DEVELOPMENT OF AN ONLINE TOOL TO ASSIST IN DECISIONS ON THE CONSUMPTION OF DIETARY SUPPLEMENTS

By
MISS Sirikanlaya BENJAWAN

A Thesis Submitted in Partial Fulfillment of the Requirements
for Doctor of Philosophy (SOCIAL AND ADMINISTRATIVE PHARMACY)
Graduate School, Silpakorn University
Academic Year 2020

การพัฒนาเครื่องมือออนไลน์เพื่อสนับสนุนการตัดสินใจบริโภคผลิตภัณฑ์เสริมอาหาร

โดย
นางสาวสิริกัลยา เบ็ญจวรรณ์

วิทยานิพนธ์นี้เป็นส่วนหนึ่งของการศึกษาตามหลักสูตรเภสัชศาสตรดุษฎีบัณฑิต
สาขาวิชาเภสัชศาสตร์สังคมและการบริหาร แบบ 1.1 เภสัชศาสตรดุษฎีบัณฑิต
บัณฑิตวิทยาลัย มหาวิทยาลัยศิลปากร
ปีการศึกษา 2563

DEVELOPMENT OF AN ONLINE TOOL TO ASSIST IN DECISIONS ON THE CONSUMPTION OF DIETARY SUPPLEMENTS

By
MISS Sirikanlaya BENJAWAN

A Thesis Submitted in Partial Fulfillment of the Requirements
for Doctor of Philosophy (SOCIAL AND ADMINISTRATIVE PHARMACY)
Graduate School, Silpakorn University
Academic Year 2020

Title	Development of an online tool to assist in decisions on the consumption of dietary supplements
By	Sirikanlaya BENJAWAN
Field of Study	(SOCIAL AND ADMINISTRATIVE PHARMACY)
Advisor	Assistant Professor NATTIYA KAPOL , Ph.D.

Graduate School Silpakorn University in Partial Fulfillment of the Requirements for the Doctor of Philosophy

.....Dean of graduate school

(Associate Professor Jurairat Nunthanid, Ph.D.)

Approved by

.....Chair person

(Assistant Professor SURASIT LOCHIDAMNUAY , Ph.D.)

.....Advisor

(Assistant Professor NATTIYA KAPOL , Ph.D.)

.....Co advisor

(Associate Professor LAWAN SRATTHAPHUT , Ph.D.)

.....Co advisor

(Assistant Professor PANOOPAT POOMPRUEK , Ph.D.)

.....External Examiner

(Associate Professor Wanna Sriviriyanupap , Ph.D.)

58354801 : Major (SOCIAL AND ADMINISTRATIVE PHARMACY)
Keyword : decision support, dietary supplement, online tool

MISS SIRIKANLAYA BENJAWAN : DEVELOPMENT OF AN ONLINE TOOL TO ASSIST IN DECISIONSON THE CONSUMPTION OF DIETARY SUPPLEMENTS THESIS ADVISOR : ASSISTANT PROFESSOR NATTIYA KAPOL, Ph.D.

The increasing consumption of dietary supplements raises the public concern on their efficacy and safety. There has been reports of serious health problems from taking the dietary supplements. Therefore, the development of a decision-making tool may help consumers to choose dietary supplements appropriately. This study aimed to identify variables that influence the safe decision of consumers in dietary supplements consumption and to develop a decision support online tool for consumers. The methodology consisted of three phases. Phase I, the situations and factors affecting the safe selection of dietary supplements were investigated. Nine consumers, two state authorities, and two entrepreneurs were in-depth interviewed for their experiences on dietary supplement consumption and problems. In addition, variables of dietary supplements available online in e-marketplaces and the examination report from MoPH were analyzed to summarize factors affecting the safe selection. Phase II, an online tool to support consumers' decision was developed. Four consumers, one state authority, and one technology expert provided advice to the tool development. Phase III, an online tool was tested and evaluated with 30 consumers. The results were found that stakeholders had different perspectives on the problems because they perceived the risks with different recognition methods and they managed them with different approaches. Empowering consumers was the appropriate solution for the existing situation. Factors related to consumer decision making were the accuracy of manufacturer information, showing expiration date, showing lot number, showing extra caution, showing distributor information, the accuracy of component format, and showing 3 typical cautions. The decision tree with 92.31% accuracy of the safety prediction was created and used as the processing structure for a decision support tool. The tool named Check4Safety was created using the web application technology. Finally, the Check4Safety was assessed by users using the THARS assessment, which had an average score of 28.27 (74.39%). Consequently, the Check4Safety is an online tool that can be used to support the decision making of consumers in dietary supplement consumption safely.

ACKNOWLEDGEMENTS

First of all, I would like to express a special thank to Assistant Professor Dr. Nattiya Kapol, my major advisor, for her helpful guidance, motivation, encouragement, and financial support throughout my doctoral study period. She was always available and dedicated her time to discuss with me. Therefore, without her crucial advice and suggestion, I could not complete my degree fully.

In addition, I wish to give my gratitude to Associate Professor Dr. Lawan Sratthaphut, my co-advisor, for her valuable guidance and constructive advice. I am also grateful to Assistant Professor Dr. Panoopat Poompruek, my co-advisor, for his worthy suggestion as well. Without their advice and assistance, my work could not be finished successfully.

Besides, I am most grateful to Assistant Professor Dr. Surasit Lochidamnuay and Associate Processor Dr. Wanna Sriviriyanupap, my thesis committee, for their useful recommendations and discussion in my dissertation.

I would like to acknowledge the Faculty of Pharmacy and Graduate School, Silpakorn University for financial support.

I cannot forget to warmly thank my friends and colleagues for their kind support, friendship, and assistance.

Finally, I would like to especially thank my super dad, my beloved mom, and my brother for their love and encouragement. I would like to give a big thank to Abid Hussain Bhat, my dear, for his love, understanding, and everything. I could not have been able to overcome any obstacles without them. All of you guys are really important to my success.

Sirikanlaya BENJAWAN

TABLE OF CONTENTS

LIST OF TABLES

Page

LIST OF FIGURES

Page

CHAPTER 1

Introduction

1.1 Background and significance of the study

Health promotion is the goal of preserving the health of the people. The policy of promoting health in Thailand started from the eighth National Economic and Social Development Plan (1997 - 2001) (1). The Thai government has implemented a concrete public policy in 2002 and declared this year was the year of health promotion (2). The policy has brought people awareness to maintaining their health and changing their lifestyle. Thai people eat healthier and exercise more. Searching for health information and setting a group of people interested in the same health issues have also been found. Moreover, the consumption of dietary supplements has grown in popularity.

The consumption of dietary supplements in Thailand has steadily increased over the years. According to the report by the Food Industry Intelligence Center that the dietary supplement market growth rate is 11.3% yearly. It is forecast that in 2020 the dietary supplement market value in Thailand will reach sixty-nine billion baht (3). Dietary supplements have been used for a variety of purposes such as strengthen the immune system, promote good health, and also contribute to good personal appearance (4).

A dietary supplement is a type of food under the jurisdiction of the Food Act 1979. Dietary supplements cover eatable health products in addition to the main diet, with consumers expecting health effects. These products have no preventive or curative effects. They are found in many forms, such as tablets, capsules, powders,

flakes, liquids, or others. Therefore, dietary supplements are targeted towards healthy consumers, not for patients (5). The classification of dietary supplements according to the announcement of the Ministry of Public Health is divided into eight groups, including vitamins, products to reduce fat absorption, products to increase metabolism, products extracted from grains, herbal extract products, antioxidant products, anti-aging products, and products to aid bowel movements (6). Besides, the Food and Drug Administration has classified dietary supplements according to their intended use as well. They are divided into three groups: beauty products, sexual enhancement products, and panacea products (7).

Dietary supplements have been produced to respond to the diverse needs of consumers (8). Entrepreneurs facilitate consumers with easy access to purchasing channels (9). Direct and indirect trading incentive strategies are used to increase the consumption of dietary supplements, such as product advertising and product reviews provided by consumers to convince buyers reliably. As a result, some consumers have misunderstood then they ultimately decided to consume them (10). However, the Thai Food and Drug Administration and other relevant agencies make great efforts to provide information about the safe selection of dietary supplements. There were campaigns that indicated consumers to choose safe products including considering the food serial number before buying a product, observing the manufacturer's information, production and expiration dates, and also presenting news about the dangers of consuming unsafe dietary supplements (11). The Food and Drug Administration issues more than thirty warnings about dietary supplements through various media every year. Even so, the problems of dietary supplement consumption continue to increase (12).

The problems of dietary supplement consumption increase the risks for consumers' health as well. Those risks were evidenced by consumer complaints and surveillance data on the dangers of consuming dietary supplements. The number of complaints from the Complaint and Suppression Center for Health Products, the Food and Drug Administration, the Ministry of Public Health, Thailand about dietary supplements has been steadily increasing over the years. In the fiscal year 2020, There were 1,506 complaints related to dietary supplements, which accounted for a third of all complaints, 36.91% of complaints related to dietary supplements (13). There have been deaths and many serious health effects of consuming dietary supplements over the years. There were ten deaths from consuming dietary supplements from 2014 to 2018, between March and April 2018, three deaths were attributed to the consumption of the same brand of weight-loss dietary supplements. So we should realize that the consumption of dietary supplements is a public health risk.

Dietary supplements have limitations in personal use. The health effects can occur through slight misunderstandings. Therefore, consumers have to select them specifically and carefully for safety (14). Besides, the problems of illegal dietary supplements and dietary supplements containing pharmaceutical substances are other issues that affect consumer’s safety. In 2020, the Bureau of Quality and Safety of Food, Department of Medical Sciences reported that of 919 dietary supplements, 121 (13.17%) products were adulterated by the addition of pharmaceutical substances, for instance, dexamethasone, sibutramine, sildenafil, etc (15). There were reports about adulteration of harmful substances in products (16), advertising exaggerating product properties, and consumers trust reviews more than considering any other information

(17). These situations increase the risks of consuming dietary supplements in Thailand nowadays.

Safe selection of dietary supplements by considering food serial numbers recommended by the Food and Drug Administration may not be applicable in reality because many dietary supplements do not show them or display fake food serial numbers. A study in Loei, Thailand found that 48.98% of dietary supplements were unspecified or incorrectly identified of the food serial number (18).

The dietary supplements quality control in Thailand is specified in the Food Act 1979, which has set the standard for quality inspection of product registration and the boundaries of information that can be shown on a product label and advertisement (5). However, the ability of the government agencies to monitor those products and information after products were launched to the market remains a gap (19). Unregistered products, product labels with incorrect information, and illegal advertisements are still being found (20).

The consumer safety of dietary supplement consumption is the responsibility of all sectors. The public sector, the private sector, as well as independent organizations working on consumer protection, have attempted to increase public knowledge on the safe selection of dietary supplement products. Although the strategies for choosing dietary supplements are being campaigned, practically people are still confused when applying them (4). Moreover, they also trust advertisements that boast of product properties (21). Therefore, considering dietary supplements as recommended by the Food and Drug Administration cannot comprehensively support consumers' safe decision-making. Consumers need to adapt and learn how to consider products safely themselves (22). Most consumers search for product information from

the internet or social media (23). Product reviews and ratings influence their decision-making as well. Consumers are eager to protect their safety, but lacking an appropriate decision support tool.

Therefore, it is imperative to develop a tool to support consumers' decisions on the safe consumption of dietary supplements. A suitable tool does not only supporting safe decision-making but also should be easy to use and accessible. Consequently, the study aims to identify variables that influence the safe decision of consuming dietary supplements and to develop a suitable and functional decision-support tool for dietary supplement consumption in the context of Thai society.

1.2 Research questions

1. What variables influence safe decision-making to consume dietary supplements?
2. How should develop an appropriate tool to support consumers' decision-making in dietary supplement consuming?

1.3 General objectives

1. To identify variables that influence the safe decision of consumers in dietary supplements consuming.
2. To develop an online tool for supporting dietary supplement decisions for consumers.

1.4 Specific objectives

1. To identify factors predicting the safe dietary supplements
2. To analyse consumers' feelings toward safe and dangerous dietary supplement consumptions
3. To develop a decision support online tool for consumers' decision
4. To evaluate the use of a decision support tool.

1.5 Conceptual framework

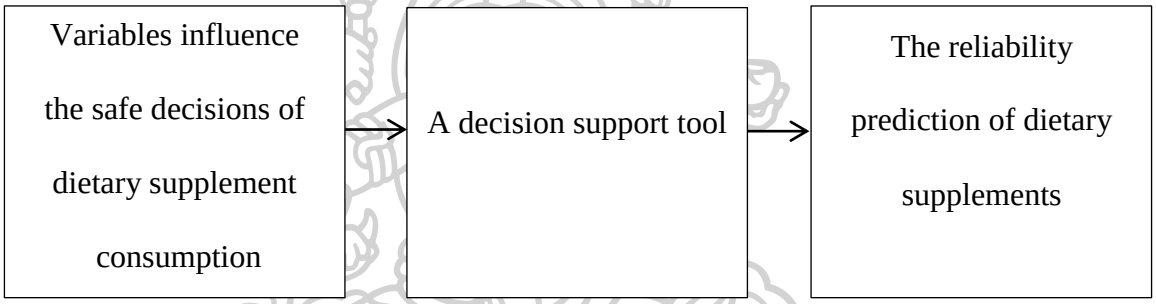

Figure 1 Conceptual framework

1.6 Definition of terms

Decision support means providing useful information for decision making.

Dietary supplement refers to edible health products for healthy people that are used in addition to the main diet with a health benefit. They contain nutrients or other substances but no preventive or curative effects. Dietary supplements are found in many forms, such as tablets, capsules, powder, flakes, liquids, or others (5).

Online tool is a tool designed for a specific purpose that can be used over a network.

CHAPTER 2

Literature Review

This chapter presents the principles, theories, and relevant information that form the basis of the research. The literature review is divided into three topics. Firstly, dietary supplements and consumer protection in Thailand, which consists of the situations of dietary supplement in Thailand, the relevant laws and regulations, and strategies for consumer protection. Secondly, related principles and theories including marketing mix theory, consumer behavior principles, sentiment analysis technique, Principle Component Analysis (PCA) technique, association rule discovery technique, and decision tree creation. Lastly, programs, tools, and assessments were used in the study. This section provides information about the Waikato Environment for Knowledge Analysis (WEKA) and the PSPP programs, which are free software under the GNU public license. The web application technology that is used to develop an online tool and also the Thai Mobile Health Apps Rating Scale (THARS) for an online tool evaluation.

2.1 Dietary supplements and consumer protection in Thailand

2.1.1 The situations of dietary supplements in Thailand

The consumption of dietary supplements in Thailand is steadily growing (3). The estimated value of the dietary supplement market in Thailand could reach sixty-nine billion baht by 2020, and according to the Food Industry Intelligence Center's report, the market is growing over eleven percent every year. Many dietary supplements are produced to meet the needs of consumers (4). Therefore competition

in the market is inevitable. Entrepreneurs recruiting many strategies to increase the purchase amount, such as increasing sales channels, advertising, adulteration of harmful substances to increase the effectiveness of their products (24). These approaches are also the cause of increasing dietary supplement consumption problems as well.

The number of complaints associated with dietary supplements continues to increase. The performance summary report by the Complaint and Suppression Center for Health Products, the Food and Drug Administration, the Ministry of Public Health, Thailand in the fiscal year 2020 had a total of 1,506 complaints. Which is 36.91% of complaints related to dietary supplements (25). Moreover, more than half of the complaints were sourced online. The effects of dietary supplement consumption were listed in order of severity from dissatisfaction without adverse health effects to disability and death (26). Consumers who were not severely affected tend not to complain. They believed that complaining is difficult and time-consuming (4). Therefore, problems with the consumption of dietary supplements have a greater impact on people than the number of complaints shown. So we should realize that the consumption of dietary supplements is a public health risk.

Examples of problem situations, the announcement of the Food and Drug Administration regarding the inspection of dietary supplements produced by Magic Skin Company Limited on March 23, 2018. This was a warning to dietary supplement distributors, sellers, and consumers that products from this company were classified as fake dietary supplements. The Magic Skin Company Limited was facing legal action and government officials froze dietary supplements worth more than one hundred million baht. These products included weight loss products, body slimming

products, skin whitening products. The main distribution channels were via social media, which makes it difficult for government audits (27).

Another case study on advertising exaggerates its properties, the Food and Drug Administration released data to monitor the dangers of advertising and exaggerating the product's properties on social media, which are detrimental to the health of consumers on March 26, 2018. The Ministry of Public Health monitored advertisements for dietary supplements on Facebook and the Thaishopnow website and found several brands of dietary supplements claiming to be weight loss products, including Licho Lida, Baschi Quick Slimming Capsule, Bashi, Bashi Gold, and Licho coffee. Those advertising messages were not permitted. Besides, the contents were exaggerated, therefore these were considered a scam to consumers. When those products were examined in the Health Products Alarm System by the Ministry of Public Health, some of them had also been found to be contaminated with Sibutramine, a dangerous substance. The Food and Drug Administration made this notification twice, in 2014 and 2017, but the products were still being found. Therefore, the Food and Drug Administration has warned consumers not to be convinced to buy such products (28).

The case studies above illustrated the problems of dietary supplement consumption, including the problem of products that do not meet the safety standard, the problem of exaggerating advertising, and the problem that arose from the distribution channels that cause harm to consumers.

