การสร้างแบบจำลองการตัดสินใจซื้อบนพื้นฐานคุณลักษณะสี สำหรับทุเรียน *Durio zibethinus* L. พันธุ์หมอนทอง

นางสุภาวดี ธีรธรรมากร

วิทยานิพนธ์นี้เป็นส่วนหนึ่งของการศึกษาตามหลักสูตรปริญญาวิทยาศาสตรดุษฎีบัณฑิต
สาขาวิชาเทคโนโลยีทางภาพ ภาควิชาเทคโนโลยีทางภาพและการพิมพ์
คณะวิทยาศาสตร์ จุฬาลงกรณ์มหาวิทยาลัย
ปีการศึกษา 2560

ESTABLISHING BUYING DECISION MODEL BASED ON COLOR ATTRIBUTES FOR *Durio zibethinus* L.

Mrs. Supawadee Theerathammakorn

A Dissertation Submitted in Partial Fulfillment of the Requirements
for the Degree of Doctor of Philosophy Program in Imaging Technology
Department of Imaging and Printing Technology
Faculty of Science
Chulalongkorn University
Academic Year 2017

Thesis Title	ESTABLISHING BUYING DECISION MODEL BASED ON COLOR ATTRIBUTES FOR *Durio zibethinus* L.
By	Mrs. Supawadee Theerathammakorn
Field of Study	Imaging Technology
Thesis Advisor	Associate Professor Aran Hansuebsai, Ph.D.
Thesis Co-Advisor	Professor Yasushi Hoshino, 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 Polkit Sangvanich, Ph.D.)

THESIS COMMITTEE

....Chairman

(Kuntinee Suvarnakich, Ph.D.)

....Thesis Advisor

(Associate Professor Aran Hansuebsai, Ph.D.)

....Thesis Co-Advisor

(Professor Yasushi Hoshino, Ph.D.)

....Examiner

(Associate Professor Pichayada Katemake, Ph.D.)

....Examiner

(Assistant Professor Chawan Koopipat, Ph.D.)

....External Examiner

(Assistant Professor Uravis Tangkijviwat, Ph.D.)

สุภาวดี ธีรธรรมากร : การสร้างแบบจำลองการตัดสินใจซื้อบนพื้นฐานคุณลักษณะสีสำหรับทุเรียน *Durio zibethinus* L. พันธุ์หมอนทอง (ESTABLISHING BUYING DECISION MODEL BASED ON COLOR ATTRIBUTES FOR *Durio zibethinus* L.) อ.ที่ปรึกษาวิทยานิพนธ์หลัก: รศ. ดร.อรัญ หาญสืบสาย, อ.ที่ปรึกษาวิทยานิพนธ์ร่วม: ศ. ดร.ยาซูชิ โฮชิโนะ, 147 หน้า.

ภาพผลิตภัณฑ์อาหารที่ปรากฏบนบรรจุภัณฑ์มักมีสีสันสดใสเพื่อดึงดูดความสนใจของลูกค้าและมีอิทธิพลต่อการตัดสินใจซื้อผลิตภัณฑ์ บรรจุภัณฑ์ทุเรียนเป็นเครื่องมือสำคัญในการผสมผสานด้านการตลาดเพื่อให้เกิดการตัดสินใจซื้อโดยเฉพาะสีที่สอดคล้องกับความคาดหวังของลูกค้า นักออกแบบและนักการตลาดบรรจุภัณฑ์จำเป็นต้องเข้าใจว่า สีมีผลต่อกระบวนการตัดสินใจซื้อของลูกค้าอย่างไร การวิจัยครั้งนี้มีวัตถุประสงค์เพื่อ สร้างแบบจำลองการตัดสินใจเลือกซื้อสินค้าโดยพิจารณาจากคุณลักษณะของสีที่มีต่อ Durio zibethinus cv.Monthong และเพื่อประเมินความสัมพันธ์ระหว่าง "Deliciousness", "Naturalness" และ "Attractiveness" กับการตัดสินใจซื้อ คุณลักษณะสีของภาพทุเรียน เช่น สีความอิ่มตัวของสี CIELAB ภายใต้อุณหภูมิสีที่ต่างกัน (CCTs) และความสว่าง (illuminances) การทดลองทางจิตวิทยาได้ดำเนินการขึ้นอยู่กับความรู้สึกของ "ความอร่อย" ความน่าดึงดูดใจ และความเป็นธรรมชาติจากบรรจุภัณฑ์ ด้วย เนื่องจากความรู้สึกเหล่านี้ส่งผลต่อการตัดสินใจซื้อ ผลการวิเคราะห์ความแปรปรวนแบบหลายตัวแปร (MANOVA) ระบุว่า ความอิ่มตัวของสีมีผลต่อความรู้สึกทั้งหมดที่มีอิทธิพลต่อการตัดสินใจซื้อ การวิเคราะห์ถดถอยพหุคูณพบว่าความสัมพันธ์ระหว่าง "ความดึงดูดใจเนื้อทุเรียน (Attractiveness of Flesh, Att-F)" และ "ความน่ารับประทานของเนื้อทุเรียน (Deliciousness of Flesh, Del-F)" สัมพันธ์ต่อการตัดสินใจซื้อ Att-F และ Del-F มีความสัมพันธ์กันมาก นอกจากนี้การคาดการณ์ความน่าจะเป็นมากกว่า 90% ของการซื้อสำหรับความคาดหวังของมนุษย์สูงโดยใช้การวิเคราะห์การถดถอยโลจิสติกระบุว่า ระดับความอิ่มตัวอยู่ที่ 45 และ 60% การประยุกต์ใช้แบบจำลองเพื่อปรับภาพทุเรียนพันธุ์หมอนทองแสดงให้เห็นว่า ค่าความเข้มของสีอ้างอิงอยู่ในช่วง 51 ถึง 58 และค่าความแตกต่างของความเข้มสีอยู่ในช่วง 21 ถึง 28

ภาควิชา	เทคโนโลยีทางภาพและการพิมพ์	ลายมือชื่อนิสิต	....
สาขาวิชา	เทคโนโลยีทางภาพ	ลายมือชื่อ อ.ที่ปรึกษาหลัก	....
ปีการศึกษา	2560	ลายมือชื่อ อ.ที่ปรึกษาร่วม	....

5872831123 : MAJOR IMAGING TECHNOLOGY
KEYWORDS: SATURATION, DURIAN, ATTRACTIVENESS, BUYING DECISION

SUPAWADEE THEERATHAMMAKORN: ESTABLISHING BUYING DECISION MODEL BASED ON COLOR ATTRIBUTES FOR *Durio zibethinus* L.. ADVISOR: ASSOC. PROF. ARAN HANSUEBSAI, Ph.D., CO-ADVISOR: PROF. YASUSHI HOSHINO, Ph.D., 147 pp.

Printed images of food products appearing on packaging usually include vivid colors in order to draw the customers' attention and influence their product buying decision. Durian packaging is a vital tool in marketing mix in contributing to buying decision, especially the color that are consistent with customers' expectation. Packaging designers and marketers need to understand how color stimuli impact the customer's buying decision process. This study aims to establish buying decision model based on color attributes for *Durio zibethinus* cv.Monthong and to evaluate the relationships between "Deliciousness", "Naturalness", and "Attractiveness" and buying decision.The color attributes of durian images, such as hue, saturation, CIELAB under various correlated color temperatures (CCTs) and illuminances, were investigated. A psychophysical experiment was conducted based on the feelings of "deliciousness", "attractiveness" and "naturalness" from the packaging, as these feelings impact buying decisions. Multivariate analysis of variance (MANOVA) indicated that saturation had a significant effect on all the feelings that influence buying decision. The multiple regression analysis showed that the relationships between "Attractiveness of Flesh (Att-F)"and "Deliciousness of Flesh (Del-F)" and buying decision were significant and related significantly to each other. In addition, predicted probability of more than 90% buying with high human expectations from logistic regression analysis indicated that the saturation level were 45 and 60%. Adjusting durian cv.Monthong by using the model showed that the reference chroma were in the range of 51 to 58 and delta chroma in the range of 21 to 28.

Department:	Imaging and Printing Technology	Student's Signature	....
		Advisor's Signature	....
Field of Study:	Imaging Technology	Co-Advisor's Signature	....
Academic Year:	2017		

ACKNOWLEDGEMENTS

Firstly, I would like to express my sincere appreciation to my advisor Assoc. Prof. Dr. Aran Hansuebsai and my co-advisor Prof. Dr. Yasushi Hoshino for the continuous support of my Ph.D study and related research, for their patience, motivation, and enormous knowledge. Their guidance helped me in all the time of research and writing of this thesis. I could not have imagined having a better advisor, co-advisor and mentor for my Ph.D study.

Besides my advisor and co-advisor, I would like to thank the rest of my thesis committee: Assoc. Prof. Dr. Pichayada Katemake, Dr. Kuntinee Suvarnakich, Asst. Prof. Dr. Chawan Koopipat and Asst. Prof. Dr. Uravis Tangkijviwat, for their insightful comments and encouragement, but also for the hard question which incented me to widen my research from various perspectives.

My sincere thanks also goes to Asst. Prof. Dr. Boonchai Waleetorncheepsawat and Dr. Tomoko Obama who provided me some guidance on color research, Asst. Prof. Dr.Suchittra Sueeprasan who corrected my thesis proposal and Sukhothai Thammathirat Open University for giving me the opportunity to continue my Ph.D. at Chulalongkorn University and access to the laboratory and research facilities. I also gratefully thank my colleagues, Assoc. Prof. Sunee Poosrimuang and Assoc. Prof. Pakamas Pachonklaew at School of Science and Technology who kindly shared my work load during study. Without they precious support it would not be possible to conduct this research. I would like to thank Chulalongkorn University for granting 60/40 for supporting the 3 years course of Ph.D. study and fellowship for joining program at Chiba University to gain more on color lab research knowledge and experiences, and many thanks also goes to Shinapol Toranathumkul for his camera and color chart and Ph.D. students, Anukul Radsamrong who helped color laboratory and Nawarat Kaew-on who helped thesis writing and other Ph.D. students who sheered me up. Finally, I specially thank my father, mother, my husband, and my daughter who provided love and care.

CONTENTS

Page

Page

LIST OF TABLES

LIST OF FIGURES

CHAPTER I
INTRODUCTION

1.1 Background and rationale

Durian *(Durio zibethinus)* cv.Monthong or *Durio zibethinus L.* is an important export tropical fruit with its main market in Hong Kong, China, and Taiwan and grows in commercial orchard in Chanthaburi province located in Eastern Thailand(1, 2). Durian flesh or pulp color is yellow. Its color gains more yellowness or higher b* value and changes a little in hue angle and lightness when it is in ripen(2). It implies colorfulness changing of durian flesh during ripeness. When people buy fruits, they have their expectation on fruits before they decide to buy them. There are two interesting mechanism involved.

The first mechanism is a mechanism of buying decision on product or fruit, which concerned on manufacturers or producers and customers' expectation (3-6) as shown in Figure 1-1. Manufacturers mostly pay attention on product characteristics such as color, shape, texture, design, etc. (5-9) while customers expect on freshness, appetizing look, taste flavor, etc. from fruits (4, 10-13). Customers' buying decision response on fruit are based on their experience and cognitive (6, 7). Then which one of many factors of product characteristics and many items of customer's expectations influence human brain for buying response? Therefore the bridge of product information from manufacturers and customer's expectation in order to achieve buying decision is essential.

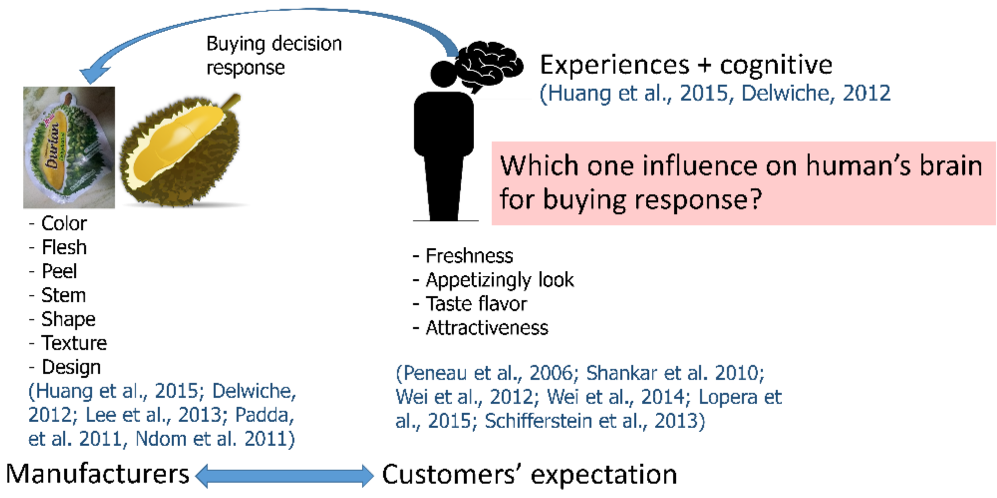


Figure 1- 1 Mechanism of buying decision on fruit (3-6)

There are many articles mentioned about relationship between vision and product taste. For example, Schifferstein et al.(3) revealed that vision was the most important factor at buying stage during selecting a product on a supermarket shelf, and taste was the second factor after opening the package and eating the food. Attractiveness was the most emotion at buying stage as well. More than 50% of the consumer (85.1%) considered on looking at the packaging in order to find out what to expect from the product at point of purchase, and almost a third (28.7%) paid attention on the image to assume what the product would taste like. Color and flavor relation were found in many articles. For example, Huang et al (6) found that package color is an essential marketing clue about the taste and healthiness perceptions of food products such as products packaged in red are perceived to be sweeter, whereas green and blue packaged products are related with the perception of healthiness. Ndom et al (5) showed that color mixed by food coloring influenced on taste and flavor perception of a drink. They found that customers hardly identify the taste of a fruit flavored drink or beverage when the color is not consistent with the expected taste. Then people prefer to perceive a higher quality product having color that are in harmony with their expectations on beverage taste.

Even if many publications were carried on color-flavor relations, recent evidence suggests that research has concerned the influence of cognitive and contextual factors on flavor perception, especially effect of consumers' expectations (4). Color on food may be the most obvious visual cue that transforms the way of taste and flavor, but customers' expectations through associative learning are set by other visual cues as well, including gloss, and shape, which should be concerned such as stronger color-lower taste (7). Understanding in cognitive behavioral responses to fruit should be considered due to interpretation of the package color of individuals is different, which involves not only the ability to balance cognitive and behavioral responses to stimuli but also cognitive behavioral responses to fruit (6). How do we know which factors that are consistent with customers' expectations?

The second mechanism is mechanism of buying decision in marketing. Kotler et al (14) mentioned that consumers make buying decisions based on the stimulus-response model, in which a stimulus enters the consumer's "black box" and generates a product confident response, as shown in Figure 1-2. The buyer processes product information, such as the product's characteristics, to determine his or her needs and make a buying decision (15). Buying decision is made using both the left and right brain. Balancing the input from the hemispheres leads to a buying decision (16). Past experiences generally influence willingness to buy in the same direction as feelings such as attractiveness (17). The freshness of fruits and vegetables also influences the customer's need for deliciousness (12, 18).

The key components of color vision are composed of color object, light source, and human eye. Color image plays an important role in customer's satisfaction. When we see color images of any food especially the familiar ones, they can trigger a signal to our brain that lead to flavor perception such as delicious, sweet, sour, etc. (4, 5, 7, 10, 19, 20). Positive perception according to customer expectation leads to a decision in purchasing the product (10, 20). Wie et al. discovered that color on package design in accordance with customer expectation influences initial appeal to procure and consequent action of buying decision.

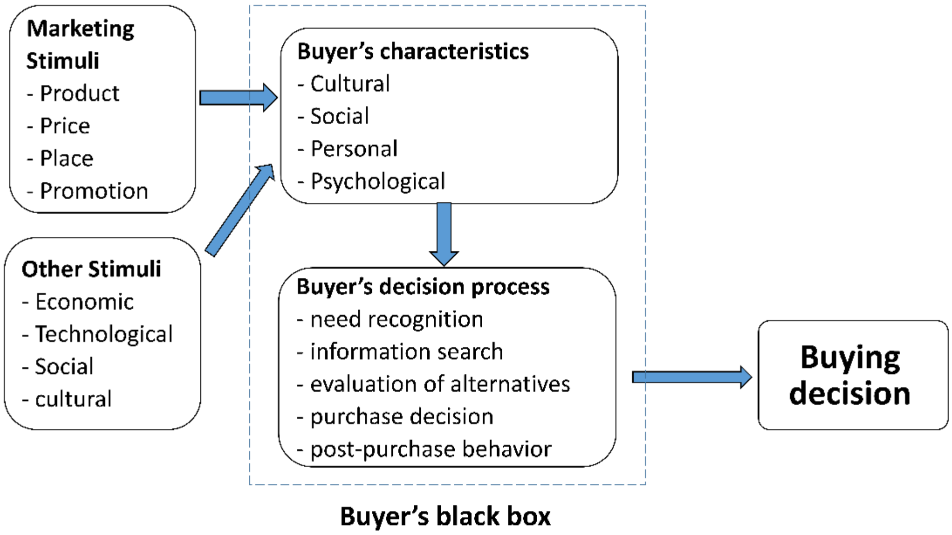


Figure 1- 2 Stimulus-response model of buying decision.

Ambient lighting presents an essential issue for visual perception in terms of stimulating food appetite, especially lighting color being similar to food color (21-23). Suk et al. found that lighting color could motivate appetite when color of foods and lighting have been similar(21). Therefore, there are many ambient lighting adjustments in supermarket, department store, and grocery store to attract customers. Light Emitting Diodes (LED) is a lighting source used frequently in retail grocery stores in order to save electrical energy (24, 25). Most lighting conditions are adjusted corresponding to Kruithof's rule of "pleasing", with high correlated color temperature (CCT) illumination at high illuminance and low CCT illumination at low illuminance (26, 27). Vienot et al. studied the effect of CCT and illuminance level of adjustable LED clusters on visual response following Kruithof's rule, which were combinations of CCT at 2700, 4000, 6500 K and illuminance level at 150, 300, and 600 lux (27). However some study found no significant difference in color perception of familiar colors under different ambient lighting (26). This might be caused by color constancy and memory color.

Some studies found that memory color influenced color perception of familiar colors (20, 22). For example, Koster et al. reviewed that color of familiar food had influence on the emotions related to eating in non-eating situation (20). Witzel et al.

mentioned that a memory color had an impact on the observer's expectation of color of an object based on his or her prior familiarities or memory experiences leading to recognition of the object color (22). It seems that different light sources may have little influence on familiar color objects. In addition, memory colors enhance hue and saturation, especially in color saturation (22, 28). There are many studies about food color of package design in respect of customer expectation (8, 29, 30). For example, Wie et al. studied color harmony and customer expectation on package design and found that chroma affected freshness perception (10). Becker et al. examined the influence of color saturation of yoghurt package on taste impressions and found that color saturation might impact product perception (30). However, there are few studies on relationships between color saturation and buying decision of familiar products color.

Therefore the present study aims to establish buying decision model based on color attributes for *Durio zibethinus* cv.Monthong and to evaluate the relationships between "Deliciousness", "Naturalness", and "Attractiveness" and buying decision.

1.2 Objectives

Two objectives are set up for the present research.

1. To establish buying decision model based on color attributes for *Durio zibethinus* cv.Monthong.
2. To evaluate the relationships between "Deliciousness", "Naturalness", and "Attractiveness" and buying decision

1.3 Conceptual framework

Conceptual framework for this study was developed by applying buying decision model based on Stimulus-response and perception theory. Stimuli in this study were durian image in 6 various color saturation levels (-15, 0, 15, 30, 45, 60 %) and 9 lighting conditions (3 CCTs; 2700, 4000, 6500 K, and 3 illuminances; 150, 300, 600 lux) (27). Thirty participants observed the printed durian image under the 9 lighting conditions. The results of perception were evaluated by focusing on human feelings and buying decision.

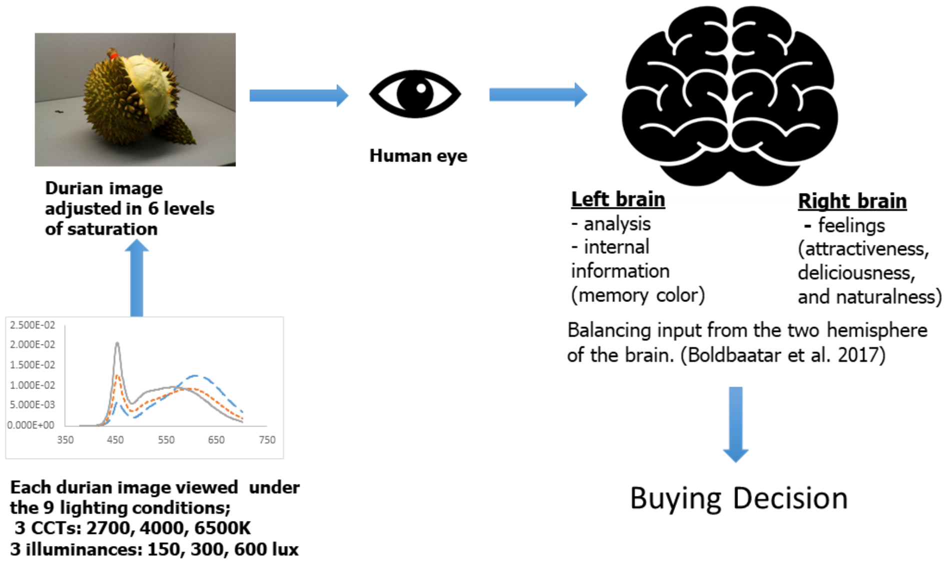


Figure 1- 3 Conceptual Framework.

The overall structure of the study takes the form of six chapters. The first chapter gives background information including objectives and conceptual framework of the study. Chapter Two begins by layout the theoretical dimensions of the research and looks at how to design for the experiment. Chapter Three presents durian image and preliminary study that provides the survey information on color attributes and characteristics of durian (*Durio zebethinus*) cv.Monthong or *Durio zebethinus L.* The fourth chapter is concerned with materials, equipment and experiments utilized for this study. Chapter Five analyses the results of human expectations by using statistical methods such as mean, MANOVA, multiple regression, and logistic regression, including the result repetition for verification. The last chapter concludes the findings following the objectives.

CHAPER II
LITERATURE REVIEW

2.1 Durian cv. Monthong attributes

Durian (Durio zibethinus) is consisted of three parts; flesh, peel and stem (see Figure 2-1). Durian is named “King of Fruit” due to the superlative flesh including its peels looks like the thorny throne of Kings, which is an expensive tropical fruit widely grown in South-East Asia. Durian is high in carbohydrate, protein, fat, phosphorus, iron and vitamin A (31). There are many durian cultivars such as Monthong, Chanee, Kanyao, etc. Durian cv. Monthong is a main tropical fruit in Hong Kong, China, and Taiwan and grows in commercial orchard in Thailand, which it is normally harvested at 123$\pm$2 days or about 17 weeks and stored about a week for ripen (adequate eating quality) (1, 2).

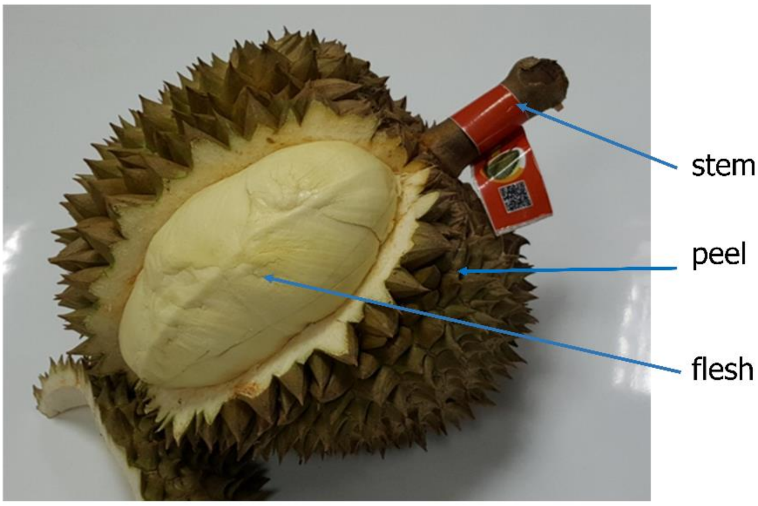


Figure 2- 1 Durian (Durio zibethinus) cv.Monthong or Durio zibethinus L.

Some related studies on Durian in terms of color. Wisutiamonkul et al (2) examined carotenoids in durian fruit flesh during growth and postharvest ripening. They detected that durian cv. Monthong provides less yellow color than cv. Chanee. The b* value of cv. Monthong from the plot of b*value and weeks after anthesis increases when it is in ripen, which is about 30 at 17 weeks or at mature stage and still increases until at ripe stage (see Figure 2-2). The hue value of cv. Monthong decreases a little from 100 degree at 10 weeks to less than 100 degree at mature and ripe stage. The L* value of durian flesh increases after anthesis until at mature stage and then decreases when it is at ripe stage. The results also agreed with Amornputti et al (1) that L* and b* value decrease when durian is in ripen. At the same time durian flesh shrinks more and leads to more space between flesh and peel due to both flesh and peel lose water when durian fruit become ripe, which notices from withered skin of durian peel or stem and knocked sound from durian fruit peel (1).

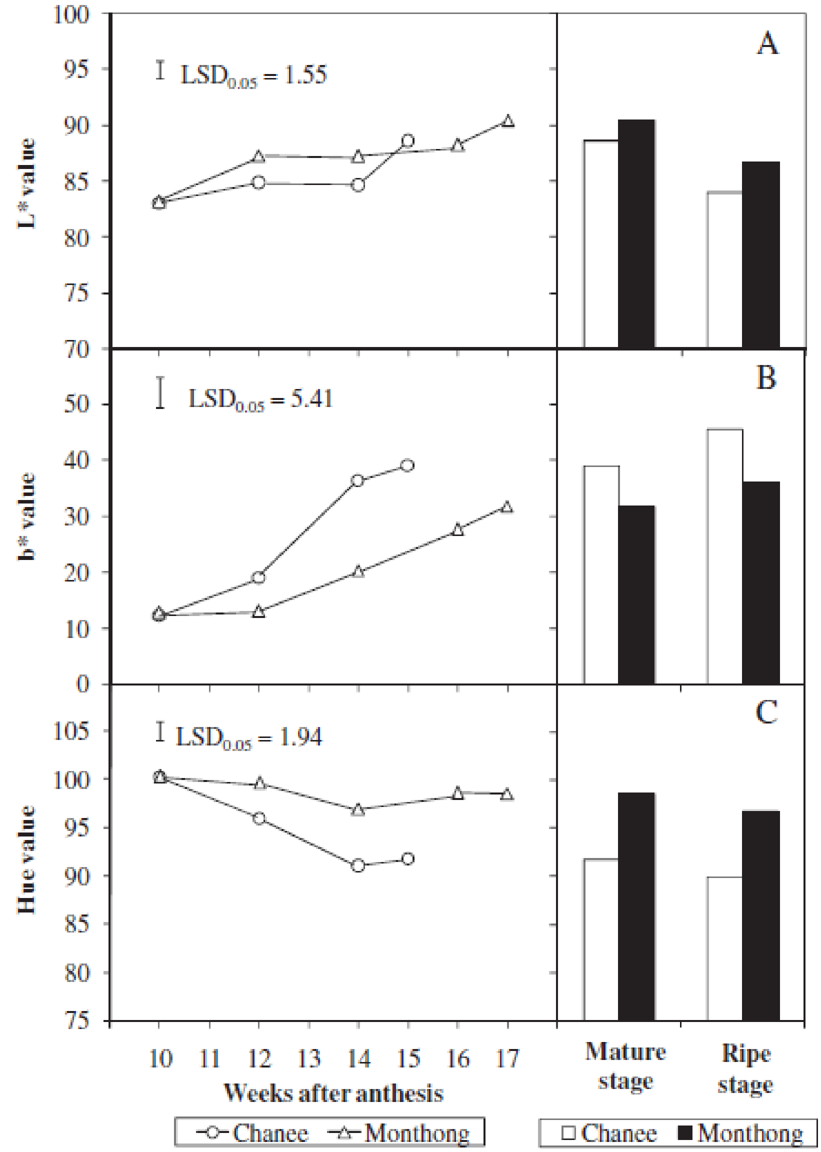


Figure 2- 2 The results of L, b*, and Hue value vs. weeks after anthesis of cv. Monthong and Chanee were studied by Wisutiamonkul et al(2).*

Durian cv. Monthong contains more carotenoids at ripe stage than mature stage (2). Increasing carotenoids influences on the a* value shifting from green to red (8).

2.2 Mechanism of buying decision

Kotler et al.(14) mentioned that consumers make buying decisions based on the stimulus-response model, in which a stimulus enters the consumer's "black box" and generates a product confident response, as shown in Figure 1-2. Understanding how the stimuli are transformed into responses inside the buyer's black box is essential to understanding buying decisions. The buyer's personal characteristics and their decision process are key components of their black box. There are four main characteristics of the buyer that affect consumer purchasing; these are cultural, social, personal, and psychological characteristics (14, 15). Motivation, perceptions, learning or memory, and beliefs and attitude are the four psychological factors that play key roles in the buying decision process (32). The process consists of five stages, which are need recognition, information search, evaluation of alternatives, purchase decision, and post-purchase behavior, as shown in Figure 1-2 (14, 15). The characteristics of the buyer are different in each person and depend upon his or her actual state and some desired state involving the basic needs described by Maslow's hierarchy such as hunger and sex. These factors present particular products to address the customer's needs through marketing stimuli and other stimuli such as color and shape of the product and promotional sales (15, 32). Once the consumer has recognized his or her unsatisfied need, they move on to information search, which is the second step in the process. This information can be obtained from both internal and external searches. An internal search refers to the information collected in the memory, while the latter relates to different sources such as friends, family, and media (14, 32). The buyer processes product information, such as the product's characteristics, to determine his or her needs and make a buying decision (15). The buying decision is made using both the left and right brain. The left brain is essential to rational thinking processes, such as analysis, attention to detail, and cognition from experiences or memory, whereas the right brain is essential to creative thinking such as imagining, feeling, and emotion. Balancing the input from the hemispheres leads to a buying decision (16). Past experiences generally influence willingness to buy in the same direction as feelings such as attractiveness (17). The freshness of fruits and vegetables also influences the customer's need for deliciousness (12, 18).

According to the literature review, another mechanism of buying decision on product or fruit, which concerned on manufacturers or producers and customers' expectation (3-6) as mentioned in Chapter I.

2.2 Color attributes

Color attributes such as lightness, hue, and saturation are fundamental properties of visual perception (33) and are important aspects of color constancy and memory color. Human beings learn by the flow of information through their five senses; sight, hearing, smell, touch, and taste. Perception is the process by which a person chooses, organizes, and interprets information to form a meaningful picture of the world (14). Each person can form different perceptions of the same stimulus depending upon his or her experiences related to the stimulus (14).

The key components of color vision are color object, light source, and the human eye. Food taste is perceived through the eyes. Even if there are dissimilar characteristics to a food item, visual appearance and color is the most recognizable stimulus (5). When we see color images of any food, especially of familiar foods, the image can trigger a signal to our brain that leads to the perception of flavors such as delicious, sweet, and sour, which are reported by many studies (4, 5, 7, 10, 19, 20). For example, Spence et al (19) found that beverage color influenced taste and flavor perception in Humans by studying 6 colored and clear (no color) drinks for two groups of participants from the UK and Taiwan. Positive perception based on customer expectations leads to a decision to purchase the product (10, 20). Ndom et al (5) examined the effect of color on taste perception of the fruit flavored drink by manipulating the color of the fruit drinks and evaluating its effects on the taste perception. They found that customers hardly identify the taste of a fruit flavored drink or beverage when the color is not consistent with the expected taste, which results that customers prefer to perceive a higher quality product having color that are in harmony with their expectations on beverage taste (5). Wie et al(10) discovered that the use of colors in the package design that are in accordance with customer expectation influences initial desire to purchase and the subsequent buying decision.

Ambient lighting is a key factor in visual perception for stimulating food appetite, and this effect is particularly noticeable when the lighting color is similar to the food color that has been found in many studies (21-23). For example, Suk et al (21) examined the best and worst arrangement of lighting color and food color that arouses or dampens one’s appetite by using an adjustable LED (lighting emitted diode). The study showed that lighting color could motivate appetite when the colors of the food and the light are similar, including yellow lighting stimulates one’s appetite except when the food is white colored. Tsujimura et al (23) proposed a visual expectation model of a food product. They conducted a sensory experiment using LED lighting and different kinds of packed and unpacked food. They found that illuminance and color temperature effected on CIE L*C*h of the packed and unpacked food for controlling the food “look appetizing”, in addition chroma of the packed and unpacked food color under various lightings showed corresponding to memory color and was higher chroma than the one under standard D50.

Supermarkets, department stores, and grocery stores use a variety of ambient lighting techniques to attract customers. Light-emitting diodes (LEDs) are frequently used as light sources in retail grocery stores to save electrical energy (24, 25). Most lighting conditions are adjusted to correspond to Kruithof’s rule regarding pleasing lighting, in which high correlated color temperature (CCT) illumination is used at high illuminance and low CCT illumination is used at low illuminance (26, 27). Vienot et al(27) studied the effect of CCT and the illuminance level of adjustable LED clusters with high color rendering more than 90 on visual response following Kruithof’s rule, and they utilized combinations of 2700, 4000, and 6500 K CCT and illuminance levels of 150, 300, and 600 lux for investigation of “pleasing” of visual test such as reading performance, visual performance, color appearance etc. They discovered that illuminance effected on performance tasks more than CCT and high CCT illuminations looked brighter than low CCT illuminations. to establish the optimal visual parameters, including illuminance, correlated color temperature (CCT) and color codes, of packaging for the elderly in a supermarket-type illuminated environment. Five illuminance levels (1100, 900, 700, 500 and 300 lux) were employed, where 700 lux was the average illuminance level found in five supermarkets in Bangkok, using light emitting diode (LED) light sources with a CCT of 6500 K, 5000 K and 3500 K. Radsamrong et al(26) investigated the optimal visual parameters like illuminance and correlated color temperature (CCT) for the elderly on packed product selection and label under various lightings compared to young. Their findings revealed that no statistical significant difference of illuminance and CCT effected on the number of incorrected items and time spent on the packaging selection between elderly and young participants. This might cause from color constancy.

Due to color constancy, objects tend to be recognized as having almost the same color under many lighting conditions due to the human visual system compensating for changes in both the level and color of the lighting (33, 34). However, the illumination level can decrease and cause color inconstancy when there is a progressive reduction in brightness and colorfulness. The color of illumination can appear different from that in average daylight when there is a progressive loss of color compensation, such as in yellower objects under candle light (33).

Granzier et al (35) mentioned that memory color is traditionally defined the memory of the color of familiar objects like a yellow banana, a red tomato etc. Memory colors tend to extend the actual hue and saturation tolerance region especially wider in saturation (22, 28). Some studies have found that memory color influences the color perception of familiar colors. For example, Koster et al. reported that the colors of familiar foods influenced emotions related to eating in noneating situations(20). Witzel et al (22) mentioned that a memory color could impact the observer's expectation of the color of an object based on his or her prior familiarities or memory experiences, which can lead to recognition of the object color.

Many studies have been conducted on food color and package design with respect to customer expectations. For example, Wie et al (10) studied color harmony and customer expectations in package design and found that chroma affected freshness perception. Arce-Lopera et al (18) found that changes in a* and b* or color in the CIELAB color space influenced the freshness of strawberry more than changes in L* and revealed that there was a significantly highly relationship between a luminance (Y value) of the image and freshness perception. Becker et al (30) examined the influence of color saturation in yogurt packaging on taste impressions and found that color saturation might impact product perception.

