845	0.332	0.860	0.172	0.805	0.807	1.049
Unsafe	0.957	1.021	0.344	0.685	0.841	1.091	0.873	0.909
Worried	0.650	0.840	0.844	1.080	0.558	0.771	0.937	0.955

Based on logistic regression analysis, using a full model of overall liking and 8 emotions. Analysis of maximum likelihood estimates was used to obtain parameter estimates. Significance of parameter estimates was based on the Wald χ^2 value at $P \leq 0.05$.

4.3 INFLUENCE OF HPMC AND EXTRA VIRGIN COCONUT OIL ON PHYSICOCHEMICAL PROPERTIES AND MICROSTRUCTURE OF SPONGE CAKE DURING STORAGE

4.3.1 Physicochemical properties of sponge cake

Based on physicochemical properties (Table 13), the addition of 0.5% (w/w) HPMC and/or 20% (w/w) EVCO significantly increased the specific volume ($P \leq 0.05$) with EVCO individually causing a higher specific volume increase (1.29-fold greater at 20% (w/w) EVCO than the control). The expansion ratio was also increased in a same trend, the latter being in the order of EVCO > HPMC ≈ combination. Moreover, the addition of EVCO significantly increased the lightness (L*) and decreased redness (a*) and yellowness (b*) ($P \leq 0.05$). From ΔE value, the results showed that the color of all treatments had just noticeable differences from control ($\Delta E > 3.2$) (Sharma, 2003), following the order of EVCO > combination > HPMC. This may be due to a mechanism of liquid film stabilization. Gas cells are probably stabilized by surface active protein and lipids (Gan et al., 1995). Lipid in sponge cake provides a source of extra material at the gas cell surface. This allows the gas cells to expand without rupturing, which leads to a large number of relatively small gas cells and, hence, produces higher specific volume and expansion ratio with a fine crumb structure with higher color difference (Chin et al., 2010). Water activity of fresh baked sponge cake increased in a HPMC-dependent manner, the water absorption property of the HPMC has been attributed to their hydroxyl groups that allows more water interactions through hydrogen bonding (Guarda et al., 2004).

Table 13 Physicochemical properties of sponge cakes added with 0.5% HPMC, 20% EVCO and combination †

	Control	0.5% HPMC	20% EVCO	combination
Specific volume (cm^3/g)	4.00 ± 0.48 c	4.44 ± 0.17 b	5.15 ± 0.40 a	4.70 ± 0.18 b
Expansion ratio	0.47 ± 0.05 c	0.59 ± 0.02 b	0.68 ± 0.03 a	0.60 ± 0.02 b
Crumb color				
L*	79.58 ± 0.76 c	80.25 ± 0.44 c	84.72 ± 0.89 a	83.35 ± 0.25 b
a*	-2.33 ± 0.07 a	-2.43 ± 0.05 a	-2.88 ± 0.06 c	-2.61 ± 0.17 b
b*	27.67 ± 0.58 a	24.81 ± 0.41 b	24.62 ± 0.75 b	24.41 ± 0.12 b
ΔE	-	2.95 ± 0.02 c	6.03 ± 0.30 a	4.99 ± 0.62 b
Water activity	0.870 ± 0.004 b	0.889 ± 0.005 a	0.873 ± 0.004 b	0.881 ± 0.004 a

Data are showed as the mean ± 1 SD, derived from two replicates. Mean within a row followed by different letters are significantly different ($P \leq 0.05$).

Color difference (ΔE: CIE76) based on sponge cake made with butter; $\Delta E > 2.3$ corresponds to just noticeable difference (Sharma, 2003) (-) indicates not determined

† Sponge cake added 0.5% HPMC, 20% EVCO and 0.5% HPMC + 20% EVCO will be referred to as 0.5% HPMC, 20% EVCO, and combination, respectively.

4.3.2 Kinetics of quality changes of sponge cake during storage

From the zero, first and second order plots of the firmness, moisture content and ^{1}H NMR T_1 (data were showed in the appendix B2) changed over time of the sponge cakes at 30 ^{O}C, the coefficients of determination are summarized in Table 14 (Figure 19 for the first order). Considering each sample of all qualities, the first-order reaction model had the generally higher R^2 values. Thus, the quality change of sponge cakes over time could be best described by a first-order reaction model. The rate constant of the changes in texture, moisture content and ^{1}H NMR T_1 of sponge cakes added with 0.5% HPMC and/or 20% EVCO are summarized in Table 15.

Table 14 Coefficient of determination of the zero, first and second order rate constant of the change in sponge cake firmness, moisture content and ^{1}H NMR T_1

	Sample†	zero order, C *vs.* time	first order ln C *vs.* time	second order 1/C *vs.* time
Firmness	Control	0.9410	0.9271	0.7101
	0.5% HPMC	0.6383	0.9029	0.9707
	20% EVCO	0.7954	0.8740	0.9155
	combination	0.9651	0.8685	0.7397
Moisture content	Control	0.6504	0.9726	0.6960
	0.5% HPMC	0.4955	0.8681	0.9938
	20% EVCO	0.6240	0.9410	0.9368
	combination	0.5265	0.9007	0.9075
^{1}H NMR T_1	Control	0.9187	0.9275	0.6489
	0.5% HPMC	0.9101	0.9955	0.9128
	20% EVCO	0.9104	0.9542	0.6782
	combination	0.9058	0.9950	0.8823

† Sponge cake added 0.5% HPMC, 20% EVCO, and 0.5% HPMC + 20% EVCO will be referred to as 0.5% HPMC, 20% EVCO, and combination, respectively.

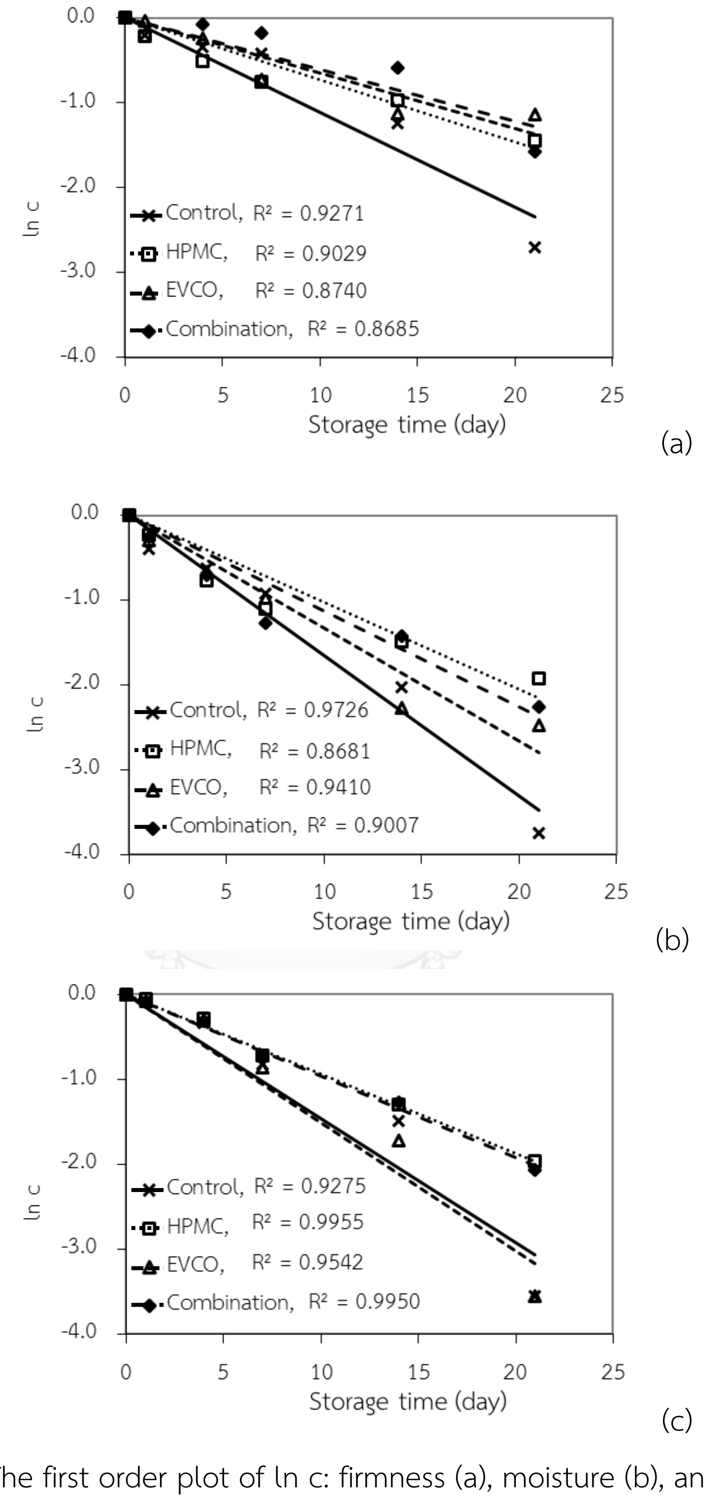


Figure 19 The first order plot of ln c: firmness (a), moisture (b), and ^{1}H NMR T_1 (c) *vs*. storage time, for sponge cakes added with 0.5% HPMC, 20% EVCO and combination. Data are showed as the means with the best fit regression line and corresponding correlation coefficient

Table 15 The first order rate constant at 30 ^{O}C of the changes in texture, moisture content and ^{1}H NMR T_1 of sponge cakes added with 0.5% HPMC, 20% EVCO and combination †

	$k_{firmness}$ (day^{-1})	$k_{moisture}$ (day^{-1})	$k_{1H\ NMR\ T1}$ (day^{-1})
Control	0.1156 ±0.0208 a	0.1776 ±0.0298 a	0.1469 ±0.0049 a
0.5% HPMC	0.0736 ±0.0063 b	0.1085 ±0.0308 b	0.0949 ±0.0133 b
20% EVCO	0.0673 ±0.0103 b	0.1406 ±0.0300 ab	0.1624 ±0.0414 a
combination	0.0615 ±0.0007 b	0.1161 ±0.0158 b	0.0966 ±0.0026 b

Data are showed as the mean ± 1 SD, derived from three replicates. Mean within a column followed by different letters are significantly different (P ≤ 0.05).