2.1.2 The relevant laws and regulations

Dietary supplements in Thailand are regulated by the Food and Drug Administration, Ministry of Public Health based on the Food Act B.E. 2522. They are

responsible for overseeing the standard of production, import, and distribution of all health product types to ensure quality and safety for health product consumption, as well as developing to raise the standards of the health product production and the development of safety consumer behavior (5). In addition to the Food Act B.E. 2522 that is directly related to dietary supplements, there are other laws and announcements of the Ministry of Public Health to mention. Product label standard requirements according to announcements of the Ministry of Public Health that must be inspected and approved. The Ministry of Public Health announced rules and regulations regarding health product advertisements as well as the Herbal Products Act B.E. 2562, which relates to some dietary supplements that contain herbs as the main ingredient (29).

Food Act B.E. 2522

The supervision of all food types in Thailand is under the Food Act B.E. 2522, which has been revised and updated content by issuing additional ministerial regulations and announcements of the Ministry of Public Health. This act has defined the definition of food in Section 4 as follows.

SECTION 4. In this Act:

"Food" means edible items and those which sustain life:

(1) Substance can be eaten, drunk, sucked, or gotten into the body either by mouth or by other means, no matter in what form, but not including medicine, psychotropic substances, narcotics under the law as the case may be.

(2) Substance intended for use or to be used as ingredients in the production of food including a food additive, coloring matter, and flavoring.

The dietary supplements in the study were classified as a specifically controlled food under this Act. The details of the dietary supplements involved in product quality control, labels, and advertising are summarized as follows.

The law requires manufacturers or importers to apply for food recipe registration and obtain a certificate successfully before being able to produce, import, or sell the products. The registration certificate can be used forever unless it has been revoked.

The law prescribes the four food types that are prohibited from being produced, imported, and distributed under Section 25 as follows:

SECTION 25. No one may produce, import for sale, or distribute the following foods:

(1) impure food;

(2) adulterated food;

(3) substandard food;

(4) other food which specified by the Minister

Each type of prohibited food is described under Section 26 to 29 as follows.

SECTION 26. Food of the following description shall be deemed impure:

(1) Food that contains anything likely to be dangerous to health

(2) Food in which a substance or chemical substance has been mixed. Which could deteriorate the quality unless such admixture is necessary to the process of production, production and has been authorized by the competent officer.

(3) Food unhygienically produce, packed, or stored.

(4) Food produced from animals having a disease which might be communicated to men.

(5) Food in containers made of materials that are likely to be dangerous to health.

SECTION 27. Food of the following description shall be deemed adulterated:

(1) Food for which other substances are partly substituted or in which valuable substances are wholly or partly removed and which is sold as or under the name of the genuine food.

(2) Substances or food produced as substitutes for any food and distributed as being genuine food.

(3) Food that is mixed or prepared in any way to conceal defects or inferior quality of the food.

(4) Foods labeled to deceive or try to deceive the purchasers in matters of quality, quantity, usefulness, or special nature or place or country of production.

(5) Food not up to the quality or standard prescribed by the Minister under Section 6 (2) or (3) and the quality or standard of that food deviate from the upper or lower specified limit more than thirty percent or its deviation may harmful to the consumer.

SECTION 28. Substandard food is food not up to the quality or standard prescribed by the Minister under Section 6 (2) or (3) but its deviation is not as high as in Section 27 (5)

SECTION 29. Food of the following description shall be deemed food under Section 25 (4).

(1) not safe for consumption;

(2) unreliable indication;

(3) value or usefulness is not appropriate to the consumer.

Content in Section 6 to expand the content in Section 27 and Section 28 as follows.

SECTION 6. In the interests of controlling food, the Minister shall be empowered to publish in the Government Gazette.

(1) prescribing controlled foods.

(2) Prescribing quality or standard of controlled food by reference to the name, class, kind, or nature of food produced for sale, import for sale, or sale including principle, conditions, and methods of production for sale, import for sale, or sale;

(3) prescribing quality or standard of food other than controlled food prescribed under (1) with or without the principle, conditions, and methods of production for sale, import for sale or sale;

Food quality control requirements are the primary safety assurance standards for consumers. Proper presentation of food-related information is also an important part of supporting consumers to choose the proper product according to their needs. Therefore, the Food Act B.E. 2522 has regulations on food labeling and advertising under Section 4 and Section 6 (10) as follows.

SECTION 4. In this Act:

"Label" includes any figure, Invented design, or text shown on the food, food container, or package;

SECTION 6. In the interests of controlling food, the Minister shall be empowered to publish in the Government Gazette.

(10) prescribing the class and kind of food produced for sale, imported for sale or sale which required labels, the texts on the labels, conditions and the display of the labels and also the principle and method of advertising on the labels.

The Ministry of Public Health has issued a notification regarding food labeling on packages as a guideline for supervising labeling and providing information to consumers. This announcement is based on the general standard for the labeling of food on containers by Codex (General standard for the labeling of pre-packaged foods-CODEX STAN 1-1985) (30). There is also a requirement for labeling of specially controlled food and other foods that the Minister declares that it must be inspected and approved by the Food and Drug Administration for the label to be used.

Advertising is information that reaches consumers to increase the purchasing power of various products. Therefore, determining the scope of the content and the format of the advertising is controlling the quality of the information and create the correct understanding for consumers. The law provides requirements to regulate advertising as well.

SECTION 40. False or deceptive advertising of the quality, usefulness, or indication of food is prohibited.

SECTION 41. Anyone wishing to advertise the qualities, usefulness of indication of food by radio, television, film, newspapers or other printed matter or by other means for business purposes must submit the sound, pictures or films or text of the advertisement to the authority for consideration. They can be advertised after receiving permission.

The Food and Drug Administration has issued a notification on Food Advertisement Principles (No. 3), which specifies rules on food advertising as a norm for implementation and review. Therefore, it is illegal to advertise dietary supplements without permission.

Herbal Products Act B.E. 2562

Dietary supplements that contain herbs as the main ingredient are regulated by this Act. The definition of herbs is specified in Section 4 as follows.

SECTION 4. In this Act stated as follow:

"Herbs" means natural products derived from plants, animals, microorganisms, or minerals, which used to mix, formulate, or transform into herbal products.

Herbal products which are controlled by this Act are exempted from the actions of the Drug Act or the Food Act as specified in Section 3. The Herbal Products Act B.E. 2562 contains requirements for formula registration, permission to produce, import, and pre-pack, as well as specifying label control requirements, and regulating advertising. This law is essentially consistent with the Food Act B.E. 2522, which is the main law regulating dietary supplements.

2.1.3 Strategies for consumer protection

At present, the competition in the dietary supplement business has rapidly changed the market environment. An increasing number of products to meet consumer demand and purchasing power. Therefore, society should pay more attention to consumer protection, as well as reducing the injustices that arise in the dietary supplement trading processes.

The concept of consumer protection emerged from the concept of liberal trade in which consumers and sellers can make trading decisions based on their preferences (31). The consumer protection concept is a mechanism created to protect fairness for consumers as they tend to be at a disadvantage and have less bargaining power than sellers (32). Consumers are entitled to be protected in four main areas: the right to be safe from products and services, the right to receive truthful and sufficient information about products and services, the right to independently choose the appropriate products and services for themselves, and the right to be considered and compensated for damages arising from products and services.

Consumer protection of health products is divided into four periods according to the trading processes: pre-marketing control, post-marketing control, surveillance, and consumer empowerment (33). Each section of consumer protection is detailed as follows.

Pre-marketing control consists of licensing related to health products. For example, a license for entrepreneurs to produce, import, and distribute all types of health products, product registration, labeling licensing, and health product advertising.

Post-marketing control is a continuous quality control process so that all types of health products maintain their quality according to the safety standards consistently. The data for conducting the health product audit is derived in part from the surveillance of health products and consumer complaints.

Monitoring the safety of health products as surveillance work consists of both proactive and reactive works. The proactive surveillance works on health product consumption include workplace sampling, sampling of health products through

various distribution channels, and examining health product advertisements published through all media. Nowadays, there are still many illegal health products available for sale. Because some distribution channels, such as the internet, social media, or others, are difficult to monitor. The reactive surveillance work is the handling of complaints. The Food and Drug Administration works to coordinate with relevant agencies to address issues appropriately. Therefore, even if there are laws governing health products, consumers are still at risk of encountering unsafe products.

Complaints are a channel for receiving information to monitor the safety of consumers. The Food and Drug Administration provides several complaint channels under the 1556 campaign for convenient access (34). The popular complaint channels in descending order are mail (29.0%), call center 1556 (27.6%), internet (21.8%), self-complaint (15.6%), telephone (5.8%), and other channels (0.2%) (35). However, the number of complaints coming to the Healthcare Complaint and Suppression Center is still small compared to the actual health product problems. This is consistent with the results of the consumer behavior survey that some of them did not make any complaints when experiencing problems with consuming dietary supplements (36). They argued for the inaction, although affected by consumption that the cost of the damage was small (56.7%), the complaint was time-consuming (55.8%), they did not know which agency to make a complaint (36.2%), and they did not know the procedure of making a complaint (32.7%). These data reflect the consumer's knowledge and attitudes about complaints. Therefore, the information that the Food and Drug Administration receives from the complaints is only a small portion of the problem. Receiving incomplete information results in incompatible solutions as well.

Consumer empowerment is the empowerment of the public sector, as real security is achieved through the people's self-defense ability. This work is divided into two areas: providing fundamental consumer education and providing authoritative resources to support decision-making for consumers.

The Food and Drug Administration, the Ministry of Public Health, Thailand recommends the safe selection of dietary supplements. Consumers should carefully consider information about health products. They should read health product labels thoroughly. The Food and Drug Administration offered three-step recommendations for safe dietary supplement selection. Firstly, considering carefully to identify right or exaggerated information about products. Secondly, reading product labels carefully. Lastly, noticing the food serial number indicating the product registration (37).

Practically, some consumers are confused about considering the information on the label. Moreover, food serial numbers have also been found a large number of false numbers. These findings were supported by the results of the study in Loei, Thailand. They found that 48.98% of dietary supplements were unspecified or incorrectly identified of the food serial number (18). Consumers also trust advertisements or reviews that boast of product properties. Therefore, considering dietary supplements as recommended by the Food and Drug Administration cannot comprehensively support consumers' safe decision-making.

2.2 Related principles and theories

2.2.1 Marketing mix theory

The marketing mix theory describes the factors that entrepreneurs can provide followed by the demand of consumers and these factors affect the consumer decision to purchase products or choose services. The 4Ps marketing mix consists of product, price, place, and promotion as shown in **Figure 2** (38).

Figure 2 Marketing mix theory

Product refers to a product or a service that is in demand of a particular market segment. One of the marketing challenges is choosing the right products for the target customers.

Price refers to the product pricing strategy, which is to find the right value between the price that the seller is satisfied with and the price that the buyer can afford. Because customers have the ability and spending behavior differently.

Place refers to the place of sale or distribution channels. Products must have a proper distribution process so that customers can easily access them. Each group of customers is convenient to access different sales channels.

Promotion is a strategy to encourage more targeted customers to purchase a specific product. This promotional strategy consists of advertising, arranging promotions, giving gimmicks, and others.

2.2.2 Consumer behavior principles

Schiffman and Kanuk consumption process model

Schiffman and Kanuk present a consumption process model under the idea that consumption consists of three interrelated phases: input stage, process stage, and output stage as shown in **Figure 3** (39).

The input stage is the stage where external factors influence the consumer's purchasing decision process, such as social and cultural factors, and 4Ps marketing mix. Both external factors influence the consumer's purchasing decision process.

The process stage is the stage that represents the consumer's purchasing decision process by internal factors including the perception of needs, attitudes, and values which influence the realization of purchase desires. Consumer research and evaluation of pre-purchase options are all involved, and the experience gained from post-consumer assessments also influences this process as well.

The output stage is the final stage of the purchasing process, use, disposal, and a post-consumption assessment. Outcomes that may be satisfactory or dissatisfaction from consumption. Which will be remembered as an experience and this result will affect further consumption.

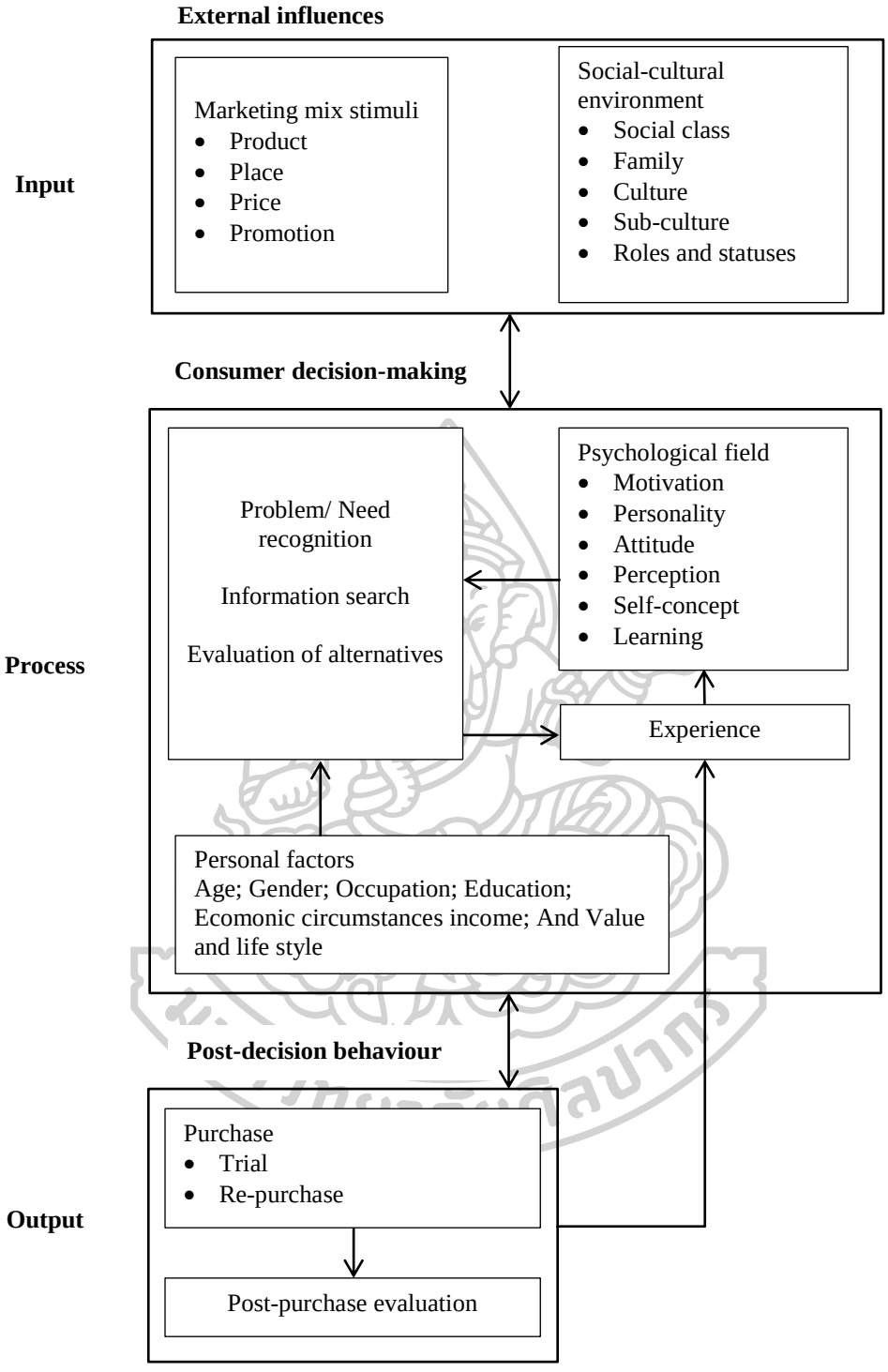

Figure 3 Schiffman and Kanuk consumption process model

2.2.3 Sentiment analysis

Sentiment analysis is the tendency analysis of an attitude towards something. The analyzed data may be in many formats such as text, symbols, or others. The analysis pattern of trends can be varied as well. Polarity is a pattern that is often used consisting of positive, neutral, and negative (40).

2.2.4 Principle Component Analysis (PCA) technique

The PCA is a type of data analysis method used for complex data or data with many related variables. This method is used to identify variables that are important to a particular feature of a data group that considers all data together. In which the characteristics of the data are not neglected during analysis. Therefore, the PCA is a computer method that analyzes multivariate data to correlate variables and group them from the nature of the data (41,42).

The PCA is one of the most commonly used unsupervised machine learning algorithms across a variety of applications (43). Machine learning is a mathematical representation of the patterns hidden in data. This analyzing method discovers some governing structures, which can be applied to new situations for predictions (44). Machine learning model can be categorized into three types based on the learning directives: supervised learning, unsupervised learning, and reinforcement learning.

2.2.5 Association rule discovery

Association rule discovery is a computer processing method that is used to find any rules within a dataset (45). Association rules are if-then statements that show the probability of relationships between data items within large data sets in various types of databases.

2.2.6 Decision tree model

A decision tree is a machine learning algorithm that partitions the data into subsets. The partitioning process starts with a binary split and continues until no further splits can be made. Various branches of variable length are formed (46). The goal of a decision tree is to encapsulate the training data in the smallest possible tree. Therefore, a decision tree can be used as a structure for developing systematic decisions.

2.3 Programs, tools, and assessment

2.3.1 Programs

Waikato Environment for Knowledge Analysis (Weka)

Waikato Environment for Knowledge Analysis (Weka), developed at the University of Waikato, New Zealand, is free software licensed under the GNU General Public License (47).

Weka is a collection of machine learning algorithms for data mining tasks. The algorithms can either be applied directly to a dataset or called from Java code. Weka contains tools for data pre-processing, classification, regression, clustering, association rules, and visualization. The front display of Weka shows in Figure 4.