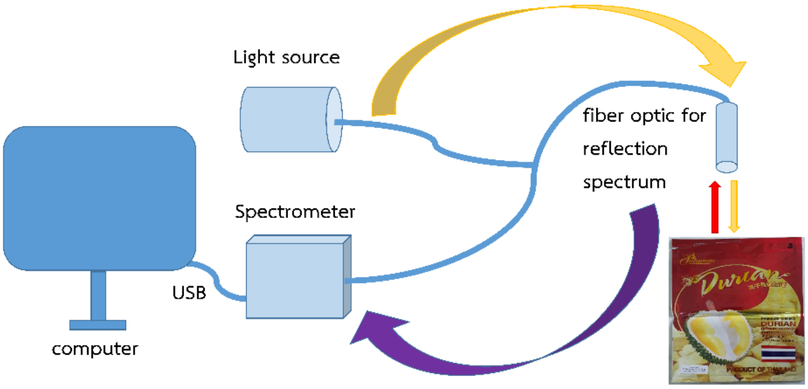
CHAPER III

DURIAN IMAGE AND PRELIMINARY STUDIES

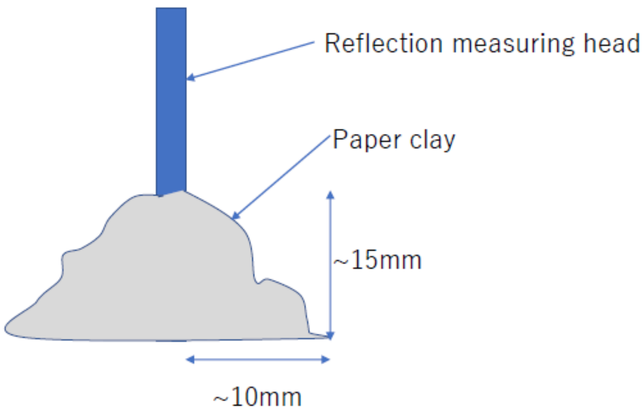
This chapter was to find out durian color image characteristics and to survey lighting conditions used in supermarkets as preliminary studies. The characteristic studies divided into two parts by using samples of food packaging with printed durian image from supermarkets. The two parts were durian image color in terms of CIELAB and durian image characteristics impacting on human expectation.

3.1 Durian image color in terms of CIELAB

Four packed durian often found in more than two supermarkets and presented a large durian image were picked up for the preliminary study. Durian flesh image on the four package samples and real Durian flesh of cv. Monthong were measured by Red Tide USB650 Fiber Optic Spectrometer (Ocean Optics) twice at Tokyo Denki University (Figure 3- 1). The end of the probe was covered with paper clay to keep the suitable distance between the probe and durian (about 3-5 millimeters) to avoid reflection from the light outside and also not flat durian flesh. The radius and the height of paper clay covered was about 10 and 15 millimeters, respectively (see Figure 3-1 b). Then check the spectrum with variation of the distance until achieve the spectrum of durian flesh before collecting the data. then calculate CIELAB and compared. The reflection of durian image were divided by the white spectrum from white of Macbeth and then calculate CIEXYZ by equation 1 to 3 (36). After that, CIELAB were calculated by equation 3.4 to 3.6 (33).



a



b

Figure 3- 1 The reflection of durian image was measured by fiber optic spectrometer; a) Illustration of setting measuring b) the outside look of the distance of paper clay covered the measuring head.

$$X = k\sum_{400}^{700} R(\lambda)x(\lambda)P(l) \quad 3.1$$

$$Y = k\sum_{400}^{700} R(\lambda)y(\lambda)P(l) \quad 3.2$$

$$Z = k\sum_{400}^{700} R(\lambda)z(\lambda)P(l) \quad 3.3$$

Where: $P(\lambda)$ is the relative spectral power distribution of an illuminant of D65 and D50

$x(\lambda), y(\lambda), z(\lambda)$ are the color matching functions for the CIE 1931 at 2 degree observer

$R(\lambda)$ is the spectral reflectance of a surface

k is a normalizing factor given by $100/\sum_{400}^{700} P(\lambda)y(\lambda)$

$$L^* = 116f\left(\frac{Y}{Y_n}\right) - 16 \quad 3.4$$

$$a^* = 500[f\left(\frac{X}{X_n}\right) - f\left(\frac{Y}{Y_n}\right)] \quad 3.5$$

$$b^* = 200[f\left(\frac{Y}{Y_n}\right) - f\left(\frac{Z}{Z_n}\right)] \quad 3.6$$

Where: $f\left(\frac{X}{X_n}\right) = \left(\frac{X}{X_n}\right)^{1/3}$ for $\left(\frac{X}{X_n}\right) > \left(\frac{6}{29}\right)^3$

$f\left(\frac{X}{X_n}\right) = \left(\frac{841}{108}\right)\left(\frac{X}{X_n}\right) + 4/29$ for $\left(\frac{X}{X_n}\right) \leq \left(\frac{6}{29}\right)^3$

and

$f\left(\frac{Y}{Y_n}\right) = \left(\frac{Y}{Y_n}\right)^{1/3}$ for $\left(\frac{Y}{Y_n}\right) > \left(\frac{6}{29}\right)^3$

$f\left(\frac{Y}{Y_n}\right) = \left(\frac{841}{108}\right)\left(\frac{Y}{Y_n}\right) + 4/29$ for $\left(\frac{Y}{Y_n}\right) \leq \left(\frac{6}{29}\right)^3$

and $f\left(\frac{Z}{Z_n}\right) = \left(\frac{Z}{Z_n}\right)^{1/3}$ for $\left(\frac{Z}{Z_n}\right) > \left(\frac{6}{29}\right)^3$

$$f\left(\frac{Z}{Z_n}\right) = \left(\frac{841}{108}\right)\left(\frac{Z}{Z_n}\right) + 4/29 \qquad \text{for } \left(\frac{Z}{Z_n}\right) \leq \left(\frac{6}{29}\right)^3$$

and $X_n = k\sum_{400}^{700} x(\lambda)P(\lambda)$

$$Y_n = k\sum_{400}^{700} y(\lambda)P(\lambda)$$
$$Z_n = k\sum_{400}^{700} z(\lambda)P(\lambda)$$

The 4 package samples of durian image were consisted of three of flexible packaging with PET (polyethylene terephtharate) surface and a folding carton with cardboard surface as shown in Figure 3-2.

package-1 package-2 package-3 package-4

Figure 3- 2The 4 package samples of durian image for CIELAB findings.

Two pieces of durian flesh cut from one Durian cv. Monthong fruit that were about two days ripen (mature or raw durian, RD). One piece of them was ripen with increasing temperature by using Microwave at 500 watts 1 minutes (ripen or cooked durian, CD). Then color of both pieces were measured twice by fiber optic spectrometer and also yellow color from Macbeth were measured. (Figure 3-3).

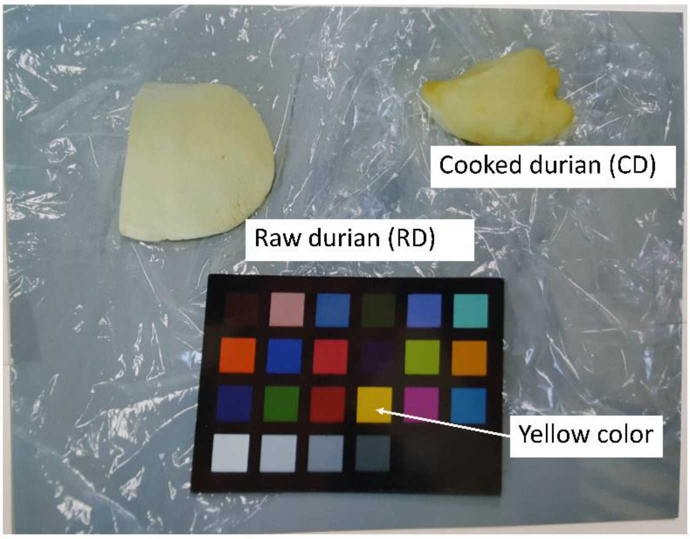


Figure 3- 3 Durian flesh and yellow color from macbeth for CIELAB findings.

The results showed that the b* value and chroma (C*ab value) from the 4 packages and real durian were similar values under both D65 and D50 (see Table 3-1). The b* value of real durian was about 30 at mature stage (about 17 weeks from anthesis) which also agreed with Wisutiamonkul et al (2). The results of durian flesh CIELAB calculation showed the same direction and color value (b*, hue angle of durian cv. Monthong of raw durian (mature) corresponding to the report of Wisutiamonkul et al.(2), except L* in the range of 55 to 60 and trend to increase.

The results of 4 packages provided higher chroma (C^*_{ab}) than both durian flesh at mature (RD) and ripen (CD) at D65 and D50 2 degree observer (Table 3-1, Figure 3-4, and APPENDIX A). Durian flesh printing image of 4 packages provides greater saturated color than one of real durian flesh. Why saturation in print is higher than the real one? Wei et al (11) suggested that fruit with more saturated color was expected to be stronger flavor. Then the thesis study concerned on saturation.

Table 3- 1 CIELAB value of printed durian image on package and real durian comparison

Items	RD (mature)	CD (ripen)	Y	Pack-1	Pack-2	Pack-3	Pack-4
D65							
L*	55.095	60.029	89.339	93.883	88.518	83.717	93.975
a*	-11.484	-11.920	-0.163	-23.247	-9.219	-4.459	-9.502
b*	32.904	40.479	63.175	90.133	120.866	108.502	49.228
h^*_{ab}	109.239	106.408	90.148	104.463	94.362	92.353	100.925
C^*_{ab}	34.851	42.198	63.175	93.082	121.218	108.593	50.137
D50							
L*	55.223	60.219	90.051	94.243	89.198	84.438	94.332
a*	-7.714	-7.731	4.377	-16.319	- 1.553	2.996	-4.120
b*	31.117	38.669	64.173	86.914	112.659	102.023	47.964
h^*_{ab}	103.924	101.305	266.097	100.634	90.790	88.318	94.910
C^*_{ab}	32.059	39.434	64.322	88.433	112.670	102.067	48.141

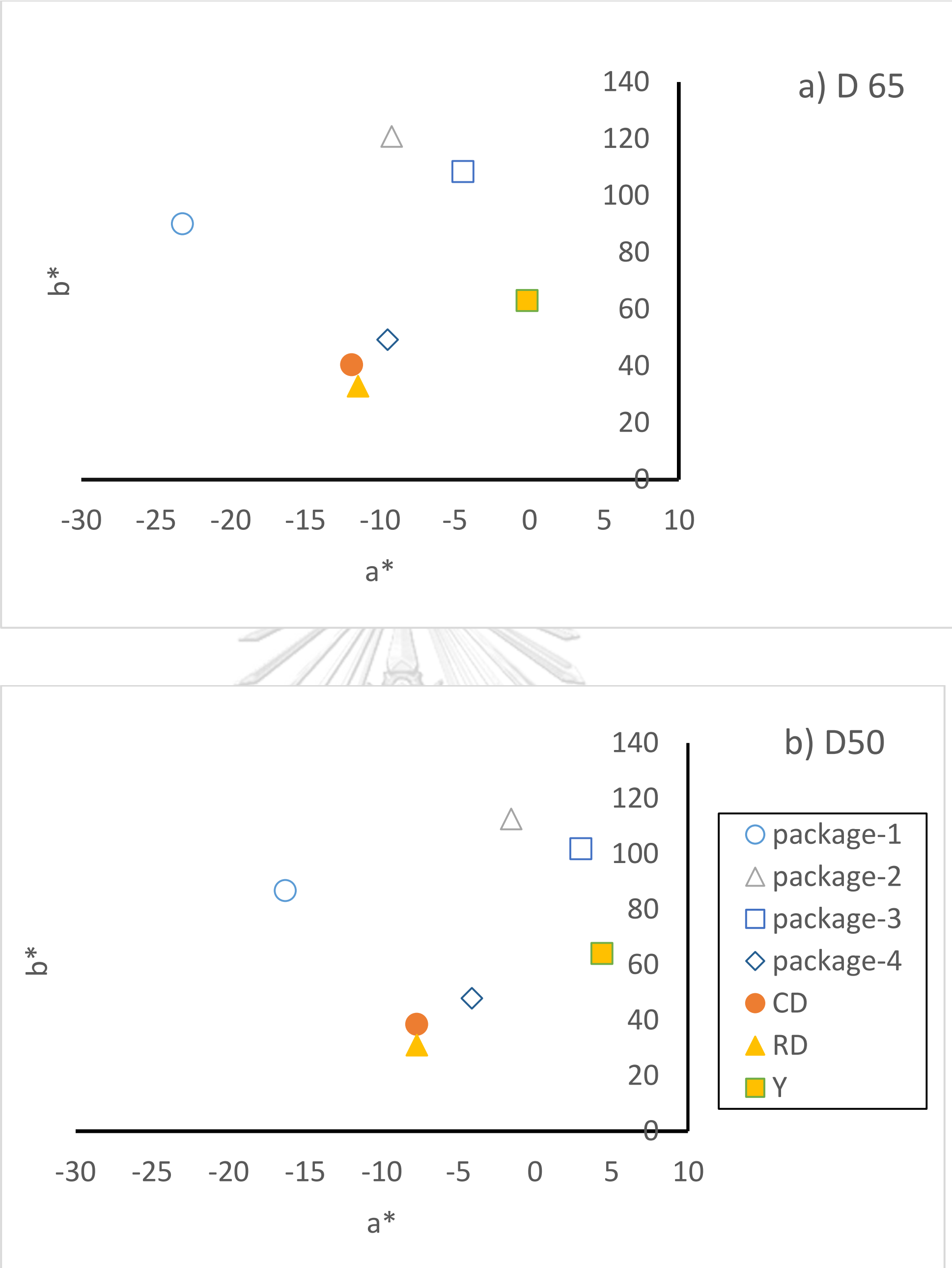


*Figure 3- 4 The plot of a*b* of CIELAB space. a. at D65 2 degrees observer b. at D50 2 degrees observer.*

3.2 Durian image characteristics impacting on human expectation

Durian fresh fruit is normally composed of three important parts; peel, fl esh, and stem. For finding durian image characteristics impacting on human aspects in terms of deliciousness, naturalness, attractiveness, and want to buy, a sample package with printed durian image from supermarket was used for discussion by 2 focus groups, 5-6 people per group (37, 38). A focus group is a tool to widely apply in the examination of applied-research problems and to utilize with several key considerations such as a narrowly focused topic, interested topic to both researchers and respondents, and concrete answers and highly detailed information occurring when the interest level is high (39).

Two groups of people who have experiences in durian such as manufacturers and customers were invited for this study. Each group consisted of at least one person who had an experience in durian farm. Each group was interrogated 7 questions for discussion (Figure 3-5). The 7 questions were focused on human expectations about durian image appearing on the packaging sample from supermarket such as "Do you like durian?", "According to the durian sample picture. Do you think it looks "Delicious"? " etc. (APPENDIX B). The data from discussion were recorded and analyzed. Discourse analysis that was utilized for focus group especially for analyzing topic obtained during conversations (40, 41) was applied to find durian characteristics impacting on the human aspects.

Figure 3- 5 Focus group discussion on the durian image of package sample.

The results (Table 3-2) of each group were similar in terms of color and texture of durian characteristics. Some durian characteristics such as peel can impact on “Deliciousness” or “Attractiveness” or “Naturalness” such as thin peel makes feeling of more freshness than thick peel and yellow-green color peel makes feeling of feshness as well. The results are in agreement with those obtained by Amornputti et al.(1) in tems of freshness that peel would shrink and color change when in more ripen.

Table 3- 2 Result of Focus group discussion

Items	Focus group 1	Focus group 2
1. Do you like to have durian?	Yes	Yes but someone in the group loves to buy for friends or families as gifts, not like to eat)
2. According to the durian sample picture. Do you think it looks "Delicious"?	Yes.	Yes.
3. How does it look "Delicious"?	- Yellow color is nice, not too yellowish. - Durian flesh looks full of husk, smooth and plump. - Durian stem still stick to the durian representing freshness.	- Big shape - Durian flesh looks firm. - Stem still stick to the durian. - Flesh durian looks nice, balance, and full of husk. - Fresh color is gold yellow. - Thin peel and small throny durian.
4. Do you think it looks "Natural"?	Not really. Because of some flesh looks decoration, too much full flesh, not natural.	Yes.
5. How do the durian picture make you feel "Natural"? Please describe.	- Component of stem, peel, and flesh show combination. - Peel durian color is green, not too green which makes it more natural.	- Show the combination of stem, peel, and flesh. - Stem should not be broken and looks firm, not withered. - Flesh color is yellow, not too pale and too yellow. - Peel color is yellow green.

Table 3-2 Result of Focus group discussion (continued)

Items	Focus group 1	Focus group 2
6. What do you think how to make the durian picture more “Attractive”?	- Durian peel looks thin which make feeling of full flesh. - The round shape of the durian looks even of the full flesh inside. - Peel color is still yellow green representing fresh durian. - Flesh color is nice yellow. - White color at core shows little which means small seed.	- White color at core shows little which means ripe enough. - Flesh is yellow, not orange color. - Flesh skin is smooth and full, not withered.
7. What kind of the durian picture make you feel “don’t want to buy”?	- too soft flesh look. - not smooth skin of flesh, withered. - lack of durian stem - too green of peel color - too yellowish like primary yellow color - asymmetrical shape of the durian - thorny durian are broken.	- still raw, not ripe enough. - not show the flesh durian - not show the durian stem - not show the peel - too soft flesh - too much peel - too yellowish flesh

According to the results, the durian characteristics impacting on “Deliciousness”, “Naturalness”, “Attractiveness”, and “Want to buy” could be concludes as shown in Table 3-3. For example, durian flesh with firm skin, nice yellow color could impact on deliciousness. Durian flesh was the most important characteristic part of durian impacting on the 4 human expectations. According to the results, the most factor related to durian characteristics impacting on human expectations was color. Then the thesis study concerns on color. The findings were also applied for establishing interview form in chapter IV.

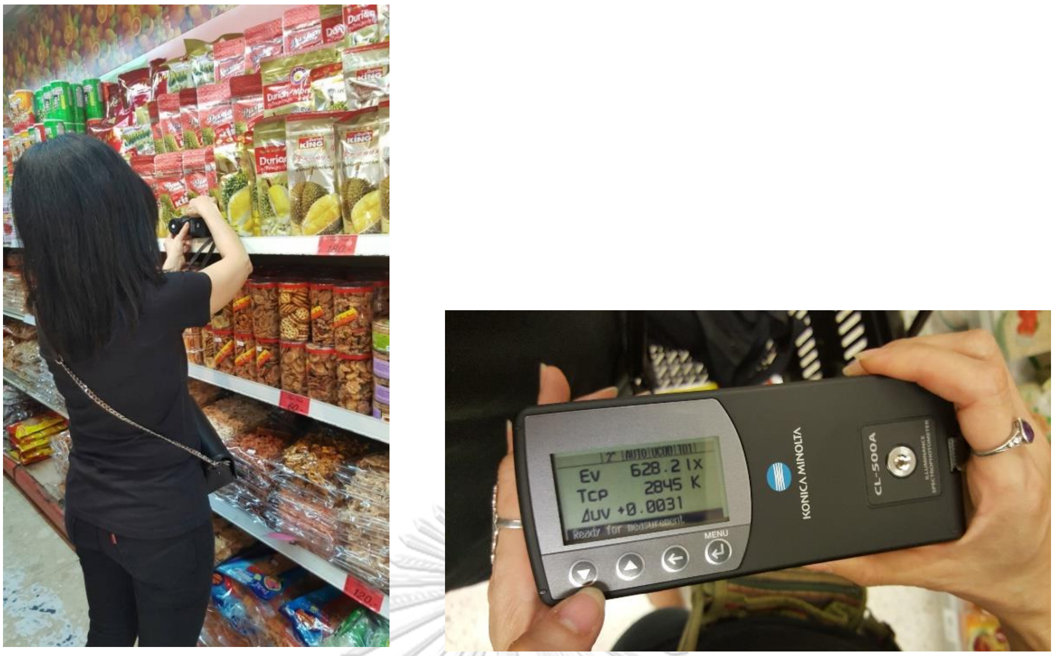
Table 3- 3 The characteristics of durian impacting on human expectations

Durian characteristics	Appearance	Impacting on human expectations
Flesh	yellow color, firm skin	Deliciousness
Stem	firm, not withered	Naturalness
Peel	yellow-green	Naturalness
Flesh	nice yellow	Naturalness
Flesh	nice yellow (not too yellowish or orange color) and less white color at core, smooth, full, and not withered	Attractiveness
Peel	yellow-green	Attractiveness
Flesh	nice yellow color, less white color at core and texture is firm, smooth, not withered, not too soft.	Want to buy
Peel	yellow-green, not too green	Want to buy

According to the results, the most factor related to durian characteristics impacting on human expectations was color. Then the thesis study concerns on color.

3.3 Survey of lighting condition used in supermarkets

Correlated color temperatures (CCTs) and Illuminance levels were explored at shelves selling package durian in supermarkets and dried food stores at 5 places around Bangkok and Nonthaburi. Lighting conditions were measured by Konica Minolta CL-500A as shown in Figure 3-6.



a b

Figure 3- 6 Exploring CCTs and illuminances; a) At shelves selling package durian, b) CCT and illuminance were displayed.

The findings revealed that the lighting ambient found was bluish and reddish light. The CCTS and illuminances were in the range from 2831 K to 6831 K and from 155 lux to 505.7 lux (Table 3-4 and Figure 3-7), which was in CCTs and illuminance corresponding to Kruithof's rule of 'pleasing' zone (27). The shelf level height of durian package was in the range from 130 to 150 centimeters. Lamp type used were fluorescent and LED lamp as spectrum shown in Figure 3-8.

How does lighting conditions affect human response to buying decision? Then 9 lighting conditions of 3 illumination levels of 150, 300, and 600 lux and 3 CCTs (correlated color temperature) of 2700, 4000, and 6500 K following Kruithof's rule of 'pleasing' zone were applied to thesis study.

Table 3- 4 CCTs and illuminance at shelves selling package durian measured with Konica Minolta CL-500A

Place	CCT (K)	Illuminance (lux)	Remark
1	5343.6	155	- measure at level at sight height about 150 cm from floor (28/12/59) - Big front panel durian picture - LED lamp
2	6386	505.7	-measure at level about 130 cm from floor (30/12/59) - LED lamp
3	2819	473.2	- measure at level about 150 cm from floor (31/12/59) - Fluorescent lamp
4	3762	228.3	- measure at level about 130 cm from floor (01/01/60) - Spot light
5	3636	333.0	-measure at level about 150 cm from floor (01/01/60) - Fluorescent lamp

Figure 3- 7 The lighting conditions at shelves selling packed durian at 5 places of supermarkets and dried food stores.

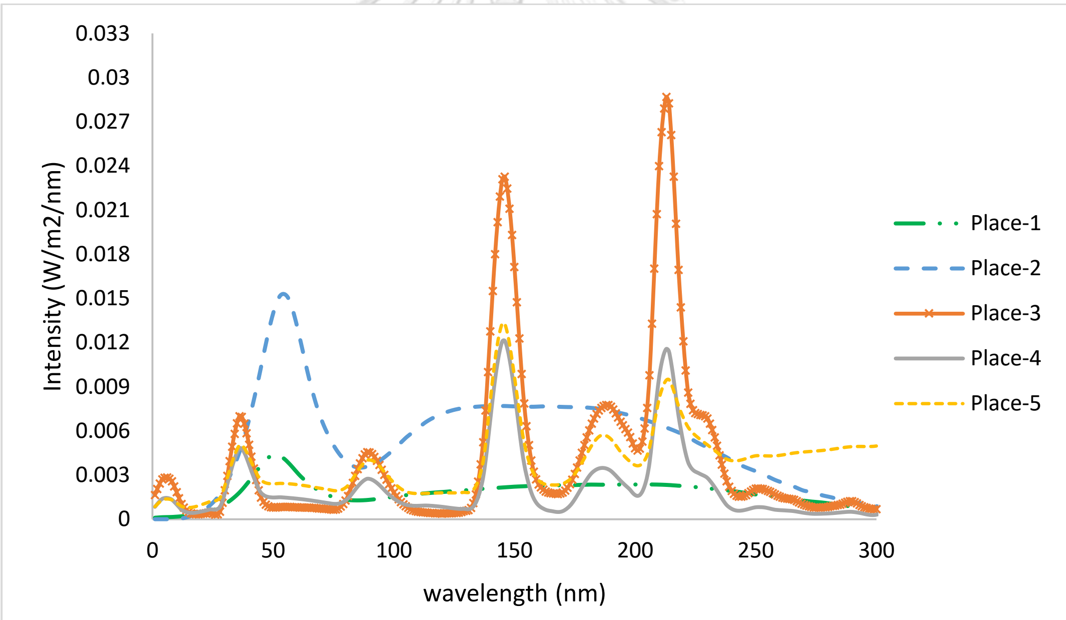


Figure 3- 8 Spectrum of light at shelves selling package durian from 5 places

CHAPTER IV
MATERIALS, EQUIPMENT AND EXPERIMENTS

4.1 Materials

4.1.1 Interview form

Interview form was divided into two parts. The first part was general questions (gender and age) and participants' experiences in durian (preference in terms of type and ripeness). The age of participants was range of 21 to 40 to avoid color vision deficiency in the middle age (42) and some studies used within this range (10, 21). The participants who answered "No" in the question of "Do you like Durian?" were rejected from the experiment. The second part was the durian characteristics evaluated from the preliminary study in section 3.2 of Chapter III. Likert's 5 rating scale that is a scale for attitude measurement created by Rensis Likert (43) was applied for scoring. Rating "1" represents the least score of human expectations of "Deliciousness", "Naturalness", "Attractiveness", and "Want to buy" while "5" means the highest one (such as "5" means extremely delicious) (APPENDIX C).

4.1.2 Durian color image

Fresh durian cv. Monthong was photographed by Canon EOS Kiss X4 under D50 in Macbeth Judge-II viewing light box at Department of Imaging and Printing Technology, Chulalongkorn University (Figure 4-1) and saved as a raw file (.CR2) in order to acquire the best detail of image. The best shot of selected image was adjusted into 5 color saturation levels of -15, 15, 30, 45, and 60 by sliding Saturation slider in Adobe Photoshop (Figure 4-2).

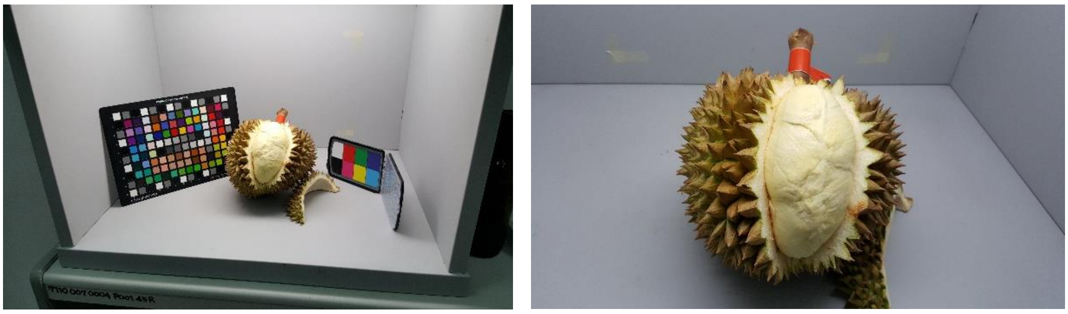


Figure 4- 1 Flesh durian cv. Monthong was arranged for taking photograph under in Macbeth Judge-II viewing light box.

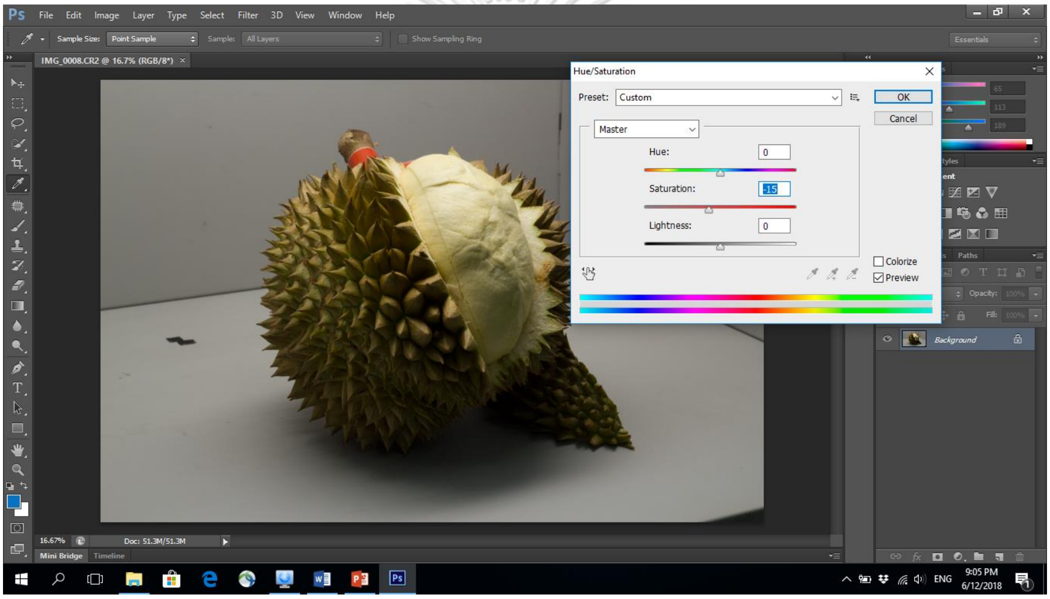


Figure 4- 2 The durian image photographed was adjusted saturation by using Adobe Photoshop.

For checking the saturation of adjusted image, total images of six (5 from the various saturation levels and the normal one or no adjustment of saturation (at zero) were evaluated in hue-saturation-intensity (HSI) values for image adjust investigation from Adobe Photoshop by using MATLAB (44) and printed with a color inkjet printer Epson Px-5v at Tokyo Denki university (Figure 4-3). The HSI color space is an ideal tool for developing image–processing algorithms based on natural color, which are corresponding to hue, saturation, and brightness when humans view a color object, whereas HSV color space focuses on presenting color in terms of a color artist's palette (44). The change of saturation evaluated by MATLAB increased in accordant with saturation level adjusted by using Adobe Photoshop while hue and intensity changed only a small amount when the saturation level changed (see Figure 4-4 and 4-5).

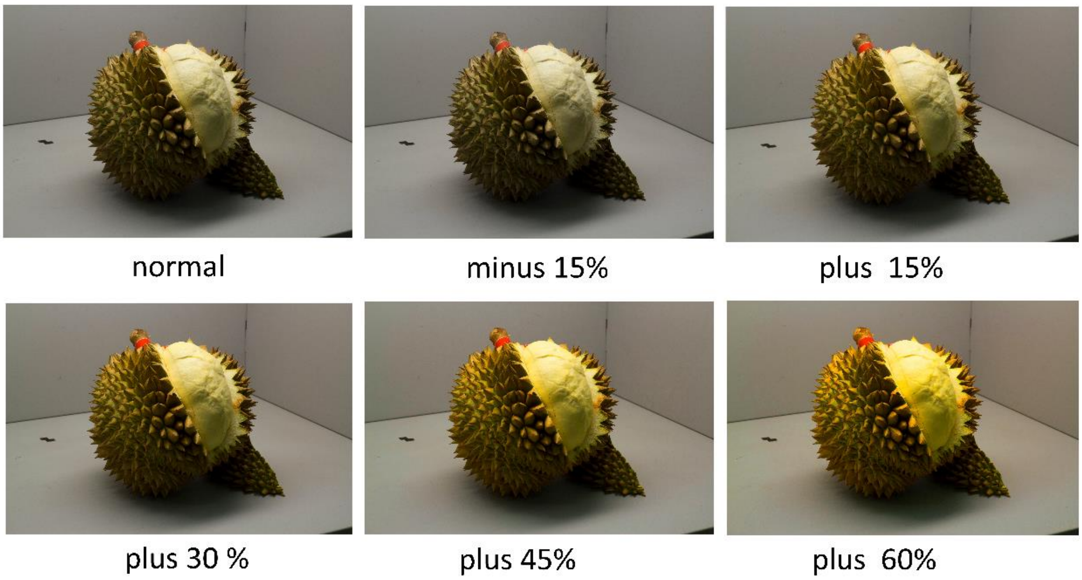


Figure 4- 3 Printed durian cv. Monthong was adjusted into 5 saturation levels of -15, 15, 30, 45, and 60% by using Adobe Photoshop.

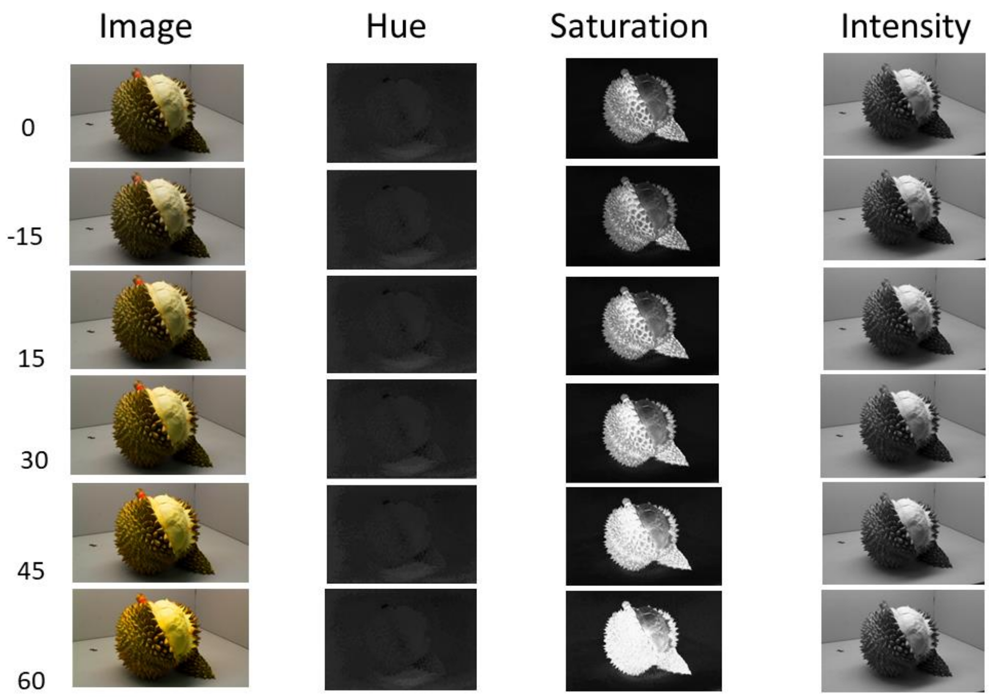


Figure 4- 4 Durian image with adjusted saturation level of -15, +15, +30, +45, and +60 by using Adobe Photoshop (left side) and analyzed HSI (Hue, Saturation, and Intensity) by using MATLAB program.

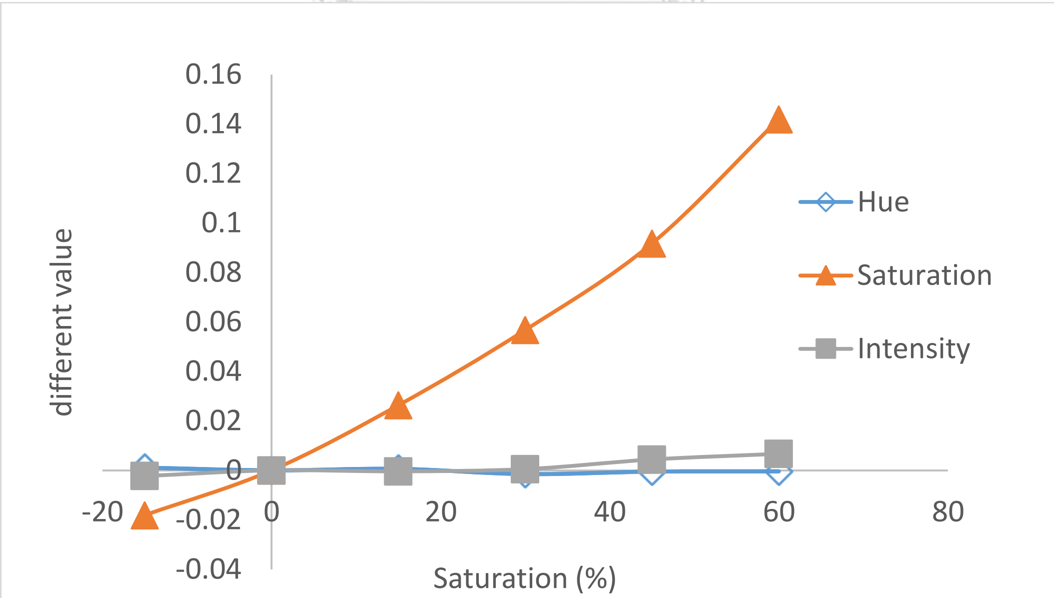


Figure 4- 5 Difference of Hue, Saturation, and Intensity of the durian image adjusted saturation vs. Saturation (%) adjusted by using Adobe Photoshop

4.2 Equipment

4.2.1. Experimental room

An experimental room (see Figure 4-6) in the size of 1.8 x 1.8 x 2.3 meters (width x length x height) was painted in neutral gray (L* 85.47, a*0.20, b* 2.85). Temporary shelf was made of corrugated plastic sheet or polypropylene (PP) board which is gray in color, with the shade approximately Munsell N6 (L* 58.25, a*-0.82, b* -1.64) for viewing sample image in order to avoid influence of background color. The shelf was fixed on the wall at the eye level height of 150 centimeters from floor.