† Sponge cake added 0.5% HPMC, 20% EVCO and 0.5% HPMC + 20% EVCO will be referred to as 0.5% HPMC, 20% EVCO, and combination, respectively.

Table 16 Analysis of variance of the changes in texture, moisture content and ^{1}H NMR T_1 data as a 2 x 2 factorial design of sponge cakes added with 0.5% HPMC, 20% EVCO and combination †

	Firmness			Moisture			^{1}H NMR T_1		
Main effect	DF	F-Ratio	P value	DF	F-Ratio	P value	DF	F-Ratio	P value
HPMC	1	11.825	0.009*	1	8.796	0.018*	1	14.422	0.019*
EVCO	1	18.886	0.002*	1	0.868	0.379	1	0.307	0.609
Interaction									
HPMC x EVCO	1	6.804	0.031*	1	1.991	0.196	1	0.201	0.677

*Indicates significant differences (P ≤ 0.05).

† Sponge cake added 0.5% HPMC, 20% EVCO and 0.5% HPMC + 20% EVCO will be referred to as 0.5% HPMC, 20% EVCO, and combination, respectively.

After storage at 30 ^{O}C, the firmness of sponge cake was directly related to the storage time. The $k_{firmness}$ value of all samples decreased with adding HPMC as well as EVCO. It can be observed that $k_{firmness}$ value of combination, HPMC and EVCO added sponge cake was significantly lower than control. These results indicated that both 0.5% HMPC and 20% EVCO individual and combined addition can retard the firmness of sponge cake (Table 16). Sawa et al. (2009) reported that monoglyceride, found in EVCO, resulted in both lower crumb firmness and delayed staling as compared to control due to the interaction of monoglyceride with amylose and amylopectin. Smith and Johansson (2004) referred to amylopectin complex formation with triacylglycerol as a reason for the lower firming rate. This seems highly unlikely for steric reasons. A more probable explanation may be that the lipid also formed a barrier to moisture migration in the crumb. While Barcenas and Rosell (2005) found that use of HPMC in bread resulted in gas cells with a more continuous surface and a thicker appearance, with respect to the control. Thus, the presence of HPMC enfolded the other bread constituents, with a consequent hindering of their interactions and avoided some of the processes involved in bread staling. Furthermore, sponge cake with combination effect of HPMC and EVCO had the lowest $k_{firmness}$ when compared to others. This might be due to the synergistic effect from hydrocolloid and lipid (Ashwini et al., 2009).

The initial moisture contents of all sponge cakes crumb were approximately 25 - 26%. After storage at 30 ^{O}C, the moisture content of all sponge cake crumbs decreased with increasing storage time. During storage of baked product with crust, the crust tended to trap moisture from the crumb, resulting in a dehydration of the crumb with faster staling (Aguirre et al., 2011). It can be observed that HPMC produced greater inhibition of the moisture loss, describing by the significantly lower $k_{moisture}$ value of HPMC added sponge cake (Table 15). As mentioned earlier, HPMC network formed during baking could act as barrier to gas diffusion, decreasing the water vapor loss (Rosell et al., 2001). Changes in the rotational mobility of water molecules were monitored by ^{1}H NMR T_1. Generally, T_1 decreased with increased storage time indicating a decrease in water mobility (Leung et al., 1983; Slade and

Levine, 1991; Wynne-Jones and Blanshard, 1986). From Table 15, the $k_{1H\ NMR\ T1}$ values of HPMC added sponge cake and combination were significantly lower than the control. This may be due to the incorporation of HPMC and water molecules, probably released from gluten upon stabilizing, to the starch crystalline structure that developed upon staling (Chen et al., 1997), while EVCO adding did not affect $k_{1H\ NMR\ T1}$ value. Moreover, the correlation between moisture content and ^{1}H NMR T_1 of sponge cake was well correlated as showed in a high R^2 (Figure 20).

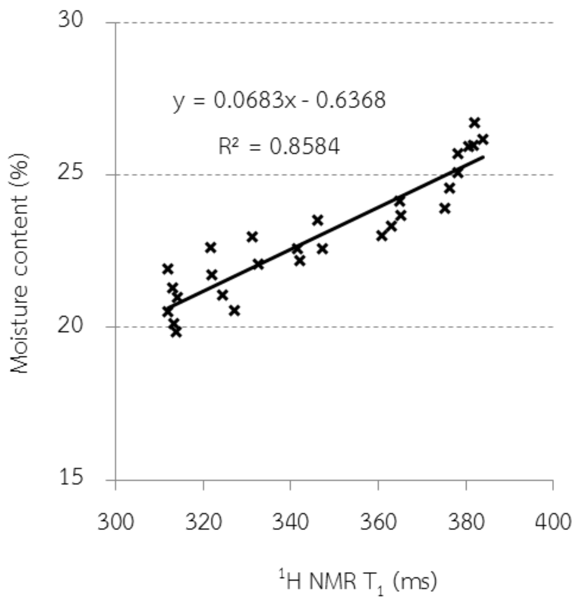


Figure 20 Correlation between moisture content and ^{1}H NMR T_1 of sponge cake

The moisture content and ^{1}H NMR T_1 of the sponge cakes were correlated with the firmness (Figure 21). The firmness of sponge cakes increased with the decreased moisture content, correlating with logarithm function (R^2 = 0.63). This results agreed with Bosmans et al. (2013) who reported that the moisture content of bread crumb lower than 33% led to water stiffened withdrawal from the protein network due to loss of plasticizer and caused an increase in firmness. The firmness of sponge cakes also increased with the decreased ^{1}H NMR T_1 (R^2 = 0.62). This is in agreement with Leung et al. (1983) who found that T_1 inversely correlated with firmness of bread.

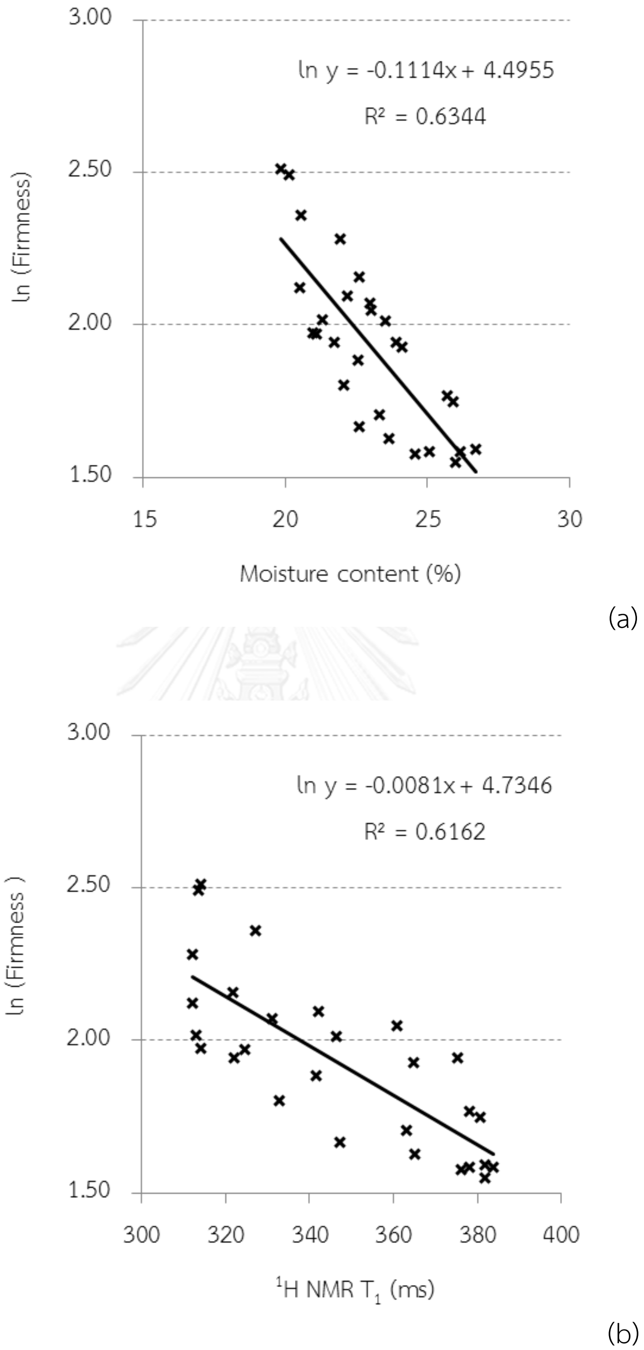


Figure 21 Correlation between firmness of sponge cake and moisture content (a); ^{1}H NMR T_1 (b)

4.3.2 Crystalline structure of sponge cake

The X-ray diffractogram of different formulations of sponge cake crumb are showed in Figure 22. An additional peak of all samples, attributed to a well formed V-structure, appeared at an angle of 20^{O}. Ribotta et al. (2004) reported that during sponge cake baking, the crystalline structure of the granule was disrupted by gelatinization, so fresh baked sponge cake showed that the four peaks at diffracted angles disappeared reflecting a substantial loss of A-type crystallinity. During storage (% total crystallinity data were showed in the appendix B3), the peak at the diffraction angle of 17^{O}, B type structure, was found to develop much faster for control sponge cake (Figure 23 a), ranging from 31% to 51% during 28 days of storage, than HPMC added sponge cake (Figure 23 b). These structures were in agreement with that obtained by Karim et al. (2000), who found that all starches with A or B diffraction patterns in their natural stage can form gels that developed in a type B pattern during aging, while V type structure decreased during storage. Osella et al. (2005) reported that a transformation of the V to the B patterns could occur during storage.