Figure 4 Weka program front display

GNU PSPP

The GNU PSPP is a program for statistical analysis of sampled data. It is a replacement for the proprietary program SPSS and appears very similar to it with a few exceptions (48).

2.3.2 Tools

Web application

A web application is an application software accessed through a web browser via the internet. It runs on a web server. Which is not the same as computer-based software that runs locally on the operating system of the device. This technology has advantages such as uses fewer device resources, keep it up to date, available for both iOS and Android, and secure as it uses the HTTPS protocol (49).

Vue.js

The Vue.js is an open-source model view front-end JavaScript framework for building user interfaces and single-page applications. It was created by Evan You in February 2014. The Vue.js is constantly being improved (50).

2.3.3 Assessment

The Thai Mobile Health Apps Rating Scale (THARS) is a Thai health application quality assessment form for a healthy user, which consists of 38 questions. That is divided into two parts: general quality assessment (29 questions) and usability risk assessment (9 questions). Cronbach's alpha coefficients of the THARS were 0.76 to 0.83. There is the study confirmed that the THARS demonstrated good validity, an acceptable level of internal consistency, and an excellent level of reliability (51).

CHAPTER 3

Methodology

This study design is mixed method which consists of three phases. Phase I studied situations and factors affecting the safe selection of dietary supplements. Phase II developed an online tool to support consumers' decision. Phase III evaluated the application of the online tool. This study has been approved by the Ethics Committee for Human Research, Faculty of Pharmacy, Silpakorn University (certificate no. 11/2018). This chapter describes the study methodology including study sample, data collection, and data analysis. Details of methodology in each phase are shown as follows.

Phase I Identification of situations and factors affecting the safe selection of dietary supplements

This phase consists of two parts. Firstly, situations of consumption and problems of dietary supplement uses in Thailand were investigated from stakeholders' attitudes and experiences. Secondly, factors affecting the safe selection of dietary supplements were determined from the Food and Drug Administration databases and e-marketplaces.

1.1 Attitudes and experiences of stakeholders towards dietary supplement uses in Thailand

Study design

This part is a qualitative study to investigate situations of dietary supplement uses and problems in Thailand.

Population and samples

In order to understand the situation of dietary supplement use in Thailand, the study population of this part were all stakeholders involved with dietary supplement consumption. They were consumers, state authorities, and entrepreneurs. However, representatives from each group of stakeholders were sampling. The researcher identified the characteristics of samples diversely according to age, education level, gender, and income. Finally, thirteen key informants participated as shown in **Table 1**.

Table 1 Characteristics of key informants

Stakeholder	Gender	Age	Education level	Monthly income	Level of knowledge about dietary supplements
Consumer	Female	18	High school	<10,000	No expertise
	Male	20	High school	10,000-20,000	No expertise
	Female	24	Bachelor's degree	10,000-20,000	No expertise
	Female	27	High school	10,000-20,000	No expertise
	Not specified	31	High school	20,000-30,000	No expertise
	Female	34	Bachelor's degree	20,000-30,000	No expertise
	Male	36	Bachelor's degree	>50,000	No expertise
	Not specified	42	Doctorate	30,000-40,000	No expertise
	Male	48	Master's degree	40,000-50,000	No expertise
State authority	Female	52	Master's degree	>50,000	Expertise
	Female	40	Master's degree	30,000-40,000	Expertise
Entrepreneur	Female	24	High school	30,000-40,000	No expertise
	Female	26	Bachelor's degree	30,000-40,000	No expertise

The nine consumers consist of three subgroups as consumers who have never purchased any dietary supplements online, consumers who purchase dietary supplements online but have never been affected by their usages, and consumers who have been affected by the use of dietary supplements.

The two state authorities from the Health Product Surveillance and Complaint Center, Food and Drug Administration and the Provincial Public Health Office.

The two entrepreneurs who sell dietary supplements.

Data collection instrument

The semi-structured questionnaire was developed to be a guideline for the interviewer. The questions for each stakeholder group were different but focus on dietary supplement consumption as well. The questionnaire consisted of four main questions. The questionnaire for the consumers is shown below.

1. The consumers' basic information included age, education level, and income.
2. The experiences and attitude toward dietary supplements in Thailand.
   - What were the experiences of dietary supplement uses and problems?
   - Which dietary supplement types they found the problems with?
   - What was the most important concern for dietary supplements?
3. The experiences on the problem-solving of the dietary supplement consumptions.
4. The recommendation of problem-solving strategies toward dietary supplements for Thai society.

The questionnaire for the state authorities is shown below.

1. The state authorities' basic information included age, education level, and income.
2. The experiences and attitude toward their responsibility about dietary supplements in Thailand.

   - What were the experiences from their work about consumers' dietary supplement uses and problems?

   - Which dietary supplement types the consumers found problems with?

   - What was the most important concern for dietary supplements of consumers?
3. The experiences from their work on the consumers' problem-solving about the dietary supplement consumptions.
4. The recommendation of problem-solving strategies toward dietary supplements for Thai society.

The questionnaire for the entrepreneurs is shown below.

1. The entrepreneurs' basic information included age, education level, and income.
2. The experiences and attitude toward dietary supplements in Thailand.

   - What are the experiences of their consumers about dietary supplement uses and problems?

   - Which dietary supplement types their consumers found problems with?

   - What is the most important concern for dietary supplements of consumers?

3. The experiences of their consumers' problem-solving about the dietary supplement consumptions.
4. The recommendation of problem-solving strategies toward dietary supplements for Thai society.

Data collection and analysis

All key informants were purposive sampling according to a variety of age, gender, occupation, income, and education status. They were given detailed explanations about the research objectives, method, risks and benefits of research participation. The study started after they responded voluntarily. They were interviewed using a developed semi-structured questionnaire.

Data were collected during May and June 2018. The researcher contacted the first key informant who was nearby the researcher's working place and was known that had experience in dietary supplement consumption. Another sample was included by the suggestion from the former sample by the snowball sampling technique. The interview process took approximately an hour per individual key informant. All interviews were recorded. The audio files were converted into verbatim conversations. Then they were analyzed using typological analysis. The results were considered and summarized by three persons, the researcher and two other experts.

1.2 Factors affecting the safe selection of dietary supplement

Study design

This part is a cross-sectional analytical study to determine factors affecting to the detection of adulterated dietary supplements.

Variables in the study

The expected variables related to the decision on dietary supplement consumption were reviewed and identified from the related laws, consumer behavior theories, and the dietary supplement trading information. The thirty-eight expected variables related to dietary supplement consumption were included. The variables were divided into three groups: product-related variables, trading process-related variables, and vendor-related variables as shown in **Table 2**.

Table 2 Expected variables related to the dietary supplement consumption

Code	Variable name
Product-related variables	
V1	Product name that induces consumers
V2	Product for beauty
V3	Product for panacea
V4	Product for sex enhancement
V5	Product score
V6	Total sale
V7	Showing of food serial number
V8	Accuracy of food serial number
V9	Showing quality symbol
V10	Showing of components
V11	Accuracy of component format
V12	Showing manufacture date
V13	Showing expiration date
V14	Showing lot number
V15	Showing of manufacturer information
V16	Accuracy of manufacturer information
V17	Showing distributor information
V18	Showing indication
V19	Accuracy of indication
V20	Showing instruction
V21	Showing 3 standard cautions
V22	Showing extra caution
V30	Capsule dosage
V31	Tablet dosage
V32	Others dosage form

Code	Variable name
Variables involved in the trading process	
V23	Text advertising
V24	Image advertising
V25	Advertisement with a presenter
V26	Sale price
V27	Price discount
V28	Promotion
V29	Amount per package
Vendor-related variables	
V33	Registered shop in the e-marketplaces' system
V34	Location of shop
V35	Shop score
V36	Total sale
V37	Years of service
V38	Customer response rate

The values of the variables were assigned to two options, yes and no. In case of the variables' responses were not yes or no. The researcher categorized responses into sub-variables. For example, the responses of a variable regarding the purposes of using a dietary supplement were product for beauty, product for panacea, and product for sex enhancement. Therefore, the researcher categorized the responses into 3 variables (V2-V4), which each variable values were represented as yes or no. In addition, if any variables were recorded as a number, they must be used to determine the central tendency and applied that value as a cut point for converting the value to yes or no as well.

Population and samples

The population in this part were online dietary supplements available in Thailand. The samples were dietary supplement products that were available on the e-marketplaces (LAZADA or Shopee) from October to December 2019. The inclusion criteria of selected samples were dietary supplements that were tested for contaminants by the Department of Medical Sciences, Ministry of Public Health in 2016 - 2018. The Exclusion criteria were dietary supplements that data was lost from the e-marketplaces' system during the data collection, and products' information not covered 38 expected variables. A total of 132 products were included in the study and they were grouped according to the contaminant test results. Products have not reported a contamination of hazardous substances in the reference report were representative of the safe product samples. On the other hand, products reported a contamination were dangerous product samples. During the data collection, 4 products were deleted from the e-marketplaces' system. So they were excluded from the study as well. Finally, 128 products were included in the study with 64

products per group. The selection of dietary supplements in this study is shown in **Figure 5**. The variables related to the dietary supplement consumption were collected and recorded using a licensed Microsoft Excel 2010.

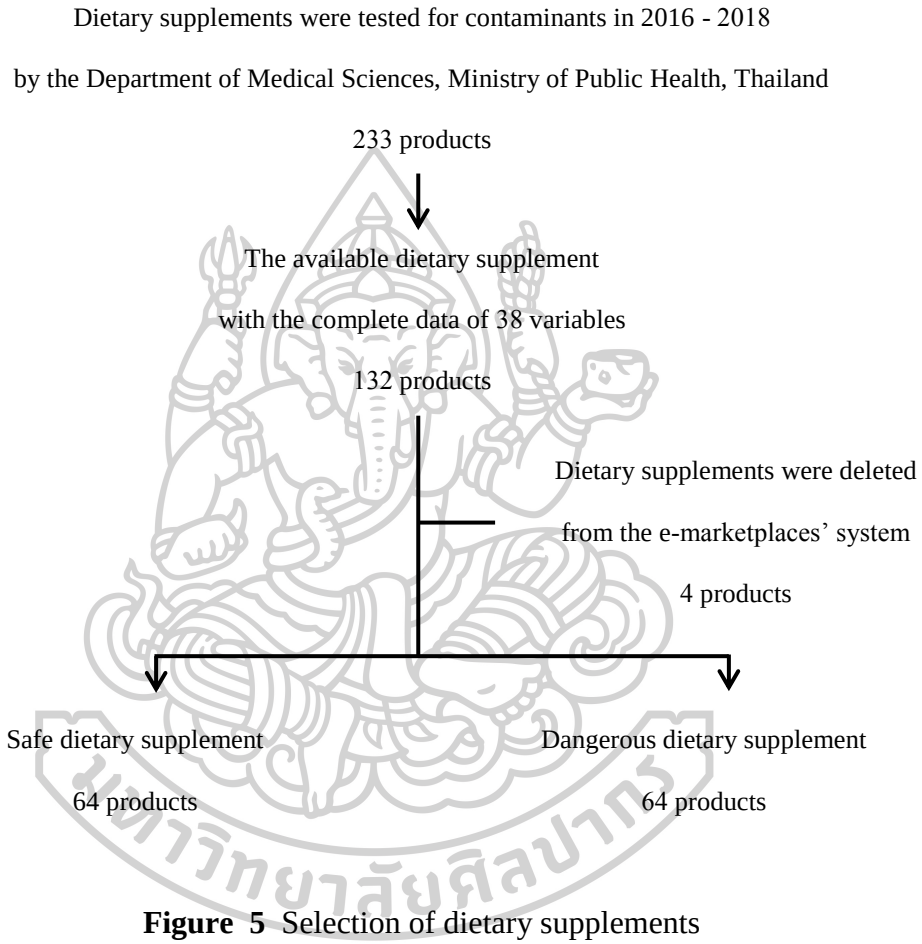

Figure 5 Selection of dietary supplements

Data collection

Product information was recorded with 38 variables in the data collection form. The values of all variables were defined by three independent experts before being finalized.

In addition, a consumer's opinion was determined as the other factor that may affect to consumer decision. Therefore, ratings and reviews of the product samples were retrieved from the e-marketplaces between October to December 2019. Finally, we included 46 products, 23 each group with 288 ratings and 496 reviews.

Data analysis

Variables in this part were analysed according to types of variables. For 38 expected variables from product information, the analytical techniques used in the study included association rule discovery, Chi-square test, Principal Component Analysis (PCA) technique, and decision tree creation. The computer programs used for data analysis were the WEKA version 3.8.3 and the PSPP version 1.2.0.

In this work, association rules discovery was used to find the relationships between variables within the product group. Dietary supplement consumption data were analyzed using the WEKA version 3.8.3 with the Apriori algorithm. The confidence of the test equal to 1 means if the events on the left side of the rule arise, then the events on the right side of the rule will surely happen.

The analytical data by the Chi-square test used PSPP 1.2.0 at 95% confidence interval. This method considered a pair of variables and identified the variables that influence the separation of dietary supplement groups.

The PCA is a machine learning model that analyzes multivariate data to correlate variables and group them from the nature of the data. Two sets of data that were taken into account in this process were all 38 variables and 19 variables from an analysis using the Chi-square test. The analysis results were used to create the principal components plot and the PC1 principal factors bar chart. After that, the point distribution on the principal components plot and the cut points of the PC1 principal

factors bar chart were considered to identify the factors affecting the separation of the product groups. The PC1 cut points were determined to define diverse groups of variables by 2 independent experts.

A decision tree creation is a data analysis method to create step-by-step decision processes that mimic the structure of a tree. The various groups of variables that affect dietary supplement grouping were used to create decision trees. Then the most accurate and suitable one was selected for further consideration of dietary supplements' safety.

The four data analysis methods above were a variety of data analysis tests to determine the most accurate approaches for dietary supplement selection. However, all data analysis methods were independent.

Consumer opinions were another part of information that influences consumer decisions. Therefore, the data were analyzed separately according to the data type. Product ratings were analysed using t-test. Product reviews were analysed using three methods including Chi-square test, sentiment analysis, and the PCA. The statistical analysis program used in the study was the PSPP version 1.2.0 under the GNU general public license and the Waikato Environment for Knowledge Analysis (WEKA) version 3.8.3. The WEKA is the data analysis program used for PCA. Both the PSPP and the WEKA are free software.

The factors affecting the safe selection of dietary supplements, including the order in which they were considered, were shown in the form of the decision tree with the highest accuracy. This was the result of Phase I, which was used as a processing structure of the tool developing in the second phase.

Phase II An online tool development to support consumers' decision

The findings from phase I revealed that consumers need a support tool to help them making decisions on dietary supplement consumption. The online tool should be developed based on the factors related to the safe selection of dietary supplements. Therefore, this phase applied the factors found in phase I to develop an online tool to support consumers' decision.

A literature review of appropriate consumer decision-support tools was conducted before an online tool as an application was selected for the development of a tool in this study.

Study samples

The samples in this phase are stakeholders who involve to this online tool. They are four consumers, one state authority, and one technology expert.

The four consumers who have experience in consuming dietary supplements. The state authority who has been responsible for consumer protection related to health products. The technology expert who has experience in application development.

Data collection

A storyboard was drafted by the researcher under the guidance of technology experts. The processing method in the storyboard was based on the decision tree of phase I.

The storyboard was considered by stakeholders to gather feedback on how to develop a tool. Opinions of four consumers, one state authority, and one technology expert were collected by an in-depth interview. The storyboard was sent to them at least a week before the interview. They were asked the same three questions. Firstly, would you like more explanation about this storyboard? Next, would you like any

adjustments to the storyboard and how should it be? Lastly, do you have any further advice?

The storyboard was adjusted based on the opinions of stakeholders. Then, an online tool in the form of an application was created using Veu.js. This is a free tool to create a web application. The online decision support tool was developed until it was ready for testing.

Therefore, The online tool supports safe dietary supplement decision-making as a result of Phase II operations. This tool has been tested and evaluated by consumers in the third phase.

Phase III Application of the online tool evaluation

Study design

The study design in this phase is a cross-sectional study. This evaluation phase is an important step before implementation. The online tool developed in phase II was tested for this pilot study.

Study samples

Consumers are the target audience for developing the decision support tool. Therefore, they were chosen to participate in the test and evaluation the online tool developed. The participants consisted of 30 consumers who were specifically selected by the inclusion criteria as healthy Thai dietary supplement consumers and consented to participate in the study. Participants who discontinue providing information or provide incomplete responses to the questionnaire were excluded.

Data collection tool

The literature review was conducted to select an application evaluation tool. The criteria for the tool are able to evaluate an application, target users are healthy people and the questions are in Thai language. Eventually, the Thai Mobile Health Apps Rating Scale (THARS) was chosen. This questionnaire was developed by Wilasinee Hongsanun and Suppachai Insuk from Faculty of Pharmaceutical Sciences, Naresuan University, Thailand. And this study has received permission from the corresponding author.

The THARS consists of thirty-eight questions. Which is divided into two sections: general quality assessment (29 questions) and usability risk assessment (9 questions). Assessors are required to answer all thirty-eight questions, each question being scored by one point if the assessors choose “Yes” and get a score equal to zero if they choose “No” or “Not sure”. Therefore, the full score of this assessment is thirty-eight. The score conversion criteria are not fully set but are described as if the score is close to the full score, the application being evaluated is functional and reliable.