4.2.2 Light source

An adjustable LED light of PANASONIC with color rendering index (CRI) 85 was applied in this study. The light was mounted on the experimental room ceiling (Figure 4-6). The effect of CCT and illuminance level of the adjustable LED clusters on the visual response followed Kruithof's rule. A total of 9 lighting conditions, namely, combinations of 2700, 4000, and 6500 K CCT and illuminance levels of 150, 300, and 600 lux (27) were selected to generate pleasing conditions according to Kruithof's rule; these values of CCT and illuminance levels were determined by evaluation of these parameters at shelves of packaged durian at a minimum of 5 supermarkets and dried food stores around Bangkok and Nonthaburi in Thailand.

Figure 4- 6 Experimental room, temporary shelf fixed on the wall, and adjustable LED light mounted on the room ceiling.

The spectral radiance of each of the 9 lighting conditions was determined by using a Konica Minolta Illuminance Spectrophotometer CL500A in order to check the emission of white light from LED used in this study. The spectrographs show that the emission of white light from an LED is achieved by a combination of red-, green- and blue-emitting LEDs (33). The spectrographs of the radiation emitted from the LEDs with CCTs of 2700, 4000, and 6500 K with the same illuminance showed that lighting conditions involving of 2700 K emitted less blue and green light (approximately 450 to 550 nm) than was seen at 6500 K (see Figure 4-7), while at 2700 K, more red light (wavelengths of approximately 600 to 700 nm) was emitted than was observed at 6500 K. The high CCT illumination conditions appeared brighter than low illumination conditions. This finding is consistent with that of Vienot et al.(27) who also found that cluster LED illumination with these 9 lighting conditions provided emissions that generated a pleasing visual response following Kruithof's rule.

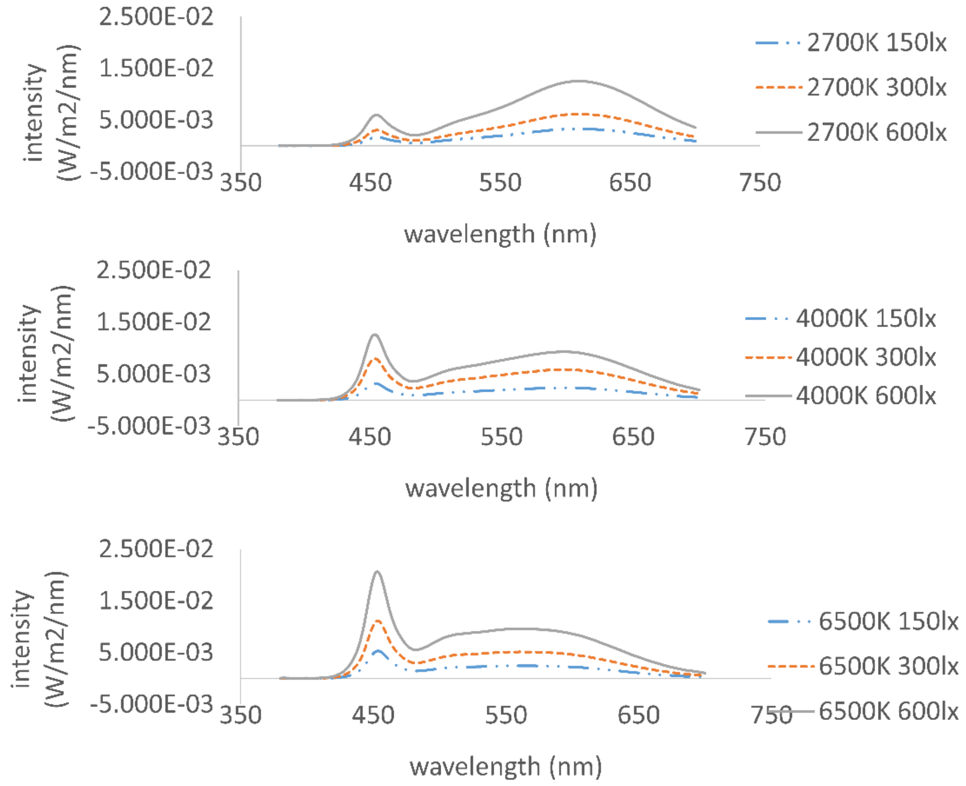


Figure 4- 7 Spectral intensity of the 9 lighting conditions.

4.3 Experiments

4.3.1 Evaluate participants' color discrimination

All participants took the Farnsworth Munsell (FM) 100 Hue test to evaluate their color discrimination abilities (45) before providing their expectations.

Figure 4- 8 Participant was testing color discrimination abilities.

4.3.2 Collect the human expectations data

Thirty Thai participants with the age in the range of 21-40 years old who have experiences in durian fruit were invited to provide their expectations upon the 6 durian printed images under the lighting conditions chosen from 4.2.2. The CCT and illuminance was measured by KONICA MINOLTA CL-500A for all lighting conditions. Each participant sat on a chair which can be adjusted so the participant's eyes was at the same level as the image on the shelf. Viewing distance and angle were 40 centimeters and 45/0 degree respectively (see Figure 4-9). The 6 images were presented on the shelf one at a time under each lighting with about 3 minutes for light adaptation (27). The sequence started with 3 minutes adaptation to the illumination. Each participant was asked questions about his or her expectations from durian characteristics of all 6 images of "Deliciousness", "Naturalness", "Attractiveness" and "Want to buy". Then the participant evaluated how well each image conveys the human expectations and rate them based on 5 Likert's scale.

Figure 4- 9 Participant look at the durian image at the viewing of 45/0 degree in the distance of 40 centimeters.

4.3.3 Measure CIELAB of durian flesh color image on each of the six digital durian image

To investigate color changing in durian flesh image, the six saturated durian digital image from Adobe Photoshop were pointed in 3 regions of interest (ROI) on durian flesh and processed to obtain CIELAB from RGB by MATLAB

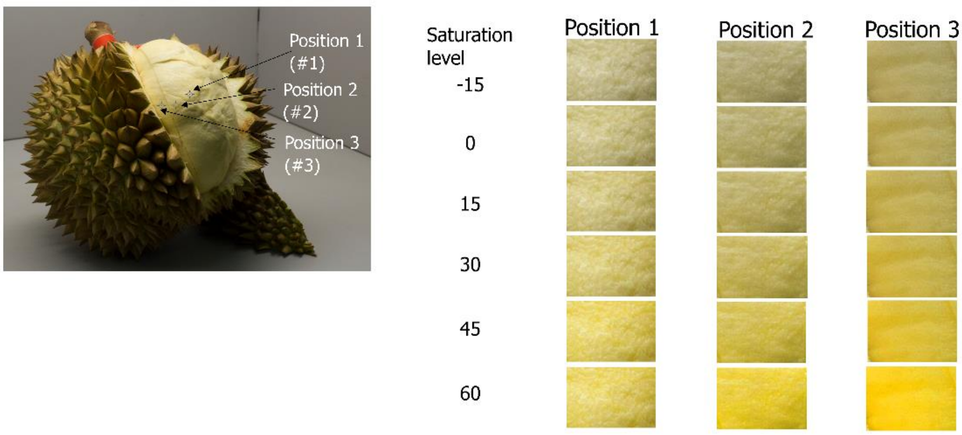


Figure 4- 10 The 3 positions on digital durian image (left) and the 3 crop durian flesh image areas of each digital durian image (right).

4.3.4 Measure CIELAB of durian flesh color image on each of the six printed durian images

The CIELAB values for the printed images of durian fruit at the 3 ROI were measured by using a TECHKON Spectro-Densitometer at D65 illumination and 2-degree observer.

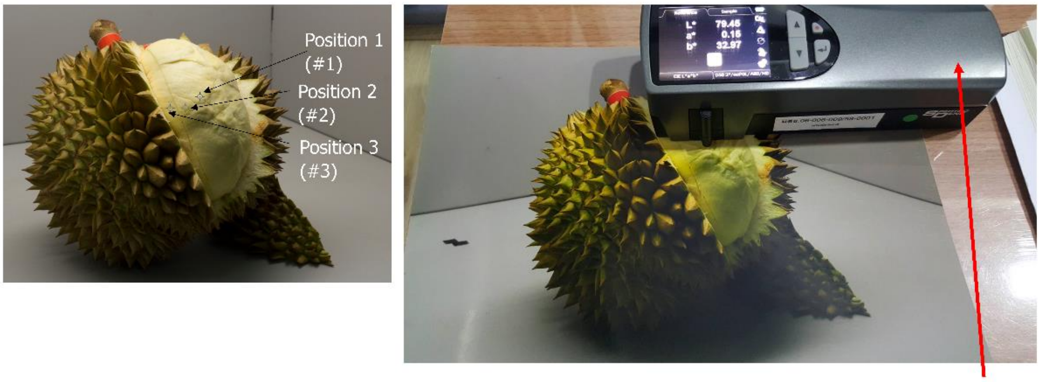


Figure 4- 11 Measuring CIELAB of durian flesh on printed durian image by using TECHKON Spectro-Densitometer.

4.3.4 Measure Yxy value of durian flesh color image on each of the six printed durian image and calculate CIELAB

Y, x, and y at the same ROI (positions 1, 2 and 3) on the printed images of the durian fruit were measured by using a Chroma-meter (see Figure 4-12) and determined the calculated CIELAB values at D65 using the 2-degree color matching function for viewing the trend in the change in the color between the 9 lighting conditions (see Figure 4-12). CIEXYZ were calculated from Y, x, and y (33). Then CIELAB were calculated by using equation 3.4 to 3.6.

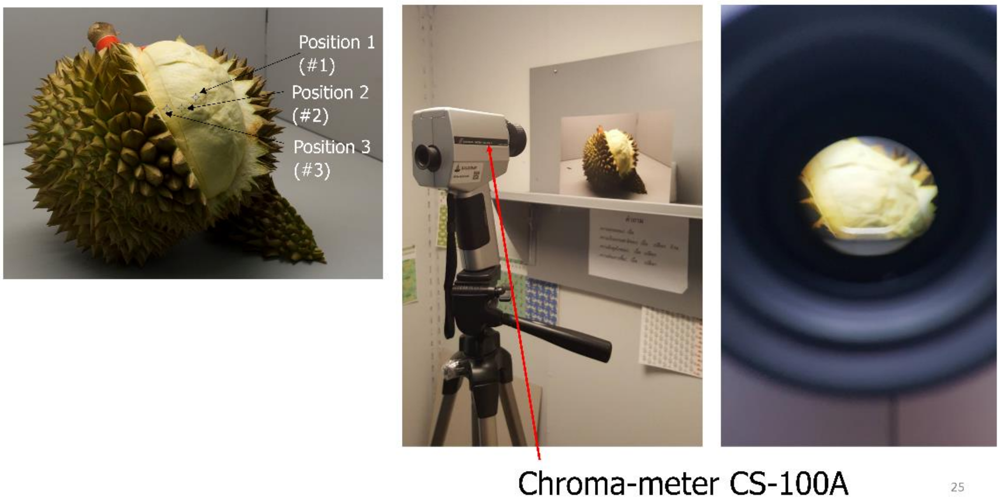


Figure 4- 12 Measuring Yxy of durian flesh under the 9 lighting conditions by using Chroma-meter CS-100A.

4.3.3 Analyze the data

1) Analyze the data to evaluate the relationships between human expectations and buying decision. Average mean and standard deviation of obtained ratings of each human expectation was calculated for each image under each of the 9 lighting conditions. The optimal level of saturation of each human expectation was assessed at above 3.51 average mean for high level of customer satisfaction (43). MANOVA (Mutivariate Analysis of Variance) was applied to assess saturation, CCTs, and illumination value affecting to the human expectations. Multiple regression was employed to evaluate the relationships between "Deliciousness", "Naturalness", and "Attractiveness" and buying decision. At the same time, CIELAB of the 3 positions of the six original durian flesh digital image and printed image and the corresponding durian flesh printed image under the 9 lighting conditions were evaluated (see Figure 4-13).

2) Analyze the data to establish buying decision model based on color attributes for Durio zibethinus L. cv. Monthong. The relationships between want to buy and saturation, CCTs, and illuminance were evaluated to establish the buying decision model. The logistic regression that is a kind of prediction model commonly used for buying behavior model (46), was applied. Dependent variable (buying decision) is a categorical variable having two categories and Independent variables (saturation, CCT, illuminance) are either numerical or categorical (46). The results of 5 rating scores of Wan-F (Wan to buy due to durian flesh) were categorized in 2 groups with the coding of “0” for “not buying” (score lower than and equal to 3) and the coding of “0” for “buying” (score greater than and equal to 5).

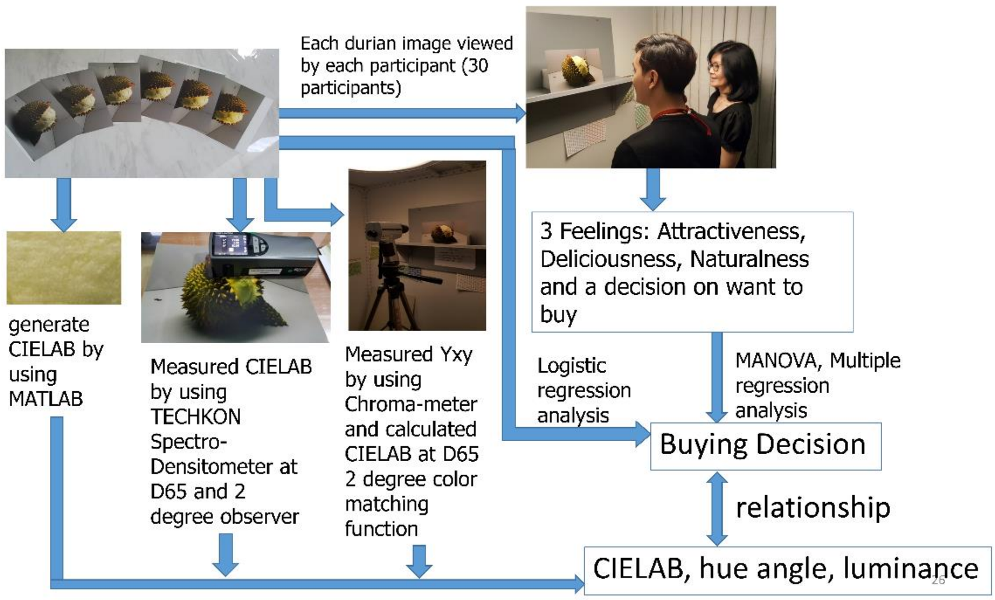


Figure 4- 13 Data analysis diagram for the first set of six printed durian images.

4.3.4 Verify the results

Another set of six printed durian images was conducted by repeating the same experiment with the same group of participants to verify the results (see Figure 4-14). The buying decision obtained in the repeat experiment was evaluated by the predicted buying decision model of the first experiment.

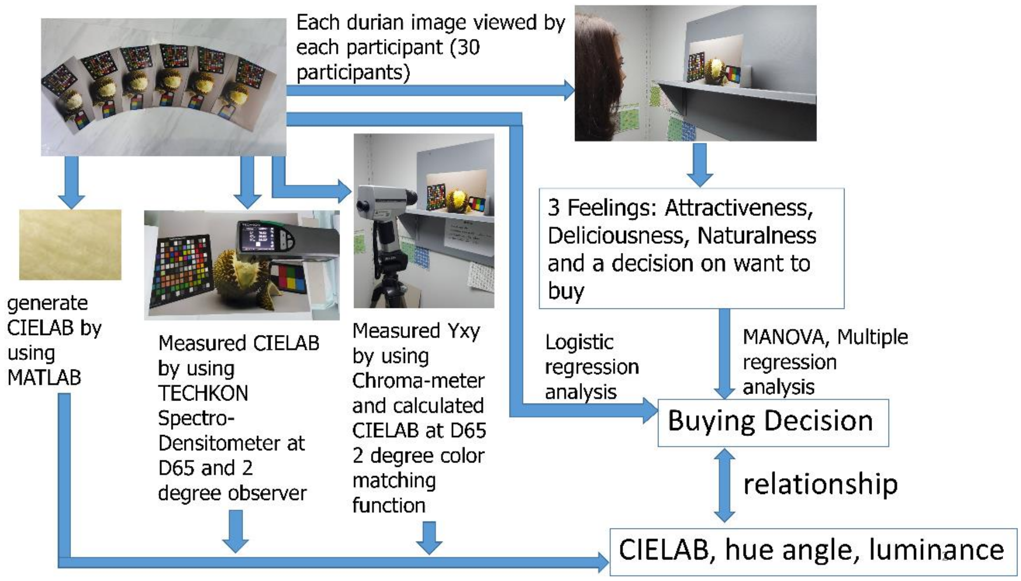


Figure 4- 14 Data analysis diagram for the second set of six printed durian images for repeat experiment.

CHAPTER V
RESULTS AND DISCUSSION

5.1 Information of participants

A total of 30 observers who participated in this study were 16 female and 14 male with ages ranging from 21 to 40. Most of them more than 80% liked Durian cv. Monthong and more than 50% preferred normal durian flesh (see Table 5-1). All participants took the FM100 Hue test to evaluate their color discrimination abilities(45), which were 52.6% showed average discrimination (score between 0 and 16), 33.33% showed superior discrimination (score between 20 and 100) and 3.33% showed low discrimination (score above 100) (Figure 5-1). A sample of FM 100 Hue test was shown more detail in APPENDIX D. The results of low discrimination were deleted from the analysis. Then the total number of data were 29 x 6 x 8 = 1566 data (29 participants, 6 pictures and 8 human expectations).

Table 5- 1 General information of the 30 participants

Items		Frequency	Percent
Gender	male	14	46.67
	female	16	53.33
Age	21-30	20	66.67
	31-40	10	33.33
Likeness of durian cultivar	Chanee	2	6.67
	Monthong	26	86.67
	others	2	6.67
Durian flesh likeness	normal	20	66.67
	Soft	7	23.33
	Too soft	3	10

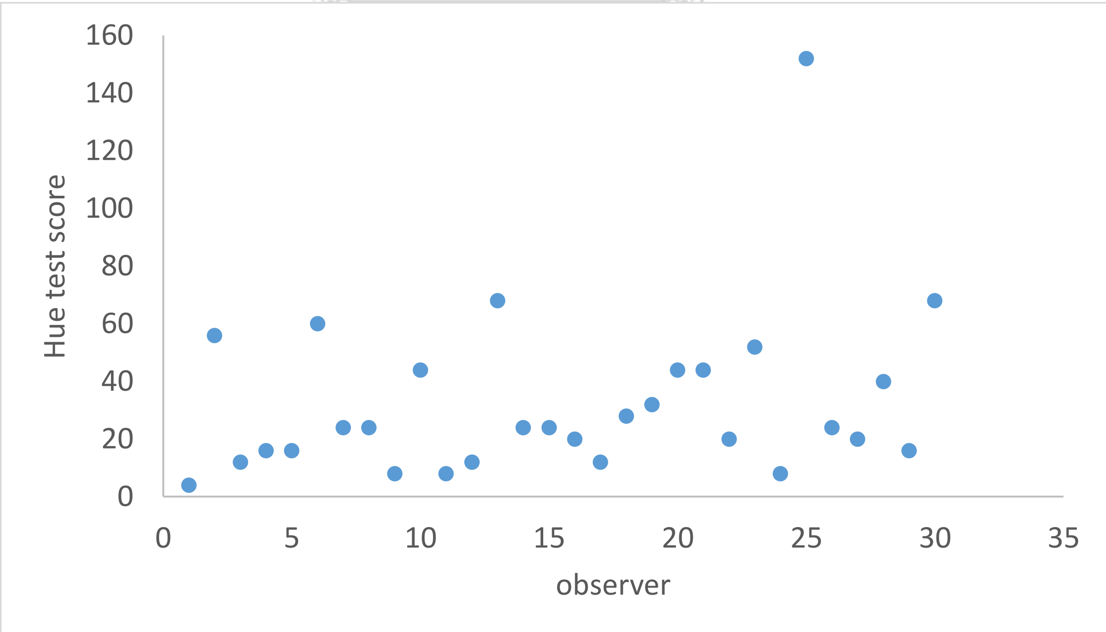


Figure 5- 1 FM Hue test score results of the 30 participants.

5.2 Human expectations data

The results of customers' expectations showed that their scores of Deliciousness of Flesh (Del-F), Attractiveness of Flesh (Att-F), and Want to buy Flesh (Wan-F) under the 9 lighting conditions increased as the saturation level increased (see Figure 5-2, 5-6 and 5-8). The rest of the 5 expectations showed the same trend (Figure 5-3 to 5-5, 5-7, and 5-9). The means of the scores reported by the participants for the 8 main questions could be divided into 2 groups. The first group, those with scores greater than or equal to 3.51, and lower than 3.51 (Table 5-1), were Nat-F, Nat-P, Nat-S, Att-P, and Wan-P, which means more variation in satisfaction. The other group, those with scores greater than or equal to 3.51 that means high satisfaction (43) (see Table 5-1), were Del-F, Att-F, and Wan-F. The optimum saturation for Wan-F was reported to be between 30-45%, and the scores of Del-F and Att-F increased as the saturation approached 45%, as shown in Table 5-1 and more detail in APPENDIX E.

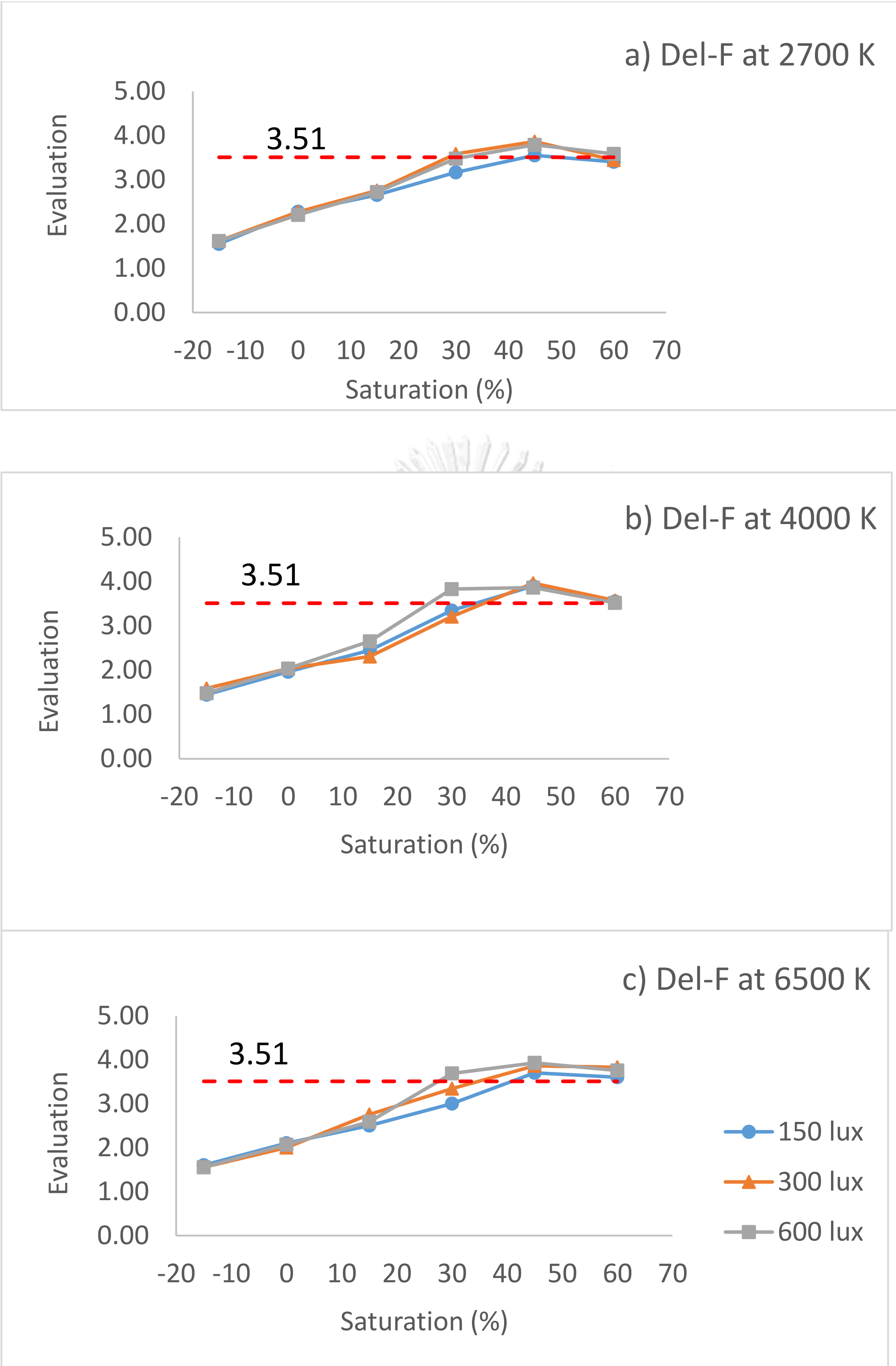


Figure 5- 2 Evaluation of Deliciousness of flesh (Del-F) vs. Saturation (%) under 3 CCTs; a) 2700 K b) 4000 K and c) 6500 K.

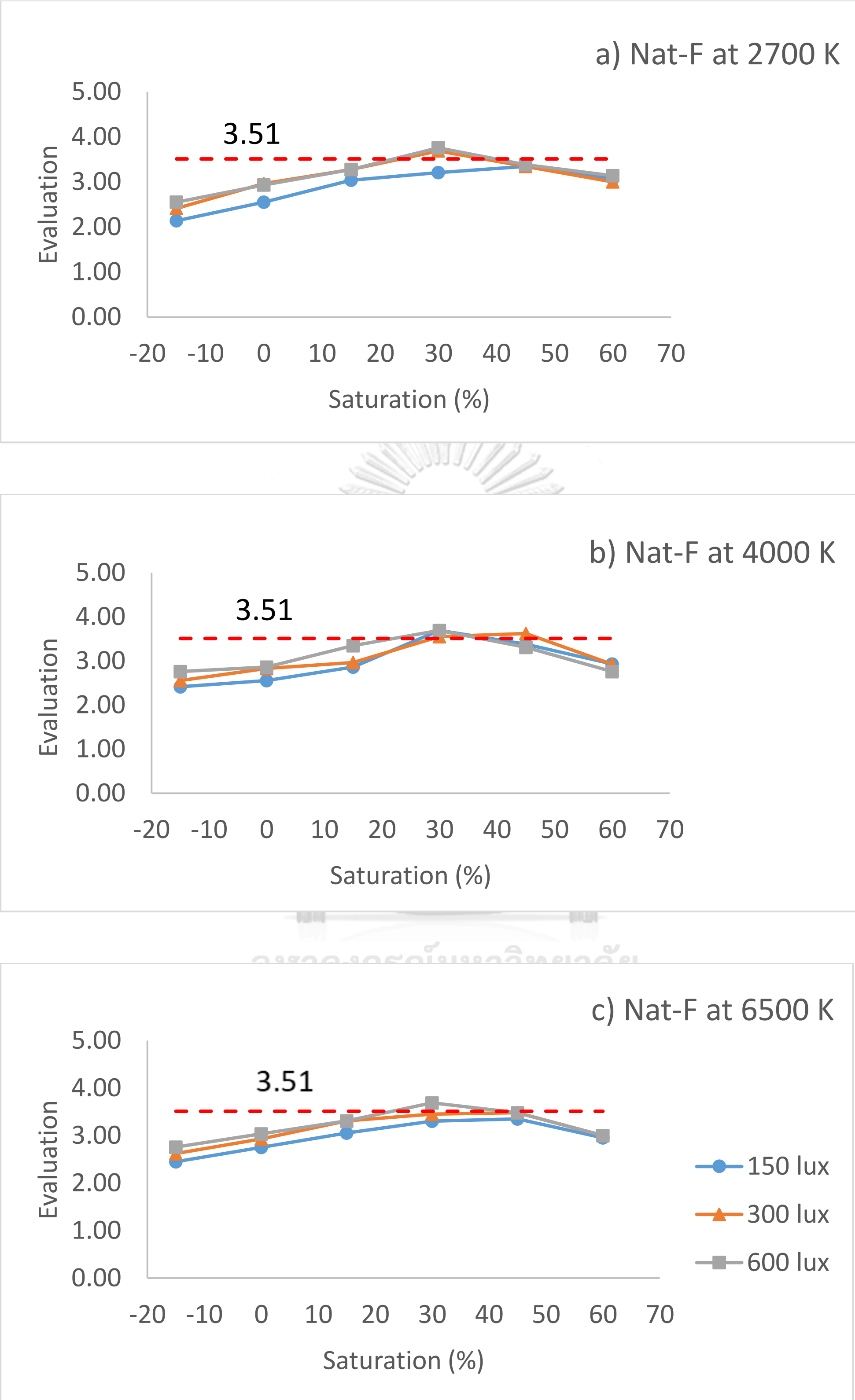


Figure 5- 3 Evaluation of Naturalness of flesh (Nat-F) vs. Saturation (%) under 3 CCTs; a) 2700 K b) 4000 K and c) 6500 K.

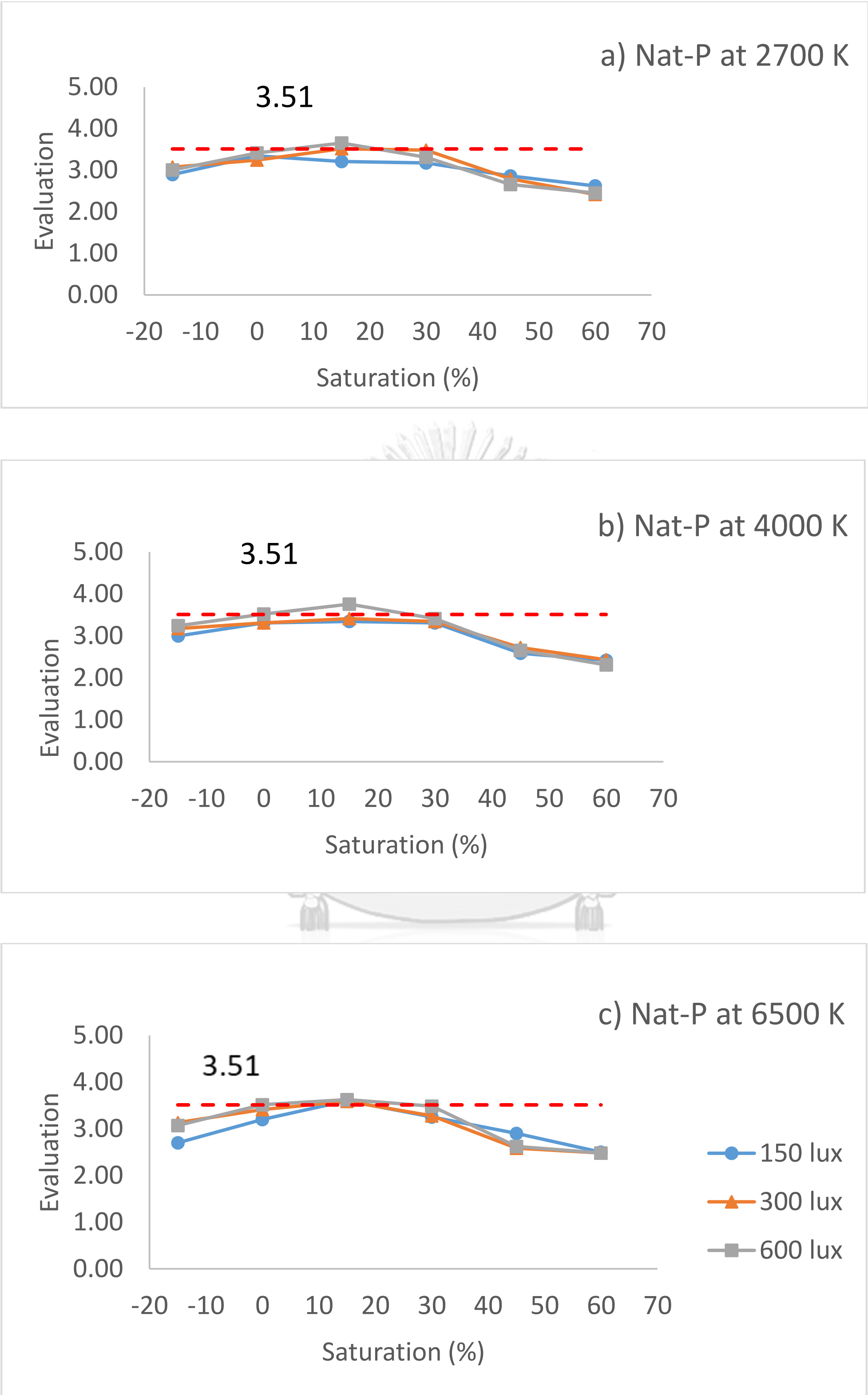


Figure 5- 4 Evaluaiton of Naturalness of peel (Nat-P) vs. Saturation (%) under 3 CCTs; a) 2700 K b) 4000 K and c) 6500 K.

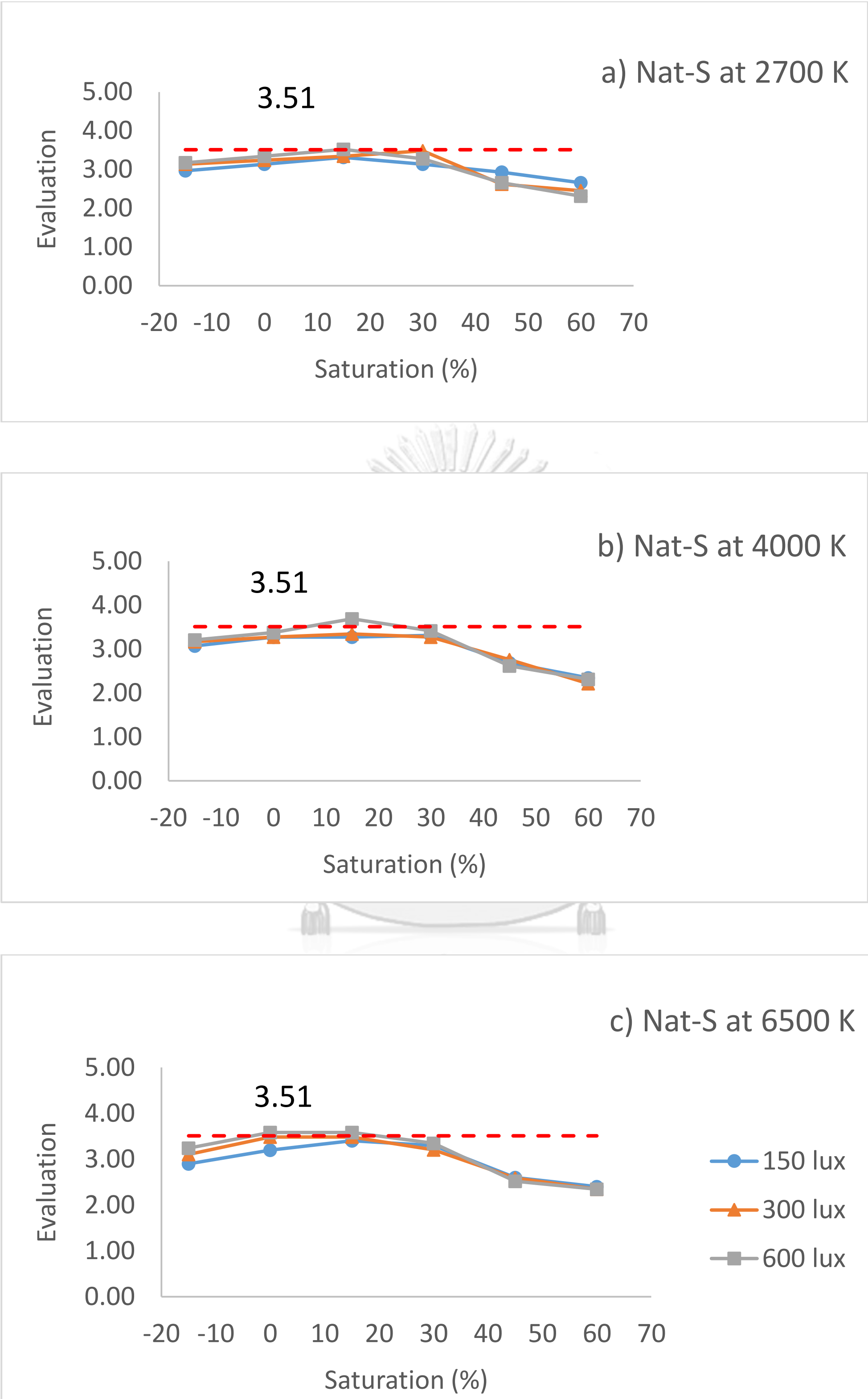


Figure 5- 5 Evaluation of Naturalness of stem (Nat-S) vs. Saturation (%) under 3 CCTs; a) 2700 K b) 4000 K and c) 6500 K.