On the contrary, combination and EVCO added sponge cake show only a little growth of peak at the diffraction angle of 17^{O} (Figure 23 c-d). Rogers et al. (1988) proposed that the interaction between lipids and endogenous flour lipids are responsible for the slower firming rate. They also found a synergistic action of lipid and wheat flour lipids in terms of anti-firming effects, since the effects of shortening depend on the presence of wheat flour lipids. While Smith and Johansson (2004) referred to amylopectin complex formation with lipid as a reason for the lower firming rate in bread. Becke et al. (2001) reported that amylopectin is also believed to be capable of forming insoluble complexes via the outer branches lipids.

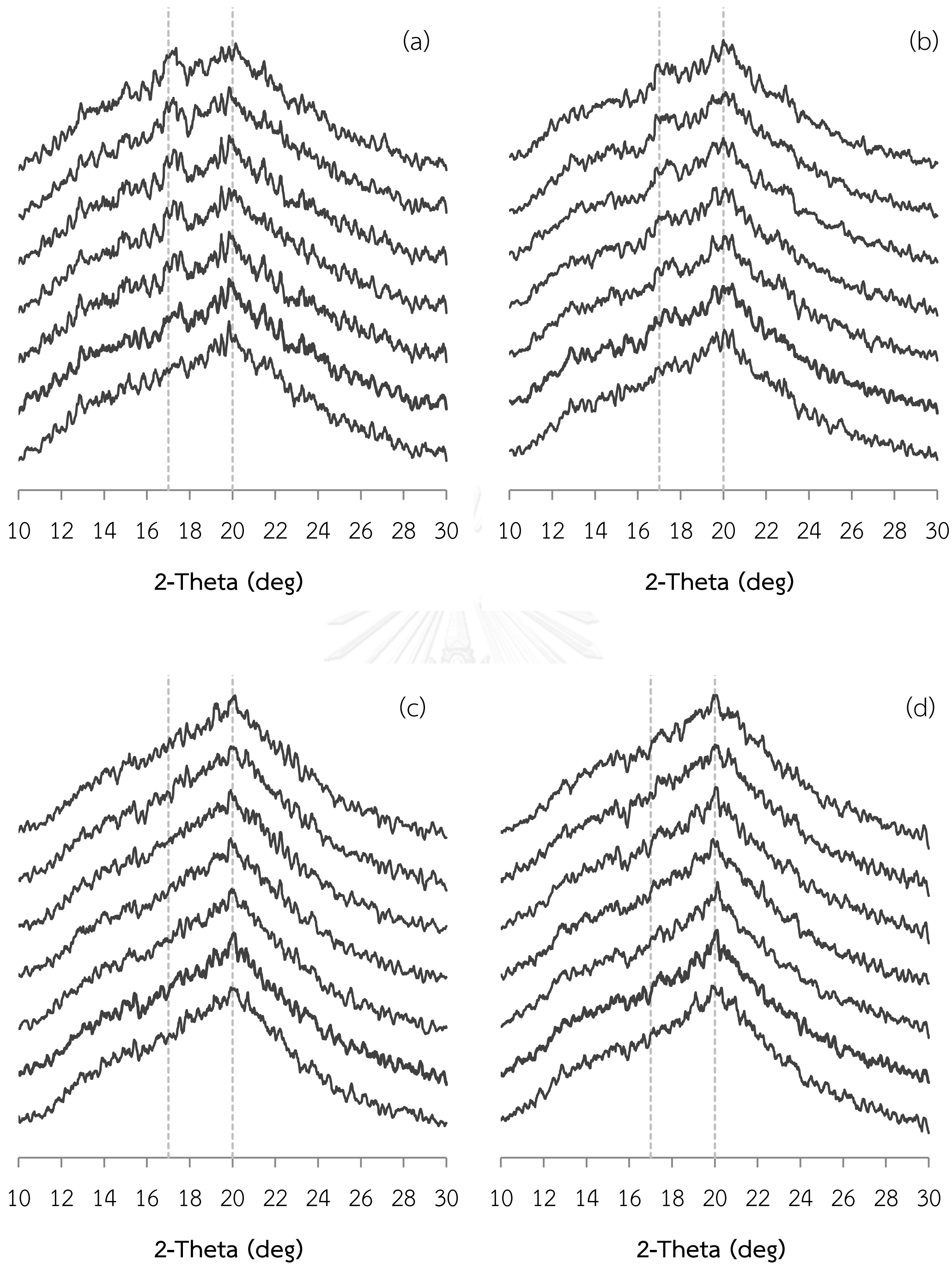


Figure 22 XRD patterns for sponge cakes crumb: control (a), 0.5% HPMC (b), 20% EVCO (c) and combination (d) during storage at 30 ^{O}C (0, 1, 4, 7, 14, 21 and 28 day from bottom to top for all samples)

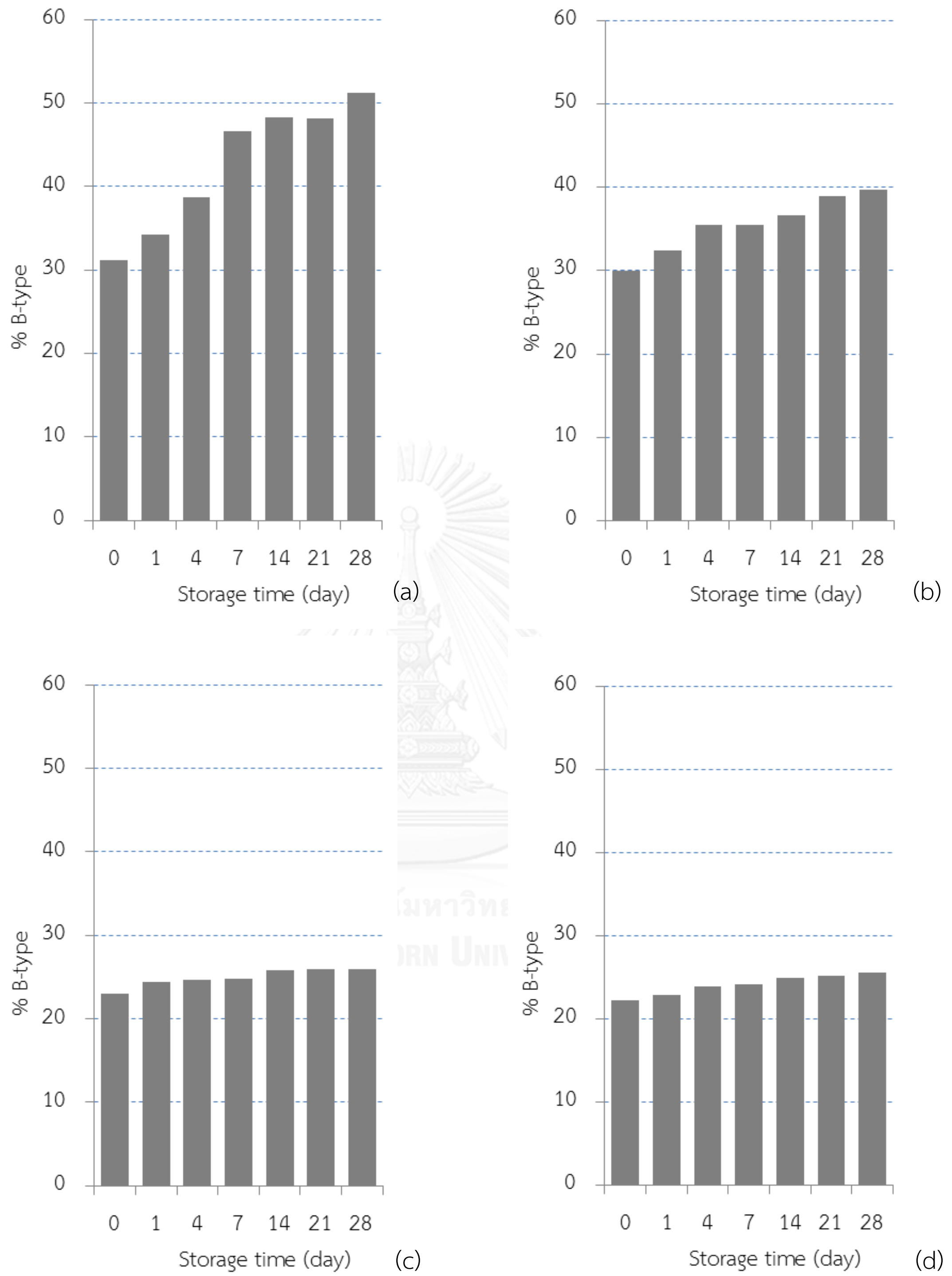


Figure 23 Sponge cake crumb crystallinity, as % of B-type structure of total crumb crystallinity: control (a), 0.5% HPMC (b), 20% EVCO (c) and combination (d) during storage at 30 ^{O}C

Figure 24 presents the starch crystallinity level $\Gamma(t)$ calculated using Equation (7) and plotted as a function of storage time for each sponge cakes crumb added with HPMC and/or EVCO. The lines representing the best fit of Equation (8) to the experimental data are also presented. The Avrami equation parameters (P_1, P_2 and P_3) obtained by fitting Equation (9) to the experimental data are presented in Table 17. As can be seen from the best fit line presented by Figure 24 and the R^2 values listed in Table 17 that the Avrami model fits the experimental data satisfactorily.