Data collection

Participants were informed about online tool development objectives and the assessment method. There were no commercial reasons involved in the study. We provided information that the study did not collect any personal information. They can discontinue the process at any time. They can ask any questions and the process began after they accepted all conditions voluntarily.

The users can download an online tool by their smartphone or a prepared device. They selected dietary supplements for testing from the products they have, the

products they are interested in, or the prepared products. They learn how to use an online tool from the manual and try it themselves. After that, users tested at least two dietary supplements before evaluated the use of an online tool by the THARS. Users placed the form in a receiving box. where the researcher opened it at the end of the data collection. The whole process took about 20-30 minutes.

Data analysis

The assessment results by THARS were shown as scores. The full score of the THARS is thirty-eight, divided into two parts: general quality assessment 29 points and usability risk assessment 9 points. Scores from all evaluators were compiled. Descriptive statistics were used to analyze the data by calculating mean and standard deviation of each question, section, and whole assessment. Further suggestions on the tool from the user's perspective were also collected to summarized and discussed.

CHAPTER 4

Results

This chapter is a result compilation of all three phases. The first phase was the identification of situations and factors that influence the safe selection of dietary supplements by considering consumer opinions and information related to the products. The second phase presented the development of a decision support tool in the form of a web application called the Check4Safety. The final phase showed the results of the Check4Safety assessment by the THARS and recommendations.

Phase I Identification of situations and factors affecting the safe selection of dietary supplements

1.1 Attitudes and experiences of stakeholders towards dietary supplement uses in Thailand

Key informants have the characteristics as shown in **Table 1**. Consumers have males, females, and alternative sexes. Their age was between 18-48 years old. Most of them have an education level between high school and bachelor's degrees. Their estimated income was between 20,000 and 30,000 baht per month. They have no expertise in health products but they have direct experience in purchasing them.

State authorities have a higher education level than a bachelor's degree. They have expertise in health products and have more than fifteen years of working experience in this field.

Entrepreneurs a high school education to a bachelor's degree. They sell all types of health products both topical and oral products. They have a store as well as

sell through online channels such as Facebook, Line, Instagram, LAZADA, Shopee, and others. They have selling experience of over three years. Their average income was more than 30,000 baht a month.

The findings from the interviews can be grouped into three issues. Firstly, stakeholders have a different perspective on health product problems. They have a variety of opinions about problem-solving and who should be responsible for it. Secondly, all stakeholders perceive the risks of health product problems with different recognition methods. Thirdly, consumers have different approaches to manage risks.

1.1.1 Stakeholders have a different perspective on health product problems

Stakeholders have consistent opinions about problematic health products. However, they have an absolutely different attitude towards priorities about the problems and current problem-solving. The perspective of the stakeholders towards health products in Thailand was summarized into three points as follows.

Problematic product group

Consumers provided information that the popularity of health products consumption can be summarized respectively as follows: beauty products, health promotion products, and sexual enhancement products. They mostly prefer to consume beauty products and have high expectations from using them such as weight loss, good shape, light skin, smooth skin, etc. The beauty product was the group that has found direct suffering experienced from the interviews. One consumer who experienced the use of dietary supplements for weight loss provided the following information about adverse reactions.

"I used a weight loss product.

It caused me to not be able to breathe normally.

At that time, I felt like I was dying."

Government officials categorized problematic health products into three groups, which were composed of beauty products, illness treatment products, and sexual enhancement products. They said that beauty products were the most problematic group, which has the highest number of complaints and the biggest proportion of severe health effects as well.

Entrepreneurs provided consistent information with other stakeholders that the demand for beauty products was the highest and consumers have high purchasing power than other health product groups. One entrepreneur who had more than three years of experience selling dietary supplements stated the following.

"Everyone wants to have a nice look.

So, beauty products always have good sales."

All stakeholders agreed that beauty products were the most problematic product group of health products in Thailand, which was expanding in both the number and severity of the problems.

Priorities for the problems of stakeholders

The stakeholders had different priorities for health product problems. Expected results from using health products were the most important for consumers. They knew that there were both safe and dangerous products on the

market. They have to search for information cautiously. However, they were at risk if they try out the products. Even so, some consumers were willing to accept the risks in exchange for the results they desire. One consumer who had been affected by dietary supplement consumption and continued to use them stated the following.

"If you never try you'll never know."

Another consumer provided consistent data and demonstrated a strong focus on expected outcomes as stated in the following.

"If I'm not beautiful, it would be better to die."

Government officials paid attention to various illegal acts and health effects that occurred to consumers after using health products. Solving the problem of illegal advertising was a top priority of the government sector. They realized that advertising influenced the purchasing decision of consumers. Health effects that cannot be treated such as disfigurement, disabilities, or fatalities were what the government gives priority to. These severe consequences had caused people to lose their life potential and it is the responsibility of the state to assist them.

Entrepreneurs focused on sales and reputation. They tried to select good products and provided the best services. However, they said that the problems arising from the consumption of health products were unavoidable.

Each group of stakeholders focused on the problems from different perspectives according to their needs and roles. Consumers focused on expected results from using health products. Government officials prioritized illegal advertising and health effects on consumers that cannot be treated. Entrepreneurs gave the utmost importance to sales and reputation.

Current problem-solving

Each stakeholder recognized that problem-solving was the responsibility of other stakeholders. Consumers wanted the state to work seriously to protect their safety. They knew that the government works for the safe consumption of health products. However, the performance was delayed and indecisive. Consumers provided the opinion that the government greatly focused on the prevention of the problems. Which was not an effective strategy because problem-solving requires proactive measures. Consumers stated the following.

"Prohibition of buying and selling is not possible.
The state must control all products that are sold safely for people."

"The government only provides knowledge,
but they do not suppress dangerous products.
How can we be safe?"

Whereas, government officials showed that they have limitations in their work; the number of staff was not enough, some information was difficult to access due to data security systems, and some necessary actions, they have

no direct power to do. For all those reasons, government officials were not able to deal with the problems that occur thoroughly. Therefore, they expected that consumers should have a safe consumption behavior to protect their safety.

Entrepreneurs expressed ideas that providing safety in health product consumption should be the responsibility of the government and consumers because the state is obliged by law to monitor the safety of health products. Consumers know best which product they can use safely. One entrepreneur who used to encounter problems from consumers that be allergic to dietary supplements stated the following.

"If the state controls the quality of all products well,
both sellers and consumers will be safe."

1.1.2 Stakeholders perceive the risks with different recognition methods

The second finding from the interviews was that stakeholders perceive the risks with different recognition methods. Although they were also fully aware of the risks, they gave priority to different channels of information. The channels of information acquisition included consumer experience, word of mouth, various public media, and survey data.

The perception of the risks that affected consumers the most was a direct experience. Consumers who were affected by purchasing or using health products tend to tell their experiences with others. Nevertheless, they complained only when they were affected by severe consequences such as disfigurement, disability, fatality, or high damage value. They believed that complaining is complicated, time-

consuming and issues may not be resolved. Word of mouth and information on various public media had greatly affected the risk perception of consumers as well.

Government officials gave the priority to the risk data from surveys and research studies. They used that information to determine their work goals. The risks from consumer experiences through the complaints were also perceived. Risk perception by tracking information through various public media was difficult for the state authorities because they lack advanced technology skills to access information. Therefore, the perceived risk of the government sector comes from limited sources.

Entrepreneurs paid attention to searching for information about health products in various public media before selling. They recognized the risks of health product problems from consumer experiences through product reviews. However, reviews were only part of the information because most consumers said that if the problems were not severe, they usually did not have any replies back from the seller. After that, they will look for new products.

1.1.3 Consumers manage the risks with different approaches

The third finding from the interviews was consumers managed the risks with different approaches. Consumers were the direct recipient of health product risks. They were aware of the dangers that may arise and decide to deal with the risks based on the information they can access. The most popular sources of information that consumers were searching for were on the internet. Nevertheless, information on the internet was both true and deceptive. Therefore, consumers make decisions based on uncertain data.

Consumers tried to protect themselves by learning from their personal experiences. They can be divided into two groups according to the risk management strategies. The first group was comprised of consumers who cannot assume the risks, so they do not purchase any health products. One consumer who had never bought dietary supplements stated the following.

"Online products are both good and bad. If I'm not sure that
I will get a good thing, it's better not to buy it."

The second group was consumers who seek safe consumption strategies themselves. This consumer group believed that they can use various health products if they considered them carefully. One consumer who bought dietary supplements regularly stated the following.

"I have the right to try out any products that
I believe they are good for me."

Consumers had a variety of approaches to protect their safety; searching for product information from various sources. Information from acquaintances was the first thing that consumers regard when they have to decide on a new health product. Reviews on social media about products they were interested in also greatly influence the purchase decision. One consumer who had the experience to try new products stated the following.

"Recommended products from friends or online products with good reviews, those I would like to try out."

Consumers learned to reduce the risks of using health products. They tried to use a new product gradually to observe whether the allergic reaction will occur or not. Consumers who have been affected by the use of health products stated the following.

"Items that I have never used must be tested gradually. If allergic reactions occur, it will not be severe and can be treated in time."

Consumers had their self-care methods when they faced the effects of using health products. These methods can be summarized in the following steps. Firstly, consumers stop using that product immediately. Then, they try to treat the symptoms on their own. Eventually, if the symptoms cannot be treated, they decided to accept medical services. One consumer who ever suffered from consuming the dietary supplements provided the following information.

"I had palpitation after using a weight loss product. At that time, I tried to drink a lot of water and thought that if the symptoms do not subside, I will go to the hospital."

Consumers did not succumb to the limitations that make them far from being safe. They tried to protect their safety as much as they can. One consumer shared her opinion about the stakeholders stated the following.

"The state is not serious to solve the problems.

Sellers also do not know different from us.

So, we have to choose products safely by ourselves."

Moreover, consumers demonstrated their ability to protect themselves. This can be developed if appropriate supports were provided. One consumer presented his point of view stated the following.

"I'm not medical staff. I don't know which one is dangerous or not.

If you tell me how to be safe, I will definitely do it."

1.2 Factors affecting the safe selection of dietary supplement

1.2.1 Data analysis of 38 expected variables of dietary supplements

Of 64 dietary supplements, product information according to expected variables between safe and dangerous products was shown in **Table 3**. Most of the products were products for beauty. The information of food serial number was the most shown on the product label. The results of the data analysis were separated into four parts according to the data analysis methods; association rule discovery results, Chi-square test results, PCA results, and decision tree creation.

Table 3 Variable information

Code	Variable name	Safe product group (yes value)	Dangerous product group (yes value)	*p-value* at 95% CI
Product-related variables				
V1	Product name that induces consumers	20 (31.25%)	19 (29.69%)	0.848
V2	Product for beauty	50 (78.13%)	45 (70.31%)	0.312
V3	Product for panacea	10 (15.63%)	7 (10.94%)	0.435
V4	Product for sex enhancement	4 (6.25%)	12 (18.75%)	**0.036***
V5	Product score	35 (54.69%)	29 (45.31%)	0.289
V6	Total sale	28 (43.75%)	36 (56.25%)	0.157
V7	Showing of food serial number	64 (100.00%)	62 (96.88%)	0.154
V8	Accuracy of food serial number	55 (85.94%)	35 (54.69%)	**<0.001**
V9	Showing quality symbol	46 (71.88%)	28 (43.75%)	**0.001**
V10	Showing of components	63 (98.44%)	53 (82.81%)	**0.002**
V11	Accuracy of component format	56 (87.50%)	28 (43.75%)	**<0.001**
V12	Showing manufacture date	60 (93.75%)	33 (51.56%)	**<0.001**
V13	Showing expiration date	62 (96.88%)	33 (51.56%)	**<0.001**
V14	Showing lot number	49 (76.56%)	20 (31.25%)	**<0.001**
V15	Showing of manufacturer information	61 (95.31%)	43 (67.19%)	**<0.001**
V16	Accuracy of manufacturer information	60 (93.75%)	25 (39.06%)	**<0.001**
V17	Showing distributor information	58 (90.63%)	40 (62.50%)	**<0.001**
V18	Showing indication	0 (0.00%)	11 (17.19%)	**<0.001***
V19	Accuracy of indication	0 (0.00%)	1 (1.56%)	0.500*
V20	Showing instruction	60 (93.75%)	49 (76.56%)	**0.006**
V21	Showing 3 standard cautions	57 (89.06%)	35 (54.69%)	**<0.001**
V22	Showing extra caution	36 (56.25%)	6 (9.38%)	**<0.001***
V30	Capsule dosage	36 (56.25%)	50 (78.13%)	**0.008**
V31	Tablet dosage	9 (14.06%)	3 (4.69%)	0.078*
V32	Others dosage form	19 (29.69%)	11 (17.19%)	0.095
Variables involved in the trading process				
V23	Text advertising	52 (81.25%)	60 (93.75%)	**0.033**
V24	Image advertising	35 (54.69%)	35 (54.69%)	0.859
V25	Advertisement with a presenter	20 (31.25%)	9 (14.07%)	**0.020**
V26	Sale price	37 (57.81%)	27 (42.19%)	0.077
V27	Price discount	32 (50.00%)	32 (50.00%)	0.860
V28	Promotion	53 (82.81%)	44 (68.75%)	0.063
V29	Amount per package	37 (57.81%)	34 (53.13%)	0.594
Vendor-related variables				
V33	Registered shop in the e-marketplaces' system	4 (6.25%)	5 (7.81%)	0.746*
V34	Location of shop	25 (39.06%)	29 (45.31%)	0.474
V35	Shop score	35 (54.69%)	32 (50.00%)	0.595
V36	Total sale	37 (57.81%)	27 (42.19%)	0.077
V37	Years of service	39 (60.94%)	46 (71.88%)	0.190
V38	Customer response rate	35 (54.69%)	23 (35.94%)	**0.033**

* Fisher's exact test results

Association rule discovery results

This study investigated the association rules for correlation within the product groups. The association rule with a confident value of one provides that if an event on the left side of the rule has occurred, the event on the right side of the rule surely happens. These rules represent the characteristics of each product group extracted from big data. Finding correlation rules by this process is highly accurate as it is generated through machine learning. The association rules within the safe product group at the confident equal to one are shown in **Table 4** and the association rules within the dangerous product group at the same confident value are shown in **Table 5**, respectively.

Table 4 Association rules were found from the safe product group

Rule (confident=1)
1. Showing manufacture date=True ==> Showing expiration date=True
2. Accuracy of manufacturer information=True ==> Showing of manufacturer information =True
3. Showing expiration date=True & Accuracy of manufacturer information=True ==> Showing of manufacturer information=True
4. Showing distributor information=True ==> Showing of manufacturer information=True
5. Showing manufacture date=True & Showing of manufacturer information=True ==> Showing expiration date=True

The five true rules were discovered from the safe product group. Firstly, if the manufacture date is presented on the label, the expiration date is also showed as well. Secondly, if the manufacturer information presented on the label is accurate, the manufacturer information is revealed. Thirdly, if the expiration date is presented and the manufacturer information on the label is accurate, the manufacturer

information is publicized. Fourthly, if the distributor information is shown on the label, the manufacturer information is correct. Lastly, if the manufacture date and the manufacturer information are accessible, the expiration date is also presented as well.

Table 5 Association rules were found from the dangerous product group

Rule (confident=1)
1. Tablet dosage=False ==> Accuracy of indication=False
2. Showing of food serial number=True & Tablet dosage=False ==> Accuracy of indication=False
3. Text advertising=True & Tablet dosage=False ==> Accuracy of indication=False
4. Tablet dosage=False & Registered shop=False ==> Accuracy of indication=False
5. Showing of food serial number=True & Text advertising=True & Tablet dosage=False ==> Accuracy of indication=False
6. Showing extra caution=False & Tablet dosage=False ==> Accuracy of indication=False
7. Showing of food serial number=True & Tablet dosage=False & Registered shop=False ==> Accuracy of indication=False
8. Product for panacea=False & Tablet dosage=False ==> Accuracy of indication=False
9. Showing of food serial number=True & Showing extra caution=False & Tablet dosage=False ==> Accuracy of indication=False
10. Text advertising=True & Tablet dosage=False & Registered shop=False ==> Accuracy of indication=False

The ten true rules were discovered from the dangerous product group. Firstly, if the dangerous product is not in a tablet dosage form, the indication is shown on the label also incorrect. Secondly, if the food serial number is presented and the dosage form of the product is not a tablet, the indication is mistaken. Thirdly, if the dangerous product has been advertised by text form and the dosage form is not a tablet, the indication is wrong as well. Fourthly, if the product is not a tablet and the

shop is not a registered shop in the e-marketplace system, the showing indication is erroneous. The fifth rule is if the food serial number is presented and the product advertising by text form and also the dosage form is not a tablet, the indication is wrong. The sixth rule is if the extra caution is not noticed on the label and the dosage form is not a tablet, the indication is wrong as well. The seventh rule is if the food serial number showed on the label is correct and the dosage form is not a tablet and the shop is not registered, the indication is also wrong. The eighth rule is if the purpose of product use is not for panacea and the dosage form is not a tablet, the indication is incorrect. The ninth rule is the food serial number and the extra caution are not showed and the dosage form is not a tablet, the indication is wrong. The last one is if the product advertising is in the text form and the dosage form is not a tablet and the shop is not registered, the indication is also incorrect. The variables appearing in all relationship rules of both groups were important to characterize the groups of products.

Chi-square test results

The data analyzed using the Chi-square test at 95% confident interval is shown in the last column of **Table 3**. Fisher's exact test was used to analyze the variables with a small number instead of Chi-square test for accuracy. 19 variables had statistically significant differences between both product groups, which were divided into three groups, including sixteen product-related variables, two trading process-related variables, and one vendor-related variable. In this part, the different variables between the two product groups were selected for data analysis in the PCA and decision tree creation step.