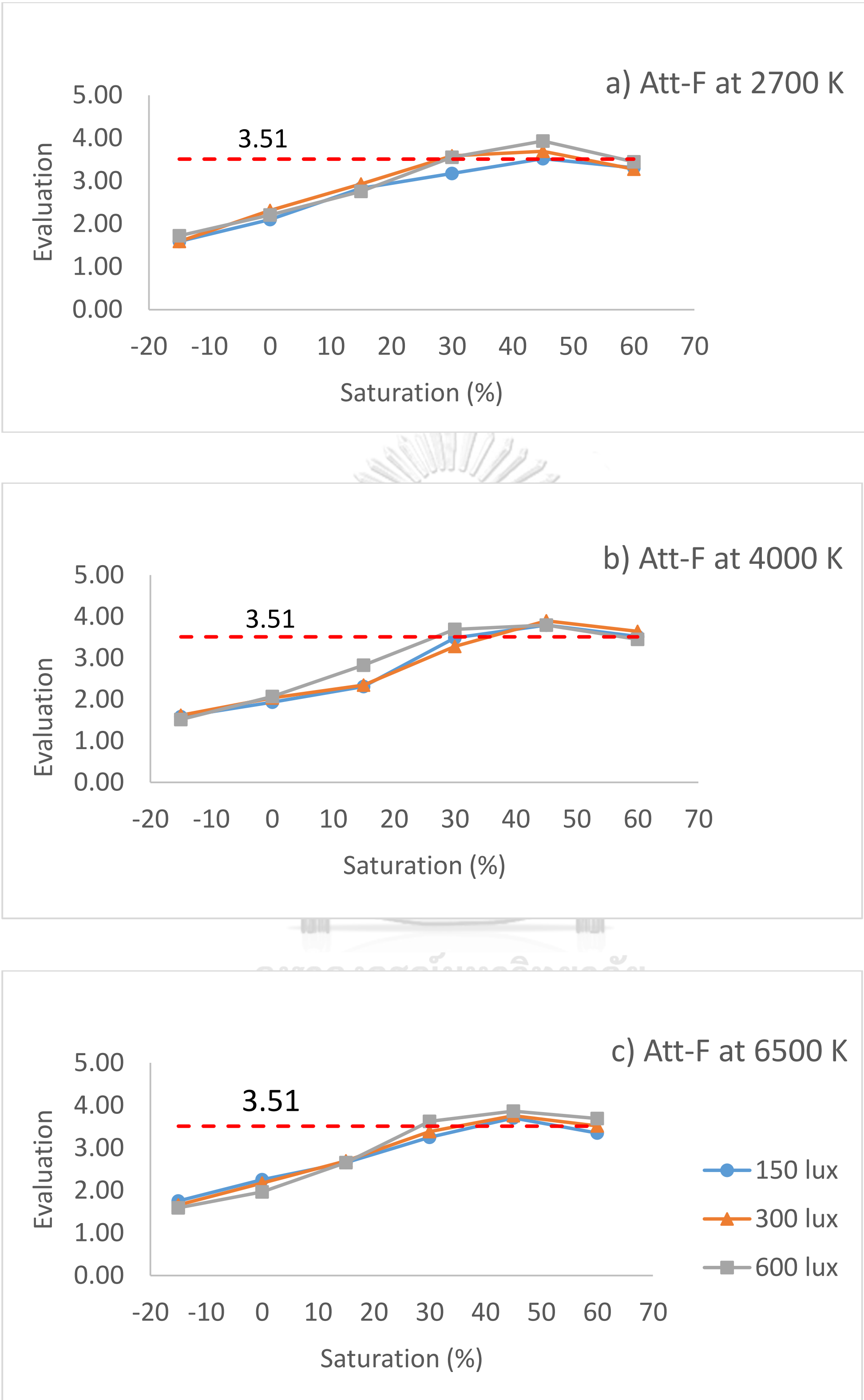


Figure 5- 6 Evaluaiton of Attractiveness of flesh (Att-F) vs. Saturation (%) under 3 CCTs; a) 2700 K b) 4000 K and c) 6500 K.

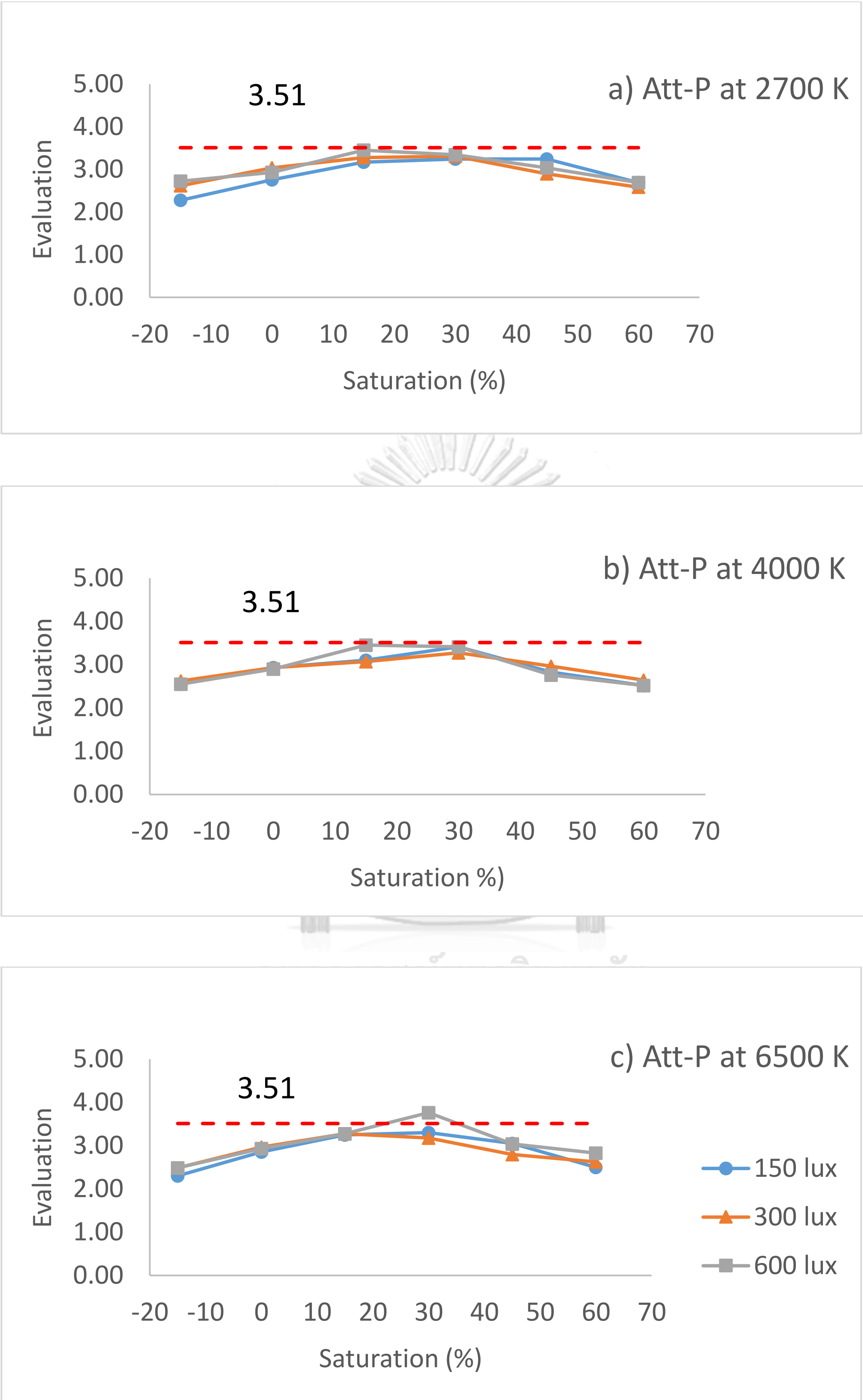


Figure 5- 7 Evaluaion of Attractiveness of peel (Att-P) vs. Saturation (%) under 3 CCTs; a) 2700 K b) 4000 K and c) 6500 K.

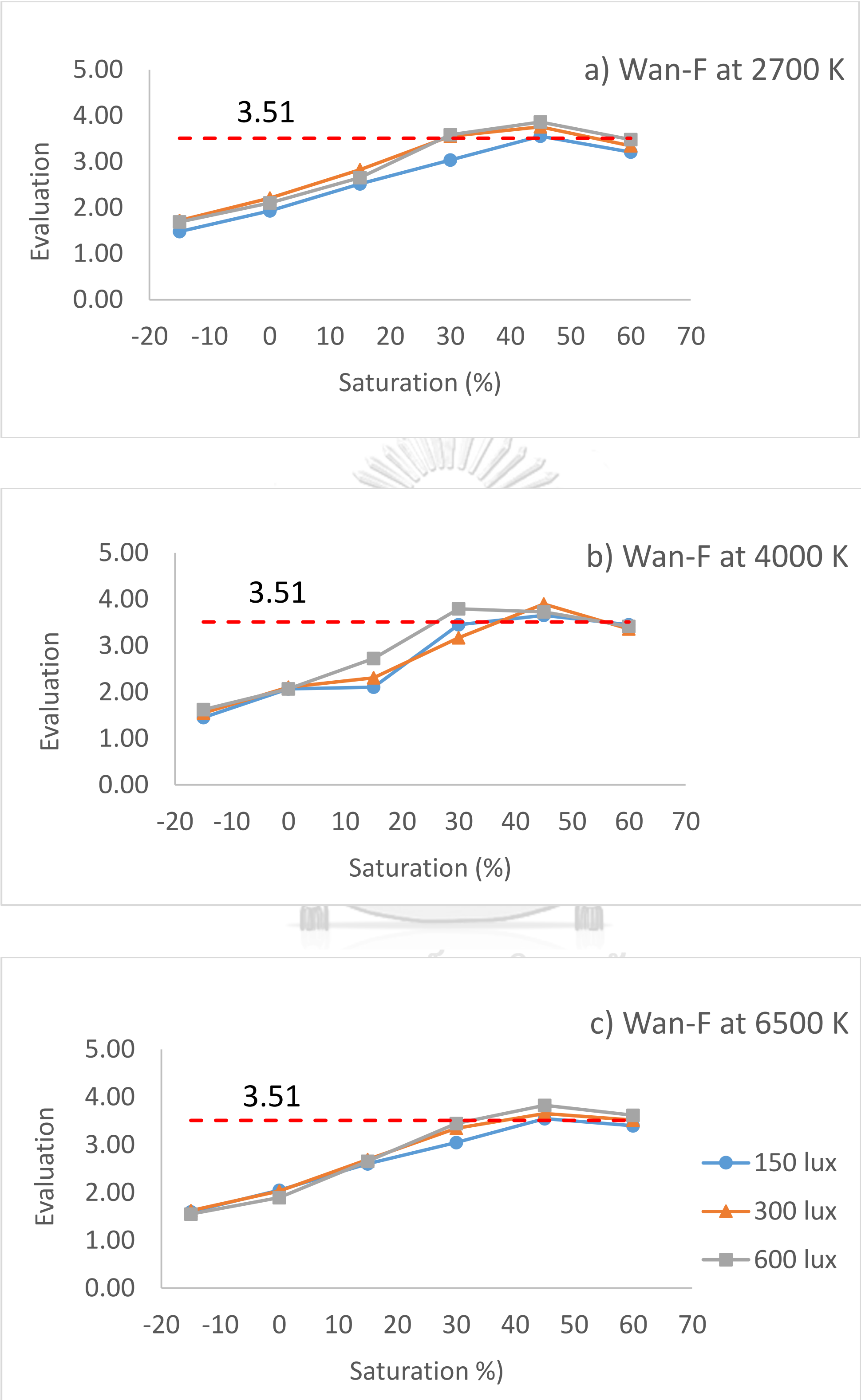
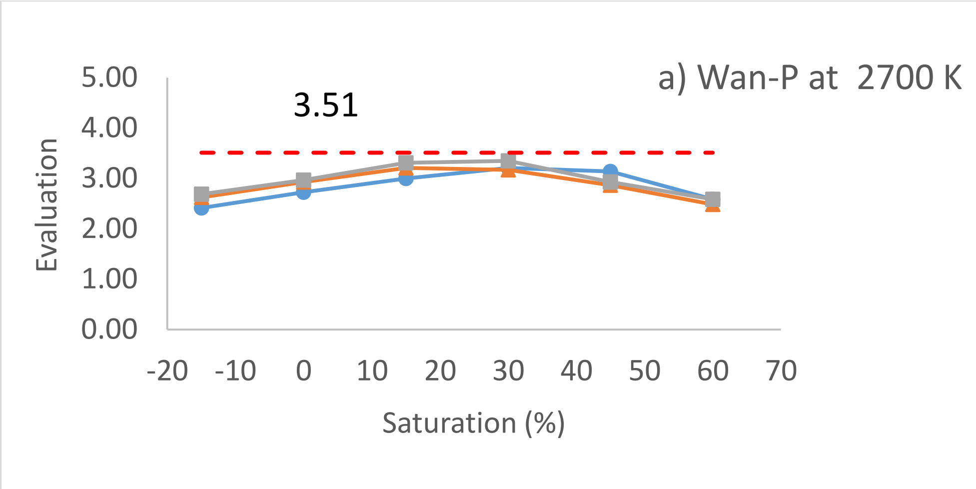
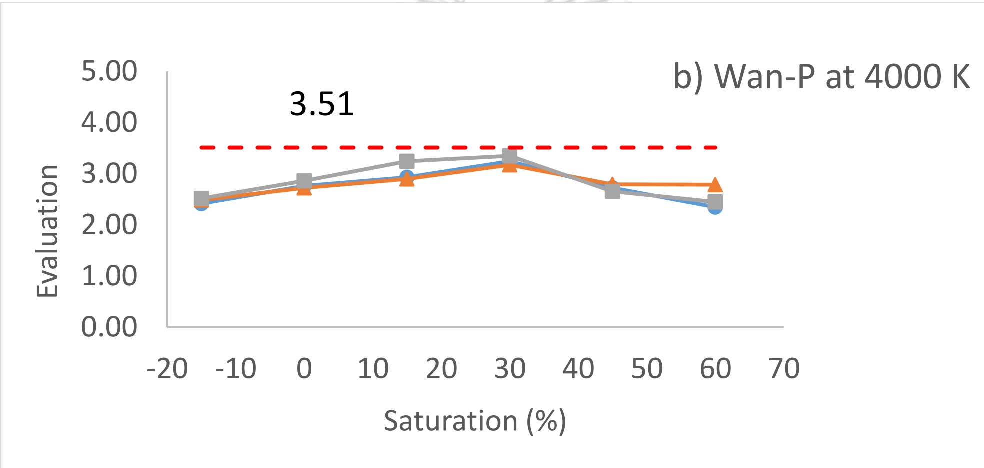


Figure 5- 8 Evaluaiton of Want to buy from flesh (Wan-F) vs. Saturation (%) under 3 CCTs; a) 2700 K b) 4000 K and c) 6500 K.





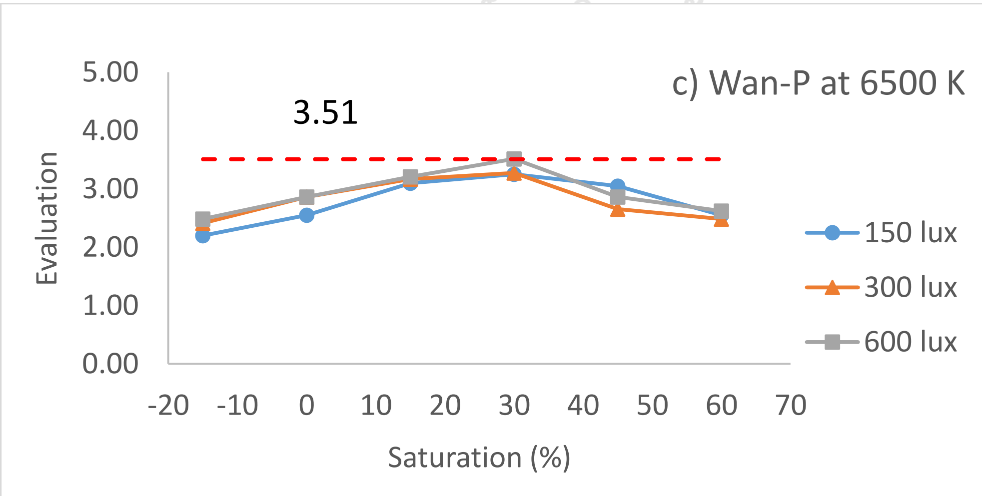


Figure 5- 9 Evaluaiton of Want to buy from peel (Wan-P) vs. Saturation (%) under 3 CCTs; a) 2700 K b) 4000 K and c) 6500 K

Table 5- 2 Optimum saturation and mean of Customers' expectations on the eight main expectations of Durian images under the 9 lighting conditions

Aspects	Maximum saturation level (%) for various 3 CCTs and 3 illuminances									Average means
	2700 K			4000 K			6500 K			
	150 lux	300 lux	600 lux	150 lux	300 lux	600 lux	150 lux	300 lux	600 lux	
Del-F	+45	+45	+45	+45	+45	+45	+45	+45	+45	≥3.51
Att-F	+45	+45	+45	+45	+45	+45	+45	+45	+45	≥3.51
Wan-F	+45	+45	+45	+45	+45	+30	+45	+45	+45	≥3.51
Nat-F	+45	+30	+30*	+30*	+45*	+30*	+45	+45	+30*	*≥3.51, <3.51
Nat-P	0	+15	+15*	+15	+15	+15*	+15*	+15*	+15*	*≥3.51, <3.51
Nat-S	+15	+30	+15*	+30	+15	+15*	+15	0, +15	0*, +15*	*≥3.51, <3.51
Att-P	+30, +45	+30	+15	+30	+30	+30	+30	+15	+15*	*≥3.51, <3.51
Wan-P	+30	+15	+30	+30	+30	+30	+30	+30	+30	*≥3.51, <3.51

N = 29 (see more detail in Appendix E)

5.3 Factors impacting on human expectations

According to the many dependent and independent variables present in this study, MANOVA was applied to determine the factors influencing customers' expectations. The results shown in Table 5-2 indicate that only saturation significantly impacted the 8 expectations [F(40, 6562.94) = 35.352 (Wilk's Lambda) p- value <0.001]. Wilk's Lambda is a probability distribution mostly used for multivariate hypotheses in statistics (47). The CCTs and illuminances had no significant effects on the expectations. No interaction among CCTs, illuminances, and saturation was observed.

Table 5- 3Multivariate Tests of customers' expectation and factors of saturation, CCTs, and illuminances

Effect		Value	F	Hypothesis df	Error df	Sig.
Intercept	Pillai's Trace	.933	2605.383[b]	8.000	1505.000	.000
	Wilks' Lambda	.067	2605.383[b]	8.000	1505.000	.000
	Hotelling's Trace	13.849	2605.383[b]	8.000	1505.000	.000
	Roy's Largest Root	13.849	2605.383[b]	8.000	1505.000	.000
Saturation	Pillai's Trace	.629	27.158	40.000	7545.000	.000
	Wilks' Lambda	.427	35.352	40.000	6562.937	.000
	Hotelling's Trace	1.211	45.500	40.000	7517.000	.000
	Roy's Largest Root	1.095	206.508[c]	8.000	1509.000	.000
CCT	Pillai's Trace	.010	.921	16.000	3012.000	.544
	Wilks' Lambda	.990	.921[b]	16.000	3010.000	.544
	Hotelling's Trace	.010	.920	16.000	3008.000	.545
	Roy's Largest Root	.006	1.191[c]	8.000	1506.000	.300
Illuminance	Pillai's Trace	.016	1.538	16.000	3012.000	.078
	Wilks' Lambda	.984	1.542[b]	16.000	3010.000	.077
	Hotelling's Trace	.016	1.545	16.000	3008.000	.076
	Roy's Largest Root	.015	2.855[c]	8.000	1506.000	.004
Saturation * CCT	Pillai's Trace	.048	.922	80.000	12096.000	.674
	Wilks' Lambda	.952	.922	80.000	9553.925	.675
	Hotelling's Trace	.049	.921	80.000	12026.000	.676
	Roy's Largest Root	.018	2.728[c]	10.000	1512.000	.003
Saturation * Illuminance	Pillai's Trace	.033	.620	80.000	12096.000	.997
	Wilks' Lambda	.968	.619	80.000	9553.925	.997
	Hotelling's Trace	.033	.619	80.000	12026.000	.997
	Roy's Largest Root	.012	1.824[c]	10.000	1512.000	.052
CCT * Illuminance	Pillai's Trace	.015	.709	32.000	6032.000	.888
	Wilks' Lambda	.985	.708	32.000	5551.761	.889
	Hotelling's Trace	.015	.707	32.000	6014.000	.889
	Roy's Largest Root	.006	1.043[c]	8.000	1508.000	.401
Saturation * CCT * Illuminance	Pillai's Trace	.057	.544	160.000	12096.000	1.000
	Wilks' Lambda	.944	.543	160.000	11253.048	1.000
	Hotelling's Trace	.058	.543	160.000	12026.000	1.000
	Roy's Largest Root	.018	1.377[c]	20.000	1512.000	.123

b. Exact statistic

c. The statistic is an upper bound on F that yields a lower bound on the significance level.

5.4 Human feelings impacting on buying decision

According to the results of human expectation data, the score results of maximum mean of want to buy durian from flesh (Wan-F), deliciousness of flesh (Del-F) and attractiveness of flesh (Att-F) under the 9 lighting conditions were high scores more than or equal to 3.51, which is high satisfaction level in evaluation criteria (43). Then the relationship among expectations on buying decision (Wan-F) was evaluated by applying multiple regression, and the findings indicated that there were high correlation more than 0.7 (48) among deliciousness of flesh (Del-F), attractiveness of flesh (Att-F), and want to buy from flesh (Wan-F) (see Table 5-3), which should select only one attribute of Del-F or Att-F for the model to avoid multicollinearity.

There were three models of significant relationships between feelings and buying decision (see Table 5-4). The model 3 indicated that Att-F, Del-F, and Att-P influenced significantly on Wan-F. According to the variation optimum level of satisfaction mean, the model 3 was rejected. For the model 2, the result revealed that Att-F and Del-F impacted significantly on Wan-F, which these results reflect those of Ndom et al. (5) that food taste is perceived through the eyes from the most recognizable stimuli, visual appearance and color. However, the model 1 with R-square 87.2% was selected by concerning on problem of multicollinearity instead of the model 2 (VIF (the variance inflation factor) should not be more than 2), which the variance inflation factor (VIF) is computed as 1 divided by tolerance. The higher tolerance (more than or equal to 0.5 is acceptable (48). The model 1 indicated that attractiveness had the greatest influence on buying decision, which is the same as what was reported by Rebollar et al (17). According to human expectation data plots showed non-linear regression, then logistic regression analysis was applied for buying decision model.

Table 5- 4 Correlations among 8 human expectations

		Wan-F	Del-F	Nat-F	Nat-P	Nat-S	Att-F	Att-P
Pearson Correlation	Wan-F	1.000	.900	.608	.196	.138	.934	.423
	Del-F	.900	1.000	.611	.144	.088	.906	.358
	Nat-F	.608	.611	1.000	.523	.474	.622	.466
	Nat-P	.196	.144	.523	1.000	.869	.199	.717
	Nat-S	.138	.088	.474	.869	1.000	.137	.641
	Att-F	.934	.906	.622	.199	.137	1.000	.445
	Att-P	.423	.358	.466	.717	.641	.445	1.000

Table 5- 5 Multiple regression analysis for buying decision

Model	Coefficient (B)	t	Sig. t	R^2	SEE	F	Sig.F	VIF
1				0.872	0.47591	10692.20	0.000	
(Constant)	.078	2.724	.007					
Att-F	.953	103.403	.000					1.000
2				0.888	0.44518	6221.81	0.000	
(Constant)	-.008	-.291	.771					
Att-F	.676	33.097	.000					5.609
Del-F	.308	14.979	.000					5.609
3				0.889	0.44421	4168.64	0.000	
(Constant)	-.065	-1.904	.057					
Att-F	.657	30.732	.000					6.185
Del-F	.315	15.239	.000					5.690
Att-P	.030	2.800	.005					1.264

Dependent Variable: Wan-F

5.5 Color attributes effecting on buying decision

To determine the relationship between color attributes effecting on buying decision, logistic regression was utilized to determine the relationship between saturation and buying decision. According to the data analysis of human expectations, durian flesh is an important part of durian related to attractiveness and want to buy. Then CIELAB of durian flesh of the six durian digital images was cropped and processed by using MATLAB including HSI value. Delta chroma (Del C^*_{ab}) was evaluated by equation (5.1-5.2) (33) and then was applied for finding relationship to saturation level adjusted from Adobe Photoshop.

$$C^*_{ab} = (a^{*2} + b^{*2})^{1/2} \tag{5.1}$$

$$Del\ C^*ab = C^*_{ab,1} - C^*_{ab,2} \tag{5.2}$$

Where: $C^*_{ab,1}$ and $C^*_{ab,2}$ - the value of C^*_{ab} of the two samples being compared

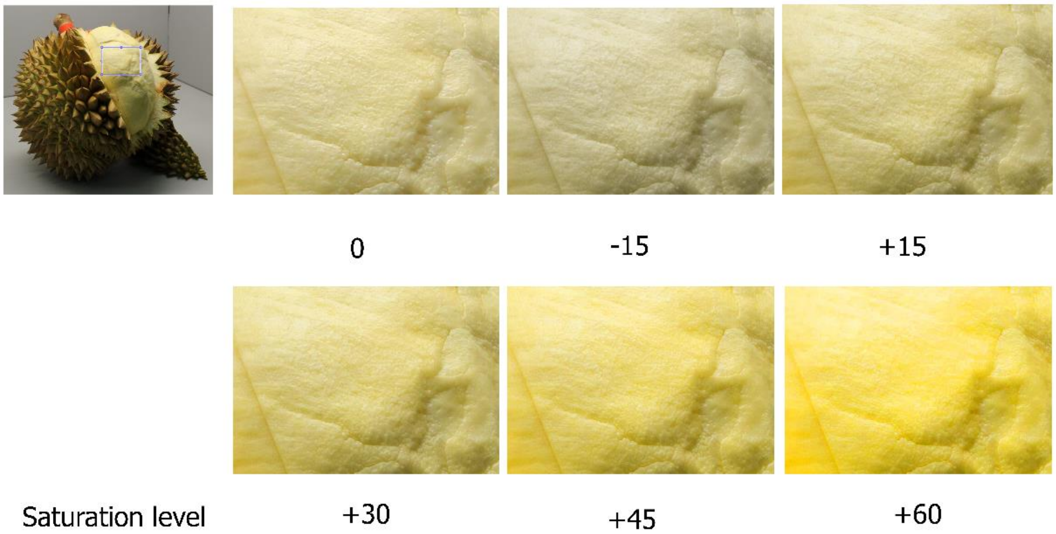


Figure 5- 10 The cropped durian flesh from digital durian image for CIELAB processed by using MATLAB.

The results of HSI value of durian flesh showed that the change of saturation evaluated by MATLAB increased in accordant with saturation level adjusted by using Adobe Photoshop while hue and intensity changed only a small amount when the saturation level changed (see Table 5-5, Figure 5-11). Mean of difference of H,S,I value from the original to each saturation level adjusted by Adobe Photoshop showed that saturation change increased in accordant with saturation level from Adobe Photoshop while hue (H) and intensity (I) changed a little. (see Figure 5-12).

Table 5- 6 HSI value and mean of difference of H, S, and I of the durian flesh image in 6 saturation levels obtained by MATLAB program

Saturation(%)	H	S	I	Mean of diff H	Mean of diff S	Mean of Diff I
0	0.1382	0.2335	0.7183	0	0	0
-15	0.1414	0.2008	0.6722	0.0032	-0.0327	-0.0461
+15	0.1413	0.2724	0.6804	0.0031	0.0389	-0.0379
+30	0.1421	0.3262	0.6869	0.0039	0.0927	-0.0314
+45	0.1417	0.4077	0.6971	0.0035	0.1742	-0.0213
+60	0.1421	0.5212	0.7132	0.0039	0.2877	-0.0052

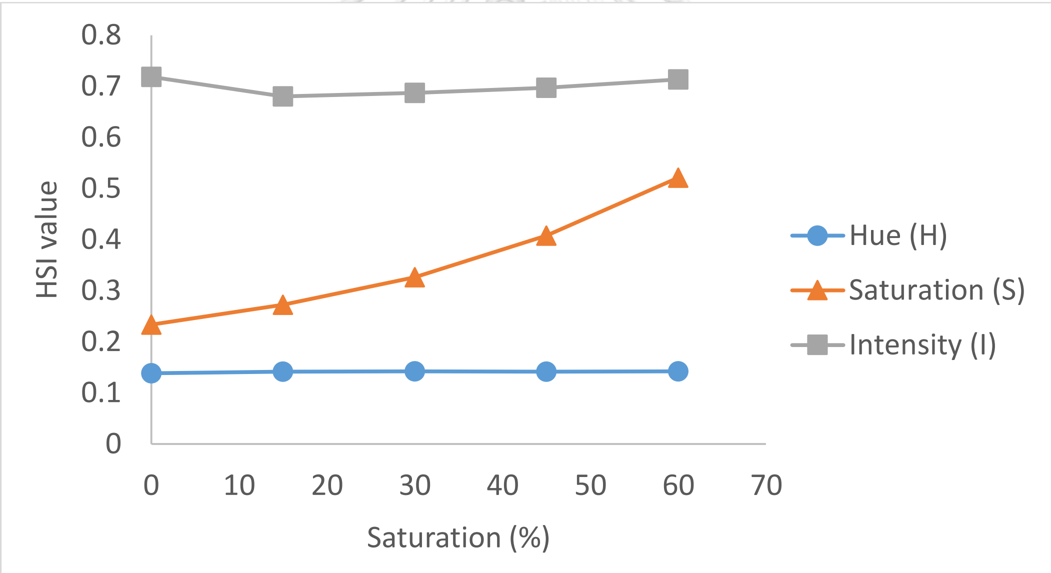


Figure 5- 11 HSI value vs. Saturation (%) of the six durian flesh images.

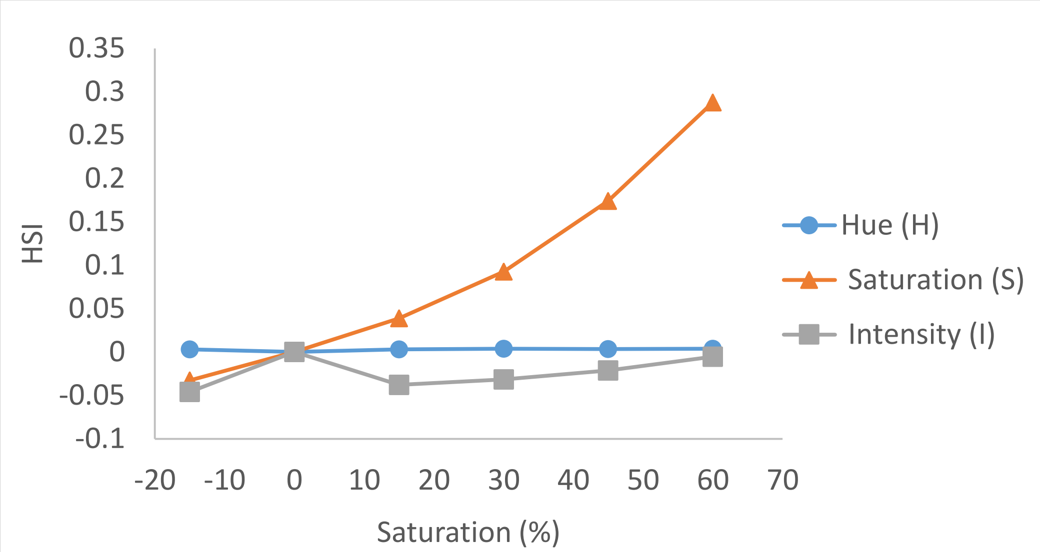


Figure 5- 12 Mean of difference of H, S, and I value vs. Saturation (%) of the six durian flesh images.

The results of CIELAB evaluated by MATLAB showed that the change in L* and b* increased when saturation level increased while a* value decrease a little when the saturation level changed (see Table 5-6 and Figure 5-13). The change of h_{ab} (hue angle) decreased from about 100 to 90 degree or yellow color (33) (see Figure 5-14). The transformation of chroma (C^*_{ab}) and saturation level adjusted in Adobe Photoshop were accordant with each other. The change of Del C*ab (difference chroma from the control (zero saturation level or saturation at mature stage) increased in the same direction of the change in saturation (Figure 5-14). All Del C^*_{ab} corresponding to saturation level adjusted by Adobe Photoshop were put into the human expectation data to establish buying decision model by using logistic regression analysis.