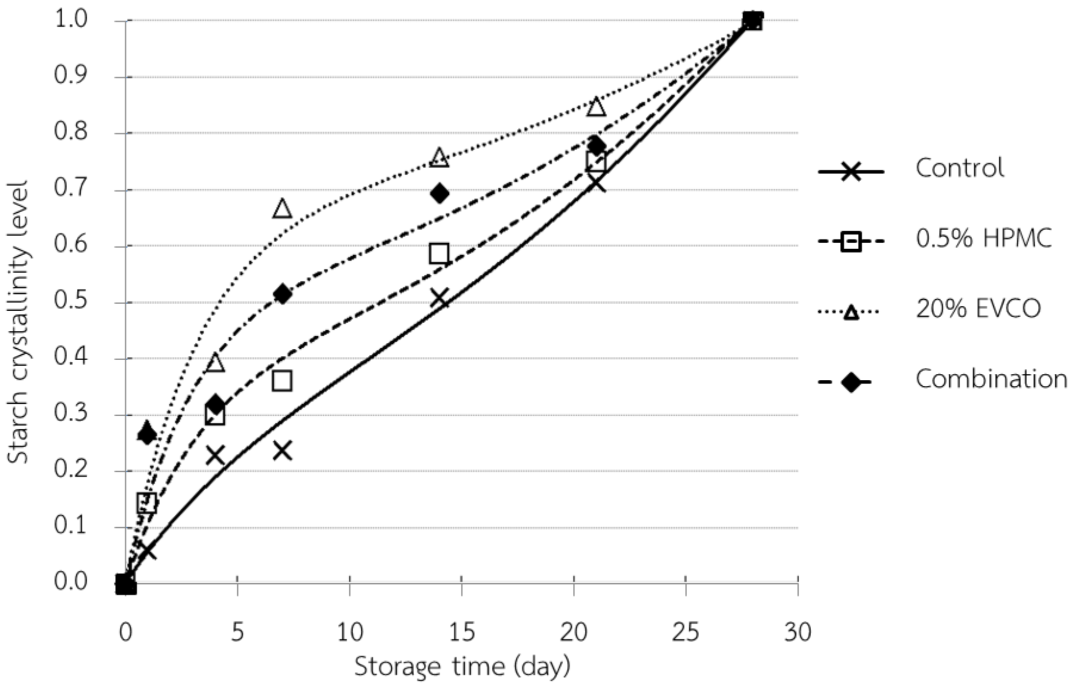


Figure 24 Starch crystallinity level plotted of sponge cakes crumb added 0.5% HPMC, 20% EVCO and combination during storage

Table 17 The Avrami equation parameters obtained by fitting the experimental data of sponge cakes added with 0.5% HPMC, 20% EVCO and combination †

	P_1 (day^{-1})	P_2 (x10^{-3} day^{-1})	P_3	R^2	a_w
Control	0.164	2.254	2.750	0.994	0.817-0.870
0.5% HPMC	0.291	1.800	2.397	0.995	0.840-0.889
20% EVCO	0.303	0.587	1.465	0.974	0.829-0.873
combination	0.326	1.091	1.857	0.968	0.836-0.881

† Sponge cake added 0.5% HPMC, 20% EVCO and 0.5% HPMC + 20% EVCO will be referred to as 0.5% HPMC, 20% EVCO, and combination, respectively.

Starch retrogradation is in part due to the growth of starch crystals already presented in partially gelatinized starch granules and in part due to nucleation and growth of new crystals. According to the Avrami theory (Del-Nobile et al., 2003), P_1 depends on the mobility of macromolecules and it is in relation with the growth of the remaining crystals (type I) in starch granules. This means that the higher P_1 values indicated the slower growth of the crystal. From Table 17, the P_1 value of control sponge cake was the lowest. This suggested that the growth of remainder crystals is faster in control due to its higher initial crystallinity. Conversely, addition of 0.5% HPMC and/or 20% EVCO increased *P1* value.

Regarding P_2 parameter, it depends on both the growth and nucleation rates of new formed crystals (type II). Thus the higher P_2 values are the higher the magnitude of crystallinity will be. Since P_2 value was greater for control sponge cake than HPMC, combination and EVCO, respectively, the nucleation rate and growth was the maximum for control. The P_3, in turn, depends on the final crystallinity. The higher the P_3 values, the higher will be the final crystallinity values. The P_3 values of control and HPMC were higher than those of EVCO and combination. This suggested that the final crystallinity was higher for control and HPMC sponge cakes. From P_2 and P_3 results, it can be observed that EVCO addition produced greater effect. This could be explained by the steric effect of amylopectin complex formation with lipid leading to retardation of retrograded starch crystallinity.

The crystallization degree of the sponge cakes was well correlated with the firmness (Figure 25). The firmness of sponge cakes increased as the crystallization degree increased (R^2 = 0.74) which may be due to amylopectin retrogradation mechanism (Ribotta et al., 2004).

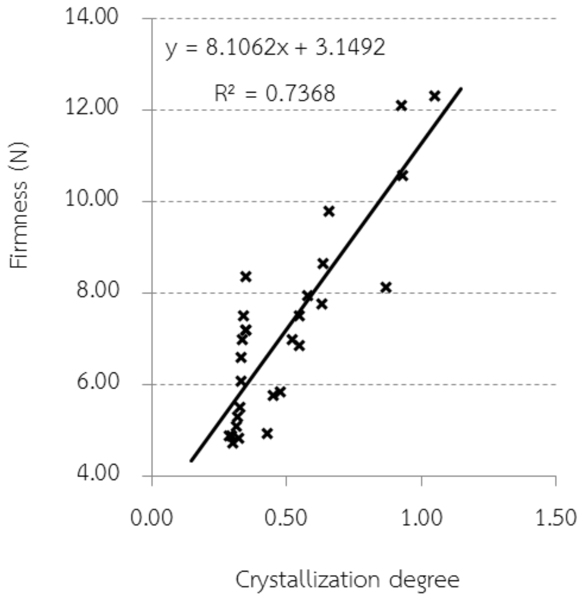


Figure 25 Correlation between firmness of sponge cake and crystallization degree

CHAPTER V
CONCLUSION AND SUGGESTIONS

5.1 CONCLUSION

This study demonstrated the effect of hydrocolloids and lipids on physicochemical properties of sponge cake. The individual inclusion of the hydrocolloids HPMC, XG and AG at 0.5 or 1.0% (w/w) was found to affect the density and viscosity of the cake batter and the specific volume, crumb moisture and firmness of the final baked sponge cake, but to different extents depending on their chemical structure. HPMC only increased the batter viscosity and crumb moisture, while XG and AG increased the density and viscosity of the batter and crumb moisture, but decreased the specific volume of the sponge cake. Each hydrocolloid could increase the moisture content. The firmness change of sponge cakes during storage followed a first-order kinetics reaction. The addition of 0.5% (w/w) of HPMC or AG decreased the rate (*k*) compared to the control, while 1.0% (w/w) of HPMC or AG did not show this effect. In contrast, XG did not show any significant effect as a firmness retarding agent. The order of Ea for the hydrocolloids was HPMC > AG > XG, with 0.5% (w/w) HPMC giving the highest *Ea* value and so reflecting its better effect as a firmness retarding agent.

Furthermore, this study revealed the effects of the oil type and oil health benefit statements given to consumers on sensory liking, emotional responses, and purchase intent of sponge cakes. Eight emotion terms were selected (*calm, good, happy, pleased, satisfied, guilty, unsafe* and *worried*). The effects of oil types on sensory liking of sponge cakes were more pronounced for aroma, taste and texture-related attributes than for appearance-related attributes. The magnitude of positive emotion scores was greater than the negative emotion scores. Both the oil type and oil health benefit statements had more significant impacts on consumer positive emotions elicited by sponge cakes than negative emotions. Overall liking, overall aroma and taste, texture-related attributes contributed more toward the overall differences across sponge cakes than appearance-related attributes. Likewise, negative emotion terms (*guilty, worried* and *unsafe)* were more discriminating than positive terms. Overall, overall liking and *pleased* were significant predictors after additional oil type and health benefit information has been given to consumers. Generally, an increase of the overall liking and *pleased* scores will likely increase the purchase intent of the product up to 375% and 235%, respectively.

Finally, the study also presented the influence of HPMC at 0.5% and EVCO at 20% on physicochemical properties and microstructure of sponge cake during storage. Sponge cake made with EVCO had the highest specific volume and expansion ratio. The firmness change, moisture content and ^{1}H NMR T_1 of sponge cakes during storage followed a first-order kinetics reaction. The use of HPMC and/or EVCO in sponge cake could retard the firmness rate in the following order: combination < EVCO < HPMC < control. The moisture content and ^{1}H NMR T_1 decreased with increasing time. The results were confirmed by XRD data of crystallization degree and starch crystallinity level $\Gamma(t)$ using Avrami equation. From correlation, it can be concluded that firmness of sponge cake directly related to crystallization degree but inversely related to moisture content and ^{1}H NMR T_1.

5.2 SUGGESTIONS FOR FURTHER RESEARCH

The further study of model system of starch (amylose and amylopectin) and lipid (fatty acids) on retrogradation is suggested to investigate the mechanisms of starch and lipid interaction during storage. It is also suggested that a closed system may be applied using edible coating to retard deterioration of sponge cake such as firmness increase, moisture loss and flavor loss.

REFERENCES

AACC (2000). American Association of Cereal Chemists International. Methods 74-09.01. Measurement of bread firmness by universal testing machine. Approved Methods of the American Association of Cereal Chemists, 10th ed. AACC, St. Paul, MN.

Aguirre, J. F., Osella, C. A., Carrara, C. R., Sanchez, H. D., and Buera, M. D. P. (2011). Effect of storage temperature on starch retrogradation of bread staling. *Starch/Starke* **63**, 587-593.

AOAC (1990). Association of Official Analytical Chemists. Method 945.14.Moisture in cereal adjuncts: Air oven method (103 to 104 C). In: Official Methods of Analysis. Association of Official Analytical Chemists. 15th ed. AOAC, Arlington, VA.

Armstrong, J. (2011). "General, Organic, and Biochemistry: An Applied Approach," Brooks/Cole, Belmont, CA.

Ashwini, A., Jyotsna, R., and Indrani, D. (2009). Effect of hydrocolloids and emulsifiers on the rheological, micro structural and quality characteristics of eggless cake. *Food Hydrocolloids* **23**, 700-707.