PCA results

PCA technique was used to analyze all variables to detect a small number of principal components (PCs) that influence the difference between safe and dangerous products. The results of the PCA analysis were divided into two parts according to the data set: a total of 38 variables and 19 variables from the results of the Chi-square test and the Fisher's exact test.

PCA results of 38 variables

In the score plot **Figure 6**, products were grouped according to the safety status. The two axes of the diagram (PC1 and PC2) represent dietary supplements. Most of the safe products (green dots) were clustered on the right side of **Figure 6**. While dangerous products (red dots) were distributed evenly. The distribution of the points shows that the X-axis, which represents PC1, can be used to separate groups of products.

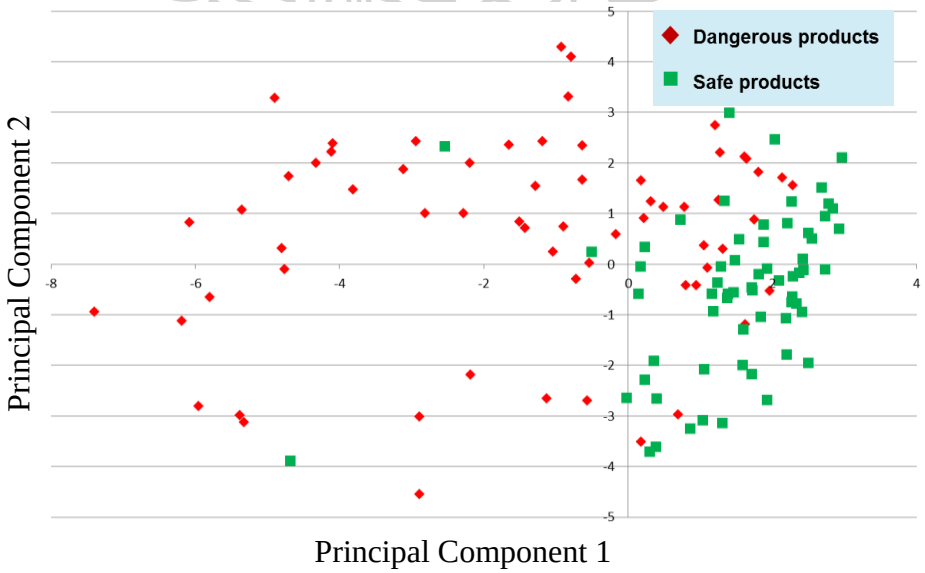

Figure 6 Safety status of dietary supplements on PC1 and PC2 of 38 variables

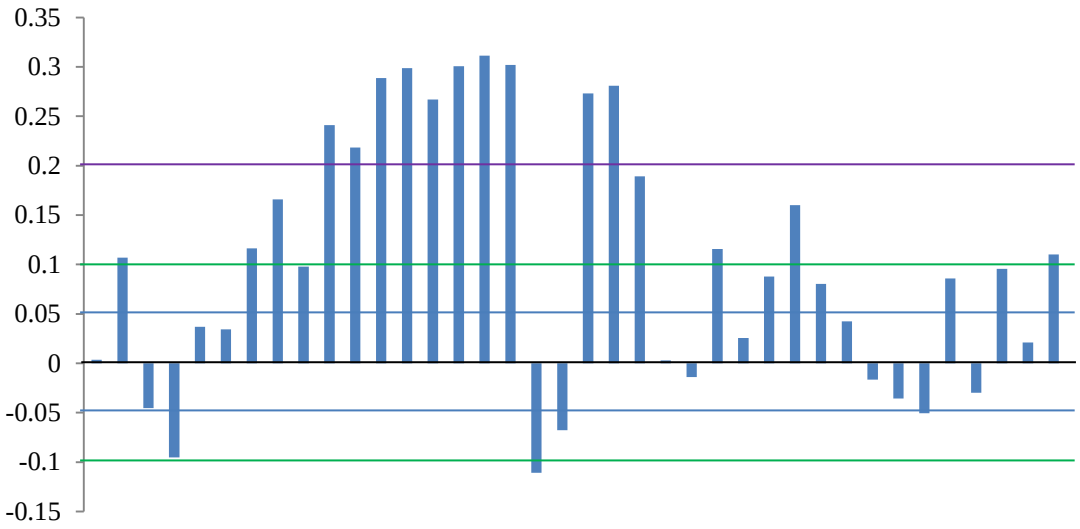

Figure 7 PC1 principal factors bar chart of 38 variables

Therefore, the PC1 principal factors bar chart of 38 variables as **Figure 7** was considered. The values of PC1's factors away from 0 indicate the positive and negative influences on the product classifications. The PC1 cut points, used for determining the group of variables, were a conclusion from two expert opinions. The three selected values were ±0.05, ±0.10, and ±0.20. The groups of variables from the three cut points are shown in **Table 6**.

Table 6 The groups of variables from the PC1 cut point of 38 variables

PC1 cut point	Number of variables	Code
± 0.05	26	V2, V4, V7, V8, V9, V10, V11, V12, V13, V14, V15, V16, V17, V18, V19, V20, V21, V22, V25, V27, V28, V29, V33, V34, V36, V38
± 0.10	18	V2, V7, V8, V10, V11, V12, V13, V14, V15, V16, V17, V18, V20, V21, V22, V25, V28, V38
± 0.20	10	V10, V11, V12, V13, V14, V15, V16, V17, V20, V21

PCA results of 19 variables

In the score plot **Figure 8**, products were grouped according to the safety status as well. The two axes of the diagram (PC1 and PC2) represent dietary supplements. Most of the safe products (green dots) were clustered on the left side of **Figure 8**. While dangerous products (red dots) were distributed evenly. The distribution of the points shows that the X-axis, which represents PC1, can be used to separate groups of products.

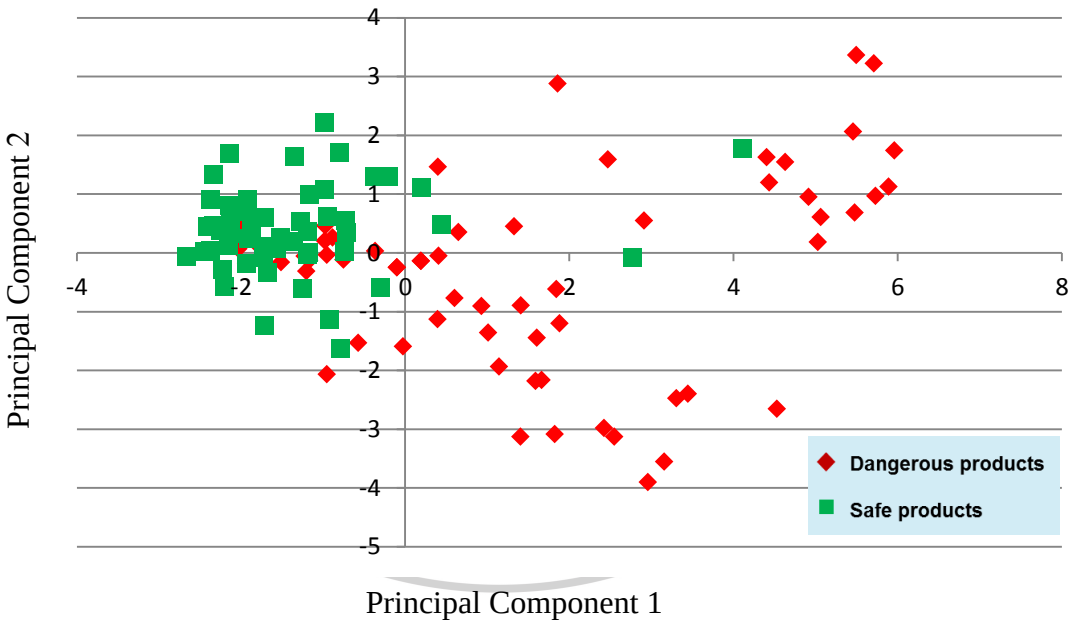

Figure 8 Safety status of dietary supplements on PC1 and PC2 of 19 variables

Therefore, the PC1 principal factors bar chart of 19 variables as **Figure 9** was considered. The PC1 cut points, used for determining the group of variables, were a conclusion from two expert opinions. The four selected values were ±0.05, ±0.10, ±0.20 and ±0.25. The groups of variables from the four cut points are shown in **Table 7**.

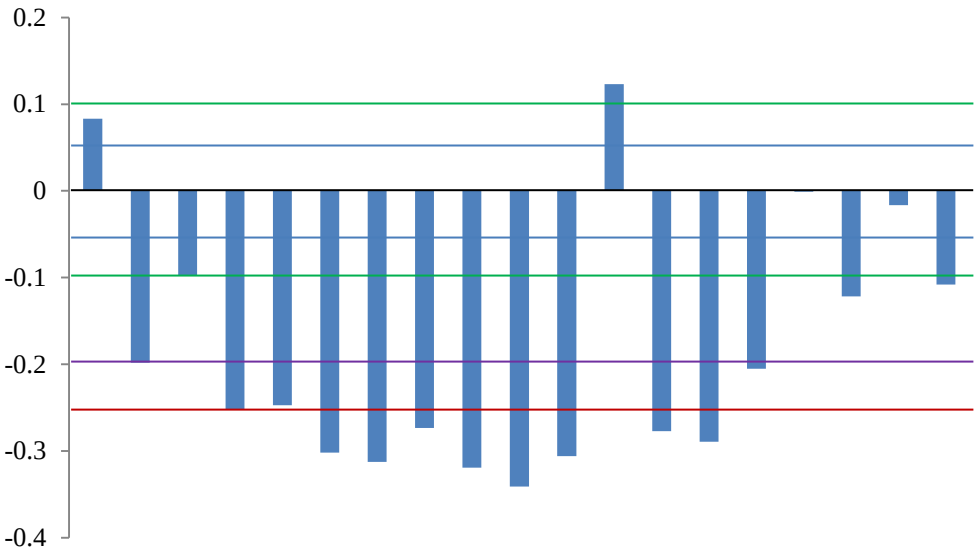

Figure 9 PC1 principal factors bar chart of 19 variables

Table 7 The groups of variables from the PC1 cut point of 19 variables

PC1 cut point	Number of variables	Code
± 0.05	17	V4, V8, V9, V10, V11, V12, V13, V14, V15, V16, V17, V18, V20, V21, V22, V25, V38
± 0.10	15	V8, V10, V11, V12, V13, V14, V15, V16, V17, V18, V20, V21, V22, V25, V38
± 0.20	12	V8, V10, V11, V12, V13, V14, V15, V16, V17, V20, V21, V22
± 0.25	9	V10, V12, V13, V14, V15, V16, V17, V20, V21

Decision tree creation

Creating a decision tree is the statistical method used to determine the safety of dietary supplements from analyzed variable groups. It is also possible to estimate the validity of decision-making methods as well. This method selected the variables that affect the decision-making process and ordered the consideration until

the probable outcome can be identified. The nine groups of variables were all thirty-eight variables, nineteen variables from the Chi-square test, three groups of variables from the PCA of thirty-eight variables at three cut points, and four groups of variables from the PCA of nineteen variables at four cut points. All of them were taken to create decision trees and the results are shown in **Table 8**. The number of leaves is represented as the number of the final result level of the decision tree. Moreover, the size of the tree is the number, which exposed counting every node of the tree.

The percentage of correctly classified instances is represented as an accurate percentage that the tree can support the precise of identifying product groups. The highest accuracy in predicting dietary supplement safety is 92.3077% from four groups of variables. The structures of the decision trees were also the same. The suitable decision tree is shown in **Figure 10**. This decision tree contains eight leaves and fifteen is the size of the tree.

Table 8 Decision trees of the variable groups

Variable group	Number of leaves	Size of the tree	Percentage of correctly classified instances
All variables (38 variables)	11	21	84.6154%
Chi-square test (19 variables)	12	23	84.6154%
PCA of 38 variables at ± 0.05 cut point (26 variables)	14	27	88.4615%
PCA of 38 variables at ± 0.10 cut point (18 variables)	8	15	92.3077%
PCA of 38 variables at ± 0.20 cut point (10 variables)	7	13	88.4615%

Variable group	Number of leaves	Size of the tree	Percentage of correctly classified instances
PCA of 19 variables at ± 0.05 cut point (17 variables)	8	15	92.3077%
PCA of 19 variables at ± 0.10 cut point (15 variables)	8	15	92.3077%
PCA of 19 variables at ± 0.20 cut point (12 variables)	8	15	92.3077%
PCA of 19 variables at ± 0.25 cut point (9 variables)	5	9	88.4615%

The consideration of the product group was followed by the hierarchy of the decision tree. From figure 10, the decision structure starts with checking the correctness of the manufacturing information (manu_cor) presented on the label from the Food and Drug Administration's website. If the information (manu_core) is true (T), the determination step go to the left side of the tree (exp_date), on the contrary, if the information (manu_cor) is false (F) the determination step go to the right side of the tree (lot). The left branch of the tree starts by checking the expiration date (exp_date) display. If yes, the next node to the left (ext_caut) is measured, if not this product is marked as a suspicious product. The next node is the extra caution (ext_caut) checking. If warnings other than the three cautions required by law are displayed, the product is defined as a reliable product. Otherwise, the correctness of the product ingredients (compo_cor) display is considered next. If the product's composition is listed in descending order by weight, the three warnings required by law (caut) are considered further, if not the product is labeled as suspicious. The last node of the left branch is the checking of three warnings required by law (caut). If the

three warnings are presented on the label the product is identified as a reliable product, if not the product is recognized as a suspicious one.

The right branch of the tree starts by checking the showing a lot number (lot). If yes, the presenting of distributor information (distri) is checking next, if not the product is defined as a suspicious product. Lastly, if the information of the distributor (distri) is presented on the label the product is marked as a suspicious product, if not the product is accepted as a reliable one.

The decision tree was chosen as the method for determining the safety of dietary supplements. This was used as a framework for developing a decision support tool in the next step.

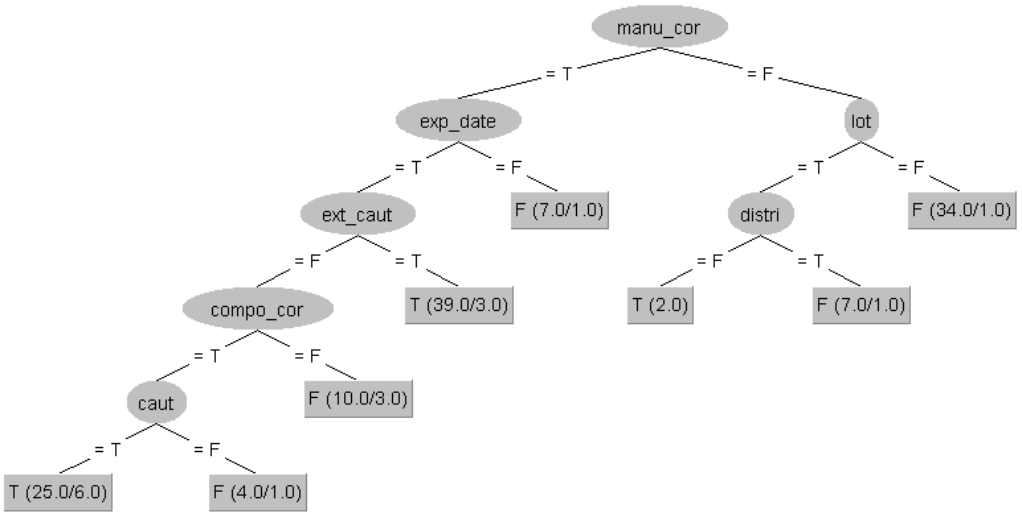

Figure 10 The decision tree represented the method for determining the safety of dietary supplements

1.2.2 Analysis of consumer opinions using sentiment analysis

Analysis of consumer opinions was divided into two parts according to the type of data. Which were product rating and product review as follows.

Characteristics of analyzed products

Dietary supplements can be divided into three categories by purpose of use including beauty products, health care products, and sexual health products. The numbers of safe and unsafe products classified according to their intended use are shown in **Table 9**.

Table 9 Analyzed products classified by the purpose of use

Purpose of use	Safe product group (N=23)	Unsafe product group (N=23)
Product for beauty	20	16
Product for health care	2	2
Product for sexual health	1	5

Beauty products were found in the highest proportion. Health care products were found the same proportions in safe and unsafe product groups, while sexual health products were found higher in the unsafe product group than the other.

Pharmaceutical substances found in unsafe products for beauty purposes were sibutramine, fluoxetine, fenfluramine, and orlistat. These substances have an effect on weight loss. Unsafe products used for health care were often adulterated with steroids or pain relievers, such as dexamethasone, diclofenac, and paracetamol. Unsafe products used for sexual health were adulterated with one or more sex enhancers including sildenafil, tadalafil, or vardenafil.

Product rating

The e-marketplaces specify product satisfaction levels in the form of product ratings ranging from one to five stars. During the data collection period, 288 product ratings were collected into the study. The safe product group had 109 ratings. The average was 4.53 stars (SD = 1.05). The dangerous product group had 179 ratings. The average was 4.43 stars (SD = 1.23).

The difference in product ratings of safe and dangerous product groups has evaluated using t-test. The p-value was 0.471 at 95% confident interval. The product ratings from both groups of products were not significantly different.

Product review

Product reviews in e-marketplaces generate from consumers who have previously purchased those products only. During the data collection period, 496 product reviews were collected into the study. There are 217 and 279 reviews from safe and dangerous product groups respectively.