*Table 5- 7 CIELAB, C^*_{ab}, h_{ab}, and delta C^*_{ab} (Del C*ab) of the durian flesh evaluated by MATLAB*

Saturation(%)	L*	a*	b*	C^*_{ab}	h_{ab}	Del C^*_{ab}
0	79.426	-3.6495	29.6114	29.835	97.026	0
-15	74.1154	-3.7226	24.0036	24.291	98.815	-5.545
+15	76.5131	-4.4193	32.683	32.980	97.701	3.145
+30	78.4453	-4.9893	39.2355	39.551	97.247	9.716
+45	81.3954	-5.199	48.8322	49.108	96.077	19.273
+60	85.8866	-5.204	61.0862	61.307	94.869	31.472

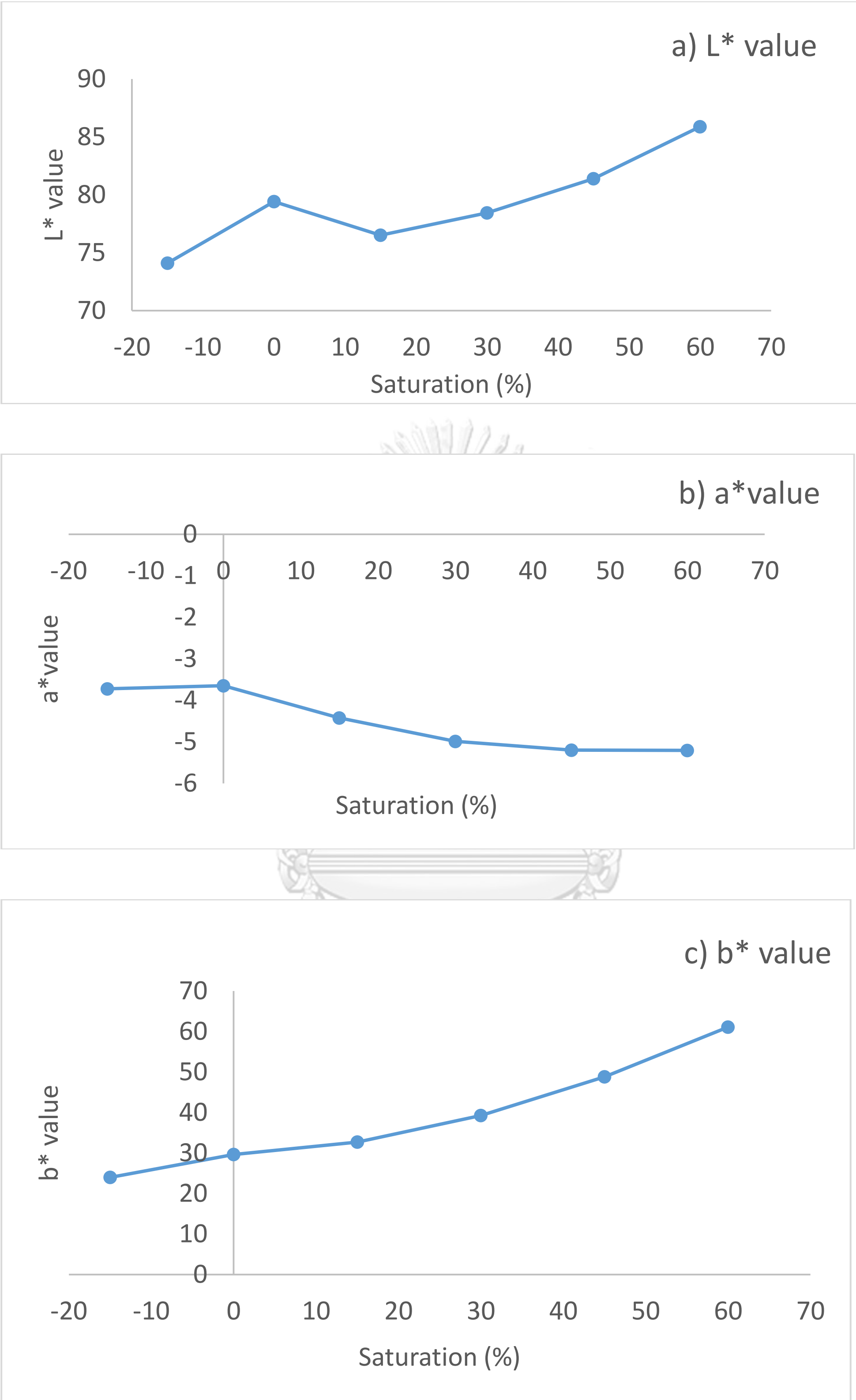


Figure 5- 13 CIELAB of durian flesh obtained from MATLAB vs. Saturation; a) L value b) a*value, and c) b* value.*

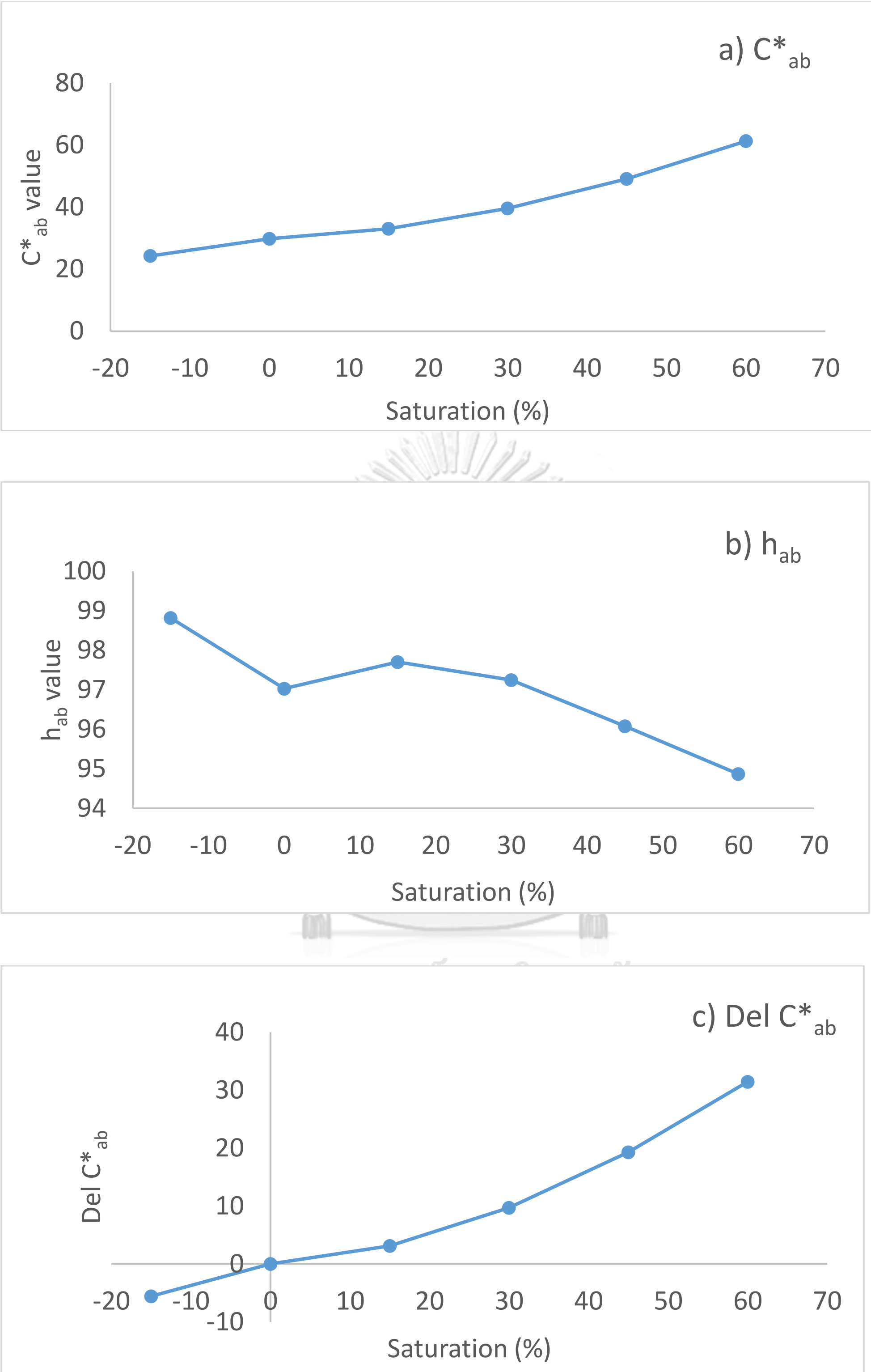


*Figure 5- 14 C*ab, hab, and Del C*ab of durian flesh vs. Saturation; a) C*ab value b) hab value, and c) Del C*ab value.*

According to the logistic regression analysis, dependent variable (buying decision) is a categorical variable having two categories (46, 48). Then all scores of Wan-F were transformed into “0” and “1”, which “0” refers to the scores less than 4 (no for buying) and “1” refers to the scores more than or equal to 4 (yes for buying). Three independent variables of Att-F, DelC*$_{ab}$, and saturation were expected to put into logistic regression analysis. Owning to Att-F value in 5 scales and high influence on Wan-F, Att-F value were transformed into two categories for efficient and simple prediction in model (48). The evaluation scores of Att-F were transformed into “0” and “1”, which “0” was score less than 4 (less attractiveness) and “1” was score higher than or equal to 4 (high attractiveness). Correlations of CAtt-F (transformed Att-F), Del C*ab, saturation and buying decision (transform Wan-F) were analyzed before putting then in logistic regression analysis. Owning to the correlations of Del C*$_{ab}$ and saturation were higher than 0.7 (0.975) (see Table 5-7), then only CAtt-F, saturation, and buying decision were utilized for the logistic regression analysis.

*Table 5- 8 Correlation of Del C*ab, saturation, Att-F code and buying decision*

		Saturation	CAtt-F	Del C*$_{ab}$	buying decision
Saturation	Pearson Correlation	1	.456**	.975**	.464**
	Sig. (2-tailed)		.000	.000	.000
	N	1566	1566	1566	1566
CAtt-F	Pearson Correlation	.456**	1	.426**	.858**
	Sig. (2-tailed)	.000		.000	.000
	N	1566	1566	1566	1566
Del C*$_{ab}$	Pearson Correlation	.975**	.426**	1	.434**
	Sig. (2-tailed)	.000	.000		.000
	N	1566	1566	1566	1566
buying decision	Pearson Correlation	.464**	.858**	.434**	1
	Sig. (2-tailed)	.000	.000	.000	
	N	1566	1566	1566	1566

**. Correlation is significant at the 0.01 level (2-tailed).

Examining efficiency of the predicted buying decision model, the classification table of buying decision model has to reveal no significance of Chi-Square value (48). The results shown in Table 5-8 indicated that the overall predictive accuracy is 93.6

%, which the model predicted for no for buying and yes for buying are nearly 1:1 ratio of no for buying and yes for buying. Chi-square value is 12.620, which is associated with a *p*-value of 0.082 (no significant difference between predicted and observed probability), indicating an acceptable match between predicted and observed probabilities (48).

Table 5- 9 Classification table of buying decision model

Observed		Predicted buying decision no	yes	Percentage Correct
buying decision	no	971	55	94.6
	yes	46	494	91.5
Overall Percentage				93.6

Note: The cut value is .500. Chi-square value is 12.620, which is associated with a *p*-value of 0.082.

The results of buying decision model from logistic regression analysis presented that CAtt-F was the more influential factor for buying than saturation owning to higher coefficient of CAtt-F (4.906) than of saturation (0.028) ($p < 0.05$) (see Table 5-9). Approximately 78.8 % of the variance in buying decision could be explained by the variables in the logistic regression model in equation 5.1 and 5.2 (Nagelkerke pseudo $R^2 = 0.788$) (48).

$$\text{Buying decision or log (ODDS)} = b_0 + b_1 \text{ CAtt-F} + b_2 \text{ Saturation} \quad 5.1$$

Where: ODDs – probability of buying/probability of not buying or p/(1-p)

b_0 – intercept when x =0

b_1 ,– slope coefficient, which shows ln(Odds) change when CAtt-F change one point

b_2 - slope coefficient, which shows ln(Odds) change when saturation change one point

Buying decision model or log (ODDs) = -3.673 + 4.906 CAtt-F + 0.028 Saturation 5.2

Table 5- 10 Logistic Regression Model for Buying Decision

Model	*B*	*SE-b*	Wald	*df*	Exp(*B*)	95% CI Exp(*B*)
Buying decision = -3.673 + 4.906 CAtt-F + 0.028 Saturation						
Intercept*	-3.673	0.205	321.598	1	0.025	
CAtt-F*	4.906	0.211	542.670	1	135.051	89.381-204.055
Saturation*	0.028	0.005	39.382	1	1.029	1.020 - 1.038

Note. The dependent variable was buying decision with buying as the target category and no for buying as the reference category; high score more than or equal to 4 was the focus group of Att-F variable; Nagelkerke R^2 = 0.788.
*$p < 0.05$.

In logistic regression, Exp *(B)* is the exponential of regression coefficient or odds ratio, which are computed by the formula (P/1-P), where P is the probability of yes for buying and 1-P is the probability of no for buying (48). With multiple variables (two in this case) used as predictors in the logistic analysis, the odds ratio is an adjusted odd ratio to indicate the contribution of particular variable when other variable are controlled (48). In this case, the odd ratio of 1.029 (saturation, $e^{0.028}$ = 1.029) indicates that the probability of yes for buying decision is 1.029 times as likely as the value saturation is augmented by one unit. The odd ratio 1.0 reveals that the probability of buying decision is 1 (yes for buying) to 1 (no for buying) or there is no relationship between independent and dependent variable(46). Predicted probability in this case can calculated by equation 5.3.

$$\text{Predicted probability(48)} = \frac{e^{b_0 + \, b_1 \, CAtt-F \, + \, b_1 \, Saturation}}{1+e^{b_0 + \, b_1 \, CAtt-F \, + \, b_1 \, Saturation}} \quad 5.3$$

where: e = exponential = 2.718, equation (5.2) is antilog equation

Criteria predicted probability <0.5 means no for buying decision

$\geq$ 0.5 means yes for buying decision

Owning to the model refer to criteria ≥ 0.5 which related to CAtt-F equal to 1 (high satisfaction), saturation used for the study was in the range of -15 to 60. Then for saturation = -15, the predicted probability for buying at high satisfaction was about 69 percent. The change of predicted probability increased in accordant with the change of saturation level. Then the saturation about 45 and 60% can be used to achieve higher predicted probability than 90%.

$$\text{Predicted probability} = \frac{e^{(-3.673 + 4.906 + 0.028*(-15))}}{1+e^{(-3.673 + 4.906 + 0.028*(-15))}}$$

$= 2.718^{(0.813)}/1+2.718^{(0.813)}$

$= 2.26/\ 1+2.26$

$= 0.69$ or 69 %

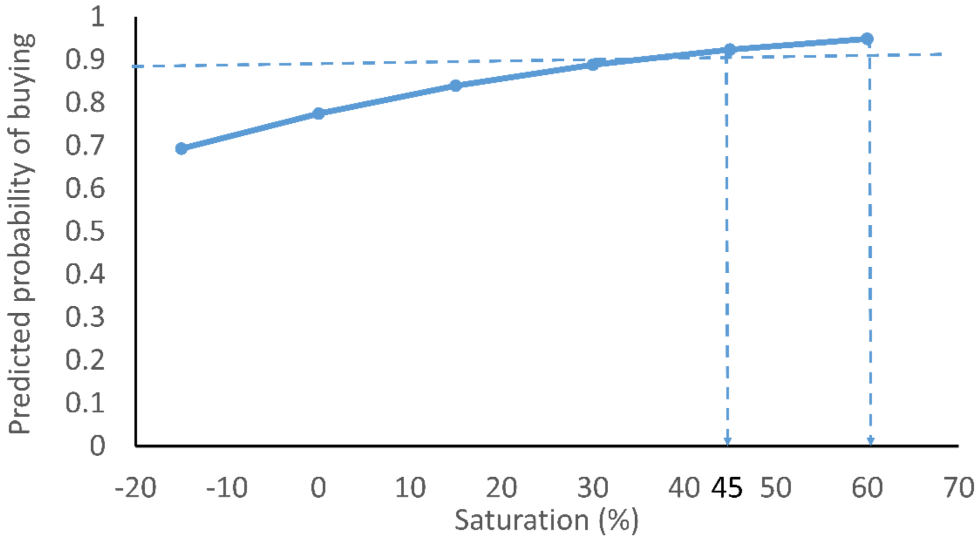


Figure 5- 15 Probability of buying with high satisfaction of CAtt-F vs. Saturation.

According to the high correlation of Del C^*_{ab} and saturation level, linear regression was applied to find the relationship of both color attributes from 1566 data (29 participants, 6 durian images, and 9 lighting conditions). The relationship of Del C^*_{ab} and saturation showed in the equation 5.4.

$$\text{Saturation} = 3.138 + 2.001 \text{ Del } C^*_{ab} \quad (5.4)$$

Table 5- 11 Linear regression analysis of Del C^*_{ab} and saturation

Model	Coefficient (B)	t	Sig. t	R^2	SEE	F	Sig.F
				0.951	5.68644	30217.922	0.000
(Constant)	3.138	17.260	.000				
Del C^*_{ab}	2.001	173.833	.000				

Dependent Variable: Saturation

Refer to CIELAB in Table 5-6, the adjusted Del C^*_{ab} (ADel C^*_{ab}) at different saturation level were calculated by using the equation 5.4. An example of calculating ADel C^*_{ab} and AC^*_{ab} at 45% as following, ADel C^*_{ab} was 20.92 which was the output of 45 minus 3.138 dividing by 2.001 and AC^*_{ab} was 50.756. ADel C*ab and AC*ab at other saturation calculated in the same way as shown in Table 5-18.

Adjusted Del C^*_{ab} or ADelC^*_{ab} = (Saturation – 3.138)/2.001

= (45 -3.138)/2.001 = 20.92

Del C^*_{ab} = $C^*_{ab,1} - C^*_{ab,2}$

where $C^*_{ab,1}$ - AC^*_{ab}

$C^*_{ab,2}$ - 29.835

Del C^*_{ab} - 20.921

then, AC^*_{ab} = 20.921 + 29.835 = 50.756

According to the high predicted probability of buying, saturation level at 45 and 60% were selected. The suitable C^*_{ab} should be in the range of about 51 to 58 and suitable delta chroma of the sample and reference should be in the range of about 21 to 28 (from mature stage of durian flesh) in order to achieve the predicted buying decision model. The application of the model was presented in section 5.8.

Table 5- 12 C^*_{ab}, delta C^*_{ab} (Del C^*_{ab}) of the durian flesh evaluated by MATLAB, and adjusted delta C^*_{ab} (Adel C^*_{ab}) and adjusted chroma (AC^*_{ab}) at particular saturation level

Saturation(%)	C^*_{ab}	Del C^*_{ab}	ADel C^*_{ab}	AC^*_{ab}
0	29.835	0	-1.568	28.267
-15	24.291	-5.545	-9.064	20.771
+15	32.980	3.145	5.928	35.763
+30	39.551	9.716	13.424	43.260
+45	49.108	19.273	20.921	50.756
+60	61.307	31.472	28.417	58.250

5.6 CIELAB of durian flesh image

In addition, Y, x, and y were measured at positions 1, 2 and 3 (selected from the area in the middle of the picture and without shade and no reflection) on the printed images of the durian fruit by using a Chroma-meter and determining the calculated CIELAB values at D65 using the 2-degree color matching function for viewing the trend in the change in the color between the 9 lighting conditions. The CIELAB color space of the durian flesh images at positions 1, 2, and 3 (see Figure 4-10) under the 9 lighting conditions shifted away from the CIELAB color space of the original and printed image and hue became more yellowish and reddish as the saturation level increased at 2700 K for all 3 illuminances, especially at 600 lux. The color appeared closer to that in the original and printed image (yellow with some green) when under 6500 K 150 lux (Figure 5-16). Changes in the hues of the 3 positions observed under the 9 lighting conditions presented smaller hue angles that were more yellowish when the saturation level increased (Figure 5-17).

According to luminance indicates the freshness of fruit and vegetable, which leads to deliciousness and attractiveness of customers (12, 18), then luminance of the durian flesh image at the 3 positions was calculated by the equation 5.5. Increasing in saturation level have an effect on luminance in the same direction for all three positions (see Figure 5-18), which are different from the luminance effects of freshness found by Arce-Lopera et al (12, 18).

$$Y = Y_n f^{-1}(\frac{L^{*}+16}{116}) \qquad 5.5$$

Where: if $f^{-1}(t) > 6/29$, $f^{-1} = t^3$ then other,

$f^{-1} = 3(6/29)^2(t-(4/29))$

$Y_n = 100$

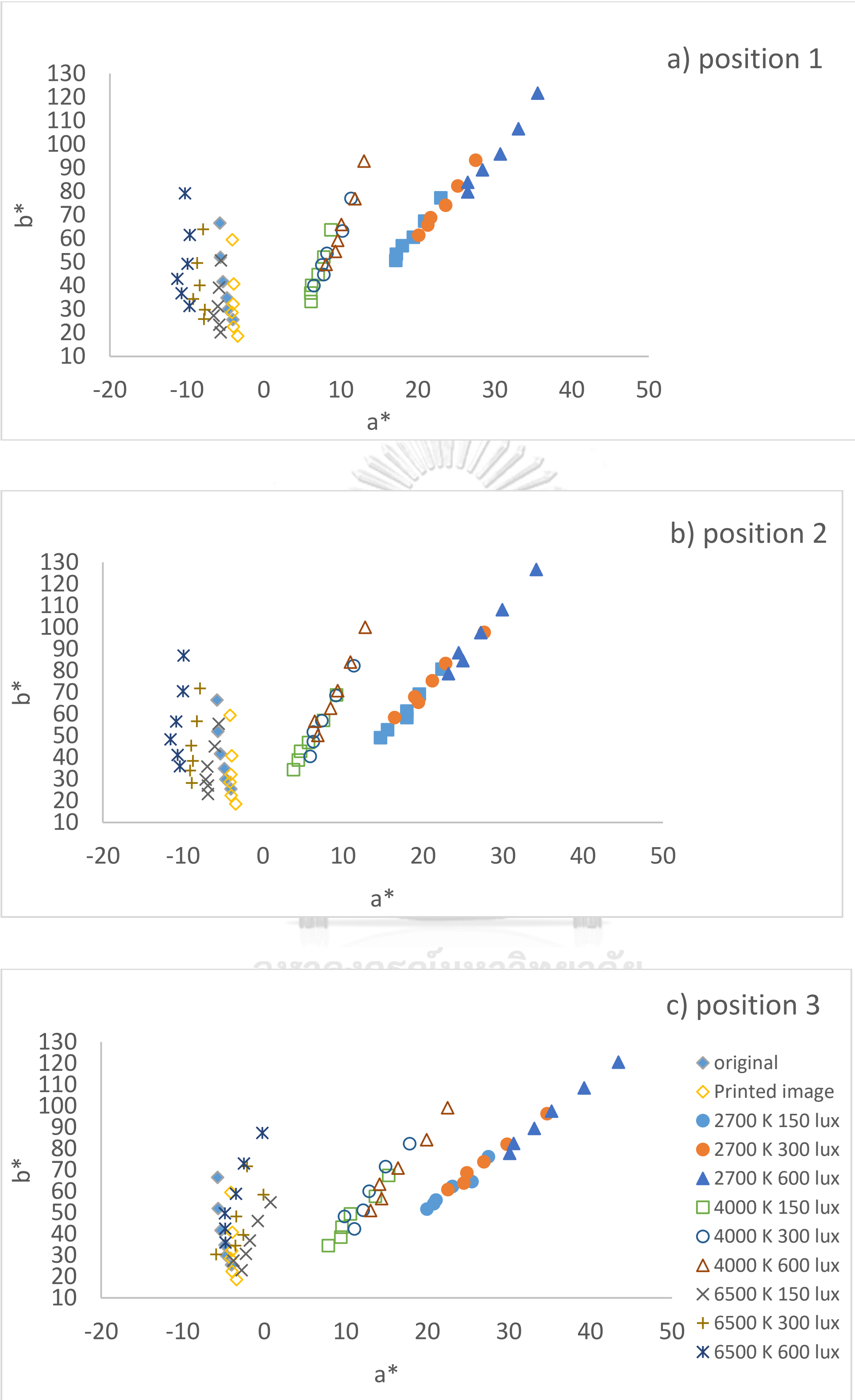


*Figure 5- 16 The plot of a*b* value of durain flesh image at 3 positions; a) position 1, b) position 2, and c) position 3.*

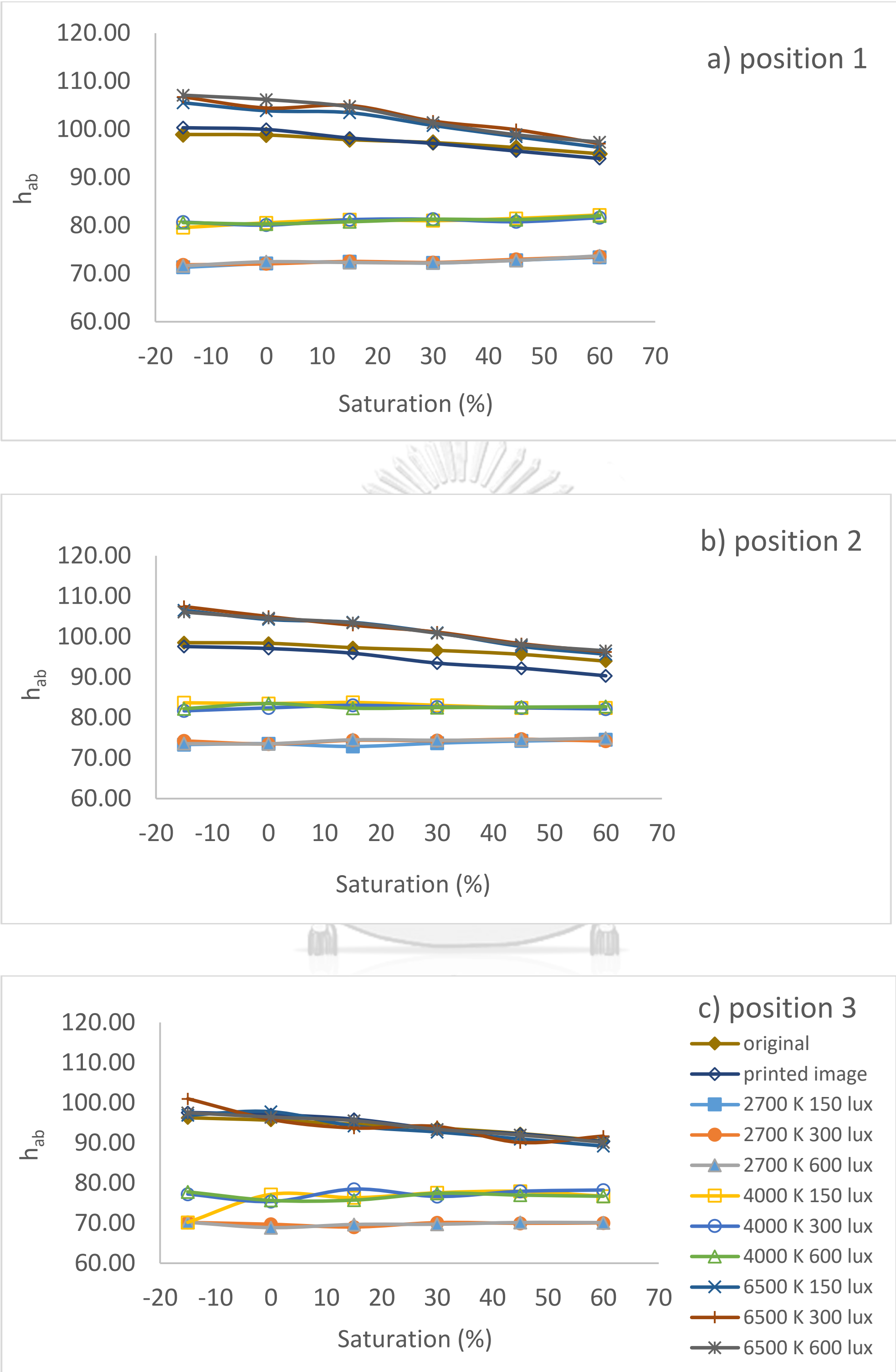


Figure 5- 17 The plot of hab vs. saturation of of durain flesh image at 3 positions under the 9 lighting conditions; a) position 1 b) position 2, and c) position 3.

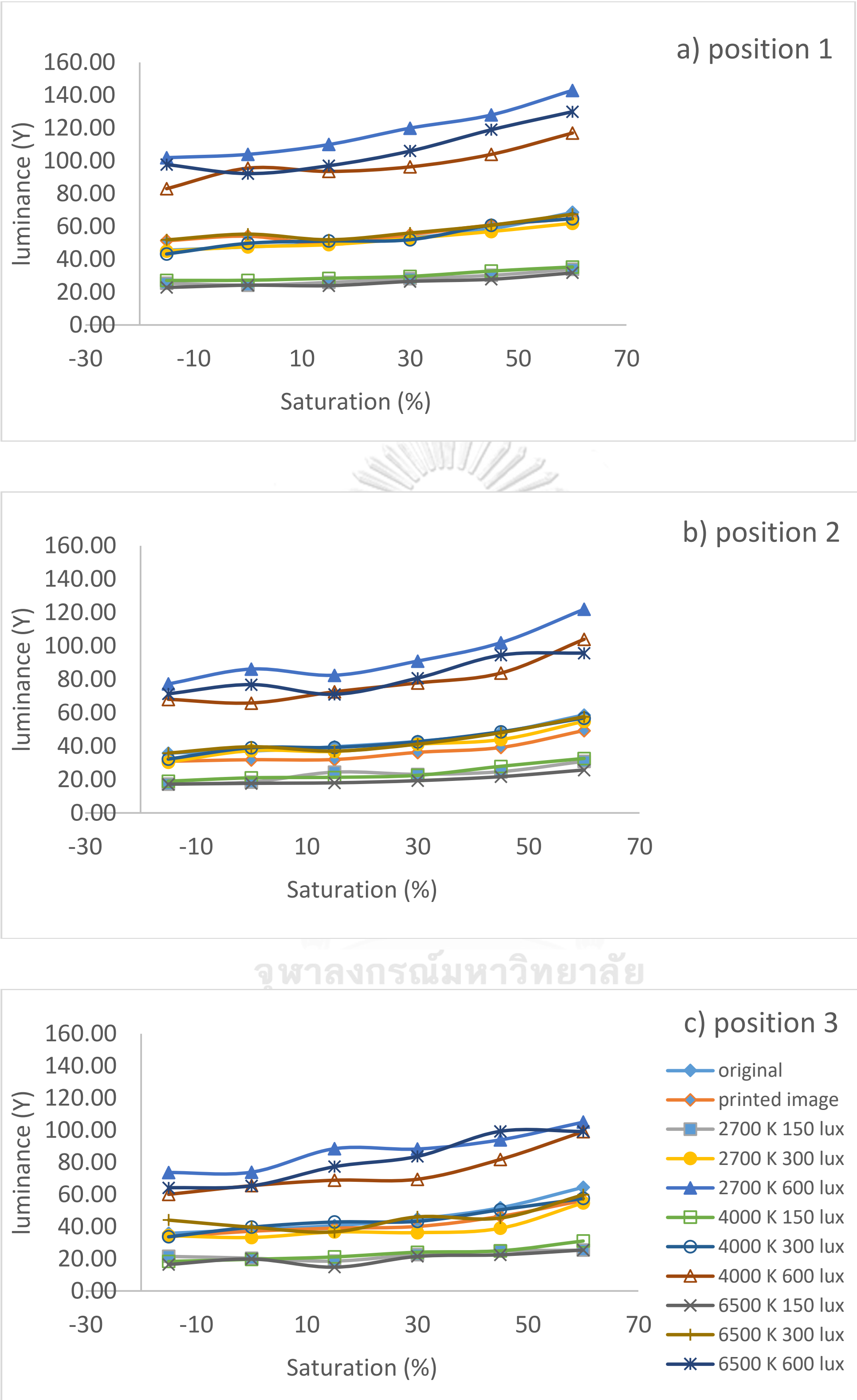


Figure 5- 18 The plot of luminance (Y) vs. saturation of of durain flesh image at 3 positions under the 9 lighting conditions; a) position1 b) position2, and c) position3.

5.7 Verification results and discussion

The same durian of the first experiment was photographed in another view, adjusted saturation and printed in the same as the first experiment. The second durian image width for the second experiment (11 centimeters) were smaller than of the first image (15 centimeters). Then the distance of viewing was 30 centimeters instead of 40 centimeters in order to keep the same ratio of vision in the first experiment. The results of the repeat experiments of the same group of participants (low vision were rejected from the experiment) were presented in the same procedure as the first experiment, except the distance of viewing and buyinf decision model. Viewing distance of the repeat experiment was 30 centimeters instead of 40 centimeters like the first experiment to keep the same ratio of viewing distance. This is because the smaller width size of the repeat durian image (11 centimenters) than of the first durian image (15 centimeters) (see Figure 5-19). In addition, buying decision in the repeat experiment was evaluated by the predicted model from the first experiment instead of using logistic regression analysis to predict another model.

Figure 5- 19 The width size of the first durian image (left) and the repest durian image in another view (right)

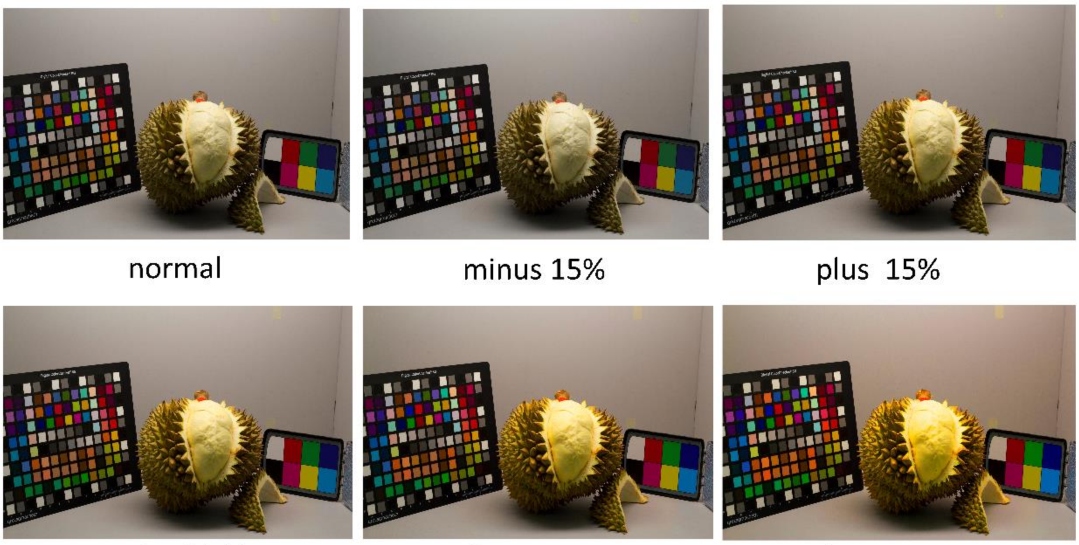


Figure 5- 20 Printed durian cv. Monthong of the second experiment was adjusted into 5 saturation levels of -15, 15, 30, 45, and 60% by using Adobe Photoshop.

5.7.1 Human expectation data The results of customers' expectations showed that their scores of Deliciousness of Flesh (Del-F1), Attractiveness of Flesh (Att-F1), Want to buy Flesh (Wan-F1), and Naturalness of Flesh (Nat-F1) under the 9 lighting conditions increased corresponding to saturation level up to optimum (see Figure 5-21, 5-25, 5-27, and 5-22) in the same as the first experiment. The rest of the 4 expectations showed the same trend. The means of the scores reported by the participants for the 8 main questions could be divided into 3 groups. The first group, those with scores lower than 3.51 (See Table 5-12), were Att-P1, and Wan-P1. The second group, those with scores greater than or equal to 3.51, and lower than 3.51 were Nat-P1 and Nat-S1. The last group, those with scores greater than or equal to 3.51 that means high satisfaction(43) (see Figure 5-3), were Del-F1, Att-F1, and Wan-F1. The optimum saturation for Nat-F1 was reported to be between 30-45%, and the scores of Del-F1, Att-F1, and Wan-F1 increased as the saturation approached 45%, as shown in Table 5-12.

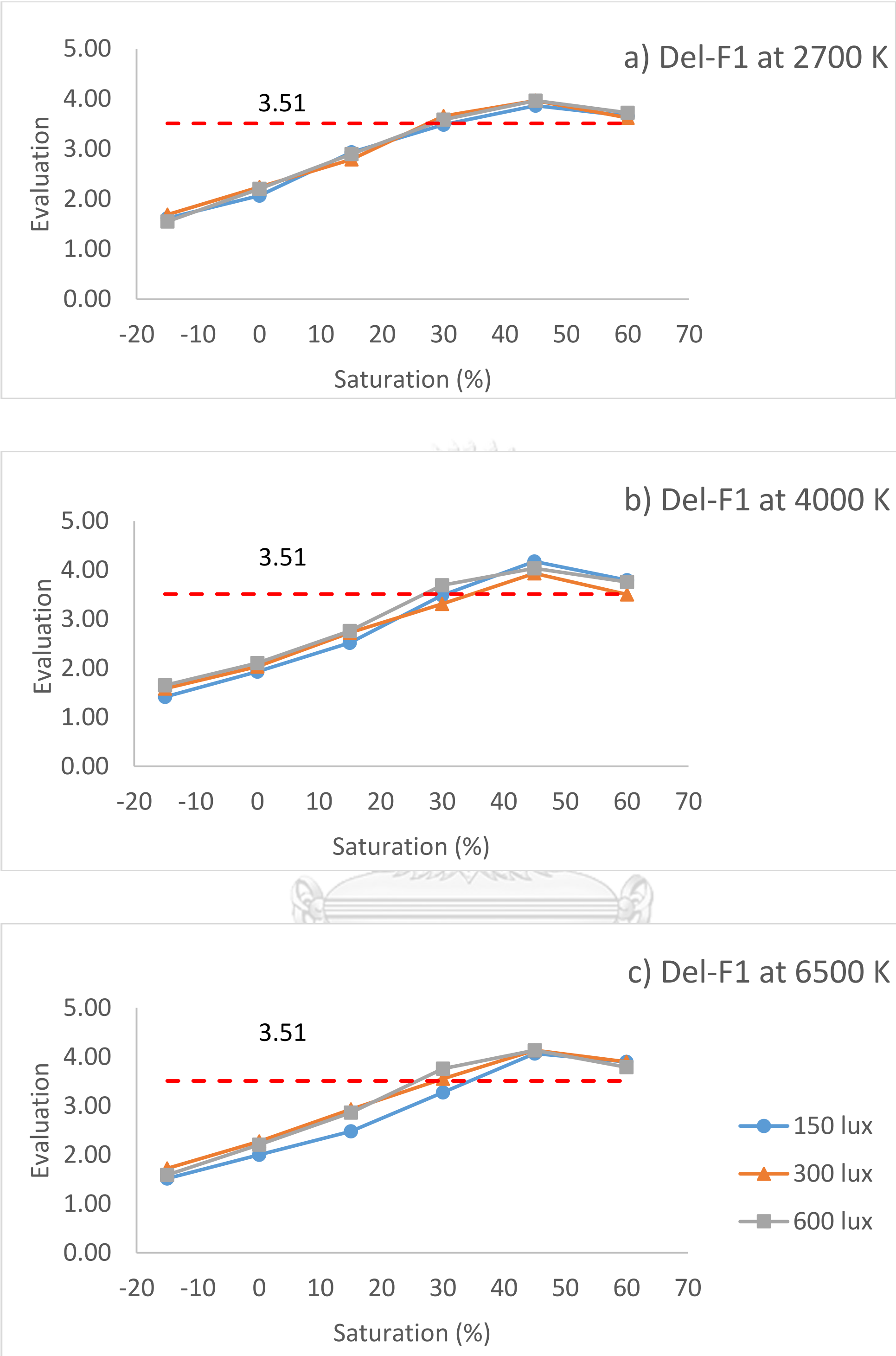


Figure 5- 21 Evaluation of Deliciousness of flesh of the repeat experiment (Del-F1) vs. Saturation (%) under 3 CCTs; a) 2700 K b) 4000 K and c) 6500 K.