Assunção, M. L., Ferreira, H. S., dosSantos, A. F., Cabral, C. R., and Florêncio, T. M. (2009). Effects of dietary coconut oil on the biochemical and anthropometric profiles of women presenting abdominal obesity. *Lipids* **44**, 593-601.

Baik, M. Y., and Chinachoti, P. (2000). Moisture redistribution and phase transition during bread staling. *Cereal Chemistry* **77**, 484-488.

Baik, M. Y., Kim, K. J., Cheon, K. C., Ha, Y. C., and Kim, W. S. (1997). Recrystallization kinetics and glass transition of rice starch gel system. *Journal of Agricultural and Food Chemistry* **45**, 4242-4248.

Barcenas, M. E., and Rosell, C. M. (2005). Effect of HPMC addition on the microstructure, quality and aging of wheat bread. *Food Hydrocolloids* **19**, 1037-1043.

Barcenas, M. E., and Rosell, C. M. (2006). Different approaches for increasing the shelf life of partially baked bread: low temperatures and hydrocolloid addition. *Food Chemistry* **100**, 1594-1601.

Barreiro-Hurlé, J., Gracia, A., and de-Magistris, T. (2010). Does nutrition information on food products lead to healthier food choices? *Food Policy* **35**, 221-229.

Becke, A., Hill, S. E., and Mitchell, J. R. (2001). Relevance of amylose–lipid complexes to the behavior of thermally processed starches. *Starch/Stärke* **53**, 121–130.

Boskou, G., Salta, F. N., Chiou, A., Troullidou, E., and Andrikopoulos, N. K. (2006). Content of trans, trans-2,4-decadienal in deep-fried and pan-fried potatoes. *European Journal of Lipid Science and Technology* **108**, 109–115.

Bosmans, G. M., Lagrain, B., Ooms, N., Fierens, E., and Delcour, J. A. (2013). Biopolymer interactions, water dynamics, and bread crumb firming. *Journal of Agricultural and Food Chemistry* **61**, 4646−4654.

Bower, J. A., Saadat, M. A., and Whitten, C. (2003). Effect of liking, information and consumer characteristics on purchase intention and willingness to pay more for a fat spread with a proven health benefit. *Food Quality and Preference* **14**, 65-74.

Cardello, A. V., Miselman, H. L., Schutz, H. G., Craig, C., Given, Z., Lesher, L., and Eicher, S. (2012). Measuring emotional responses to foods and food names using questionnaires. *Food Quality and Preference* **24**, 243–250.

Carneiro, J. D. S., Minim, V. P. R., Deliza, R., Silva, C. H. O., Carneiro, J. C. D., and Leao, F. P. (2005). Labelling effects on consumer intention to purchase for soybean oil. *Food Quality and Preference* **16**, 275–282.

Chaiya, B., and Pongsawatmanit, R. (2011). Quality of batter and sponge cake prepared from wheat-tapioca flour blends. *Kasetsart Journal : Natural Science* **45**, 305 – 313.

Chaiya, B., Pongsawatmanit, R., and Prinyawiwatkul, W. (2015). Optimisation of wheat flour-based sponge cake formulation containing tapioca starch and xanthan gum. *International Journal of Food Science and Technology* **50**, 532–540.

Chen, C. S. H., and Sheppard, E. W. (1980). Conformation and shear stability of xanthan gum in solution. *Polymer Engineering & Science* **20**, 512-516.

Chen, P. L., Long, Z., Ruan, R., and Labuza, T. P. (1997). Nuclear magnetic resonance studies of water mobility in bread during storage. *LWT- Food Science and Technology* **30**, 178–183.

Chin, N. L., Rahman, R. A., Hashim, D. M., and Kowng, S. Y. (2010). Palm oil shortening effects on baking performance of white bread. *Journal of Food Process Engineering* **33**, 413-433.

Chinachoti, P., and Vodovotz, Y. (2001). "Bread Staling," CRC Press, Boca Raton, FL.

Collar, C., Martinez, J. C., and Rosell, C. M. (2001). Lipid binding of fresh and stored formulated wheat breads. Relationships with dough and bread technological performance. *Food Science and Technology International* **7**, 501-510.

Das, L., Raychaudhuri, U., and Chakraborty, R. (2013). Role of hydrocolloids in improving the physical and textural characteristics of fennel bread. *International Food Research Journal* **20**, 2253 - 2259.

Davidou, S., LeMeste, M., Debever, E., and Bekaert, D. (1996). A contribution to the study of staling of white bread: Effect of water and hydrocolloid. *Food Hydrocolloids* **10**, 375-383.

Del-Nobile, M. A., Martoriello, T., Mocci, G., and Notte, E. L. (2003). Modeling the starch retrogradation kinetic of durum wheat bread. *Journal of Food Engineering* **59**, 123-128.

Di-Monaco, R., Ollilla, S., and Tuorila, H. (2005). Effect of price on pleasantness ratings and use intentions for a chocolate bar in the presence and absence of a health claim. *Journal of Sensory Studies* **20**, 1-16.

Döring, C., Jekle, M., and Becker, T. (2013). Pound cake quality as a function of time and temperature. *Baking+Biscuit* **5**, 58-62.

Ereifej, K. I., and Shibli, R. (1993). Rheological properties and baking quality of flour from a landrace and durum wheat cultivars grown in Jordan. *Cereal Chemistry* **70**, 486-488.

Figoni, P. (2008). "How baking works," John Wiley and Sons, Hoboken, NJ.

Fleiss, J. L., and Everitt, B. S. (1971). Comparing the marginal totals of square contingency tables. *British Journal of Mathematical and Statistical Psychology* **24**, 117–123.

Gan, Z., Ellis, P. R., and Schofield, J. D. (1995). Gas cell stabilisation and gas retention in wheat bread dough. *Journal of Cereal Science* **21**, 215-230.

Garcia, K., Sriwattana, S., No, H. K., Corredor, J. A., and Prinyawiwatkul, W. (2009). Sensory optimization of a mayonnaise-type spread made with rice bran oil and soy protein. *Journal of Food Science* **74**, 248-254.

Gisslen, W. (2013). "Professional Baking," John Wiley and Sons, Hoboken, NJ.

Gomez, M., Oliete, B., Rosell, C. M., Pando, V., and Fernandez, E. (2008). Studies on cake quality made of wheat-chickpea flour blends. *LWT- Food Science and Technology* **41**, 1701–1709.

Gomez, M., Ronda, F., Caballero, P. A., Blanco, C. A., and Rosell, C. M. (2007). Functionality of different hydrocolloids on the quality and shelf-life of yellow layer cakes. *Food Hydrocolloids* **21**, 167–173.

Gomez, M., Ruiz-Paris, E., Oliete, B., and Pando, V. (2010). Modelling of texture evolution of cakes during storage. *Journal of Texture Studies* **41**, 17-33.

Gray, J. A., and Bemiller, J. N. (2003). Bread staling: molecular basis and control. *Comprehensive Reviews in Food Science and Food Safety* **2**, 1-21.

Guarda, A., Rosell, C. M., Benedito, C., and Galotto, M. J. (2004). Different hydrocolloids as bread improvers and antistaling agents. *Food Hydrocolloids* **18**, 241-247.

Guillard, V., Bourlieu, C., and Gontard, N. (2013). "Food Structure and Moisture Transfer," Springer Science & Business Media, New York, NJ.

Guinot, P., and Mathlouthi, M. (1991). Instron measurement of sponge cake firmness: Effect of additives and storage conditions. *Journal of the Science of Food and Agriculture* **54**, 413–420.

Heflich, L. W. (1996). " A Baker's Perspective. In: Baked Goods Freshness, Technology, Evaluation and Inhibition of Staling," Marcel Dekker, New York.

Imeson, A. (2010). "Handbook of hydrocolloids," Woodhead, New York, NJ.

Irene, A., Gaena, R. B. E., Gros, J. B., and Trystram, G. (2006). Influence of egg type, pressure and mode of incorporation on density and bubble distribution of a lady finger batter. *Journal of Food Engineering* **74**, 198–210.

Jiang, Y., King, J. M., and Prinyawiwatkul, W. (2014). A review of measurement and relationships between food, eating behavior and emotion. *Trends in Food Science & Technology* **36**, 15-28.

Kang, J. H., Jin, B., and Gavin, M. (2010). The positive emotion elicitation process of Chinese consumers toward a U.S. apparel brand: a cognitive appraisal perspective. *Journal of the Korean Society of Clothing and Textiles* **34**, 1992-2005.

Karim, A. A., Norziah, M. H., and Seow, C. C. (2000). Methods for the study of starch retrogradation. *Food Chemistry* **71**, 9-36.

King, S. C., and Meiselman, H. L. (2010). Development of a method to measure consumer emotions associated with foods. *Food Quality and Preference* **21**, 168–77.

King, S. C., Meiselman, H. L., and Carr, B. T. (2010). Measuring emotions associated with foods in consumer testing. *Food Quality and Preference* **21**, 1114-1116.

King, S. C., Meiselman, H. L., and Carr, B. T. (2013). Measuring emotions associated with foods: Important elements of questionnaire and test design. *Food Quality and Preference* **28**, 8–16.

Koksel, H., Sahbaz, F., and Ozboy, O. (1993). Influence of wheat-drying temperatures on the birefringence and X-ray diffraction patterns of wet-harvested wheat starch. *Cereal Chemistry* **70**, 481-483.

Koster, E. P. (2003). The psychology of food choice: some often encountered fallacies. *Food Quality and Preference* **14**, 359-273.

Kuijer, R. G., and Boyce, J. A. (2014). Chocolate cake. Guilt or celebration? Associations with healthy eating attitudes, perceived behavioural control, intentions and weight-loss. *Appetite* **74**, 48–54.

Kumar, A. J., Singh, R. R. B., Patel, A. A., and Patil, G. R. (2006). Kinetics of colour and texture changes in Gulabjamun balls during deep-fat frying. *LWT- Food Science and Technology* **39**, 827-833.