Product reviews were classified based on 4P's marketing mix theory as aspect groups consist of product, price, place, and promotion. They are organized into subgroups according to the characteristics of the data as well. Each review was configured with a polarity value for sentiment analysis. The polarity was divided into three values including positive, neutral, and negative. The aspect and polarity values of each review were determined by two experts. If both opinions were inconsistent, the third expert's opinion was used for consideration. Data analysis of product reviews was divided into three parts; analysis of product reviews based on aspect groups, analysis of product reviews based on polarities, and analysis of product reviews based on aspect groups with polarities together.

Analysis of product reviews based on aspect groups

The numbers of product reviews classified by 4 aspect groups of safe and dangerous products are shown in **Figure 11** and the proportions are shown in **Figure 12**. Chi-square test has been used to analyze the differences of product reviews divided by aspect groups from both groups of products. The p-value was less than 0.01 at 95% confidence interval. Therefore, product reviews classified by aspect groups were statistically significant differences.

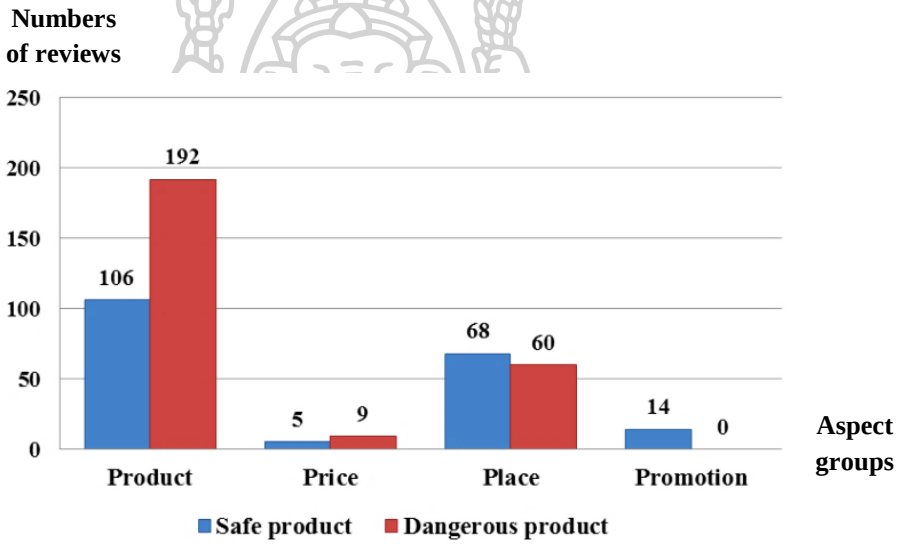

Figure 11 The numbers of product reviews classified by aspect groups

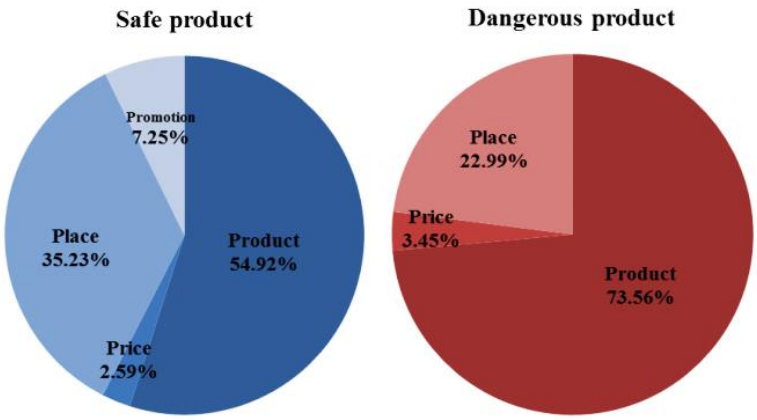

Figure 12 The proportions of product reviews classified by aspect groups

The proportion of the product aspect was higher than other aspects. In which the proportion of product aspect in the dangerous product group was higher than the safe product group. The reviews related to product and price aspects in the dangerous product group were higher than the safe product group in both the numbers and proportions. Especially in the very different product aspect that the dangerous product group had 73.56%. While the safe product group had 54.92%.

The aspects related to place and promotion performed the opposite results. In which the numbers and proportions of the safe product group were higher than another group.

Product aspect

A product aspect was a group of reviews related to dietary supplement products in various fields. This can be divided into subgroups as follows; product overview, results of using the product, adverse effects, continuous product consumption, general services, product characteristics, and information services. The product aspect subgroups of safe and dangerous product groups are shown in **Table 10**.

Table 10 Subgroups of product aspect

Subgroups of product aspect	Safe product group	Dangerous product group
Product overview	37 (34.91%)	71 (36.98%)
Results of using the product	35 (33.02%)	78 (40.63%)
Adverse effects	8 (7.55%)	25 (13.02%)
Continuous product consumption	8 (7.55%)	8 (4.17%)
General services	8 (7.55%)	3 (1.56%)
Product characteristics	7 (6.60%)	6 (3.12%)
Information services	3 (2.83%)	1 (0.52%)

The trend of the product aspect subgroups was the same in both groups of products. Consumers highly valued the results of using the product and product overview. The proportion of reviews in these two subgroups was higher than thirty percent of all reviews in this aspect group. The subgroup about adverse effects was found next. The proportion of reviews about adverse effects in the dangerous product group (13.02%) was almost one-fold higher than the safe product group (7.55%). The reviews about other subgroups were found in less than ten percent. The subgroup of information services was found at the lowest proportion in both groups. Although this was an important service that affects the safety of dietary supplement consumption. The proportion of the information services subgroup in the safe product group (2.83%) was higher than the dangerous product group (0.52%).

Price aspect

A price aspect was a group of reviews related to all the expenses that consumers have to spend when they consume any products or services. This aspect can be divided into subgroups as follows; product price, value of product, and shipping cost as shown in **Table 11**.

Table 11 Subgroups of price aspect

Subgroups of price aspect	Safe product group	Dangerous product group
Product price	3 (60.00%)	6 (66.67%)
Value of the product	2 (40.00%)	2 (22.22%)
Shipping cost	0 (0.00%)	1 (11.11%)

Reviews about product price were found more than sixty percent in this aspect. The reviews about value of the product in the safe product group (40.00%) were almost twice as much as the dangerous product group (22.22%). Reviews of shipping costs were rarely found.

Place aspect

A place aspect was a group of reviews related to the ease of accessing any products or services. This can be divided into subgroups as follows; delivery by the seller, receiving the product, product preparation, and completeness of the product as shown in **Table 12**.

Table 12 Subgroups of the place aspect

Subgroups of place aspect	Safe product group	Dangerous product group
Delivery by seller	35 (51.47%)	40 (66.67%)
Receiving the product	17 (25.00%)	13 (21.67%)
Product preparation	16 (23.53%)	6 (10.00%)
Completeness of the product	0 (0.00%)	1 (1.67%)

More than fifty percent of the reviews from both groups of products in this aspect related to the delivery by seller. The subgroup receiving the product had a similar proportion of reviews in both product groups. The product preparation subgroup from the safe product group (23.53%) had a higher proportion than the dangerous product group (10.00%). The completeness of the product subgroup was rarely found in all the reviews.

Promotion aspect

A promotion aspect was a group of reviews related to activities or benefits available to consumers to promote the sale of products or services. The reviews of this aspect were found in a safe product group. Giving some gimmick was just the only one subgroup.

Analysis of product reviews based on polarities

The numbers of product reviews classified by three polarities of safe and dangerous products are shown in **Figure 13** and the proportions are shown in **Figure 14** respectively. Chi-square test has been used to analyze the differences of product reviews divided by polarities from both groups of products. The p-value was 0.01 at 95% confidence interval. Therefore, product reviews classified by polarities were statistically significant differences.

The proportions of positive polarity from both groups of products were almost the same. In the safe product group, there were 68.66 percent and 68.10 percent in the dangerous product group. While the proportion of negative polarity in the dangerous product group (22.22%) was higher than the safe product group (14.29%). Conversely, the proportions of neutral polarity showed opposite results.

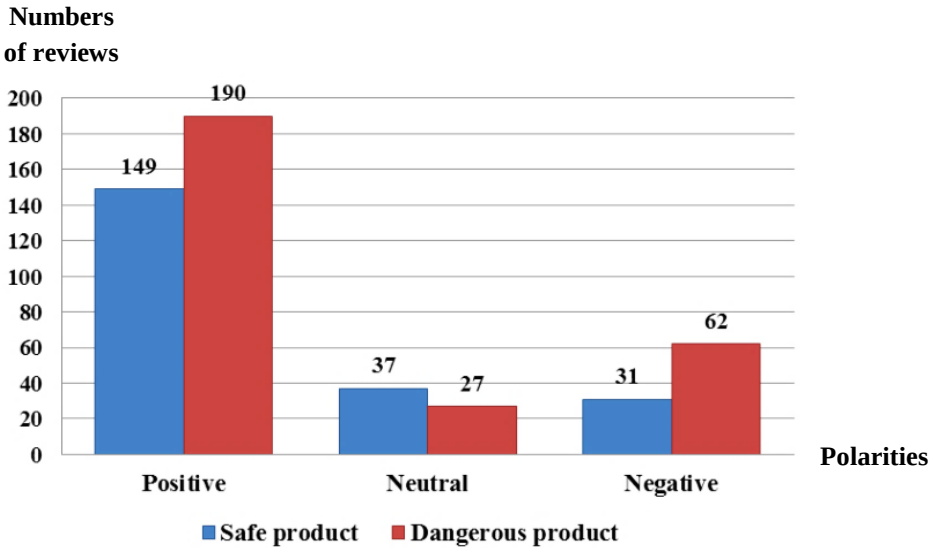

Figure 13 The numbers of product reviews classified by polarities

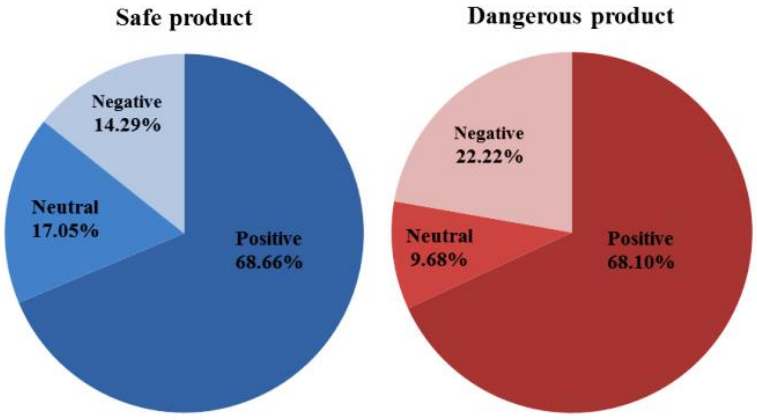

Figure 14 The proportions of product reviews classified by polarities

Analysis of product reviews based on aspect groups with polarities

Comparison of consumer reviews on both groups of products divided according to aspect groups and polarities found that both were different. Therefore, considering these two factors together about the ability to differentiate consumer reviews between safe and dangerous products was studied. The proportions of the polarities in each aspect group from safe and dangerous product groups are shown in **Table 13**.

Table 13 The proportion of polarities in the aspect groups

Aspect groups	Safe product group			Dangerous product group		
	Positive	Neutral	Negative	Positive	Neutral	Negative
Product asprct	76.4%	3.8%	19.8%	66.6%	2.1%	31.3%
Price aspect	80.0%	0.0%	20.0%	100.0%	0.0%	0.0%
Place aspect	67.7%	23.5%	8.8%	85.0%	11.7%	3.3%
Promotion aspect	100.0%	0.0%	0.0%	0.0%	0.0%	0.0%

The polarity trends of all aspect groups in both product groups were not different. The positive polarity had a large proportion, which accounted for over two-thirds of all aspect groups except for the promotion aspect of the dangerous product group. Which did not find any reviews. The negative reviews were found in a lower proportion of the product aspect of safe products. While neutral reviews were found in a lower proportion in the place aspect of dangerous products.

PCA was used to analyze the differences of the product reviews considering both aspect groups and polarity from both groups of products. The

principal component plot and the principal factor plot were generated as shown in **Figure 15** and **Figure 16** respectively.

The principal component plot shows the distribution of points representing each component of both product groups. Which the green dots represent the safe products and the red dots represent the dangerous products. The principal factor plot shows the distribution of all related factors.

Both two diagrams were considered together to identify the factors affecting the separation of product reviews in safe and dangerous product groups. The distribution of the two colored dots from the principal component plot had a similar pattern. The product reviews of both product groups consider by aspect group with polarity cannot be separated by PCA. Therefore, consumer attitudes towards safe and dangerous dietary supplements cannot be clearly distinguished by consideration of aspect group together with polarity.

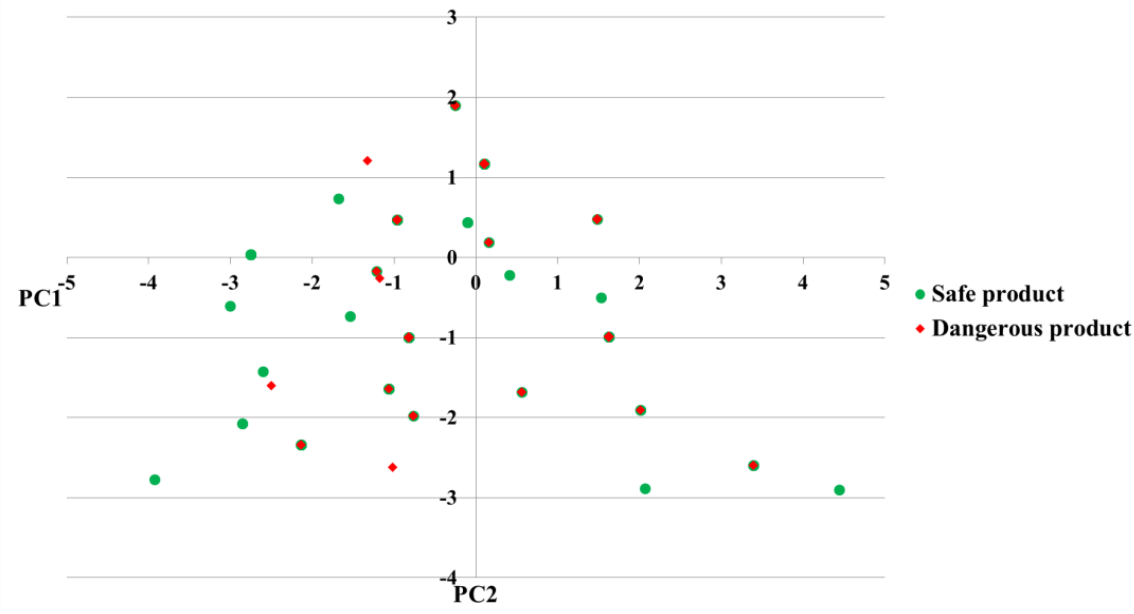

Figure 15 Principal component plot

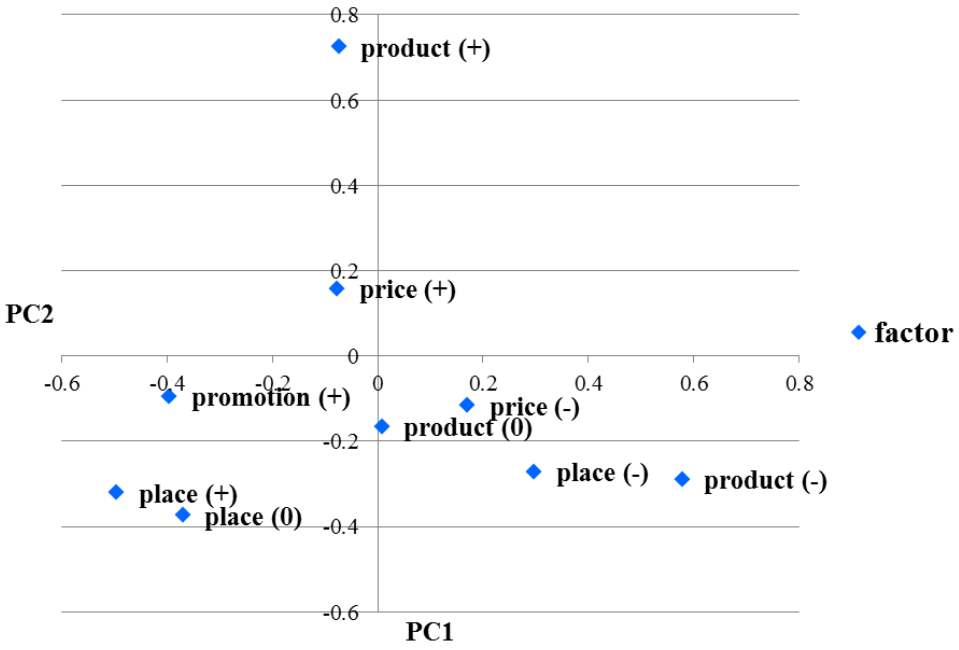

Figure 16 Principal Factor plot

In this phase, the decision tree extracted from the data analysis was used as an analytical structure in the further development of the online decision support tool in the second phase.

Phase II An online tool development to support consumers' decision

This section presents the processes of developing an online tool from drafting up the storyboard until the tool is fully developed. The tool processing was based on the decision tree which was the result of phase I. The storyboard was drafted by the researcher under the guidance of technology experts. Stakeholders who advised on the storyboard of the tool development included four consumers, one state authority, and one technology expert, through in-depth interviews.