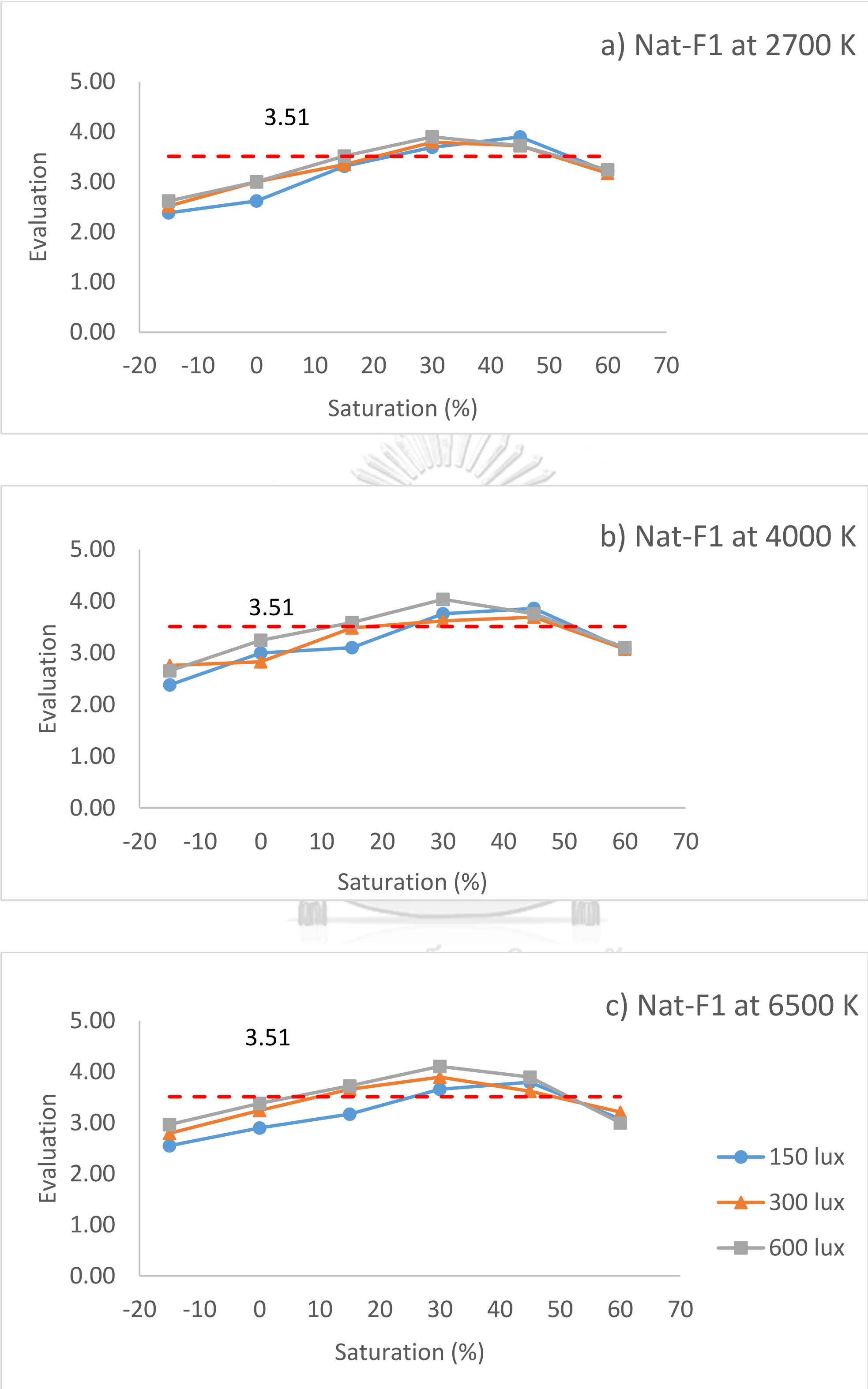


Figure 5- 22 Evaluation of Naturalness of flesh of the repeat experiment (Nat-F1) vs. Saturation (%) under 3 CCTs; a) 2700 K b) 4000 K and c) 6500 K.

Figure 5- 23 Evaluation of Naturalness of peel of the repeat experiment (Nat-P1) vs. Saturation (%) under 3 CCTs; a) 2700 K b) 4000 K and c) 6500 K.

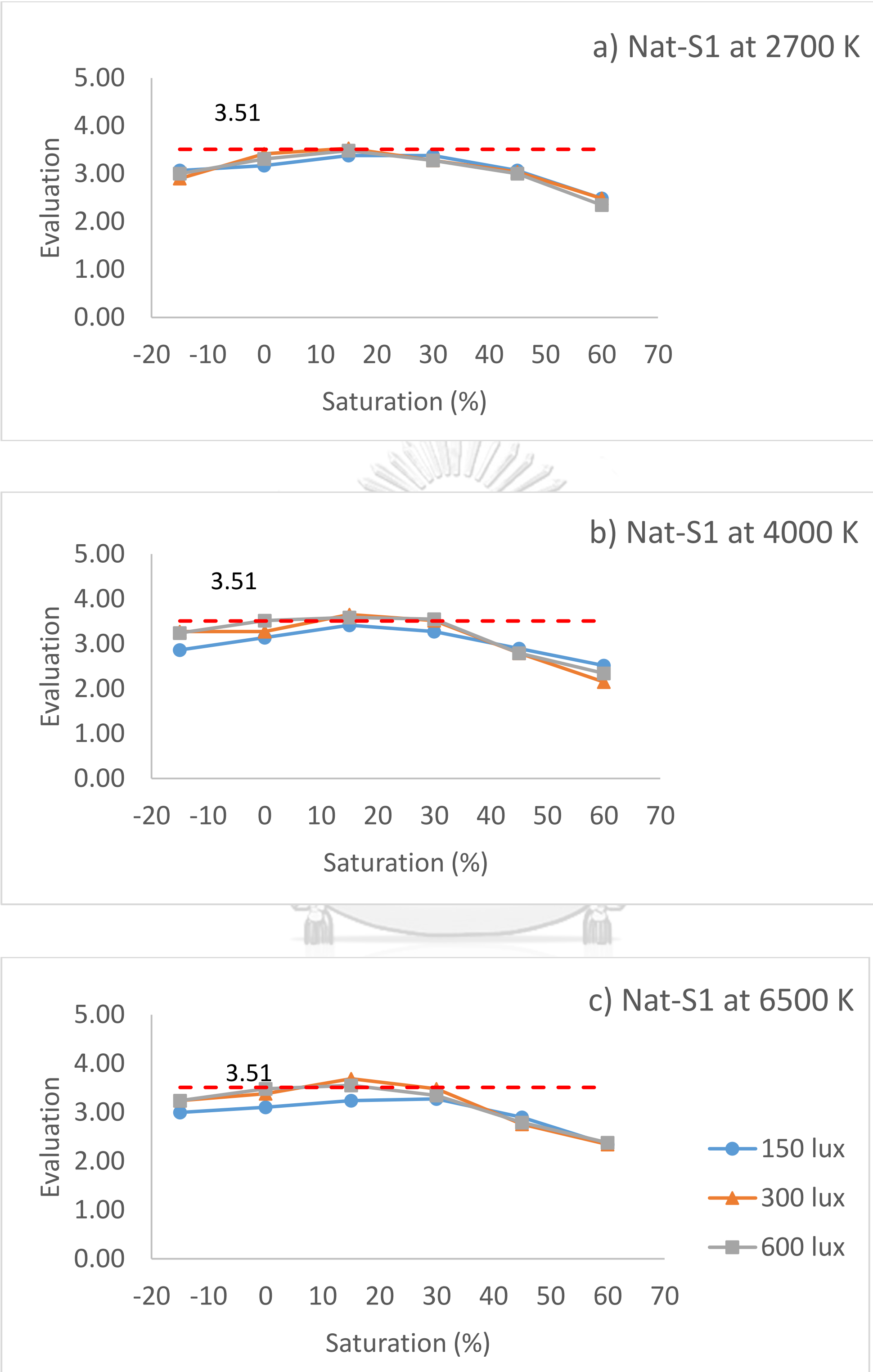


Figure 5- 24 Evaluation of Naturalness of stem of the repeat experiment (Nat-S1) vs. Saturation (%) under 3 CCTs; a) 2700 K b) 4000 K and c) 6500 K.

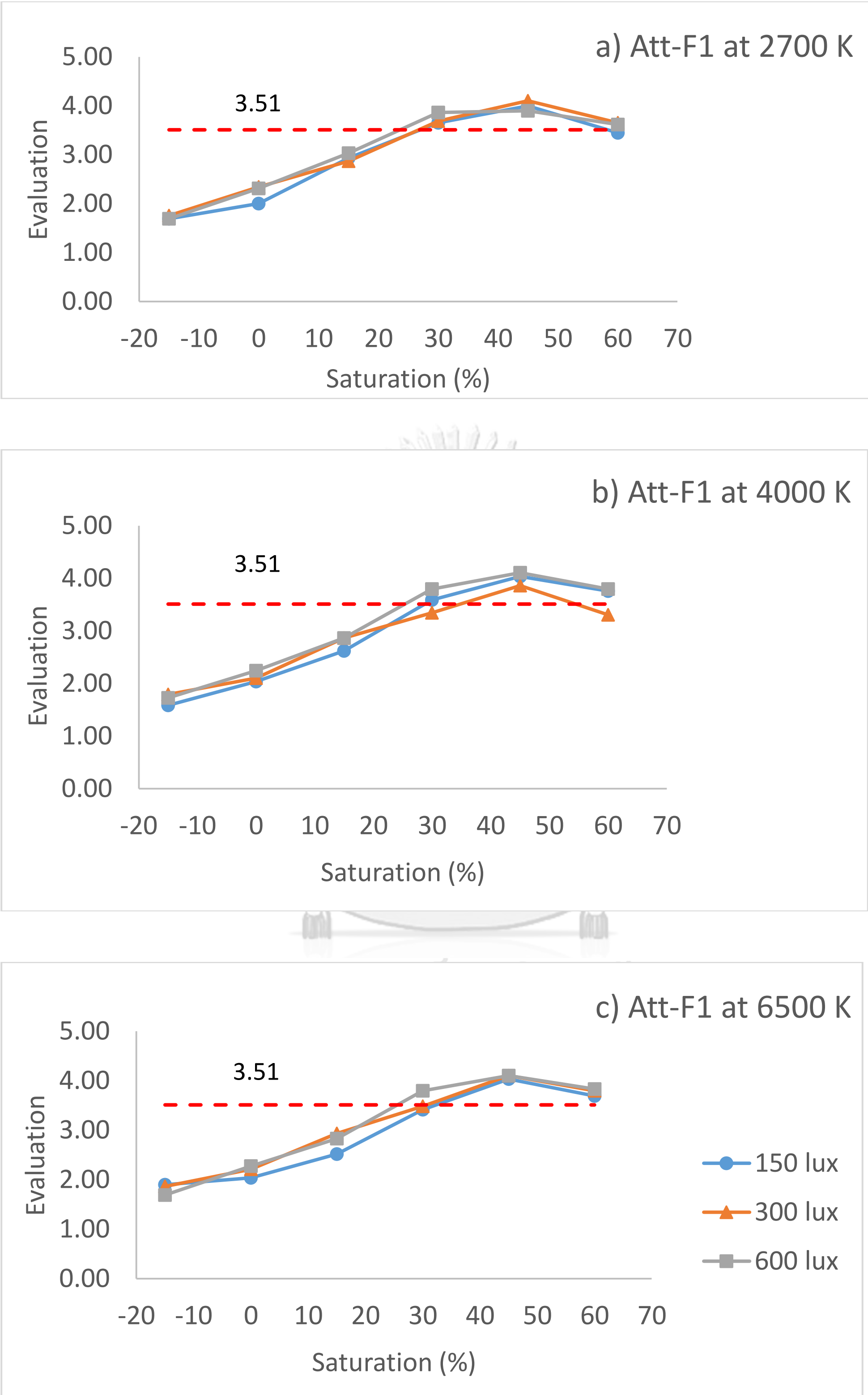


Figure 5- 25 Evaluation of Attractiveness of flesh of the repeat experiment (Att-F1) vs. Saturation (%) under 3 CCTs; a) 2700 K b) 4000 K and c) 6500 K.

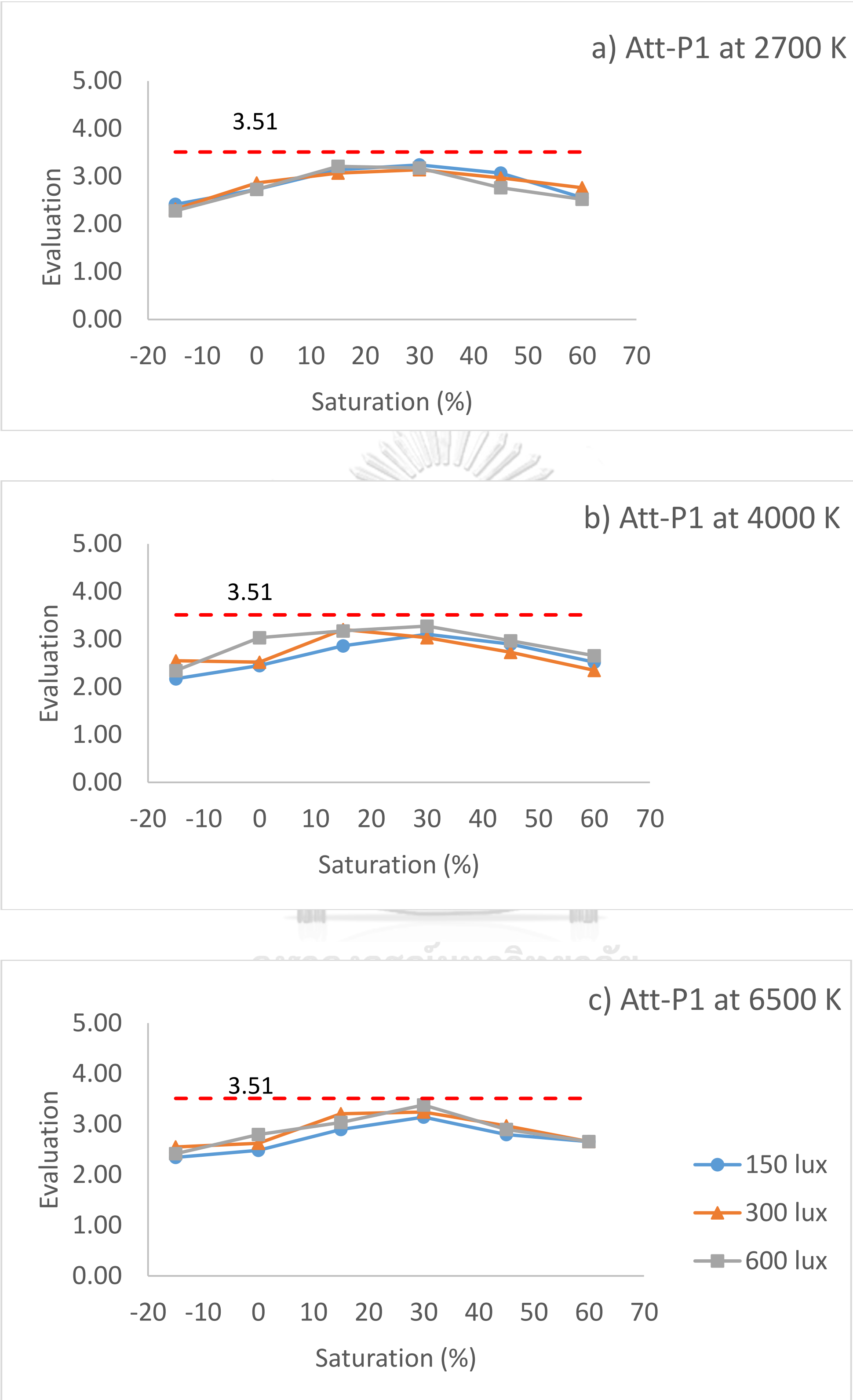


Figure 5- 26 Evaluation of Attractiveness of peel of the repeat experiment (Att-P1) vs. Saturation (%) under 3 CCTs; a) 2700 K b) 4000 K and c) 6500 K.

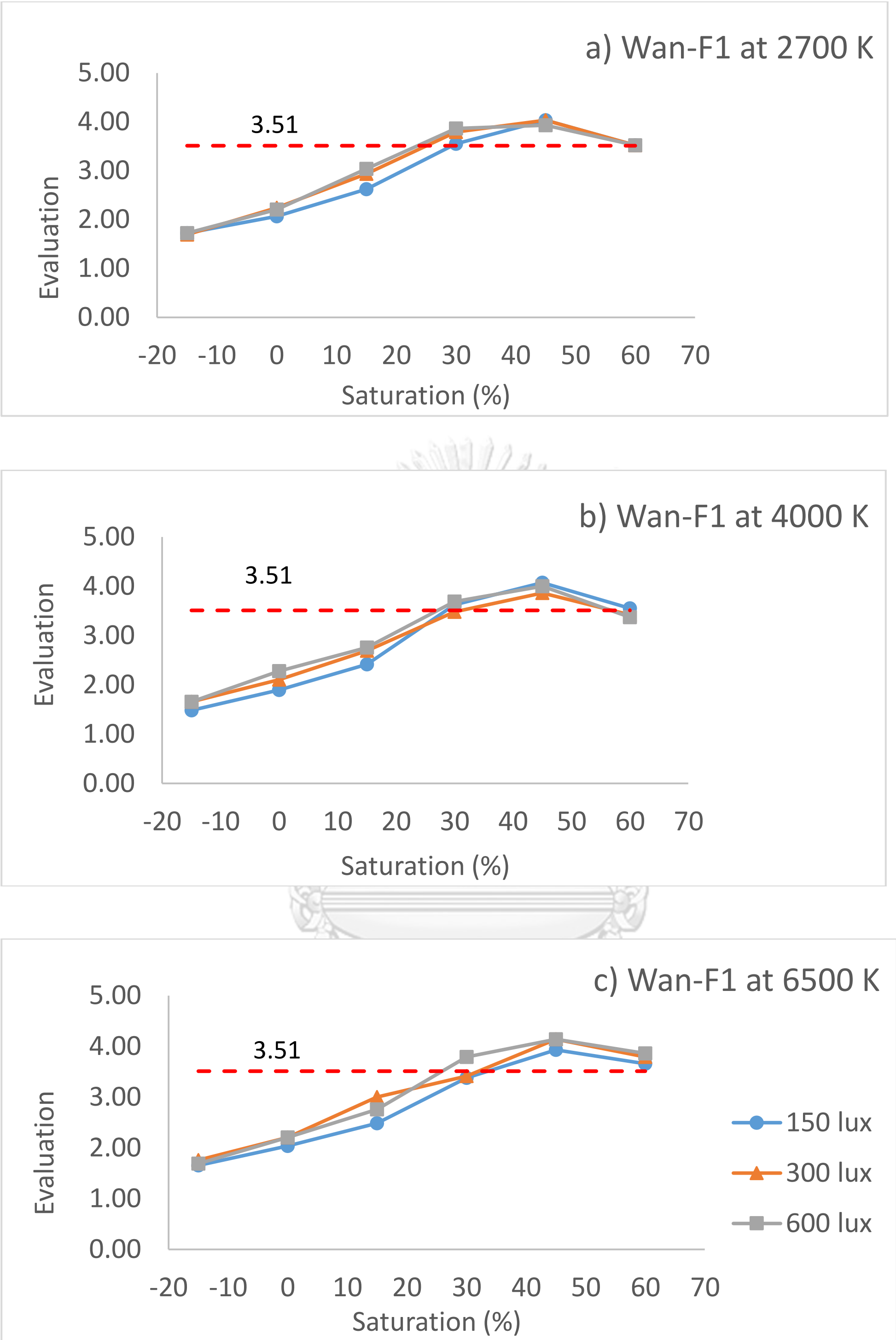
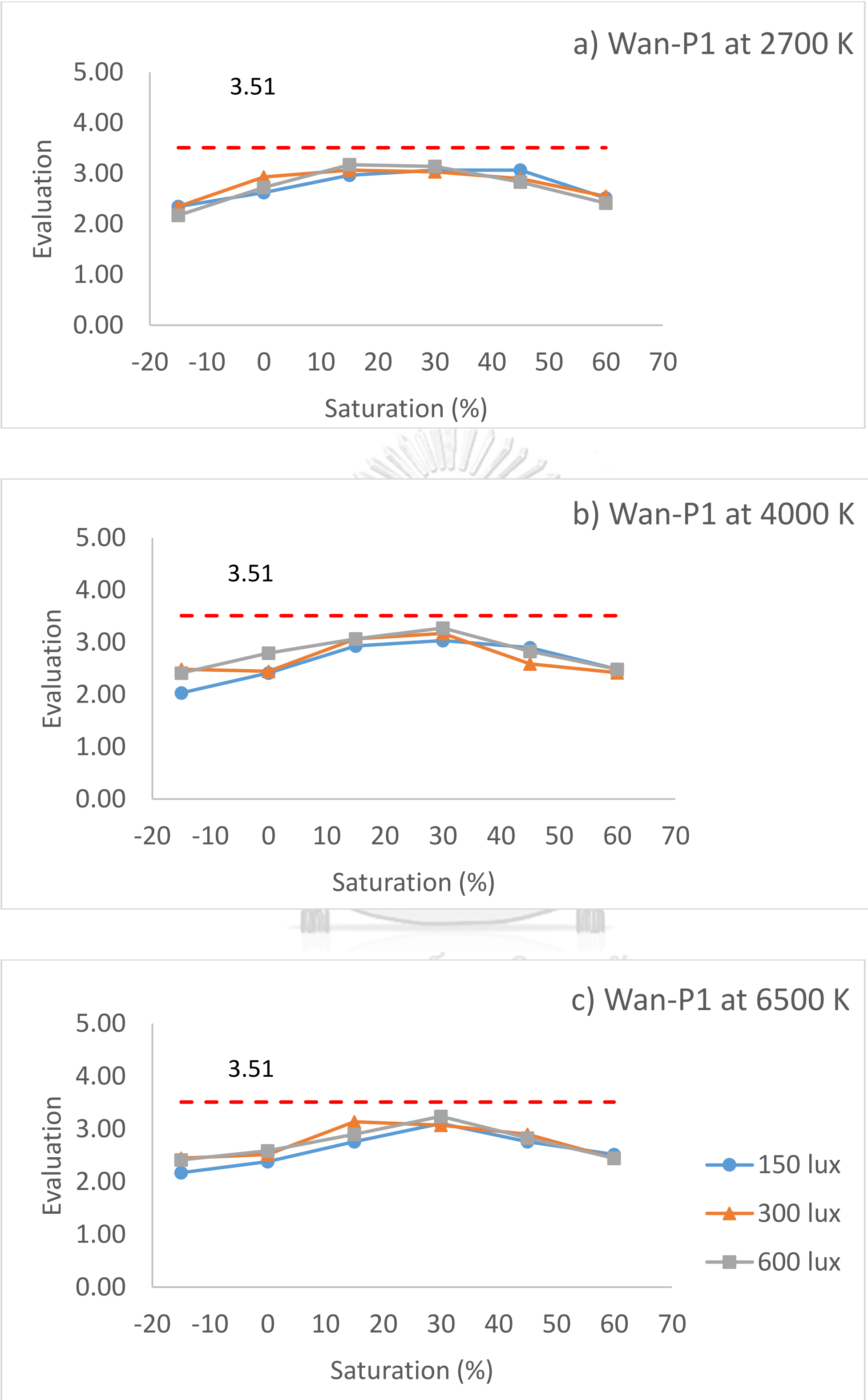


Figure 5- 27 Evaluation of Want to buy from flesh of the repeat experiment (Wan-F1) vs. Saturation (%) under 3 CCTs; a) 2700 K b) 4000 K and c) 6500 K.



c

Figure 5- 28 Evaluation of Want to buy from peel of the repeat experiment (Wan-P1) vs. Saturation (%) under 3 CCTs; a) 2700 K b) 4000 K and c) 6500 K.

Table 5- 13 Optimum saturation and mean of Customers' expectation on the eight main expectations of the repeat experiment of Durian images under the 9 lighting conditions

Aspects	Maximum saturation level (%) for various 3 CCTs and 3 illuminances									Average means
	2700 K			4000 K			6500 K			
	150 lux	300 lux	600 lux	150 lux	300 lux	600 lux	150 lux	300 lux	600 lux	
Del-F1	+45	+45	+45	+45	+45	+45	+45	+45	+45	≥3.51
Att-F1	+45	+45	+45	+45	+45	+45	+45	+45	+45	≥3.51
Wan-F1	+45	+45	+45	+45	+45	+30	+45	+45	+45	≥3.51
Nat-F1	+45	+30*	+30*	+45	+45	+30	+45	+30	+30	≥3.51
Nat-P1	+15	0	+15	+15	+15*	+15*	+30*	+15*	0	*≥3.51, <3.51
Nat-S1	+15, +30	+15*	+15	+15	+15*	+15*	+30	+15*	+15*	*≥3.51, <3.51
Att-P1	+30	+30	+15	+30	+15	+30	+30	+30	+30	<3.51
Wan-P1	+30, +45	+15	+15	+30	+30	+30	+30	+15	+30	<3.51

5.7.2 Factors impacting on human expectations MANOVA result of the second experiment shown in Table 5-13 indicate that only saturation significantly impacted the 8 expectations [F(40, 6562.94) = 39.342 (Wilk's Lambda) p- value <0.001]. The CCTs and illuminances had no significant effects on the expectations. No interaction among CCTs, illuminances, and saturation was observed as the same results in the first experiment.

Table 5- 14 Multivariate Tests of customers' expectation and factors of saturation, CCTs, and illuminances for the repeat experiment.

Effect		Value	F	Hypothesis df	Error df	Sig.
Intercept	Pillai's Trace	.941	3012.228[b]	8.000	1505.000	.000
	Wilks' Lambda	.059	3012.228[b]	8.000	1505.000	.000
	Hotelling's Trace	16.012	3012.228[b]	8.000	1505.000	.000
	Roy's Largest Root	16.012	3012.228[b]	8.000	1505.000	.000
Saturation	Pillai's Trace	.681	29.728	40.000	7545.000	.000
	Wilks' Lambda	.392	39.342	40.000	6562.937	.000
	Hotelling's Trace	1.370	51.481	40.000	7517.000	.000
	Roy's Largest Root	1.225	231.106[c]	8.000	1509.000	.000
CCT	Pillai's Trace	.011	1.063	16.000	3012.000	.386
	Wilks' Lambda	.989	1.062[b]	16.000	3010.000	.386
	Hotelling's Trace	.011	1.062	16.000	3008.000	.387
	Roy's Largest Root	.008	1.473[c]	8.000	1506.000	.162
Illuminance	Pillai's Trace	.013	1.205	16.000	3012.000	.255
	Wilks' Lambda	.987	1.207[b]	16.000	3010.000	.254
	Hotelling's Trace	.013	1.208	16.000	3008.000	.253
	Roy's Largest Root	.011	2.086[c]	8.000	1506.000	.034
Saturation * CCT	Pillai's Trace	.041	.778	80.000	12096.000	.928
	Wilks' Lambda	.960	.778	80.000	9553.925	.929
	Hotelling's Trace	.041	.777	80.000	12026.000	.930
	Roy's Largest Root	.015	2.279[c]	10.000	1512.000	.012
Saturation * Illuminance	Pillai's Trace	.035	.666	80.000	12096.000	.991
	Wilks' Lambda	.965	.665	80.000	9553.925	.991
	Hotelling's Trace	.035	.664	80.000	12026.000	.991
	Roy's Largest Root	.011	1.709[c]	10.000	1512.000	.073
CCT * Illuminance	Pillai's Trace	.011	.502	32.000	6032.000	.991
	Wilks' Lambda	.989	.502	32.000	5551.761	.991
	Hotelling's Trace	.011	.502	32.000	6014.000	.991
	Roy's Largest Root	.006	1.090[c]	8.000	1508.000	.367
Saturation * CCT * Illuminance	Pillai's Trace	.064	.614	160.000	12096.000	1.000
	Wilks' Lambda	.937	.614	160.000	11253.048	1.000
	Hotelling's Trace	.065	.614	160.000	12026.000	1.000
	Roy's Largest Root	.024	1.833[c]	20.000	1512.000	.014

b. Exact statistic

c. The statistic is an upper bound on F that yields a lower bound on the significance level.

5.7.3 Human feelings impacting on buying decision For the repeat experiment, the relationship among human expectations on buying decision was evaluated by applying multiple regression. The findings indicated that there were high correlation more than 0.7 (48) among deliciousness of flesh (Del-F1), attractiveness of flesh (Att-F1), and want to buy from flesh (Wan-F1) (see Table 5-14), which should select only one attribute of Del-F1 and Att-F1 for the model in order to avoid multicollinearity as the same results of the first experiment. There were three models of significant relationships between feelings and buying decision (see Table 5-15). However, the model 1 with R-square 87.8% was selected by concerning on problem of multicollinearity (VIF (the variance inflation factor) more than 2) (48) as the same in the first experiment. The variance inflation factor (VIF) is computed as 1 divided by tolerance. The higher tolerance (more than or equal to 0.5 is acceptable (48). Attractiveness had the greatest influence on buying decision, which is the same as what was reported by Rebollar et al (17). The results of repeat experiment in terms of human expectations were the same as the first experiment.

Table 5- 15 Correlations among human expectations of the repeat experiment

		Wan-F1	Del-F1	Nat-F1	Nat-P1	Nat-S1	Att-F1	AttP1
Pearson Correlation	Wan-F1	1.000	.900	.615	.203	.179	.937	.433
	Del-F1	.900	1.000	.594	.165	.124	.904	.396
	Nat-F1	.615	.594	1.000	.508	.504	.613	.475
	Nat-P1	.203	.165	.508	1.000	.836	.195	.689
	Nat-S1	.179	.124	.504	.836	1.000	.170	.603
	Att-F1	.937	.904	.613	.195	.170	1.000	.453
	Att-P1	.433	.396	.475	.689	.603	.453	1.000

Table 5- 16 Multiple regression analysis for buying decision in the repeat experiment.

Model	Coefficient (B)	t	Sig.t	R^2	SEE	F	Sig.F	VIF
1				0.878	0.47114	11274.34	0.000	
(Constant)	.065	2.191	.029					
Att-F1	.965	106.181	.000					1.000
2				0.894	0.44040	6564.92	0.000	
(Constant)	-.009	-.330	.741					
Att-F1	.695	34.982	.000					5.463
Del-F1	.300	15.064	.000					5.463
3				0.895	0.43768	4438.11	0.000	
(Constant)	-.112	-3.101	.002					
Att-F1	.674	33.316	.000					5.746
Del-F1	.289	14.522	.000					5.539
Nat-F1	.059	4.530	.000					1.624

Dependent variable Wan-F1

5.7.4 CIELAB of durian color image The results of CIELAB color space at D65, 2 degrees observer of positions 1, 2, and 3 of the durian flesh images under the 9 lighting conditions showed the same results of the first experiment, which shifted away from the CIELAB color space of the original and printed image and became more yellowish and reddish as the saturation level increased at 2700 K for all 3 illuminances, especially at 600 lux. The color appeared closer to that in the original and printed image (yellow with some green) when under 6500 K 150 lux (Figure 5-29). Changes in the hues of the 3 positions observed under the 9 lighting conditions presented smaller hue angles that were more yellowish when the saturation level increased (Figure 5-30). In addition, increasing in saturation level have an effect on luminance in the same direction for all three positions as the first experiment (see Figure 5-31), which are different from the luminance effects of freshness found by Arce-Lopera et al (12, 18).