Laitinen, J., Hyvönen, T., and Maliranta, H. (1993). Sensory evaluation of sweet rolls, ginger cookies and cakes made with butter, oil or margarine. *Food Quality and Preference* **4**, 94.

Lau, M. H., Tang, J., and Swanson, B. G. (2000). Kinetics of textural and color changes in green asparagus during thermal treatments. *Journal of Food Engineering* **45**, 231–236.

Leung, H. K., Mahnuson, J. A., and Bruinsma, B. L. (1983). Water binding of wheat flour doughs and breads as studied by duteron relaxation. *Journal of Food Science* **48**, 95-99.

Li, X. E., Jervis, S. M., and Drake, M. A. (2015). Examining extrinsic factors that influence product acceptance: a review. *Journal of Food Science* **80**, R901-09.

Lostie, M., Peczalski, R., Andrieu, J., and Laurent, M. (2002). Study of sponge cake batter baking process. Part I: Experimental data. *Journal of Food Engineering* **51**, 131-137.

Luyts, A., Wilderjans, E., Haesendonck, I. V., Brijs, K., Courtin, C. M., and Delcour, J. A. (2013). Relative importance of moisture migration and amylopectin retrogradation for pound cake crumb firming. *Food Chemistry* **141**, 3960-3966.

Marina, A. M., CheMan, Y. B., and Amin, I. (2009). Virgin coconut oil: emerging functional food oil. *Trends in Food Science & Technology* **20**, 481-487.

Matsakidou, A., Blekas, G., and Paraskevopoulou, A. (2010). Aroma and physical characteristics of cakes prepared by replacing margarine with extra virgin olive oil. *LWT- Food Science and Technology* **43**, 949-957.

Mohamed, S., and Abdul-Hamid, N. (1998). Effects of ingredients on the characteristics of rice cakes. *Journal of the Science of Food and Agriculture* **76**, 464-468.

Moskowitz, H. R., and Krieger, B. (1995). The contribution of sensory liking to overall liking: an analysis of six food categories. *Food Quality and Preference* **6**, 83–90.

Nakazawa, F., Takahashi, J., Noguchi, S., and Takada, M. (1983). Pulsed NMR study of water behavior in retrogradation process in rice and rice starch. *Journal of Home Economics of Japan* **34**, 566-570.

Nanua, J. N., McGregor, J. U., and Godber, J. S. (2000). Influence of high-oryzanol rice bran oil on the oxidative stability of whole milk powder. *Journal of Dairy Science* **83**, 2426–2431.

Nevin, K. G., and Rajamohan, T. (2006). Virgin coconut oil supplemented diet increases the antioxidant status in rats. *Food Chemistry* **99**, 260-266.

Ng, M., Lawlor, J. B., Chandra, S., Chaya, C., Hewson, L., and Hort, J. (2013). Using quantitative descriptive analysis and temporal dominance of sensations analysis as complementary methods for profiling commercial blackcurrant squashes. *Food Quality and Preference* **25**, 121–134.

Nourian, F., Ramaswamy, H. S., and Kushalappa, A. C. (2003). Kinetic changes in cooking quality of potatoes stored at different temperatures. *Journal of Food Engineering* **60**, 257-266.

Olias, J. M., Perez, A. G., Rios, J. J., and Sanz, L. C. (1993). Aroma of virgin olive oil: biogenesis of the green odor notes. *Journal of Agricultural and Food Chemistry* **41**, 2368–73.

Olivera, D. F., Bambicha, R., and Laporte, G. (2013). Kinetics of colour and texture changes of beef during storage. *Journal of Food Science and Technology* **50**.

Olsen, N. V., Røssvoll, E., Langsrud, S., and Scholderer, J. (2014). Hamburger hazards and emotions. *Appetite* **78**, 95–101.

Osella, C. A., Sánchez, H. D., Carrara, C. R., dela-Torre, M. A., and Buera, M. P. (2005). Water Redistribution and Structural Changes of Starch During Storage of a Gluten-free Bread. *Starch/Stärke* **57**, 208–216.

Peng, J., Tang, J., Barrett, D. M., Sablani, S. S., and Powers, J. R. (2014). Kinetics of carrot texture degradation under pasteurization conditions. *Journal of Food Engineering* **122**, 84–91.

Phillips, G. O., and Williams, P. A. (2000). "Handbook of Hydrocolloids," CRC Press, Boca Raton, FL.

Piazza, L., and Masi, P. (1995). Moisture redistribution throughout the bread loaf during staling and its effect on mechanical properties. *Cereal Chemistry* **72**, 320-325.

Pongjaruvat, W., Methacanon, P., Seetapan, N., and Fuongfuchat, A. (2014). Influence of pregelatinised tapioca starch and transglutaminase on dough rheology and quality of gluten-free jasmine rice breads. *Food Hydrocolloids* **36**, 143–150.

Prinyawiwatkul, W., and Chompreeda, P. (2007). "Applications of discriminant and logistic regression analysis for consumer acceptance and consumer-oriented product optimization study (chapter 16). In: Beckley JH, FoleyM, Topp EJ, Huang JC, Prinyawiwatkul W, editors. Accelerating new food product design and development. ," Blackwell Publishing Professional, Ames, Iowa.

Ribotta, P. D., Cuffini, S., Leon, A. E., and Anon, M. C. (2004). The staling of bread: an X-ray diffraction study. *European Food Research and Technology* **218**, 219-223.

Rizvi, A. F., and Tong, C. H. (1997). Fractional conversion for determining texture degradation kinetics of vegetables. *Jounal of Food Science* **62**, 1-7.

Roca, E., Guillard, V., Broyart, B., Guilbert, S., and Gontard, N. (2008). Effective moisture diffusivity modelling versus food structure and hygroscopicity. *Food chemistry* **106**, 1428-1437.

Rogers, D. E., Zeleznak, K. J., Lai, C. S., and Hoseney, R. C. (1988). Effect of native lipids, shortening, and bread moisture on bread firming. *Cereal Chemistry* **65**, 398-401.

Rosell, C. M., Rojas, J. A., and DeBarber, C. B. (2001). Influence of hydrocolloids on dough rheology and bread quality. *Food Hydrocolloids* **15**, 75–81.

Sae-Ew, A., Chompreeda, P., Prinyawiwatkul, W., Haruthaithanasan, V., Suwansichon, T., Saidu, J. E., and Xu, Z. (2007). Acceptance and purchase intent of the US consumers for the non-wheat rice butter cake. *Journal of Food Science* **72**, S92–97.

Saha, J. K., and Bhattacharyya, S. (2010). Characteristics of gellan gum based food gels. *Journal of Texture Studies* **41**, 459-471.

Sawa, K., Inoue, S., Lysenko, E., Edwards, N. M., and Preston, K. R. (2009). Effects of purified monoglycerides on Canadian short process and sponge and dough mixing properties, bread quality and crumb firmness during storage. *Food Chemistry* **115**, 884–890.

Schiraldi, A., and Fessas, D. (2001). "Mechanism of staling: an overview. In: Chinachoti P, Vodovotz Y, editors. Bread Staling," CRC Press, Boca Raton, FL.

Sharma, G. (2003). "Digital color imaging handbook," CRC Press, Florida.

Sharpless, A. (1966). "Introduction to polymer crystallization," Edward Arnold, London.

Shi, X., and BeMiller, J. N. (2002). Effects of food gums on viscosities of starch suspensions during pasting. *Carbohydrate Polymers* **50**, 7-18.

Shyu, Y. S., and Sung, W. C. (2010). Improving the emulsion stability of sponge cake by the addition of γ-polyglutamic acid. *Journal of Marine Science and Technology* **18**, 895-900.

Slade, L., and Levine, H. (1991). Beyond water activity: Recent advances based on an alternative approach to the assessment of food quality and safety. *Critical Reviews in Food Science and Nutrition* **30**, 115-360.

Smith, P. R., and Johansson, J. (2004). Influences of the proportion of solid fat in a shortening on loaf volume and staling of bread. *Journal of Food Processing and Preservation* **28**, 359-367.

Sritongtae, B., Mahawanich, T., and Duangmal, K. (2011). Drying of osmosed cantaloupe: effect of polyols on drying and water mobility. *Drying Technology: An International Journal* **29**, 527-535.

Stone, H., and Sidel, J. L. (1993). "Sensory evaluation practices," Academic Press, Inc, Califonia.

Swinburne, K. (1971). Pattern recognition for radiographers. *The Lancet* **20**, 589-590.

Taoukis, P., Labuza, T. P., and Saguy, I. S. (1997). "Kinetics of food deterioration and shelf-life prediction. In Handbook of Food Engineering Practice," CRC Press, Boca Raton, FL.

Thomson, D. M. H., Crocker, C., and Marketo, C. G. (2010). Linking sensory characteristics to emotions: An example using dark chocolate. *Food Quality and Preference* **21**, 1117–1125.

Tomita, K., Machmudah, S., Wahyudiono, N. V., Fukuzato, R., Kanda, H., Quitain, A. T., Sasaki, M., and Goto, M. (2014). Extraction of rice bran oil by supercritical carbon dioxide and solubility consideration. *Separation and Purification Technology* **125**, 319-325.

Tuorila, H., Andersson, A., Martikainen, A., and Salovaara, H. (1998). Effect of product formula, information and consumer characteristics on the acceptance of a new snack food. *Food Quality and Preference* **9**, 313-320.

VanBoekel, M. A. J. S. (1996). Statistical aspects of kinetic modeling for food science problems. *Jounal of Food Science* **61**, 477–485.

Venard, J. K., and Street, R. L. (1975). "Elementary Fluid Mechanics," Wiley, New York.

Wardy, W., Sae-Eaw, A., Sriwattana, S., No, H. K., and Prinyawiwatkul, W. (2015). Assessing consumer emotional responses in the presence and absence of critical quality attributes: A case study with chicken eggs. *Journal of Food Science* **In press**.