All four consumers were male, female, and alternative sexes. Their age was between twenty and forty-five years and they have an education level between high

school and bachelor's degrees. The average income was 25,000 per month. They have experience in consuming dietary supplements and find information to make decisions. The state authority has been responsible for consumer protection and has been responsible to receive complaints about health products served for more than ten years. The technology expert has over five years of experience in application development and network development.

The key informants agreed with the name Check4Safety because it was a name that corresponds to the purpose of use and they accepted the application icon, which is a magnifying glass. Suggestions for improving the storyboard consist of three points: proper color usage, easy-to-understand text, and displaying annotations.

Consumers targeted users of the Check4Safety, offered to adjust the background color to a bright blue for a fresh feel. They suggested changing the button color to validate the dietary supplement, arguing that the green color induces the user's senses that the product being tested is safe. Therefore, the researcher changed the color of the button to dark blue. The state authority was concerned about filling information to check dietary supplements with specific requirements that were difficult to recognize. So they offered to put a pop-up message on the checking page. Which has been added.

The adjusted storyboard based on the suggestions shows in **Figure 17**. After that, the Check4Safety was created using Veu.js and being tested until ready to use. The Check4Safety can be used on both iOS and Android operating systems.

By the end of this phase, the decision-support tool named Check4Safety in the form of a web application was ready for user testing in the last phase.

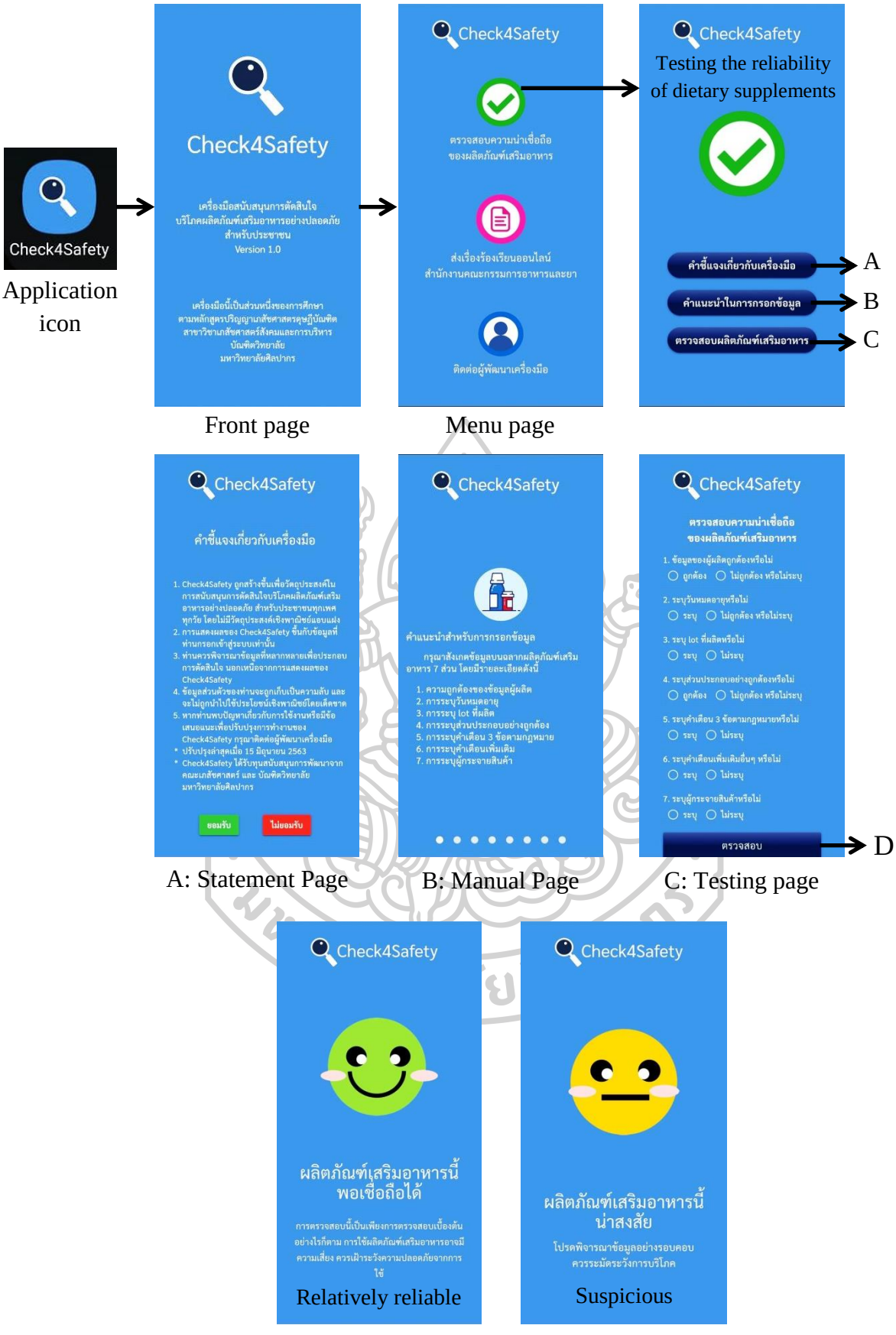

Figure 17 Storyboard of an online tool

Phase III Application of the online tool evaluation

The Check4Safety consists of three parts; testing the reliability of dietary supplements, submitting an online complaint to the Food and Drug Administration, and contacting the tool developer. A description of the Check4Safety development objective, funding source, information security, and tool improvements were clearly stated. Users can learn how to fill in the information to verify the dietary supplement from the manual. Answering all seven questions by choosing yes or no leads to two product evaluation results. These are relatively reliable and suspicious products. However, reminders for consumers to carefully consider information are always displayed together.

Dietary supplement consumers voluntarily participated in the Check4Safety use assessment. Their characteristics were shown in **Figure 18-21**. The users consist of ten males, fifteen females, and five alternative sexes. Their age was between twenty and forty-five years. They have an education level mostly between high school and bachelor's degrees and the estimated income was between 10,000 and 30,000 bath per month. They have experience in purchasing dietary supplements. Male consumers were interested in muscle building and general body care products. While female and alternative sexes consumers mostly were interested in beauty-related products such as weight management products, products that provide skincare effects, and multivitamins.

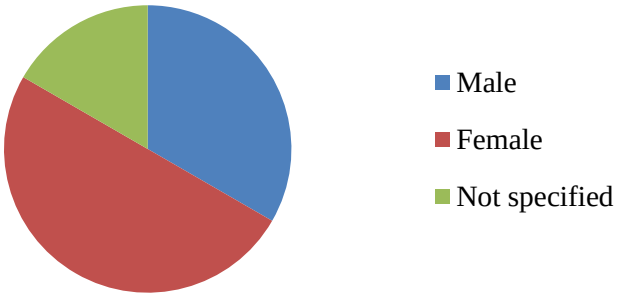

Figure 18 Participants separated by gender

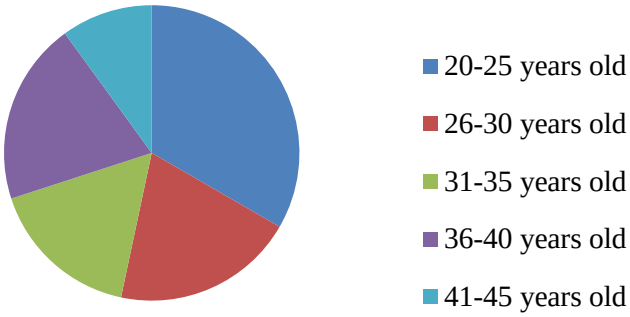

Figure 19 Participants separated by age

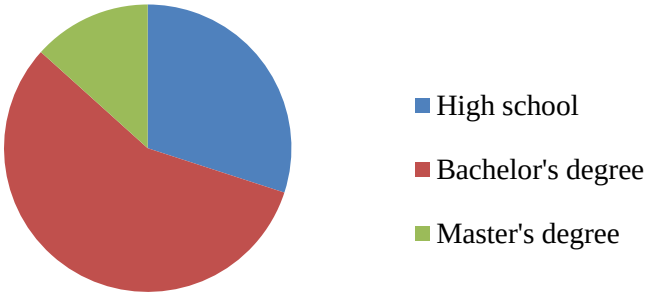

Figure 20 Participants separated by education level

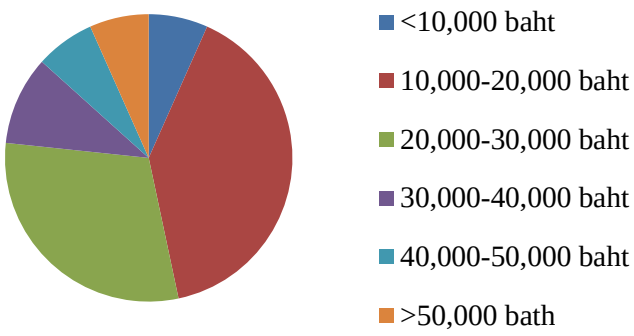

Figure 21 Participants separated by monthly income

The Check4Safety evaluation by the THARS had an average score of 28.27 from the total of 38 points accounting for 74.39% (Range:23-35, SD=2.16). The THARS score has not been assigned a grade variation. The evaluation score that is close to the full score indicates a good application. The Check4Safety evaluation results were divided into two parts according to the section of the THARS: general quality assessment and usability risk assessment.

3.1 General quality assessment

The general quality assessment section contains 29 questions. The average score was 21.63, equal to 74.60%. There were 16 questions that the Check4Safety received the full mark and 21 questions received score more than 80 percent of the full mark. The seven low-rated questions had a score range of zero to three and one question got seventeen as shown in **Table 14**.

Table 14 Check4Safety's evaluation score in the general quality assessment section

Question	Score
The application menu is designed to be user friendly	30
The application uses language that is easy to understand	30
There is a manual explaining how to use the application or a menu for help	30
The application supports the display adjustments according to users' needs, such as selecting the size of the text, choosing to display things that the user is interested in, etc.	3
Users have a communication channel between the user group and the health consultant	3
Users can propose opinions about the application to the developer	30
The application provides health benefits to users	30
Users want to use the application continuously at least once a week	17
Users are willing to purchase if the application has cost	2
Users want to recommend others to use the application	28
Users are satisfied using the application	30
Content in the application corresponds to the usefulness of the application	30
Stated about improvements to let users know the application is up to date	28
The application has an interesting form of information presentation	30
The application's menu and icon layout are well-positioned	30
The font size used can be clearly seen	30
Users can send data from the application via e-mail, bluetooth, etc.	0
The application can save usage information for future use	1
The application can report the results to users	30
The application can forward data for continuous use to other devices	1
The application supports offline use	29
The application works as fast as the user needs	30
The application provides functionality that is sufficient to meet the user's health needs	26
The application provides functionalities following the application's benefits	30
Users do not encounter any technical problems with running the application	30
Users enjoy using the application	30
The application prompts users to access or follow the instructions	2
There are no ads inserted during the use of the application	30
The application does not disturb users' private time	29

3.2 Usability risk assessment

The usability risk assessment section contains nine questions. The average score was 6.63, equal to 73.70%. There were five questions that Check4Safety received the full mark. The two low-rated questions had scores not more than three. There was one question that presented an assessment score of sixteen as shown in **Table 15**.

Table 15 Check4Safety's evaluation score in the usability risk assessment section

Question	Score
The content of the application contains references to research work or healthcare professionals	28
Healthcare professionals are involved in the development of the application	30
The application development funding sources are identified	30
The application is certified by government agencies	2
The application does not contain content inviting you to purchase medicines, health products, or healthcare services	30
The application has a privacy policy notification in Thai	16
The application informs users that their information will be kept confidential	30
Users can set a password for accessing the application and information	3
The application informs users that their information will not be used for commercial purposes	30

Users suggest additional points to improve the Check4Safety. They preferred the application to be able to record and forward the dietary supplement review data through different channels. They also suggested that it would be helpful if the Check4Safety could pass information of suspicious dietary supplements into a state audit system without identifying the sender.

Another interesting issue, which confirmed the validity of Check4Safety's result, was the validity of the testing results that Check4Safety provided when testing against another dataset. Therefore, the dangerous dietary supplements during

2019-2021 from the website of the Food and Drug Administration were collected. A total of twenty-four unsafe dietary supplements were found, and seven products were reported for the confirmation of hazardous contaminants. Seven products confirmed harmful contaminants were tested using Check4Safety. The test results showed that they were suspicious products, which all results were correct.

CHAPTER 5

Discussion

This study has two main objectives consist of the identification variables that influence the safe decision of consumers in dietary supplement consumption and the development of an online tool for supporting dietary supplement decisions for consumers. Therefore, this chapter discusses issues of study findings.

5.1 Identification of influence variables toward the safe decision to consume dietary supplements

Identification of variables that influence the safe decision of consumers in dietary supplement consumption consists of two parts: finding the situations and opinions of stakeholders on the issues and data analysis to identify the factors affecting the safe decision making of dietary supplement consumption.

Attitudes and experiences of stakeholders towards dietary supplement use in Thailand were intended to identify the method to solve problems appropriate to the current context of Thai society. In this section, The interesting points were found as follows. The health product problems grew due to the government sector not working thoroughly. The public sector has a high demand for consumption with insufficient safety capability. This information is consistent with the study of health product consumption behavior of Thai consumers by the Institute for Population and Social Research, Mahidol University in 2016. Which states that the works on consumer protection concerning public health products are limited in terms of personnel, budget, and technology. The private sector, both consumers and entrepreneurs, have trading needs that are not matched with knowledge of safety (52).

Problematic health products on social commerce were divided into three groups according to the purposes of use composing of beauty products, sexual enhancement products, and panacea products. This concept corresponds to the interview with the state authorities who have more than fifteen years of experience in handling health product complaints. Besides, this classification of health products is consistent with the classification according to the intended use from the announcement of the Food and Drug Administration (7).

All key informants have agreed that products for beauty were the most problematic product group, which encountered the highest proportion of complaints and serious health effects as well. According to the latest three-year reports of health product complaints and news about the impacts of dietary supplement consumption, according to various media, beauty products have a greater number of complaints than any other groups of dietary supplements. (16,24,25).

Each group of stakeholders has focused on the problems from different perspectives according to their needs and roles. Consumers were interested in the desired results from taking dietary supplements the most. State authorities paid attention to actions that affect safety consumption because it is their responsibility.

Stakeholders recognized that problem-solving was the responsibility of other stakeholders. Different perspectives of stakeholders made the operations of them not meet the needs of others. This was also the cause of negative attitudes towards each other. However, the consumer was the target group as all sectors expected that they should have the ability to consume dietary supplements safely themselves.

Risk perception channels included consumer experience, word of mouth, various public media, and survey data. Stakeholders had different recognition

methods to perceive the risks. Nevertheless, they had the same realization of the problems as well. The direct experience best reflected the risks to the consumer's problems. However, most consumers revealed their experiences with acquaintances. A few consumers reviewed the problems through public media and they would complain after they were severely affected as reported in the complaint guide (people's version) by the Food and Drug Administration (34). From the behavior of consumers mentioned above, entrepreneurs might not recognize the problems. Although they perceived the risks, they may ignore them because they did not affect them. The government did not receive comprehensive information. In consequence, they cannot manage the problem risks effectively.

Consumers had strategies to manage the risks by learning from their own experiences. They tried to make a safe decision based on uncertain information. Consumers' efforted to protect themselves. Their consumption of dietary supplements showed that they did not surrender to the safety limitations. They have the potential to protect themselves by developing habits. Nowadays, most of the consumer potential development was the responsibility of the government. On the other hand, a report by the Electronic Transactions Development Agency in 2017 presented that the consumer education by the government was not thoroughly public, the methods of providing knowledge were not interesting and the contents cannot be applied in real situations as well (53).

Schiffman and Kanuk's consumption process model presents that consumption steps consist of three interrelated phases: input stage, process stage, and output stage (25). Applying this consumer behavior theory with the dietary supplement problem found that the input stage contains product information issues, advertisement issues,

and quality control issues. The government has limitations on the works of protecting the safety of dietary supplements. The process stage contains attitude issues, social value issues, and knowledge issues. Consumers do not have sufficient safety knowledge to deal with problem situations but their ability can be improved. Changing social values in dietary supplement consumption is difficult. Building public knowledge for safe consumption is essential, but it will take time. So the knowledge-building cannot yield results in a short time. However, the safety of consuming dietary supplements cannot be delayed.

Therefore, developing a tool to support decision-making for consumers is the most convenient, active, accessible, and relevant solution for the current situation. The tool provides useful information based on credible academic evidence, enabling consumers to make safe decisions on dietary supplement consumption. However, the knowledge of consumers to protect their safety, the strong work of the public sector, and the entrepreneur's choice of safe products for sale are common responsibilities to ensure public safety in the consumption of dietary supplements.

The next step of the study was to investigate the factors that influence the safe selection of dietary supplements, which included the analysis of data related to the consumption of dietary supplements and the analysis of consumer opinions. This section aims to identify the factors contributing to the safe selection of dietary supplements for further development of a tool.

Firstly, data analysis of 38 expected variables of dietary supplements. The dietary supplement consumption related variables were divided into three groups. The variables associated with a product were the largest group. Both safe and dangerous products have been found the product names boasted one-third of their properties.

This is because the name of the product is memorable and can grab the attention of consumers. The name of the product also affects how consumers feel about the product as well. This information is consistent with the study named “The effects of extrinsic product cues on consumers' perceptions of quality, sacrifice, and value” states that the appearance, whether it be the name of the product, the packaging, or others, all influence the opinion of consumers about the product. Consequently, naming conveys the strength of a product is widely used to add a positive impression of the product on consumers (54).