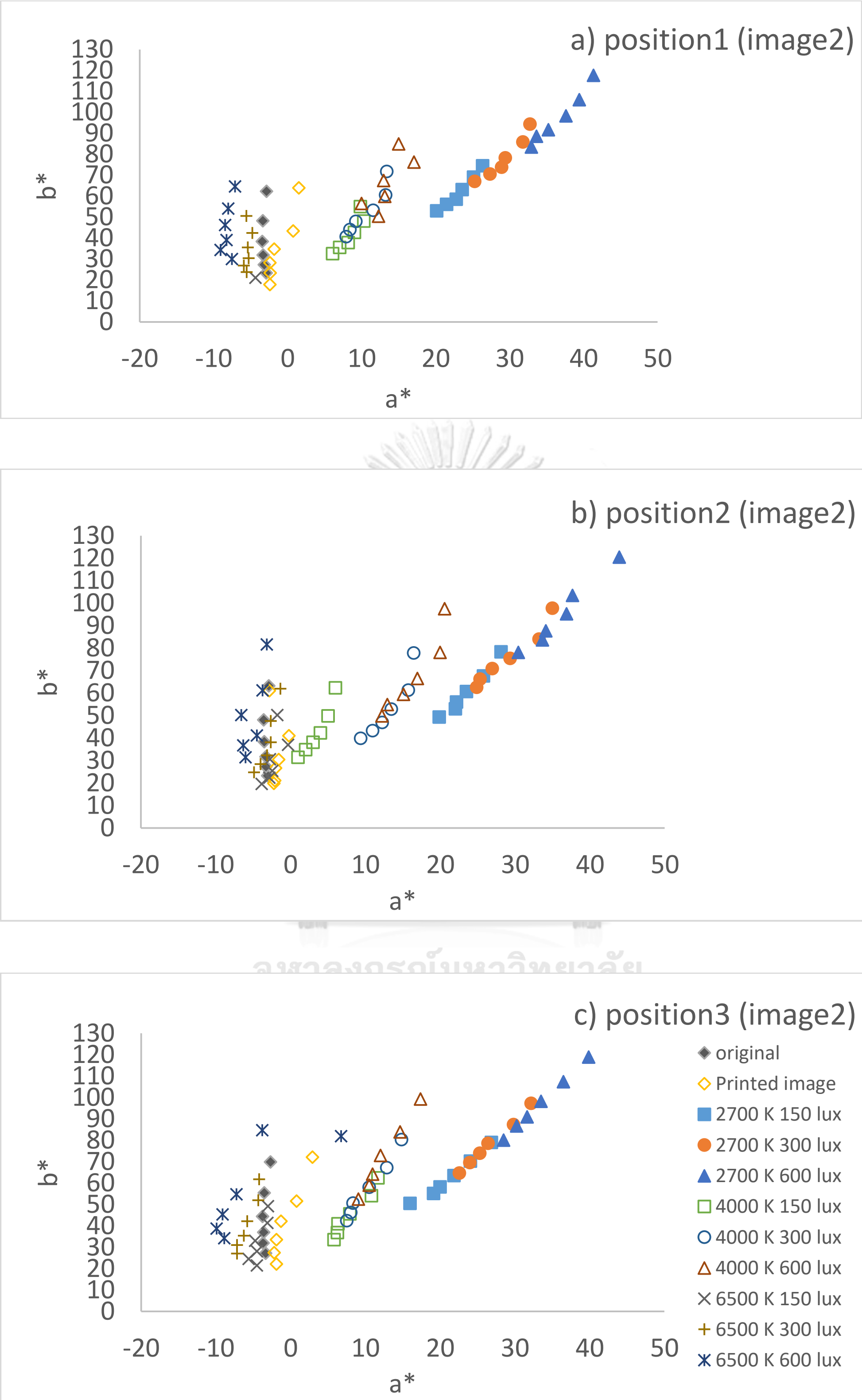


*Figure 5- 29 The plot of a*b* value of durain flesh image 2 at 3 positions; a) position 1, b) position 2, and c) position 3.*

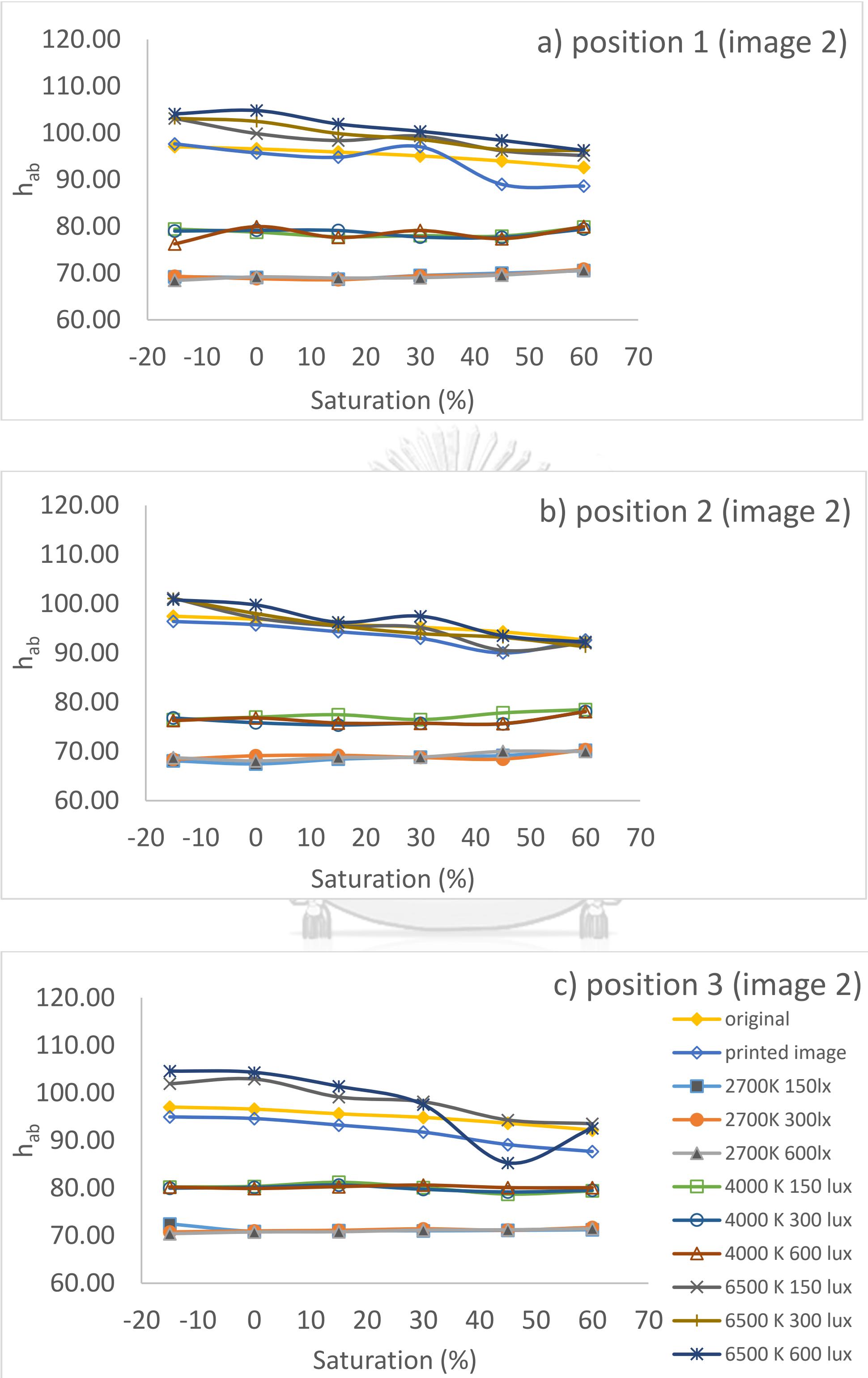


Figure 5- 30 The plot of h vs. saturation of of durain flesh image 2 at 3 positions under the 9 lighting conditions; a) position 1, b) position 2, and c) position 3.*

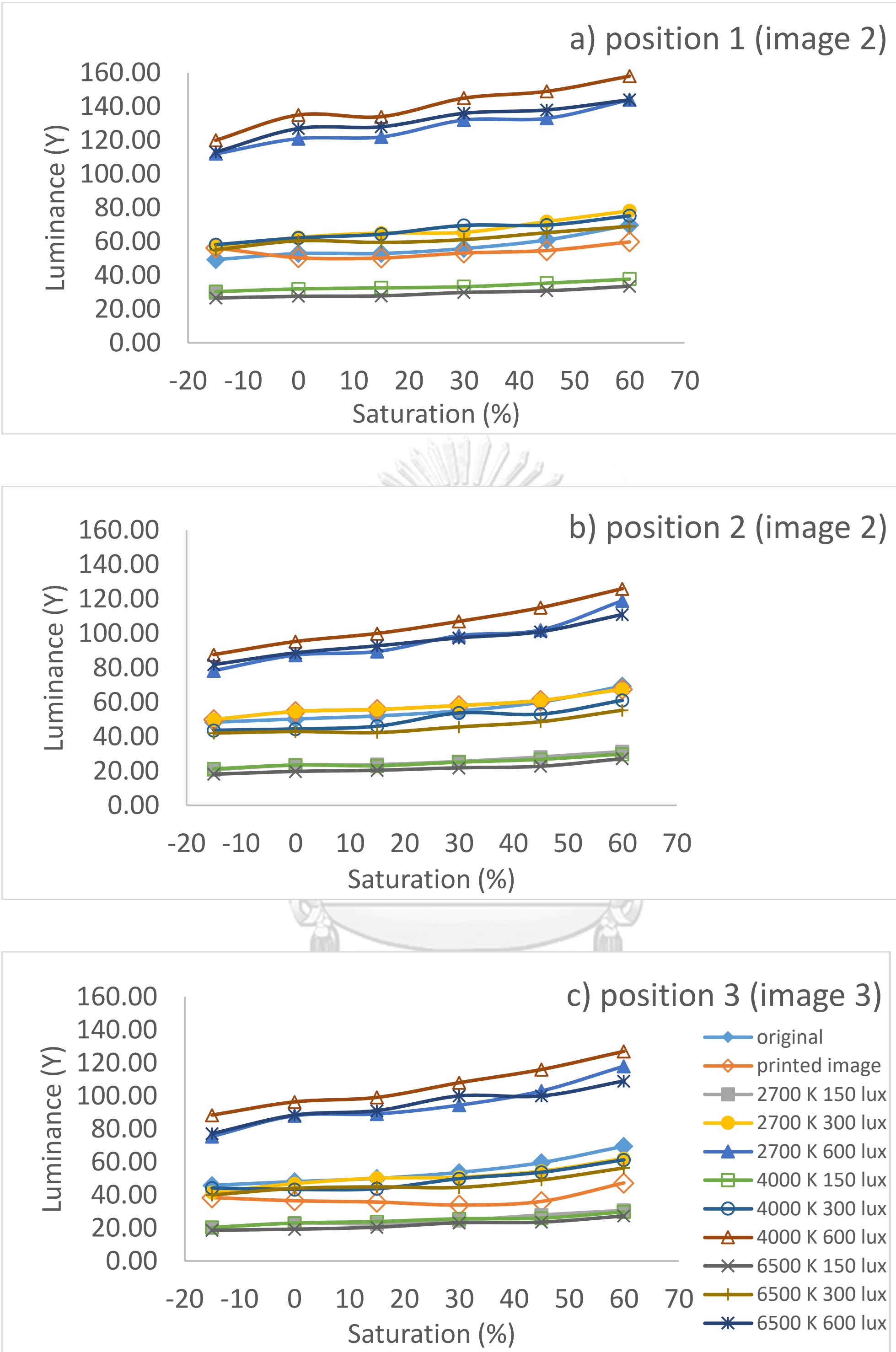


Figure 5- 31 The plot of luminance (Y) vs. saturation of of durain flesh image 2 at 3 positions under the 9 lighting conditions; a) position 1, b) position 2 and c) position 3.

5.7.5 MANOVA results of the first and the repeat experiment According to the many dependent variables related to pair comparison of the human expectations' evaluation scores of the first experiment (Image 1) and the repeat experiment (Image 2), MANOVA was applied to determine variances of the pair. The results shown in Table 5-16 indicate that the overall of the repeat experiment provided a significant difference in the mean of human expectations [$F(9, 3122) = 16.938$ (Wilk's Lambda) p- value <0.001]. Univariate ANOVA were conducted on each dependent measure separately to define the locus of the statistically significant multivariate effect (48). The Del-F, Nat-F, Nat-P, Att-F, Att-P, Wan-F and Wan-P had the statistically significant univariate effect on the comparison of the two experiments [$F(1, 3130) = 7.083$, 35.003, 6.779, 13.304, 10.192, 15.043, and 7.696 p-value <0.05 respectively). Nat-S and buying decision had no significant effects on the pair comparison. The finding confirms that buying decision on experiment repetition had no significant difference from the first experiment. Even if the human expectations on the repeat experiment revealed divergent results from the first experiment, the final result of buying decision (transformed value of Wan-F) remained the same.

Table 5- 17 Multivariate of Durian image experiment repetition

Effect		Value	F	Hypothesis df	Error df	Sig.
Intercept	Pillai's Trace	.931	4673.610[b]	9.000	3122.000	.000
	Wilks' Lambda	.069	4673.610[b]	9.000	3122.000	.000
	Hotelling's Trace	13.473	4673.610[b]	9.000	3122.000	.000
	Roy's Largest Root	13.473	4673.610[b]	9.000	3122.000	.000
Image 1 and 2	Pillai's Trace	.047	16.938[b]	9.000	3122.000	.000
	Wilks' Lambda	.953	16.938[b]	9.000	3122.000	.000
	Hotelling's Trace	.049	16.938[b]	9.000	3122.000	.000
	Roy's Largest Root	.049	16.938[b]	9.000	3122.000	.000

b. Exact statistic

Table 5-18 Univariate F-tests of human expectations (dependent variables) obtained from the two experiments

Dependent Variable		Sum of Squares	df	Mean Square	F	Sig.
Del-F	Contrast	12.017	1	12.017	7.083	.008
	Error	5310.476	3130	1.697		
Nat-F	Contrast	40.693	1	40.693	35.003	.000
	Error	3638.787	3130	1.163		
Nat-P	Contrast	7.971	1	7.971	6.779	.009
	Error	3679.986	3130	1.176		
Nat-S	Contrast	2.147	1	2.147	1.857	.173
	Error	3619.336	3130	1.156		
Att-F	Contrast	22.761	1	22.761	13.304	.000
	Error	5355.201	3130	1.711		
Att-P	Contrast	13.287	1	13.287	10.192	.001
	Error	4080.516	3130	1.304		
Wan-F	Contrast	27.037	1	27.037	15.043	.000
	Error	5625.615	3130	1.797		
Wan-P	Contrast	10.460	1	10.460	7.696	.006
	Error	4254.202	3130	1.359		
buying	Contrast	.000	1	.000	.000	1.000
decision	Error	707.586	3130	.226		

5.7.6 Verify the buying decision model The scores of want to buy from flesh (Wan-F1) were transformed into two categories of buying decision of the second (repeat) experiment; “0” and “1”, which the first code was for the scores less than 4 (no for buying) while the other code was for the scores more than or equal to 4 (yes for buying). Refer to the buying decision model from the first experiment, the predicted buying probability of the repeat experiment was evaluated by using the predicted probability of the first experiment (equation 5-2 and 5-3). The data of CAtt-F1 (transformed data from Att-F1 into “0” and “1”) and saturation were put into the predicted model. The cut off of predicted probability for buying is 0.5, which is ransformed into code “0” or no for buying when the predicted probability less than 0.5 and “1” or yes for buying when the probability more than or equal to 0.5. The results of buying decision from the prediction were compared with the buying decision transformed from Wan-F1.

The buying decision transformed from Wan-F1 in code “1” provided data number (mean = 0.39, SD = 0.488, N = 1,566) close to the code “1” when using the predicted buying decision equation from the first experiment (mean = 0.40, SD =0.489, N = 1,566). When compared each pair data of 1566 data between buying decision transformed from Wan-F1 and buying decision substituted variables of CAtt-F1 and saturation of the repeat experiment in the predicted probability of the first experiment buying decision model, two code “0” and “1”were applied; “0” means for each pair data not equal and “1” for each pair equal to each other. The results indicated that code “1” showed the data number in mean of 0.94 (SD = 0.235 and N = 1,566). Therefore, the buying decision model of the first experiment can predict 94% of the repeat experiment.

5.8 Application of the buying decision model and application to global

The buying decision model obtained from this study was applied to sample of durian image. Refer to the saturation in range of 45 to 60% corresponding to the predicted probability more than 90% (see Figure 5-15), adjusted Del C^*_{ab} (ADel C^*_{ab}) at 45 and 60 % were evaluated by following the equation 5.4. Then adjusted C*ab (AC^*_{ab}) was the summation of ADel C^*_{ab} and C^*_{ab} of zero saturation (29.835 from Table 5-6) as mentioned. Table 5-18 presented C^*_{ab}, Del C^*_{ab}, AC^*_{ab} and ADel C^*_{ab} of the Durian flesh image at 45 and 60%, which were used for model application.

Table 5- 19 C^*_{ab}, Del C^*_{ab}, AC^*_{ab} and ADel C^*_{ab} of the Durian flesh image at 45 and 60%

Saturation (%)	C^*_{ab}	Del C^*_{ab}	ADel C^*_{ab}	AC^*_{ab}
45	49.108	19.273	20.921	50.756
60	61.307	31.472	28.417	58.252

The AC^*_{ab} was used as reference to find out saturation for adjusting the images. CIELAB of durian sample image was processed by MATLAB. Del C^*_{ab} of the sample image was the output of C^*_{ab} of corresponding samples deducting from C^*_{ab} of reference (C^*_{ab} at 45%, AC^*_{ab} at 45%, and AC^*_{ab} at 60%). For example, Del C^*_{ab} of durian sample image with C^*_{ab} reference at 45% was 23.349 (see Del1 C^*_{ab} in Table 5-19), which obtained from C^*_{ab} of durian flesh image at 45% (49.108) minus C^*_{ab} of durian flesh sample image (25.759). Then saturation for adjusting the durian flesh sample image was 49.859 (see Table 5-19, Sat 1), which was calculated by using the equation 5.4. Del C^*_{ab} and saturation of the rest references were computed in the same way.

The durian sample image before and after adjusting presented in Figure 5-32. Delta E between CIELAB before and after of each adjusted saturation was computed. The increasing saturation of durian sample image with C^*_{ab} at 45% and AC^*_{ab} at 45% made the picture look better with delta E difference (between delta E1 and delta E2) about 2 while the delta E difference of increasing saturation with AC^*_{ab} at 60% was about 5 (between delta E2 and delta E3), which presents obviously color difference. The white part of durian peel became more yellow which made the durian image looked not delicious (see Figure 5-32). In addition, the Adel C^*_{ab} obtained from AC^*_{ab} at 60% was 32.493 which are out of range of Adel C*ab of 45 and 60% (21 to 28). Then the durian sample image with saturation 2 was selected. The range of C*ab reference for saturation adjustment was about 51 to 58.

Table 5- 20 CIELAB, C^*_{ab}, Del C^*_{ab}, saturation and delta E of the durian sample image

Items	Value
L^*	78.4095
a^*	0.3996
b^*	25.7563
C^*_{ab}	25.7594
Del1 C^*_{ab} from $C^*_{ab,45\%}$	23.3488
Del2 C^*_{ab} from $AC^*_{ab,45\%}$	24.9966
Del3 C^*_{ab} from $AC^*_{ab,60\%}$	32.4928
Sat 1 from Del1 C^*_{ab}	49.8589
Sat 2 from Del2 C^*_{ab}	53.1561
Sat 3 from Del3 C^*_{ab}	68.1561
Delta E1	25.0878
Delta E2	27.3290
Delta E3	32.1586

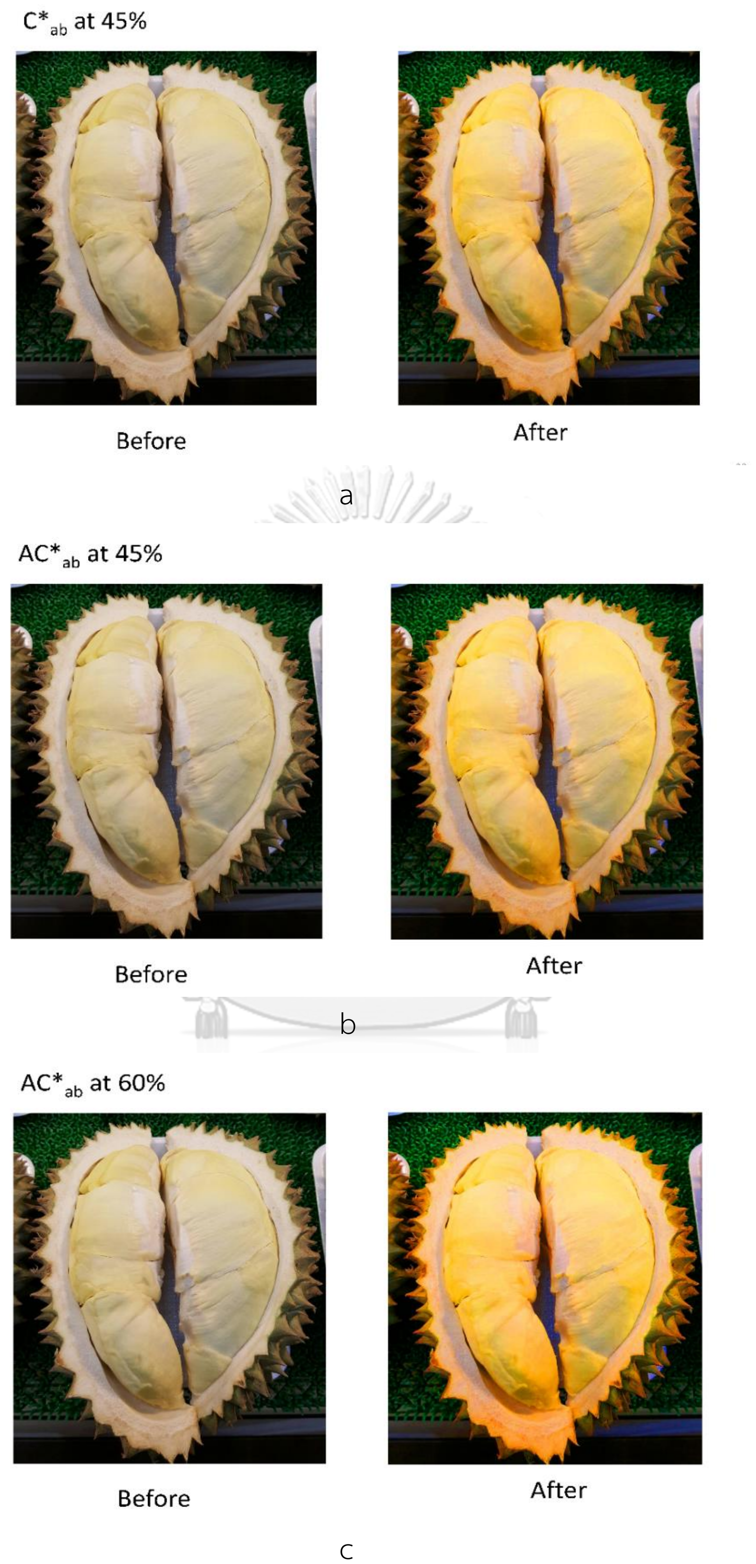


*Figure 5- 32 Durian sample image 1 before and after saturation adjustment with difference from 3 C*ab references; a) C*ab at 45% b) AC*ab at 45% c) AC*ab at 60%.*

Findings of the study are consistent with many reported in terms of color attributes. For example, the finding found that durian image with higher saturated color are attracted and appetized more than less saturated one, which the model imitates durian from mature stage to ripen stage. However there are the limit of saturation on preference durian color due to individual experiences. The finding confirmed the report of Lee et al (9) (see Table 5-21).

Table 5- 21 Comparison of the results regarding the influence of color attributes on human expectation and buying decision in previous studied and in the current research

Color attributes	**Previous studies with regard to the effects of color on buying decision**	**Findings of the current experiment**
chroma	Foods with higher chroma are more attractive even if foods are various in different colors. Foods seems more vivid color than original food color, which influence significantly on selection fresher and non-contaminated foods by using visual perception. However, food-color preference based on individual experience should concern on further studies (9).	Durian image with higher saturated color would be attracted and appetized more than less saturated one. However there are the limit of saturation on preference food color due to experiences of particular or familiar foods.
a* value of CIELAB	-Red and green foods have a strong shift for a high chromatic preference (9).	The buying decision model based on color attributes can apply to adjust red apple.
b* value of CIELAB	-Yellow foods (banana have a similar high chromatic preference (9). - Durian cv. Monthong showed more yellowish when ripen due to higher carotenoid concentration in ripen durian flesh (2). - ‘Keitt’ mango flesh color showed an increase in b* value during early stage of ripening (49).	Durian flesh have high b* value when increasing saturation.

Table 5-21 Comparison of the results regarding the influence of color attributes on human expectation and buying decision in previous studied and in the current research (continued)

Color attributes	Previous studies with regard to the effects of color on buying decision	Findings of the current experiment
Hue angle	-Yellow foods have a hue shift to more yellowish direction (9). -'Keitt' mango showed a little decrease in hue angle during fruit ripening (49).	-Durian flesh with yellow color have a hue shift to more yellowish direction, - Durian flesh color showed a little change in hue angle when increasing saturation, which causes human eyes with no difference in color change.
color	- Wine label color influences on flavor expectation leading to buying (50).	When saturation level increase, deliciousness of durian flesh also amplify and related to buying.
L*	- 'Keitt' mango flesh color exhibited a decrease in L* value throughout ripening (49).	Durian flesh exhibited an increase in L* value when saturation augmented.

CHAPTER VI
CONCLUSIONS

The food color that are consistent with customers' expectation is an essential factor to food buying decision. People can't obviously identify the taste of food from their eyes when the color is not consistent with the expected taste, especially for packed food (5). Food characteristics based on color that customers expect are the essential information for the buying decision process. Therefore the aim of the present research was to establish buying decision model based on color attributes for *Durio zibethinus* cv.Monthong and to evaluate the relationships between "Deliciousness", "Naturalness", and "Attractiveness" and buying decision, which were concluded as following.

6.1 Buying decision model based on color attributes for *Durio zibethinus* cv.Monthong

This study has identified that saturation was the most influential factor for the buying decision from both experiments. CCTs and illuminance had no significant difference in buying decision from both experiment. There are significant effect on buying decision on different view of durian image. However buying decision from both experiments remain the same. Buying decision model for *Durio zibethinus cv.Monthong* relates to changing CCTs and illuminance on durian printed images triggering to human eyes and brain. Color adjusted in saturation, hue and brightness leading to color and shape perception in eyes and brain, which impacts on human feelings of deliciousness and attractiveness. However, color and shape perception and feelings of attractiveness and attractiveness are consistent with recognition and emotion from memory and experiences leading to decide on buying (see Figure 6-1).

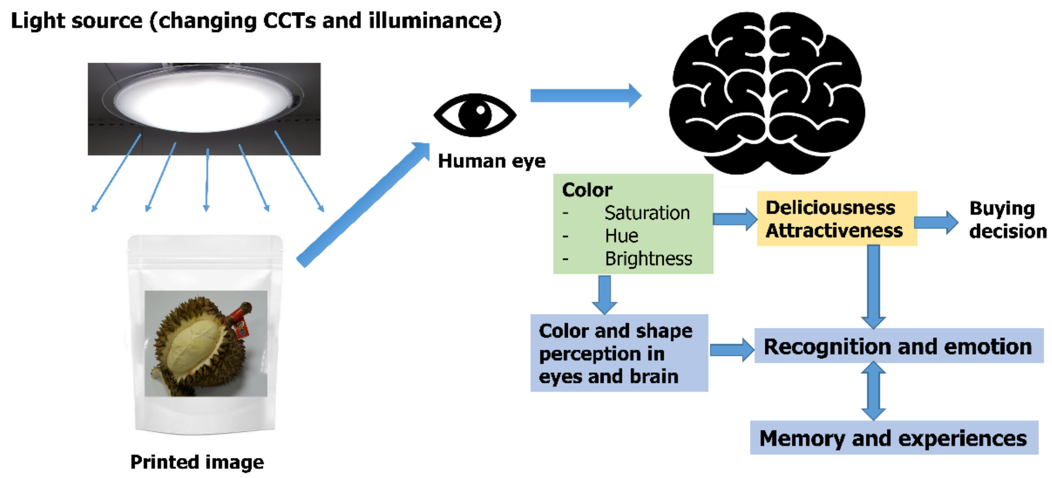


Figure 6- 1 Buying decision model of Durio zibethinus cv.Monthong

The buying decision model based on color attributes for *Durio zibethinus cv.Monthong* or *Durio zibethinus L.* could be concluded by the variables in the logistic regression model in equation 6.1 and predicted probability of the model was presented in equation 6.2.

$$\text{Buying decision or log (ODDS)} = b_0 + b_1 \text{ AttF} + b_2 \text{ Saturation} \qquad 6.1$$

Where: ODDs – probability of buying/probability of not buying or p/(1-p)

b_0 – intercept when x =0

b_1 ,– slope coefficient, which shows ln(Odds) change when AttF change one point

b_2 - slope coefficient, which shows ln(Odds) change when saturation change one point

$$\text{Predicted probability(48)} = \frac{e^{b_0 + \ b_1\ AttF + b_1\ Saturation}}{1+e^{b_0 + \ b_1\ AttF + b_1\ Saturation}} \qquad 6.2$$

where: e = exponential = 2.718, equation (5.2) is antilog equation

Criteria predicted probability <0.5 means no for buying decision

$\geq$ 0.5 means yes for buying decision

To achieve predicted probability for high satisfaction of attractiveness of durian flesh and more than 90% buying prediction, saturation of the model should be 45 and 60%. However due to the limit of saturation at optimum level of human expectations found from the both experiments, the relationship between saturation level adjusted by using Adobe Photoshop and delta chroma of durian flesh was established for the model application. The 5 sample images adjusted by saturation computed following the model and the relationship between chroma and saturation indicated that the adjusted chroma were in the range of 51 to 58 and adjusted delta chroma were in range of 21 to 28. The results indicated that chroma of durian flesh image for buying with high satisfaction was 1.7 times of durian flesh at mature stage.

6.2 The relationships between "Deliciousness", "Naturalness", and "Attractiveness" and buying decision

The empirical findings in this study provide a new understanding of buying decision involving feeling of attractiveness of flesh (Att-F) and deliciousness of flesh (Del-F), which used internal information such as expected color from memory color to reach a decision on buying, and this process involved balancing the input from the two hemispheres of the brain, as mentioned by Boldbaatar et al(16) and Rebollar et al(17).

This study has confirmed that buying decision was influenced by the feelings of attractiveness and deliciousness, which were determined using 3 CCTs, 3 illuminances, and various saturation levels. Attractiveness and deliciousness influence significantly on buying decision. Attractiveness and deliciousness are related significantly to each other and influence on buying decision more than saturation.

Saturation was an important factor in making the buying decision as well. However, the recognition of a memory color had a more limited effect than saturation in terms of perception. This study will help packaging designers to design suitable colors for Durian cv. Monthong under various lighting conditions in shops or outdoors.

6.3 Suggestion for the buying decision model application

Application of the buying decision model for other durian images for packaging designers can conduct step by step as shown in the diagram (see Figure 6-2). There are eight steps related to application of the model. The first step is uploading a digital file durian cv.Monthong sample image into MATLAB program and use Imtool command for cropping the durian flesh image (select the durian flesh that presents no reflection or shadow areas). The cropped image in the second step were processed in the third step for finding average CIELAB by using MATLAB program. In this step, it might use CIELAB measuring tool from Adobe Photoshop but it should be measured in many areas of durian flesh. Then calculate C^*_{ab} of the sample durian image from CIELAB. After that calculate Del C^*_{ab} by minus C^*_{ab} of the sample from C^*_{ab} of the reference (50.756 from 45% and 58.252 from 60%). The obtained Del C^*_{ab} in the range of 21 to 28 was multiple by 2.001 and then plus with 3.138, which is the results of saturation for adjusting the sample image in the next step. The adjusted image was shown in the last step.

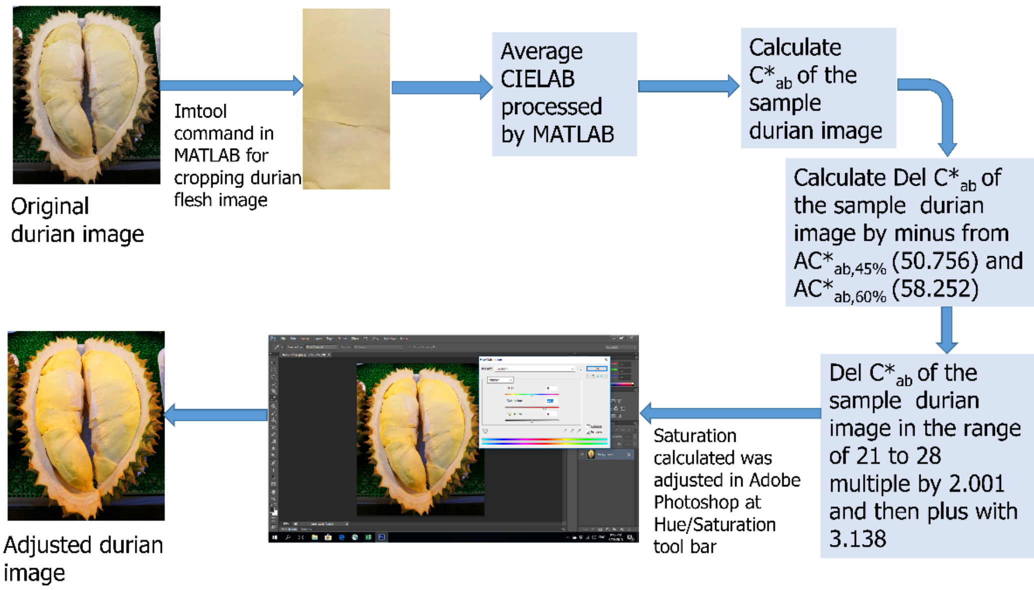


Figure 6- 2 Diagram of durian buying decision model application

This model can apply to adjust other fruits as well. However judging by observers is in need for finding the suitable human expectation on particular fruit.

REFERENCES

1. Amornputti S, Ketsa S, van Doorn WG. Effect of 1-methylcyclopropane(1-MCP) on storage life of durian fruit. Postharvest Biology and Technology 2014;97:111-4.

2. Wisutiamonkul A, Promdang S, Ketsa S, van Doorn WG. Carotenoids in durian fruit pulp during growth and postharvest ripening. Food Chem. 2015;180:301-5.

3. Schifferstein HNJ, Fenko A, Desmet PMA, Labbe D, Martin N. Influence of package design on the dynamics of multisensory and emotional food experience. Food Quality and Preference 2013;27:18–25.

4. Shankar MU, Levitan CA, Spence C. Grape expectations: the role of cognitive influences in color-flavor interactions. Conscious Cogn. 2010;19(1):380-90.

5. Ndom RJE, Elegbeleye AO, Ademoroti AO. The Effect of Colour on the Perception of Taste, Quality and Preference of Fruit Flavoured Drinks. Ife PsychologIA. 2011;19(2):167-89.

6. Huang L, Lu J. Eat with Your Eyes: Package Color Influences The Expectation of Food Taste and Healthiness Moderated by External Eating. Marketing Management Journal. 2015;25(2):71-87.

7. Delwiche JF. You eat with your eye first. . Physiology & Behavior 2012;107:502-4.

8. Padda MS, Do Amarante, C.V.T., Garcia, R.M., Slaughter, D.C., and Mitcham, E.J. Method to analyze physico-chemical changes during mango ripening: A multivariate approach. Postharvest Biology and Technology. 2011;62:267-74.

9. Lee SM, Lee KT, Lee SH, Song JK. Origin of human colour preference for food. Journal of food Engineering. 2013;119:508-15.

10. Wei ST, Ou LC, Luo MR, Hutchings JB. Package Design: Colour Harmony and Consumer Expectations. . International Journal of Design 2014;8(1):109-390.

11. Wei ST, Ou LC, Luo MR, Hutchings JB. Optimisation of food expectations using product colour and appearance. Food Quality and Preference. 2012;23:49–62.

12. Arce-Lopera C, Masuda T, Kimura A, Wada Y, Okajima K. Model of vegetable freshness perception using luminance cue. Food Quality and Preference. 2015;40:279-86.

13. Peneau S, Hoehn ER, H.R. , Escher F, Nuessli J. Importance and consumer perception of freshness of apples. Food Quality and Preference. 2006;17:9–19.

14. Kotler P, Armstrong G. Principles of Marketing. edition t, editor. Upper Saddle River, NJ: Pearson Education Limited; 2012.

15. Kotler P, Wong V, Saunders J, Armstrong G. Principle of Marketing. edition FE, editor. Harlow, Essex Pearson Education Limited; 2005.

16. Boldbaatar G. Neuromarketing A. Study on Mongolian Consumers' Buying Decision Process. Proceedings of Academy of Science2017. p. 97-108.

17. Rebollar R, Lidon I, Serrano A, Martin J, Fernandez MJ. Influence of chewing gum packaging design on consumer expectation and willingness to buy. An analysis of functional, sensory and experience attributes. Food Quality and Preference. 2012;24:162-70.

18. Arce-Lopera C, Masuda T, Kimura A, Wada Y, Okajima K. Luminance distribution modifies the perceived freshness of strawberries. Iperception. 2012;3(5):338-55.

19. Spence C, Levitan CA. Does Food Color Influence Taste and Flavor Perception in Humans? Chem Percept 2010;3 68-84.

20. Koster EP, Mojet J. From food to Mood: A psychological perspective on the measurement of food-related emotions in consumer research. Food Research International. 2015;76:180-91.

21. Suk HJ, Park GL, Kim Y. Bon Appetit! An Investigation About the Best and Worst Color Combinations of Lighting and Food. Journal of Literature and Art Studies. 2012;2(5):559-66.

22. Witzel C, Gegenfurtner KR. Memory Color. Encyclopedia of Color Science and Technology2013. p. **1-7**.

23. Tsujimura T, Yanagisawa H. Causal Relationship between Lighting Conditions and Visual Expectation of Food Products. International Journal of Affective Engineering. 2015;14(4):269-77.

24. Nagyova L, Bercik J, Horska E. The Efficiency, Energy Intensity and Visual Impact of the Accent Lighting in the Retail Grocery Stores. Scientific Journal for Food Industry. 2014;8(1):296-305.

25. Hebert P, Clare G, Chung Y, Slevitch L, Leong J. Effect of Experimental Conditions on Consumer Perceptions of Ground Beef: An Interdisciplinary Study. Journal of Social Sciences and Humanities. 2015;1(4):275-82.

26. Radsamrong A, Katemake P, Khiripet N, editors. Establishing optimal visual parameters: illuminance, correlated color temperature and color of packaging for the elderly in a supermarket-type illuminated environment. ACA CHINA: Color Driving Power, Proceedings of the 3rd International Conference of Asia Color Association,; 2016; Changshu, China: ACA CHINA.