Wynne-Jones, S., and Blanshard, J. M. V. (1986). Hydration studies of wheat starch, amylopectin, amylose gels and bread by proton magnetic resonance. *Carbohydrate Polymers* **6**, 289-306.

Young, W. E., and Bayfield, E. G. (1963). Hydrophilic colloids as additives in white layer cakes. *Cereal Chemistry* **40**, 195-207.

Yu, L., and Christie, G. (2005). Microstructure and mechanical properties of orientated thermoplastic starches. *Journal of Materials Science* **40**, 111-116.

Zhang, Y., Song, Y., Hu, X., Liao, X., Ni, Y., and Li, Q. (2012). Effects of sugars in batter formula and baking conditions on 5-hydroxymethylfurfural and furfural formation in sponge cake models. *Food Research International* **49**, 439-445.

Zigoneanu, I. G., Astete, C. E., and Sabliov, C. M. (2008). Nanoparticles with entrapped-tocopherol: synthesis, characterization, and controlled release. *Nanotechnology* **19**, 1-8.

Zobel, H. F. (1988). Starch crystal transformations and their industrial importance. *Starke* **40**, 1-7.

APPENDIX

APPENDIX A

QUESTIONNAIRE

APPENDIX A1 Consent Form

I, __________________________, agree to participate in the research entitled "Consumer Acceptance of sponge cake products" which is being conducted by Dr. Witoon Prinyawiwatkul, Professor of School of Nutrition and Food Sciences at Louisiana State University, Agricultural Center, phone number (225) 578-5188.

I understand that participation is entirely voluntary and whether or not I participate will not affect how I am treated on my job. I can withdraw my consent at any time without penalty or loss of benefits to which I am otherwise entitled and have the results of the participation returned to me, removed from the experimental records, or destroyed. For this particular research, about 15-20 minutes participation will be required for each consumer.

The following points have been explained to me:

1. In any case, it is my responsibility to report prior to participation to the investigator any food allergies I may have.
2. The reason for the research is to gather information on sensory acceptability of sponge cake products. The benefit that I may expect from it is a satisfaction that I have contributed to quality improvement of these products.
3. The procedures are as follows: 4 coded samples will be placed in front of me, and I will evaluate them by normal standard methods and indicate my evaluation on score sheets. All procedures are standard methods as published by the American Society for Testing and Materials and the Sensory Evaluation Division of the Institute of Food Technologists.
4. Participation entails minimal risk: The only risk which can be envisioned is that of an allergic reaction toward common food ingredients [wheat flour, eggs, table sugar, baking powder, dairy product, lipids and food additives]. However, because it is known to me beforehand that the food to be tested contains common food ingredients, the situation can normally be avoided.
5. The results of this study will not be released in any individual identifiable form without my prior consent unless required by law.
6. The investigator will answer any further questions about the research, either now or during the course of the project.

The study has been discussed with me, and all of my questions have been answered. I understand that additional questions regarding the study should be directed to the investigator listed above. In addition, I understand the research at Louisiana State University, Agricultural Center, which involves human participation, is carried out under the oversight of the Institutional Review Board. Questions or problems regarding these activities should be addressed to Dr. Michael Keenan, Chair of LSU AgCenter IRB, (225) 578-1708. I agree with the terms above and acknowledge.

I have been given a copy of the consent form.

__________________________ __________________________

Signature of Investigator Signature of Participant

Witness: __________________ Date: __________________

Committee Action: Exempted___ **Not Exempted**_____ **IRB#** HE12-17

Reviewer Michael Keenan **Signature** Michael Keenan **Date** 10-22-2012

APPENDIX A2 Questionnaire for consumer test

Sample # _________

Gender: [ ] Male [ ] Female

Age: [ ] 18-24 [ ] 25-34 [ ] 35-44 [ ] 45-54 [ ] 55-64 [ ] ≥65

1. How would you **rate** the following attributes of this product?

	Dislike Extremely	Dislike Very much	Dislike Moderately	Dislike Slightly	Neither Like nor Dislike	Like Slightly	Like Moderately	Like Very much	Like Extremely
Appearance	[ ] 1	[ ] 2	[ ] 3	[ ] 4	[ ] 5	[ ] 6	[ ] 7	[ ] 8	[ ] 9
Crumb color	[ ] 1	[ ] 2	[ ] 3	[ ] 4	[ ] 5	[ ] 6	[ ] 7	[ ] 8	[ ] 9
Visual volume/ Smoothness	[ ] 1	[ ] 2	[ ] 3	[ ] 4	[ ] 5	[ ] 6	[ ] 7	[ ] 8	[ ] 9
Overall aroma	[ ] 1	[ ] 2	[ ] 3	[ ] 4	[ ] 5	[ ] 6	[ ] 7	[ ] 8	[ ] 9
Moistness	[ ] 1	[ ] 2	[ ] 3	[ ] 4	[ ] 5	[ ] 6	[ ] 7	[ ] 8	[ ] 9

Moistness	[ ] Not enough	[ ] Just about right	[ ] Too much

Softness	[ ] 1	[ ] 2	[ ] 3	[ ] 4	[ ] 5	[ ] 6	[ ] 7	[ ] 8	[ ] 9

Softness	[ ] Not enough	[ ] Just about right	[ ] Too much

Overall texture	[ ] 1	[ ] 2	[ ] 3	[ ] 4	[ ] 5	[ ] 6	[ ] 7	[ ] 8	[ ] 9
Overall taste	[ ] 1	[ ] 2	[ ] 3	[ ] 4	[ ] 5	[ ] 6	[ ] 7	[ ] 8	[ ] 9
Overall liking	[ ] 1	[ ] 2	[ ] 3	[ ] 4	[ ] 5	[ ] 6	[ ] 7	[ ] 8	[ ] 9

2. How would you **emotionally feel** about this product?

	Not at all	Slightly	Moderately	Very much	Extremely
Calm	[ ] 1	[ ] 2	[ ] 3	[ ] 4	[ ] 5
Good	[ ] 1	[ ] 2	[ ] 3	[ ] 4	[ ] 5
Guilty (related to ingredients used and health)	[ ] 1	[ ] 2	[ ] 3	[ ] 4	[ ] 5
Happy	[ ] 1	[ ] 2	[ ] 3	[ ] 4	[ ] 5
Pleased	[ ] 1	[ ] 2	[ ] 3	[ ] 4	[ ] 5
Satisfied	[ ] 1	[ ] 2	[ ] 3	[ ] 4	[ ] 5
Unsafe (related to ingredients used and health)	[ ] 1	[ ] 2	[ ] 3	[ ] 4	[ ] 5
Worried (related to ingredients used and health)	[ ] 1	[ ] 2	[ ] 3	[ ] 4	[ ] 5

3. How likely will you **purchase** this product?

[ ] Yes [ ] No

APPENDIX A3 Questionnaire for consumer test (after consumers were informed)

Sample # _________

Please read this information:

This product is made with 20% butter.

--- or ---

Extra virgin coconut oil may provide health benefit. It may improve good (HDL) cholesterol, slightly boost metabolism, increase feeling of fullness and serve as a safe source of energy. **This sponge cake is made with 20% Extra virgin coconut oil.**

--- or ---

Extra virgin olive oil has been scientifically proven to have heart healthy effects. It may help increase good (HDL) cholesterol and lower bad (LDL) cholesterol. Thus, it may reduce the risk of cardiovascular diseases. **This sponge cake is made with 20% Extra virgin olive oil.**

--- or ---

Rice bran oil is rich in vitamin E and some phytonutrients. It may help reduce bad cholesterol, and combat cancer and chronic diseases. **This sponge cake is made with 20% Rice bran oil.**

1. How would you **rate** "overall liking" of this product?

Dislike Extremely	Dislike Very much	Dislike Moderately	Dislike Slightly	Neither Like nor Dislike	Like Slightly	Like Moderately	Like Very much	Like Extremely
[ ] 1	[ ] 2	[ ] 3	[ ] 4	[ ] 5	[ ] 6	[ ] 7	[ ] 8	[ ] 9

2. How would you **emotionally feel** about this product?

	Not at all	Slightly	Moderately	Very much	Extremely
Calm	[ ] 1	[ ] 2	[ ] 3	[ ] 4	[ ] 5
Good	[ ] 1	[ ] 2	[ ] 3	[ ] 4	[ ] 5
Guilty (related to ingredients used and health)	[ ] 1	[ ] 2	[ ] 3	[ ] 4	[ ] 5
Happy	[ ] 1	[ ] 2	[ ] 3	[ ] 4	[ ] 5
Pleased	[ ] 1	[ ] 2	[ ] 3	[ ] 4	[ ] 5
Satisfied	[ ] 1	[ ] 2	[ ] 3	[ ] 4	[ ] 5
Unsafe (related to ingredients used and health)	[ ] 1	[ ] 2	[ ] 3	[ ] 4	[ ] 5
Worried (related to ingredients used and health)	[ ] 1	[ ] 2	[ ] 3	[ ] 4	[ ] 5

3. How likely will you **purchase** the product?

[ ] Yes [ ] No

APPENDIX B

RAW DATA

APPENDIX B1 Effect of hydrocolloids on firmness (N) of sponge cake during storage