27. Vienot F, Durand ML, Mahler E. Kruithof's rule revised using LED illumination. Jour Modern Optics 2009;56(13):1433-46.

28. Vurro M, Ling Y, Hurlbert AC. Memory color of natural familiar objects: effects of surface texture and 3-D shape. J Vis. 2013;13(7):20.

29. Wu D, Sun DW. Colour measurements by computer vision for food quality control- A review. Trend in Food Science & Technology 2013;29:5-20.

30. Becker L, Van Rompay TIL, Schifferstein HNJ, Galetzka M. Tough package, strong taste: The influence of packaging design on taste impressions and product evaluations. . Food Quality and Preference. 2011;22:17-23.

31. Norjana I, Noor Aziah AA. Quality attributes of durian (Durio zibethinus Murr) juice after pectinase enzyme treatment. International Food Research Journal 2011;18(3):1117-22.

32. Munthiu MC. The buying decision process and types of buying decision behavior. Sibiu Alma Mater University Journals SerieA Economic Sciences. 2009;2(4):27-33.

33. Hunt RWG, Pointer MR. Measuring Colour. West Sussex: John Wiley & Sons Ltd.; 2011.

34. Foster DH. Does colour constancy exist? TRENDS in Cognitive Sciences. 2003;7(10):438-43.

35. Granzier JJ, Gegenfurtner KR. Effects of memory colour on colour constancy for unknown coloured objects. Iperception. 2012;3(3):190-215.

36. Westland S, Ripamonti C. Computational Colour Science using MATLAB. Chichester, West Sussex: John Wiley & Sons, Ltd.; 2004.

37. Krueger RA. Designing and Conducting Focus Group Interviews 2002 [Available from: http://www.eiu.edu/ihec/Krueger-FocusGroupInterviews.pdf.

38. Eliot&Associates. Guidelines for Conducting a Focus Group. . 2005.

39. Bender DE, Ewbank D. The focus group as a tool for health research: issues in design and analysis. Health Transition Review. 1994;4(1):63-79.

40. Halkier B. Focus groups as social enactments: integrating interaction and content in the analysis of focus group data. SAGE Journal. 2010;10(1):71-89.

41. Dzinovic V. Using focus groups to give voice to school underachievers. Zbornik Instituta za pedagoska istrazivanja. 2009;41(2):284-96.

42. Jafarzadehpur E, Hashemi H, Emamian MH, Khabazkhoob M, Mehravaran S, Shariati M, et al. Color vision deficiency in a middle-aged population: the Shahroud Eye Study. Int Ophthalmol. 2014;34(5):1067-74.

43. Pimentel JL. A note on the usage of Likert Scaling for research data analysis. USM R & D. 2010;18(2):109-12.

44. Gonzalez RC, Woods RE, Eddins SL. Digital Image Processing using MATLAB. Upper Saddle River, New Jersey: Pearson Education, Inc.; 2004.

45. Company X-R. FM 100 Hue Color Vision Test and Scoring Software Training. n.d.

46. Verma JP. Data Analysis in Management with SPSS Software. New Delhi: Springer India; 2013.

47. Tabachnick BG, Fidell LS. Using multivariate analysis. . edition F, editor. New York, NY: Harper Collins; 2001.

48. Meyers LS, Gamst G, Guarino AJ. Applied Multivariate Research: Design and Interpretation. Thousand Oaks, CA: SAGE Publications, Inc; 2013.

49. Padda MS, do Amarante CVT, Garcia RM, Slaughter DC, Mitcham EJ. Methods to analyze physico-chemical changes during mango ripening: A multivariate approach. Postharvest Biology and Technology. 2011;62:267-74.

50. Lick E, Konig B, Kpossa MR, Buller V. Sensory expectations generated by colours of red wine labels. Journal of Retailing and Consumer Services. 2017;37:146-58.

APPENDIX

APPENDIX A
DURIAN IMAGE COLOR IN TERMS OF CIELAB

Table A 2 degrees observer color matching functions, P(λ) at D65 and D50

Wavelength	2 degrees observer color matching functions			P(λ)	
	x	y	z	D65	D50
400	0.0143	0.0004	0.0679	82.75	49.31
405	0.0232	0.0006	0.1102	87.12	52.91
410	0.0435	0.0012	0.2074	91.49	56.51
415	0.0776	0.0022	0.3713	92.46	58.27
420	0.1344	0.0040	0.6456	93.43	60.03
425	0.2148	0.0073	1.0391	90.06	58.93
430	0.2839	0.0116	1.3856	86.68	57.82
435	0.3285	0.0168	1.6230	95.77	66.32
440	0.3483	0.0230	1.7471	104.86	74.82
445	0.3481	0.0298	1.7826	110.94	81.04
450	0.3362	0.0380	1.7721	117.01	87.25
455	0.3187	0.0480	1.7441	117.41	88.93
460	0.2908	0.0600	1.6692	117.81	90.61
465	0.2511	0.0739	1.5281	116.34	90.99
470	0.1954	0.0910	1.2876	114.86	91.37
475	0.1421	0.1126	1.0419	115.39	93.24
480	0.0956	0.1390	0.8130	115.92	95.11
485	0.0580	0.1693	0.6162	112.37	93.54
490	0.0320	0.2080	0.4652	108.81	91.96
495	0.0147	0.2586	0.3533	109.08	93.84
500	0.0049	0.3230	0.2720	109.35	95.72
505	0.0024	0.4073	0.2123	108.58	96.17

Wavelength	2 degrees observer color matching functions			P(λ)	
	x	y	z	D65	D50
510	0.0093	0.5030	0.1582	107.80	96.61
515	0.0291	0.6082	0.1117	106.30	96.87
520	0.0633	0.7100	0.0782	104.79	97.13
525	0.1096	0.7932	0.0573	106.24	99.61
530	0.1655	0.8620	0.0422	107.69	102.10
535	0.2257	0.9149	0.0298	106.05	101.43
540	0.2904	0.9540	0.0203	104.41	100.75
545	0.3597	0.9803	0.0134	104.23	101.54
550	0.4334	0.9950	0.0087	104.05	102.32
555	0.5121	1.0000	0.0057	102.02	101.16
560	0.5945	0.9950	0.0039	100.00	100.00
565	0.6784	0.9786	0.0027	98.17	98.87
570	0.7621	0.9520	0.0021	96.33	97.74
575	0.8425	0.9154	0.0018	96.06	98.33
580	0.9163	0.8700	0.0017	95.79	98.92
585	0.9786	0.8163	0.0014	92.24	96.21
590	1.0263	0.7570	0.0011	88.69	93.50
595	1.0567	0.6949	0.0010	89.35	95.59
600	1.0622	0.6310	0.0008	90.01	97.69
605	1.0456	0.5668	0.0006	89.80	98.48
610	1.0026	0.5030	0.0003	89.60	99.27
615	0.9384	0.4412	0.0002	88.65	99.16
620	0.8544	0.3810	0.0002	87.70	99.04
625	0.7514	0.3210	0.0001	85.49	97.38
630	0.6424	0.2650	0.0000	83.29	95.72
635	0.5419	0.2170	0.0000	83.49	97.29
640	0.4479	0.1750	0.0000	83.70	98.86
645	0.3608	0.1382	0.0000	81.86	97.26

Wavelength	2 degrees observer color matching functions			P(λ)	
	x	y	z	D65	D50
650	0.2835	0.1070	0.0000	80.03	95.67
655	0.2187	0.0816	0.0000	80.12	96.93
660	0.1649	0.0610	0.0000	80.21	98.19
665	0.1212	0.0446	0.0000	81.25	100.60
670	0.0874	0.0320	0.0000	82.28	103.00
675	0.0636	0.0232	0.0000	80.28	101.07
680	0.0468	0.0170	0.0000	78.28	99.13
685	0.0329	0.0119	0.0000	74.00	93.26
690	0.0227	0.0082	0.0000	69.72	87.38
695	0.0158	0.0057	0.0000	70.67	89.49
700	0.0114	0.0041	0.0000	71.61	91.60
705	0.0081	0.0029	0.0000	72.98	92.25
710	0.0058	0.0021	0.0000	74.35	92.89
715	0.0041	0.0015	0.0000	67.98	84.87
720	0.0029	0.0010	0.0000	61.60	76.85
725	0.0020	0.0007	0.0000	65.74	81.68
730	0.0014	0.0005	0.0000	69.89	86.51
735	0.0010	0.0004	0.0000	72.49	89.55
740	0.0007	0.0002	0.0000	75.09	92.58
745	0.0005	0.0002	0.0000	69.34	85.40
750	0.0003	0.0001	0.0000	63.59	78.23
755	0.0002	0.0001	0.0000	55.01	67.96
760	0.0002	0.0001	0.0000	46.42	57.69
765	0.0001	0.0000	0.0000	56.61	70.31
770	0.0001	0.0000	0.0000	66.81	82.92
775	0.0001	0.0000	0.0000	65.09	80.60
780	0.0000	0.0000	0.0000	63.38	78.27

APPENDIX B
QUESTIONS FOR FORCUS GROUP DISCUSSION

1. Do you like to have durian?

2. According to the durian sample picture. Do you think it looks “Delicious”?

3. How does it look “Delicious”? Please describe.

4. Do you think it looks “Natural”?

5. How do the durian picture make you feel “Naturalness”? Please describe.

6. What do you think how to make the durian picture more “Attractive”?

7. What kind of the durian picture make you feel “don’t want to buy”?

APPENDIX C

INTERVIEW FORM

Code ....

Hue test no.............................

The questionnaire for human expectations on durian

Please put the mark √ on the choice you select.

1. Gender: ☐ male ☐ female
2. Age: ☐ 21-30 ☐ 31-40
3. Do you like Durian? ☐ Yes ☐ No
4. If yes. Which cartivar is your favorite?

   ☐ Chanee ☐ Monthong ☐ others..................
5. If yes, how do durian flesh you like? ☐ normal ☐ soft ☐ too soft

CCT.........................K Illumination...............lux
Front: CCT.........................K Illumination...............lux
Up : CCT.........................K Illumination...............lux

Items	Delicious					Natural															Attractive										Want to buy									
	Flesh					Flesh					Peel					Stem					Flesh					Peel					Flesh					Peel				
	1.unappetizing	2.slightly delicious	3. moderate delicious	4. very delicious	5. extremely delicious	1.unnatural	2.slightly natural	3. moderate natural	4. very natural	5. extremely natural	1.unnatural	2.slightly natural	3. moderate natural	4. very natural	5. extremely natural	1.unnatural	2.slightly natural	3. moderate natural	4. very natural	5. extremely natural	1.unattractive	2.slightly attractive	3. moderate attractive	4. very attractive	5. extremely attractive	1.unattractive	2.slightly attractive	3.moderate attractive	4. very attractive	5. extremely attractive	1. want not to buy	2.slightly want to buy	3. moderate want to buy	4. very want to buy	5. extremely want to buy	1. want not to buy	2.slightly want to buy	3. moderate want to buy	4. very want to buy	5. extremely want to buy
P A																																													
A1																																													
A2																																													
A3																																													
A4																																													
A5																																													
A6																																													
PB																																													
B1																																													
B2																																													
B3																																													
B4																																													
B5																																													
B6																																													

Evaluation Criteria(43);

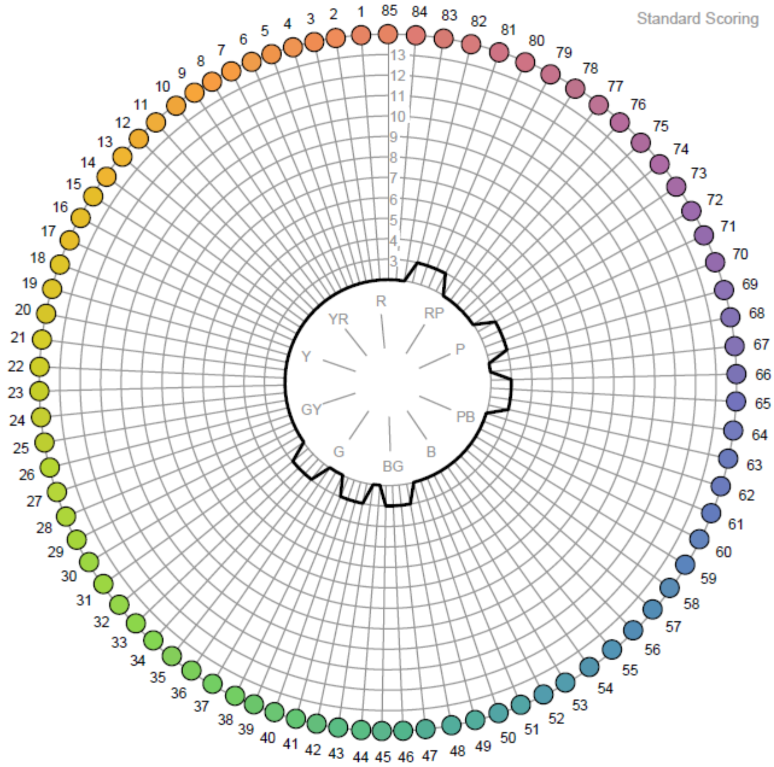
Level 5: score 4.51-5.00	extremely (delicious, natural,...)
Level 4: score 3.51-4.50	very (delicious, natural,...)
Level 3: score 2.51-3.50	moderate (delicious, natural,...)
Level 2: score 1.51-2.50	slightly (delicious, natural,...)
Level 1: score 1.00-1.50	un... (appetizing, natural, ...)

APPENDIX D

A SAMPLE OF FM 100 HUE TEST

x·rite

Farnsworth-Munsell 100 Hue Test Results



Total Error Score (TES): = 24 Classification: = Average Discrimination Subject: Ae Reference: d007 Date of Birth: Date of Test: Test Duration: (mins) Gender: Unspecified Geographic Location:Unspecified Industry Type: Unspecified Primary Job Function: Unspecified Years of Experience: Unspecified Illumination Type: D50	Cap Order: 85, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 34, 33, 35, 36, 37, 38, 39, 41, 40, 42, 43, 44, 45, 47, 46, 48, 49, 50, 51, 52, 53, 54, 55, 56, 57, 58, 59, 60, 61, 62, 63, 65, 64, 66, 67, 68, 69, 71, 70, 72, 73, 74, 75, 76, 77, 78, 79, 81, 80, 82, 83, 84 Comments: FM 100 hue test results not certified (No Serial Number).

Test produced by:
Munsell Color Services Laboratory
X-Rite Inc
Kentwood, MI

APPENDIX E

MEAN AND STANDARD DEVIATION RESULTS OF HUMAN EXPECTATIONS

Human expectation	CCT (K)	Illuminance (lux)	Saturation (%)	Mean	Std. Deviation	N
Del-F	2700	150	-15	1.5172	.91107	29
			0	2.2759	.92182	29
			15	2.6552	1.20344	29
			30	3.1724	1.16708	29
			45	3.5517	1.08845	29
			60	3.4138	1.29607	29
			Total	2.7644	1.30215	174
		300	-15	1.6207	.77523	29
			0	2.2759	.92182	29
			15	2.7586	.78627	29
			30	3.5862	.94556	29
			45	3.8621	.91512	29
			60	3.4483	1.35188	29
			Total	2.9253	1.24006	174
		600	-15	1.5862	.86674	29
			0	2.2069	.90156	29
			15	2.7241	.88223	29
			30	3.4828	.98636	29
			45	3.7931	1.08164	29
			60	3.5862	1.35006	29
			Total	2.8966	1.29056	174
	4000	150	-15	1.4483	.73612	29
			0	1.9655	.90565	29
			15	2.4483	.86957	29
			30	3.3448	1.00980	29
			45	3.8966	.93903	29
			60	3.5517	1.42894	29
			Total	2.7759	1.33052	174
		300	-15	1.5862	.73277	29
			0	2.0345	.98135	29
			15	2.3103	.96745	29
			30	3.2069	.72601	29
			45	3.9655	.98135	29
			60	3.4483	1.42894	29
			Total	2.7586	1.29441	174
		600	-15	1.4483	.73612	29
			0	2.0345	.86531	29
			15	2.6552	.97379	29
			30	3.8276	.84806	29
			45	3.8621	.91512	29
			60	3.5172	1.42980	29
			Total	2.8908	1.34062	174

(Continued)

Human expectation	CCT (K)	Illuminance (lux)	Saturation (%)	Mean	Std. Deviation	N
Del-F	6500	150	-15	1.5517	.82748	29
			0	2.0345	.98135	29
			15	2.3793	.90292	29
			30	3.2069	.97758	29
			45	3.6552	.93640	29
			60	3.6207	1.34732	29
			Total	2.7414	1.27982	174
		300	-15	1.5517	.73612	29
			0	2.0000	.84515	29
			15	2.7586	.95076	29
			30	3.3448	.89745	29
			45	3.8621	1.09297	29
			60	3.8276	1.28366	29
			Total	2.8908	1.31009	174
		600	-15	1.5517	.78314	29
			0	2.0345	.86531	29
			15	2.5862	.73277	29
			30	3.6897	.84951	29
			45	3.9310	1.03272	29
			60	3.7586	1.21465	29
			Total	3.0500	1.31291	180
Nat-F	2700	150	-15	2.1379	1.12517	29
			0	2.5517	1.15221	29
			15	3.0345	1.20957	29
			30	3.2069	.94034	29
			45	3.3448	1.26140	29
			60	3.0690	1.16285	29
			Total	2.8908	1.20434	174
		300	-15	2.4138	1.01831	29
			0	2.9655	.73108	29
			15	3.2414	.73946	29
			30	3.6897	.89056	29
			45	3.3448	1.11085	29
			60	3.0000	1.46385	29
			Total	3.1092	1.08304	174
		600	-15	2.5517	.78314	29
			0	2.9310	.75266	29
			15	3.2759	.88223	29
			30	3.7586	.98761	29
			45	3.3793	1.04928	29
			60	3.1379	1.21667	29
			Total	3.1724	1.01670	174

(Continued)

Human expectation	CCT (K)	Illuminance (lux)	Saturation (%)	Mean	Std. Deviation	N
Nat-F	4000	150	-15	2.4138	1.08619	29
			0	2.5517	.94816	29
			15	2.8621	1.05979	29
			30	3.6897	.92980	29
			45	3.3793	.86246	29
			60	2.9310	1.19317	29
			Total	2.9713	1.09875	174
		300	-15	2.5517	1.15221	29
			0	2.8276	.92848	29
			15	2.9655	.90565	29
			30	3.5517	.73612	29
			45	3.6207	.97884	29
			60	2.8966	1.17549	29
			Total	3.0690	1.05121	174
		600	-15	2.7586	.98761	29
			0	2.8621	1.09297	29
			15	3.3448	.81398	29
			30	3.6897	1.00369	29
			45	3.3103	.92980	29
			60	2.7586	1.18488	29
			Total	3.1207	1.05476	174
	6500	150	-15	2.5172	1.08958	29
			0	2.7931	1.11417	29
			15	2.9655	.82301	29
			30	3.4828	.94946	29
			45	3.3448	1.00980	29
			60	2.9310	1.13172	29
			Total	3.0057	1.06167	174
		300	-15	2.6207	1.17758	29
			0	2.9310	.96106	29
			15	3.3103	.84951	29
			30	3.4483	.94816	29
			45	3.4138	1.11858	29
			60	3.0000	1.16496	29
			Total	3.1207	1.07107	174
		600	-15	2.7586	1.02313	29
			0	3.0345	.94426	29
			15	3.3103	.84951	29
			30	3.6897	.66027	29
			45	3.4828	.98636	29
			60	3.0000	1.33631	29
			Total	3.2126	1.02323	174

(Continued)

Human expectation	CCT (K)	Illuminance (lux)	Saturation (%)	Mean	Std. Deviation	N
Nat-P	2700	150	-15	2.8966	1.14470	29
			0	3.3448	.81398	29
			15	3.2069	1.08164	29
			30	3.1724	1.10418	29
			45	2.8621	1.21667	29
			60	2.6207	1.37357	29
			Total	3.0172	1.14536	174
		300	-15	3.0690	1.06674	29
			0	3.2414	1.02313	29
			15	3.5172	.82897	29
			30	3.4828	.63362	29
			45	2.7931	1.04810	29
			60	2.4138	1.29607	29
			Total	3.0862	1.06360	174
		600	-15	3.0000	1.10195	29
			0	3.4138	.86674	29
			15	3.6552	.85673	29
			30	3.3103	1.07250	29
			45	2.6552	.89745	29
			60	2.4483	1.08845	29
			Total	3.0805	1.06134	174
	4000	150	-15	3.0000	1.13389	29
			0	3.3103	1.07250	29
			15	3.3448	1.00980	29
			30	3.3103	.92980	29
			45	2.5862	1.05279	29
			60	2.4138	1.15007	29
			Total	2.9943	1.10959	174
		300	-15	3.1724	1.19729	29
			0	3.3103	.96745	29
			15	3.4138	.90701	29
			30	3.3448	.97379	29
			45	2.7241	.99630	29
			60	2.4483	1.21262	29
			Total	3.0690	1.09432	174
		600	-15	3.2414	1.02313	29
			0	3.5172	1.05630	29
			15	3.7586	.83045	29
			30	3.4138	1.01831	29
			45	2.6897	.92980	29
			60	2.3103	1.13715	29
			Total	3.1552	1.10911	174

(Continued)

Human expectation	CCT (K)	Illuminance (lux)	Saturation (%)	Mean	Std. Deviation	N
Nat-P	6500	150	-15	3.1034	1.11307	29
			0	3.2414	1.12298	29
			15	3.4828	.91107	29
			30	3.2759	.79716	29
			45	2.7931	.94034	29
			60	2.5172	1.21363	29
			Total	3.0690	1.06215	174
		300	-15	3.0345	1.08505	29
			0	3.4138	1.05279	29
			15	3.5862	.86674	29
			30	3.2759	1.03152	29
			45	2.5862	1.08619	29
			60	2.4828	1.15328	29
			Total	3.0632	1.11299	174
		600	-15	3.1724	1.13606	29
			0	3.5172	.98636	29
			15	3.6207	1.04928	29
			30	3.4828	.94946	29
			45	2.6207	1.01467	29
			60	2.4828	1.27113	29
			Total	3.1494	1.14830	174
Nat-S	2700	150	-15	2.9655	1.05162	29
			0	3.1379	1.02554	29
			15	3.3103	1.13715	29
			30	3.1379	1.12517	29
			45	2.9310	1.03272	29
			60	2.6552	1.34366	29
			Total	3.0230	1.12745	174
		300	-15	3.1379	.91512	29
			0	3.2414	.87240	29
			15	3.3448	.72091	29
			30	3.4828	.68768	29
			45	2.6207	1.04928	29
			60	2.4483	1.18280	29
			Total	3.0460	.98436	174
		600	-15	3.1724	1.03748	29
			0	3.3448	.89745	29
			15	3.5172	.82897	29
			30	3.2759	.92182	29
			45	2.6552	.85673	29
			60	2.3103	1.07250	29
			Total	3.0460	1.01899	174

(Continued)

Human expectation	CCT (K)	Illuminance (lux)	Saturation (%)	Mean	Std. Deviation	N
Nat-S	4000	150	-15	3.0690	1.19317	29
			0	3.2759	1.03152	29
			15	3.2759	1.13063	29
			30	3.3103	.92980	29
			45	2.6897	1.03866	29
			60	2.3448	1.04457	29
			Total	2.9943	1.10959	174
		300	-15	3.1724	1.13606	29
			0	3.2759	.92182	29
			15	3.3448	.85673	29
			30	3.2759	1.03152	29
			45	2.7586	1.02313	29
			60	2.3103	1.10529	29
			Total	3.0230	1.06957	174
		600	-15	3.2069	1.01346	29
			0	3.3793	1.08278	29
			15	3.6897	.96745	29
			30	3.4138	.86674	29
			45	2.6552	1.04457	29
			60	2.3103	1.13715	29
			Total	3.1092	1.11460	174
	6500	150	-15	3.0345	1.23874	29
			0	3.2069	1.11417	29
			15	3.3448	.97379	29
			30	3.2069	.86103	29
			45	2.5862	1.01831	29
			60	2.4138	1.18072	29
			Total	2.9655	1.11166	174
		300	-15	3.1034	1.11307	29
			0	3.4828	1.05630	29
			15	3.4828	.91107	29
			30	3.2069	.97758	29
			45	2.5862	1.15007	29
			60	2.3448	1.14255	29
			Total	3.0345	1.13227	174
		600	-15	3.2414	1.15434	29
			0	3.5517	1.08845	29
			15	3.5862	1.01831	29
			30	3.3448	1.00980	29
			45	2.4828	1.05630	29
			60	2.3448	1.23276	29
			Total	3.0920	1.18889	174

(Continued)

Human expectation	CCT (K)	Illuminance (lux)	Saturation (%)	Mean	Std. Deviation	N
Att-F	2700	150	-15	1.5862	.90701	29
			0	2.1034	1.04693	29
			15	2.8276	1.25553	29
			30	3.1724	.96618	29
			45	3.5172	1.15328	29
			60	3.3103	1.36548	29
			Total	2.7529	1.30887	174
		300	-15	1.5862	.77998	29
			0	2.3103	.92980	29
			15	2.9310	.96106	29
			30	3.5862	.94556	29
			45	3.6897	1.16813	29
			60	3.2759	1.46132	29
			Total	2.8966	1.28607	174
		600	-15	1.7241	.88223	29
			0	2.2069	1.08164	29
			15	2.7586	.95076	29
			30	3.5517	.98511	29
			45	3.9310	.92316	29
			60	3.4483	1.37805	29
			Total	2.9368	1.29540	174
	4000	150	-15	1.5862	.82450	29
			0	1.9310	.88362	29
			15	2.3103	.84951	29
			30	3.4828	.94946	29
			45	3.7931	1.04810	29
			60	3.5172	1.40460	29
			Total	2.7701	1.31862	174
		300	-15	1.6207	.82001	29
			0	2.0345	1.01710	29
			15	2.3448	1.07822	29
			30	3.2759	.70186	29
			45	3.8966	1.11307	29
			60	3.5172	1.45457	29
			Total	2.7816	1.33365	174
		600	-15	1.5172	.82897	29
			0	2.0690	1.03272	29
			15	2.8276	.88918	29
			30	3.6897	.89056	29
			45	3.7931	.97758	29
			60	3.4483	1.45372	29
			Total	2.8908	1.32762	174

(Continued)

Human expectation	CCT (K)	Illuminance (lux)	Saturation (%)	Mean	Std. Deviation	N
Att-F	6500	150	-15	1.6552	.93640	29
			0	2.1379	1.09297	29
			15	2.4483	1.02072	29
			30	3.3793	.97884	29
			45	3.6552	1.00980	29
			60	3.4483	1.32520	29
			Total	2.7874	1.29278	174
		300	-15	1.6552	.93640	29
			0	2.1724	.92848	29
			15	2.6897	.92980	29
			30	3.3793	.86246	29
			45	3.7586	1.18488	29
			60	3.4828	1.35279	29
			Total	2.8563	1.27992	174
		600	-15	1.5862	.82450	29
			0	1.9655	.86531	29
			15	2.6552	.85673	29
			30	3.6207	.90292	29
			45	3.8621	1.02554	29
			60	3.6897	1.36548	29
			Total	2.8966	1.32154	174
Att-P	2700	150	-15	2.2759	1.25062	29
			0	2.7586	1.02313	29
			15	3.1724	1.03748	29
			30	3.2414	.91242	29
			45	3.2414	1.15434	29
			60	2.6897	1.33907	29
			Total	2.8966	1.16831	174
		300	-15	2.6207	1.11528	29
			0	3.0345	1.14900	29
			15	3.2759	.92182	29
			30	3.3103	.84951	29
			45	2.8966	1.17549	29
			60	2.5862	1.32334	29
			Total	2.9540	1.12160	174
		600	-15	2.7241	1.13063	29
			0	2.9310	1.03272	29
			15	3.4483	.94816	29
			30	3.3103	1.16813	29
			45	3.0345	1.01710	29
			60	2.6897	1.22776	29
			Total	3.0230	1.11196	174

(Continued)

Human expectation	CCT (K)	Illuminance (lux)	Saturation (%)	Mean	Std. Deviation	N
Att-P	4000	150	-15	2.5517	1.24172	29
			0	2.9310	1.09971	29
			15	3.1034	1.01224	29
			30	3.4138	.98261	29
			45	2.8276	1.19729	29
			60	2.5172	1.29892	29
			Total	2.8908	1.17026	174
		300	-15	2.6207	1.23675	29
			0	2.9310	1.06674	29
			15	3.0690	.92316	29
			30	3.2759	.84077	29
			45	2.9655	1.11748	29
			60	2.6207	1.37357	29
			Total	2.9138	1.11663	174
		600	-15	2.5517	1.24172	29
			0	2.8966	1.11307	29
			15	3.4483	.82748	29
			30	3.4138	1.08619	29
			45	2.7931	1.11417	29
			60	2.5172	1.29892	29
			Total	2.9368	1.16873	174
	6500	150	-15	2.4138	1.26822	29
			0	2.8966	1.20549	29
			15	3.1379	1.02554	29
			30	3.3103	.89056	29
			45	2.8276	1.07135	29
			60	2.5172	1.29892	29
			Total	2.8506	1.16330	174
		300	-15	2.4828	1.24271	29
			0	2.9655	1.11748	29
			15	3.2759	.99630	29
			30	3.1724	.92848	29
			45	2.7931	1.17654	29
			60	2.5862	1.32334	29
			Total	2.8793	1.15919	174
		600	-15	2.5172	1.32613	29
			0	2.9310	1.13172	29
			15	3.2759	1.06558	29
			30	3.7586	1.02313	29
			45	3.0345	1.17967	29
			60	2.8276	1.51349	29
			Total	3.0575	1.26177	174

(Continued)

Human expectation	CCT (K)	Illuminance (lux)	Saturation (%)	Mean	Std. Deviation	N
Wan-F	2700	150	-15	1.4828	.91107	29
			0	1.9310	.96106	29
			15	2.5172	1.35279	29
			30	3.0345	1.23874	29
			45	3.5517	1.21262	29
			60	3.2069	1.61199	29
			Total	2.6207	1.42026	174
		300	-15	1.7241	.79716	29
			0	2.2414	.95076	29
			15	2.8276	1.00246	29
			30	3.5517	.98511	29
			45	3.7586	1.09071	29
			60	3.3448	1.47057	29
			Total	2.9080	1.28245	174
		600	-15	1.6897	.84951	29
			0	2.1034	.90019	29
			15	2.6552	1.00980	29
			30	3.5862	.98261	29
			45	3.8621	1.02554	29
			60	3.4828	1.45457	29
			Total	2.8966	1.31716	174
	4000	150	-15	1.4483	.73612	29
			0	2.0690	1.03272	29
			15	2.1034	.93903	29
			30	3.4483	1.08845	29
			45	3.6552	1.14255	29
			60	3.4483	1.45372	29
			Total	2.6954	1.37032	174
		300	-15	1.5517	.82748	29
			0	2.1034	1.01224	29
			15	2.3103	1.07250	29
			30	3.1724	.96618	29
			45	3.8966	1.08050	29
			60	3.4138	1.42722	29
			Total	2.7414	1.34156	174
		600	-15	1.6207	.86246	29
			0	2.0690	.99753	29
			15	2.7241	1.06558	29
			30	3.7931	.90156	29
			45	3.7586	.95076	29
			60	3.4138	1.40197	29
			Total	2.8966	1.32590	174

(Continued)

Human expectation	CCT (K)	Illuminance (lux)	Saturation (%)	Mean	Std. Deviation	N
Wan-F	6500	150	-15	1.5517	.82748	29
			0	1.9310	.99753	29
			15	2.3793	.90292	29
			30	3.1724	1.03748	29
			45	3.5172	.98636	29
			60	3.4483	1.37805	29
			Total	2.6667	1.27372	174
		300	-15	1.6207	.90292	29
			0	2.0345	.94426	29
			15	2.6897	1.07250	29
			30	3.3448	.89745	29
			45	3.6552	1.28940	29
			60	3.5172	1.35279	29
			Total	2.8103	1.32286	174
		600	-15	1.5517	.78314	29
			0	1.8966	.93903	29
			15	2.6552	.85673	29
			30	3.4483	1.02072	29
			45	3.8276	1.03748	29
			60	3.6207	1.32055	29
			Total	2.8333	1.32160	174
Wan-P	2700	150	-15	2.4138	1.29607	29
			0	2.7241	1.06558	29
			15	3.0000	1.16496	29
			30	3.2414	1.05746	29
			45	3.1379	1.24568	29
			60	2.5862	1.42722	29
			Total	2.8506	1.23559	174
		300	-15	2.6207	1.11528	29
			0	2.9310	.99753	29
			15	3.2069	.97758	29
			30	3.1724	.92848	29
			45	2.8621	1.15648	29
			60	2.4828	1.37894	29
			Total	2.8793	1.11859	174
		600	-15	2.6897	1.22776	29
			0	2.9655	.94426	29
			15	3.3103	1.03866	29
			30	3.3448	1.00980	29
			45	2.9310	.96106	29
			60	2.5862	1.18072	29
			Total	2.9713	1.08818	174

(Continued)

Human expectation	CCT (K)	Illuminance (lux)	Saturation (%)	Mean	Std. Deviation	N
Wan-P	4000	150	-15	2.4138	1.37626	29
			0	2.7586	1.12298	29
			15	2.9310	.99753	29
			30	3.2414	.95076	29
			45	2.7241	1.25062	29
			60	2.3448	1.34366	29
			Total	2.7356	1.20653	174
		300	-15	2.4828	1.29892	29
			0	2.7241	1.16179	29
			15	2.8966	1.04693	29
			30	3.1724	1.00246	29
			45	2.7931	1.17654	29
			60	2.6552	1.39581	29
			Total	2.7874	1.19036	174
		600	-15	2.5172	1.27113	29
			0	2.8621	1.15648	29
			15	3.2414	.91242	29
			30	3.3448	1.00980	29
			45	2.6897	1.10529	29
			60	2.4483	1.27016	29
			Total	2.8506	1.16330	174
	6500	150	-15	2.3448	1.31681	29
			0	2.6897	1.25651	29
			15	3.0690	1.09971	29
			30	3.2069	.97758	29
			45	2.8621	.99010	29
			60	2.4483	1.27016	29
			Total	2.7701	1.18469	174
		300	-15	2.4138	1.26822	29
			0	2.8621	1.24568	29
			15	3.1724	1.00246	29
			30	3.2759	.95978	29
			45	2.6552	1.28940	29
			60	2.4828	1.42980	29
			Total	2.8103	1.23705	174
		600	-15	2.4828	1.32613	29
			0	2.8276	1.16708	29
			15	3.2069	1.04810	29
			30	3.5172	1.02193	29
			45	2.8621	1.12517	29
			60	2.6207	1.34732	29
			Total	2.9195	1.21378	174

VITA

SUPAWADEE THEERATHAMMAKORN

EDUCATION

1993: Master of Science in Packaging, Michigan State University, U.S.A. Thesis title: “Performance of Recycled Corrugated Fiberboard under VariousTemperatures and Humidities”.

1987: Bachelor of Science in Photographic Science and Printing Technology, Chulalongkorn University.

EMPLOYMENT

1987 - 1990: Print Production Management at Sukhothai Thammathirat Open University Press, Sukhothai Thammathirat Open University.

1993 – 1998: Lecturer at School of Science and Technology, Sukhothai Thammathirat Open University.

1998: Technical Service at Strongpak Limited Company (Amcor Flexibles Bangkok Public Limited Company in present).

1999 –present: Lecturer at School of Science and Technology, Sukhothai Thammathirat Open University.

ACADEMIC RELATED PUBLICATIONS

Theerathammakorn, S., Hansuebsai, A., and Hoshino, Y. Lighting Ambient Effect on Saturation of Durian and Sensation. Proceedings of the 13rd AIC Congress Being Color with Health. Jeju. Korea, 16-20 October, paper no. OS18-05, 2017: 46.

Theerathammakorn, S. Hansuebsai, A., and Hoshino, Y. Extraction of major term of customer satisfaction in food packaging. Proceedings of the 1st TDU-CU Joint Meeting on Imaging Science and Technology. Bangkok. Thailand, 26-29 Febrauary, 2016: 38-40.