Temperature	Storage time (day)						
(^{O}C)	0	1	4	7	14	21	28
Control							
15	1.90 ±0.17	3.35 ±0.29	4.62 ±0.46	5.55 ±0.30	7.14 ±0.43	8.22 ±0.21	9.54 ±0.03
25	1.90 ±0.17	3.63 ±1.01	4.56 ±0.52	5.73 ±0.65	7.63 ±0.74	9.26 ±0.98	10.32 ±0.77
35	1.90 ±0.17	3.37 ±1.03	5.38 ±0.67	6.51 ±0.79	8.82 ±0.67	10.79 ±1.13	11.81 ±1.00
45	1.90 ±0.17	4.17 ±0.72	6.09 ±1.42	7.40 ±0.69	10.11 ±0.68	12.03 ±1.41	12.79 ±1.26
0.5 HPMC							
15	1.64 ±0.09	2.15 ±0.19	3.74 ±0.43	4.47 ±0.95	5.75 ±0.45	6.34 ±0.31	7.78 ±0.60
25	1.64 ±0.09	2.32 ±0.68	4.24 ±0.24	4.85 ±0.92	6.04 ±0.34	7.30 ±0.80	8.47 ±0.77
35	1.64 ±0.09	2.59 ±0.60	4.26 ±0.13	5.31 ±0.24	6.98 ±0.38	8.36 ±0.52	9.35 ±0.88
45	1.64 ±0.09	2.75 ±0.61	5.02 ±0.13	5.87 ±0.57	7.85 ±0.28	9.69 ±0.37	10.35 ±0.64
1.0 HPMC							
15	1.74 ±0.12	2.31 ±0.56	3.71 ±1.06	4.74 ±0.23	6.18 ±0.70	7.40 ±0.73	8.40 ±0.74
25	1.74 ±0.12	2.43 ±0.67	4.11 ±0.51	5.10 ±0.49	7.04 ±0.75	7.99 ±0.77	8.91 ±0.81
35	1.74 ±0.12	2.42 ±0.37	4.34 ±0.34	5.68 ±0.64	7.71 ±1.30	9.00 ±0.69	9.71 ±1.03
45	1.74 ±0.12	2.83 ±0.52	5.69 ±0.91	7.16 ±0.42	8.99 ±1.31	10.07 ±0.69	10.61 ±0.79
0.5 XG							
15	3.88 ±0.33	6.22 ±0.62	7.70 ±1.79	9.70 ±1.12	11.17 ±0.85	12.78 ±1.03	14.90 ±0.60
25	3.88 ±0.33	6.04 ±0.64	8.95 ±1.16	10.39 ±1.36	12.14 ±0.32	13.30 ±0.73	14.98 ±1.30
35	3.88 ±0.33	6.83 ±1.16	10.24 ±0.88	10.97 ±0.83	13.35 ±1.77	14.73 ±1.30	16.33 ±0.89
45	3.88 ±0.33	7.00 ±1.23	10.89 ±1.03	11.32 ±0.88	14.39 ±0.84	16.15 ±0.90	17.32 ±1.20
1.0 XG							
15	3.86 ±0.73	6..35 ±1.01	7.22 ±1.48	9.78 ±0.78	11.60 ±1.04	13.79 ±1.12	15.65 ±0.51
25	3.86 ±0.73	7.19 ±0.84	8.11 ±1.19	9.84 ±1.07	12.65 ±1.09	14.25 ±1.29	15.77 ±1.17
35	3.86 ±0.73	7.13 ±1.06	9.01 ±0.67	11.45 ±1.89	14.29 ±1.46	16.48 ±1.67	17.80 ±1.17
45	3.86 ±0.73	8.14 ±0.77	10.05 ±1.36	12.48 ±1.63	15.88 ±1.45	16.97 ±0.73	18.25 ±0.52
0.5 AG							
15	1.77 ±0.30	2.50 ±0.21	3.48 ±0.06	4.35 ±0.89	5.84 ±0.60	7.21 ±0.92	8.48 ±0.86
25	1.77 ±0.30	2.70 ±0.16	4.09 ±0.20	5.67 ±0.39	6.75 ±1.01	8.16 ±0.51	9.30 ±0.67
35	1.77 ±0.30	2.76 ±0.33	4.53 ±0.42	6.17 ±0.32	7.73 ±0.70	9.33 ±0.49	10.40 ±0.50
45	1.77 ±0.30	3.10 ±0.14	5.08 ±0.19	6.78 ±0.92	9.94 ±1.14	11.35 ±1.91	12.38 ±2.08
1.0 AG							
15	2.15 ±0.45	4.25 ±0.35	4.25 ±0.61	5.15 ±0.94	6.79 ±0.10	8.65 ±0.81	9.74 ±0.48
25	2.15 ±0.45	5.16 ±0.49	5.16 ±1.57	6.19 ±1.14	7.45 ±0.46	9.40 ±1.01	10.35 ±0.89
35	2.15 ±0.45	4.88 ±0.33	4.88 ±1.31	6.70 ±1.47	9.29 ±1.21	10.49 ±1.36	11.49 ±1.04
45	2.15 ±0.45	5.41 ±0.35	5.41 ±0.84	8.04 ±0.64	11.21 ±1.26	13.29 ±0.26	14.15 ±0.31

APPENDIX B2 Effect of 0.5% HPMC and/or 20% EVCO on firmness, moisture content and ^{1}H NMR T_1 of sponge cake during storage

Sample	Storage time (day)						
	0	1	4	7	14	21	28
Firmness (N)							
Control	5.75 ±0.14	6.99 ±0.20	7.75 ±0.29	8.12 ±0.21	10.58 ±0.53	12.09 ±0.24	12.55 ±0.10
0.5% HPMC	4.92 ±0.11	5.85 ±0.17	6.86 ±0.28	7.50 ±0.15	7.96 ±0.37	8.64 ±0.25	9.78 ±0.14
20% EVCO	4.71 ±0.18	4.84 ±0.20	5.51 ±0.25	6.60 ±0.34	7.18 ±0.58	7.19 ±0.29	8.36 ±0.22
combination	4.88 ±0.11	4.88 ±0.05	5.09 ±0.24	5.30 ±0.27	6.06 ±0.37	6.97 ±0.13	7.51 ±0.24
Moisture content (%)							
Control	25.93 ±0.86	23.91 ±0.10	23.02 ±0.28	22.18 ±0.73	20.55 ±0.46	19.88 ±0.29	19.74 ±0.31
0.5% HPMC	26.71 ±0.43	25.71 ±0.62	24.13 ±0.27	23.51 ±0.37	23.00 ±0.23	22.62 ±0.47	21.92 ±0.11
20% EVCO	25.99 ±0.78	24.58 ±0.49	23.31 ±0.41	22.58 ±0.78	21.09 ±0.44	20.98 ±0.48	20.52 ±0.49
combination	26.18 ±0.22	25.07 ±0.23	23.67 ±0.98	22.61 ±0.49	22.40 ±0.32	21.72 ±0.36	21.20 ±0.48
^{1}H NMR T_1 (ms)							
Control	380.60 ±0.29	375.18 ±0.11	360.72 ±0.16	342.01 ±0.24	327.12 ±1.02	313.45 ±1.28	311.47 ±1.00
0.5% HPMC	381.91 ±0.14	378.07 ±0.66	364.78 ±0.18	346.27 ±0.10	331.12 ±0.46	321.82 ±1.94	312.03 ±0.26
20% EVCO	381.69 ±0.47	376.26 ±0.14	363.05 ±0.28	341.65 ±1.01	324.45 ±0.14	314.03 ±0.73	312.03 ±0.31
combination	383.87 ±0.27	378.09 ±0.04	365.22 ±0.26	347.31 ±0.51	332.71 ±1.18	321.92 ±0.59	312.94 ±0.25

APPENDIX B3 % Total crystallinity of sponge cakes added with 0.5% HPMC, 20% EVCO and combination during storage

Sample	Storage time (day)						
	0	1	4	7	14	21	28
Control	6.67	6.88	7.47	7.51	8.44	9.14	10.10
0.5% HPMC	6.83	6.93	7.03	7.07	7.21	7.32	7.48
20% EVCO	9.40	9.43	9.44	9.47	9.48	9.49	9.50
combination	9.53	9.59	9.60	9.65	9.69	9.70	9.75

VITA

Mr. Naratip Poonnakasem was born on May 8th, 1984 in Bangkok, Thailand. He obtained a Bachelor of Science degree (2nd class honours) in Food Technology from Faculty of Science, Chulalongkorn University in 2006. After graduating, he worked as a food and beverage training course staff at Suan Dusit International Culinary School, Suan Dusit Rajabhat University. In 2008, he obtained a Master of Science degree in Food Technology from Faculty of Science, Chulalongkorn University. After graduating, he worked as a lecturer at School of Culinary Arts, Suan Dusit Rajabhat University. In October 2011, he started his Doctor of Philosophy (Ph.D.) study in Food Technology at Faculty of Science, Chulalongkorn University. His research areas are food processing and food product development.

Publication/ Presentation:

Chaiwanichsiri, S., Poonnakasem, N., and Laohasongkram, K. (2011). Process development of ready-to-eat custard cream filled Chinese steamed bun. 11th International Congress on Engineering and Food. Procedia Food Science. 1(2011), 822–828.

Laohasongkram, K., Poonnakasem, N., and Chaiwanichsiri, S. (2011). Process development of shelf-stable Chinese steamed bun. Journal of Food Process Engineering. 34, 1114–1124.

Poonnakasem, N., Laohasongkram, K., and Chaiwanichsiri, S. (2007). Effects of humectants and lactic acid on qualities of custard cream and Chinese steamed bun. Proceedings of 33rd congress on Sci. and Tech. of Thailand. Walailak University, Thailand.

Poonnakasem, N., Laohasongkram, K., and Chaiwanichsiri, S. (in Press). Influence of hydrocolloids on batter properties and textural kinetics of sponge cake during storage. Journal of Food Quality.

Poonnakasem, N. 2013. Effect of Hydrocolloid on Bread Staling. Journal of Food Technology, Siam University. 1 (Jun 2012 - May 2013), 12-20.

Poonnakasem, N., Chaiwanichsiri, S., and Laohasongkram, K. 2015. Influence of Hydrocolloids on Batter Properties and Textural Kinetics of Sponge Cake during Storage. 2015 IFT, Chicago, 2015.

Poonnakasem, N., Pujols, K. D., Chaiwanichsiri, S., Laohasongkram, K., and Prinyawiwatkul, W. 2015. Different Oils and Health Benefit Statement Affect Consumer Liking, Emotion and Purchase Intent: a Case of Sponge Cake. 2015 IFT, Chicago, 2015.