Most safe and dangerous products showed the food serial number on the label. But only 85.94% and 54.69% of those numbers in the safe and dangerous product group were correct. The food serial number is required by law to represent the quality control of dietary supplements (5). Dietary supplements that are not properly registered, display a counterfeit food serial number to establish credibility. Therefore, considering the food serial number may not always confirm the reliability of a product.

Safe products were often found to show other quality symbols on the label. For example, the Food Safety symbol, GMP symbol, ISO symbol, HACCP symbol, or Halal symbol. The manufacturing date and expiration date were shown on the safe product label mostly, while only half of the dangerous product labels shown them. Showing a lot number, manufacturer information, and distributor information on labels had a higher proportion in the safe product group than another group.

An indication on the label was hardly found from both groups of products and all the indications that have been found were illegal. Standard warnings and other

beneficial warnings were found on the label of safe products in a greater proportion than dangerous products.

The variables involved in the trading process consist of three issues: advertising, selling price, and promotion. Both product groups were found to be exaggerated with the most ads in text format. However, advertising in image form and advertising with presenters were also found. Safe products used presenters more than dangerous products twice. Therefore, an advertising model may not be used to determine the reliability of a dietary supplement either. There was no statistically significant difference in the selling prices of both product groups. The promotion of the safe product group was found more than the dangerous product group as well. Consequently, considering selling prices or promotional arrangements may not be the difference between safe and dangerous products.

There was almost no difference in the variables associated with the vendors of the two product groups. Except for the customer message responding that the safe product seller responded higher than the dangerous product seller.

The data analysis for this study used a variety of statistics to find the most reliable and accurate decision support model. In addition, the analysis results from the different statistics also confirmed the validity of the conclusions as well. However, the data analysis method by decision tree creation can identify significant variables and the sequence to consider them finally.

Association rule discovery is the data analysis method to identify relationships within a product group. Incidents were always found within the safe product group including showing manufacturing and expiration date on the label and displaying manufacturer and distributor information. Incidents were always found within the

dangerous product group including the dosage form was not a tablet, the indication was invalid, the food serial number was shown on the label, and these products came from a store that was not registered in the e-marketplace system. The events listed in the rules corresponded with the statistical information of the variables described above.

Data analysis using the Chi-square test and the Fisher's exact test at 95% confidence interval found that nineteen out of thirty-eight variables had a statistically significant difference between the two product groups. ten of the nineteen variables had a p-value less than 0.01. These variables were strongly significantly different.

The determination of the variables affecting the safety of dietary supplements using PCA. Which was obtained by considering the principal factor plot together with the PC1 principal factors bar chart. The dot distribution of the principal factor plot showed that the PC1 cut points can use to separate the product classification. Therefore, this method had acquired seven groups of variables. Which was further analyzed in the decision tree creation part.

Decision tree creation was used to find methods for determining the safety of dietary supplements from the nine data sets. The selection of various statistics in the consideration of the data can confirm the results and make the conclusions more reliable. Prediction accuracy and tree size were examined for optimal decision tree selection. Finally, the tree with seven variable considerations gave the highest prediction accuracy at 92.3077%. The seven variables identified in the decision tree were found in all statistical data analysis methods. So it was shown that these variables influence the classification of dietary supplements' safety.

The Food and Drug Administration of Thailand provided advice for the safe consumption of dietary supplements, including observing unsafe health products and how to inspect them. They noted that unsafe health products were frequently exaggerated by advertising, repeated advertisements, and large reviews. Therefore, the three steps in determining a health product consist of analyzing reality and exaggeration from the data obtained, reading the label carefully, and noting the food serial number. The problems are consumers do not know what to consider about the true information, how to read the label carefully, and is it enough to just observe the food serial number. The study showed that safe and dangerous products had no different advertising exaggerations. Dangerous products were advertised in more text formats. While safe products had more advertising presenters. There were no differences in showing the food serial numbers on the labels of the two product groups as well. The food serial number validation found that 85.94% of the numbers from safe products and 54.69% of the numbers from dangerous products were accurate. Consequently, the consideration of exaggerating advertising and displaying the food serial number on the label as recommended by the Food and Drug Administration is not sufficient to support the decision to consume dietary supplements safely.

The seven variables that influenced the safety of dietary safety considerations in this study were consistent with the Food and Drug Administration's recommendations for health products consideration and standards for displaying information on labels under the Food Act B.E. 2522. Moreover, the study identified methods for determining each variable with a clear scheme and sequence the consideration based on the decision tree. This approach reduces the confusion among

consumers when considering dietary supplements and more tangibly than conventional considerations.

Secondly, analysis of consumer opinions using sentiment analysis. This part is divided into two sections according to the data: product rating and product reviews. The product ratings towards safe and dangerous product groups were not significantly different. Nevertheless, the average product rating in the safe product group was higher and the SD value was lower than the dangerous product group. This data showed less variation in consumer satisfaction with the safe product group than the other group.

The analysis of product reviews based on aspect groups found that the aspects from the safe and dangerous product groups were significantly different. Consumers paid attention to the product aspect the most, which was expressed as a higher percentage of product aspect than other aspects. The proportion of reviews about product aspect from safe products was greater than dangerous products. However, the differences in proportions of reviews in price, place, and promotion aspects between both groups of products were not that much.

The product aspect subgroup showed that approximately thirty-five percent of consumers expressed an opinion on the product overview, which cannot convey the specific details. The results of using the product were the point that consumers were interested most in this aspect. The dangerous product group accounted for up to forty percent of this subgroup, possibly as a result of hazardous substances adulteration in formulations. The adverse effects subgroup was found a high proportion in the dangerous product group than the safe product group. This showed the tendency of adverse effects caused by dangerous products that were greater than safe products.

Consumers referred to the continued consumption of safe products rather than dangerous products. Consumers mentioned general services and product characteristics of safe products more than dangerous products. Providing information services was very important for dietary supplement consumption because receiving complete and accurate information can reduce the health risks that may occur to consumers. But from the product reviews, this issue was rarely found.

The price aspect subgroup showed that consumers paid more attention to product prices than others. Reviews of safe products mentioned the value of the product more than twice of reviews of dangerous products. While shipping costs were rarely discussed, e-marketplaces likely offered regular discounts on shipping.

The place aspect subgroup showed that the proportion of reviews about delivery by seller was the most. In this subgroup, consumers provided opinions about the express of delivery and the variety of shipping service providers that the seller offers to them. Reviews on product preparation subgroup had information about strong packaging and preventing goods from damage during transportation.

Information about the promotion aspect was found very little during the study period. If there is a longer period of study and additional examples are available, the discussion on this issue may be more clear.

Data security was an issue that consumers should not overlook when consuming any products online. But according to the reviews that were collected, no comment related to this point. Therefore, raising awareness of the precautions about online information increases the safety of consumers.

The analysis of product reviews based on polarities found that the polarities from the safe and dangerous product groups were significantly different. Consumers

tend to present more positive reviews than negative and neutral reviews. Therefore, positive reviews were found in two-thirds of all reviews. The proportions of negative and neutral reviews difference between both groups of products. The dangerous product group found more negative reviews than the safe product group. This suggested that consumers have more negative experiences toward dangerous products than safe products.

The analysis of product reviews based on aspect groups with polarities showed consistent results from both previous analyses. Positive reviews were most commonly found in all aspects. Negative reviews were found in the product aspect of dangerous products greater than safe products. While neutral reviews were found in the place aspect of safe products more than dangerous products. Consumers had a positive attitude towards the price aspect of dangerous products (100.00%). They were satisfied that the products in this group are cheap, providing satisfactory results, and good services. The information about the promotion aspect was low. It may be that the number of samples was too small and the data collection period was short.

5.2 Development of an online tool for supporting dietary supplement decisions for consumers

The development of an online decision support tool began with finding information about a suitable tool model. An online tool should be a tool that users can access easily without any limitation of the operating system and low cost of development and maintenance. Web application technology was eventually chosen as a format for the development of an online decision support tool in this study.

The researcher created the application storyboard by applying a processing model from the decision tree, a result of the previous study, under the guidance of the

technology expert. Then the storyboard was offered to consumers, a state authority, and a technology expert to compile proposals for a more complete storyboard before being used as a prototype to build an application.

They agreed to name this application the Check4Safety. They considered that the Check4Safety is a concise and meaningful name corresponding to the purpose of use.

Three proposals were summarized to improve the storyboard. Firstly, colors affect the feel of the user. Consumers reflected how they feel about colors in different parts of the application. The blue color of the background has been brightened to grab the user's attention and gave a feeling of freshness and relaxation during use. The color of the button to verify the reliability of dietary supplements has been changed from green to dark blue because the consumers said that green gives the impression that the product being reviewed is safe.

Secondly, some of the texts in the storyboard have been adjusted for consistent understanding between the tool developer and the users. It also reduced the discrepancies that may arise from the use of written language.

Lastly, adding a description about filling information where the user can retrieve while filling them can reduce fill-in errors and make the inspection results more accurate. Hence, explanations of how to fill in each question have been added to the fill-in page in the form of a pop-up message. This display format is space-saving and the fill-in page is still shown as a single page for ease of use as before.

The adjusted storyboard was used as a prototype to create the tool. The Check4Safety was developed by Veu.js and tested on iOS and Android operating systems. The display discrepancy between the two operating systems was corrected.

Finally, the Check4Safety dietary supplement decision support tool was complete for use and evaluation.

The Check4Safety evaluation by the THARS showed that the Check4Safety is a functional health application with an average score of 28.27 (74.39%). The THARS consists of two assessment sections that have different measurement objectives. The first section was a measure of the general usage of an application and the second section measured the risks associated with the use of an application. The Check4Safety received the average percentage of scores in both sections as 74.60% and 73.70%, respectively.

The general quality assessment results were performed that users were satisfied using the Check4Safety and this application provided health benefits to them. The application function was consistent with the purposes of use and the needs of users. The language used was easy to understand. Moreover, the Check4Safety had a nice display format consisting of easy to read text size, well-positioned menu and icon layout, and interesting form of information presentation. The manual explained how to operate the Check4Safety in detail, so users can use it by themselves. The Check4Safety provided immediate responses to user inspections of dietary supplements. Users did not encounter any technical problems. They also could not find any interstitial advertising during use. Therefore, they enjoy using the Check4Safety and will recommend this application to others. Half of the users indicated that they would use the Check4Safety at least once a week. This frequency may be consistent with their dietary supplement consumption habits.

The general quality assessment section found issues that the Check4Safety should be improved. Adjusting the display style of the application, such as text size or

color, will make the display format meet the needs of users. Saving and forwarding data across channels or the ability of the application to use in multiple devices will expand the application's usability. Creating a communication channel between users and health consultants will help provide more information about dietary supplement consumption.

The usability risk assessment results showed that the Check4Safety was developed with research-based support and developed by healthcare professionals. Therefore users can be sure that the information displayed on this application was on an academic basis. The funding source for application development was clearly stated by Silpakorn University, an educational institution. Application data security clarification indicated that the information of users will be kept confidential and their information will not be used for commercial purposes. The Check4Safety did not contain any content inviting users to purchase medicines, health products, or healthcare services.

Suggestions for improving the Check4Safety based on the usability risk assessment. Certification of the application by government organizations will make the application more reliable. The ability to set up a username and password to access data in the application will provide user data more secure.

5.3 Strengths and limitations of the study

Strengths of the study

This study began with searching for gaps in the problem of dietary supplement consumption in Thailand based on literature reviews and in-depth interviews with the stakeholders. Therefore, it obtained comprehensive information in all dimensions, both theoretical and real situations of the problems. The conclusion to create a

decision-support tool for consumers to select dietary supplements safely is a fast, situational, and potential solution.

The factor identification contributing to the safe selection of dietary supplements was obtained through an analysis of consumer-related data, product information, information about the trading process, information about the entrepreneurs, and opinions of other consumers. A variety of statistical analysis methods that provide consistent analysis results make the conclusions of identifying the factors contributing to the safe selection of dietary supplements are reliable. Identifying the hierarchy of data consideration from a decision tree was another highlight of this study. As historical data and studies only identified factors that affect product reliability, it does not specify the order in which those data were considered. Therefore, this study is the first to clearly show both factors and stages of consideration to predict the safety of dietary supplements.

The decision tree of the study was used as the processing structure to developed a readily available online tool. Consequently, Check4Safety is the first Thai interactive online tool created to support decisions of dietary supplement consumption for consumers.

Limitations of the study

This study has the following limitations. In the first phase of the study to identify factors affecting the safe selection of dietary supplements, the limitations were the variety of dietary supplements. The reference products to distinguish a group of dietary supplements were based on health product contamination test reports, which may not cover all commercially available dietary supplements in Thailand. The data were collected from e-marketplace systems. Therefore, incomplete information

must be omitted as it was difficult to fulfill. During the study, the new law to regulate the herbal product was announced. Therefore, some products in the study were also overlapping under this Act, but the researcher didn't consider separately this issue.

Studying consumer opinions of dietary supplements using the sentiment analyse technique was limited to data collection. The product reviews included in the study were in text form. These can only indicate verbal information. However, this information cannot explain the opinions of consumers in any other dimension. The data collection period was three months and the samples were selected from the reference report which may not cover all available products.

The second phase of the study is the development of an online tool, there are technical and budget constraints. Check4Safety was developed by the researcher, who not an expert in creating applications. Therefore, creating some complex functions is beyond the capabilities of the researcher. This web application works on a backup area, which is free. If other functionalities will be developed in the future, developers should consider purchasing backup space for stable operation.

CHAPTER 6

Conclusions and Recommendations

This study was conducted to identify variables that influence the safe decision of consumers in dietary supplements consuming and develop an online tool for supporting dietary supplement decisions for consumers. This chapter summarized the findings based on the study phase. The findings of Phase I consist of the factors predicting the safe dietary supplements and consumers' feelings toward safe and dangerous dietary supplement consumptions. In Phase II, the online tool development process was concluded. Finally, the evaluation of a decision support tool was established.

Presently, a dietary supplement is one of the problematic health products. The impact of dietary supplement consumption is a problem that society should be concern about. These problems intensify although various solutions have been applied. Perspectives of stakeholders were collected by an in-depth interview to summarize the situations and problem-solving concepts that are suitable for the Thai context. The three findings were found.

Firstly, stakeholders have a different perspective on dietary supplement problems and management. The beauty product is the most problematic product group. Consumers pay the greatest attention to the expected results from consuming dietary supplements. They recognize the risks of consuming dietary supplements but they are willing to accept in return for the desired outcome. State authorities pay attention to illegal advertisings and health effects on consumers that cannot be treated. However, they are not capable enough to act proactively on those issues.

Entrepreneurs focus on sales and reputation. Each stakeholder recognizes that problem-solving is the responsibility of other stakeholders.

Secondly, stakeholders perceive the risks of the problems with different recognition methods, such as consumer experience, word of mouth, various public media, and survey data.

Thirdly, consumers manage the risks with different approaches. They deal with the risks based on the information they can access without knowing that the information is true or false. They try to protect themselves by learning from their personal experiences. Moreover, consumers do not succumb to any restrictions. They are still trying to protect their safety in ways that can be done. Therefore, it can be concluded that the development of consumer potential to protect themselves from unsafe health product consumption is a suitable problem-solving concept for the current situation of Thailand. This brings us to the concept of tool development. Finding the factors that determine the safe selection of dietary supplements was studied.

A study of consumer attitudes about dietary supplements based on the marketing mix theory by the sentiment analysis techniques was applied. The consumption behavior of dietary supplements among Thai consumers presented that they pay great attention to the expected results of the products. The price of products has taken precedence over their value and other costs. Providing great shipping services and offering shipping service providers that consumers can choose themselves promote satisfaction. Considerations of product ratings and product reviews indicate the trend of other consumers' attitudes about the products. But these cannot be used to screen safe or dangerous products from many commercially

available products. Consumers should not pay attention to opinions from other consumers without carefully considering any other information. Therefore, deliberation of all dietary supplement information has become a necessity for consumers to make safe consumption decisions.

Subsequently, information related to the consumption of dietary supplements was studied. In this part, we discovered groups of variables that influence the safety of dietary supplements using various statistical methods. Finally, all 7 variables and the order of consideration were identified by the decision tree that provided the 92.3077% accuracy of the dietary supplement's safety prediction. A group of 7 variables consists of the accuracy of manufacturer information, showing expiration date, showing lot number, showing extra caution, showing distributor information, the accuracy of component format, and showing 3 standard cautions. The clearly defined variables and sequences for considering dietary supplements were the hallmarks of this study and the processing structure of an online tool.

After the online tool processing structure was completed, the tool design began by creating a storyboard. Then the Storyboard was presented to the stakeholders to make it more relevant to the user's needs. Consumers offered feedback on the tool's display style and caution about the use of meaningful colors in different display segments. The state authority presented issues to collect information about dietary supplements from consumer searches for future proactive actions such as collecting product names, images, and trading locations. The technological expert provided advice on suitable online tool creation schemes and the possibility of developing the capabilities of the tool according to the needs of the user. They all agreed with the name of the online tool the Check4Safety. The storyboard was

adjusted based on the recommendations of the stakeholders. After that, the Check4Safety was created using the web application technology and tested on iOS and Android operating systems. Finally, the Check4Safety was ready for assessment.

The Check4Safety use evaluation by the THARS had an average score of 28.27 (74.39%). The rating range was 23-35 points (SD=2.16). It showed that the Check4Safety is a functional health application. The average scores of general quality assessment and usability risk assessment parts were 74.60% and 73.70% respectively. Users were satisfied using the Check4Safety because this application provided health benefits. This application had a suitable format to display the information and proper data security. Therefore, the Check4Safety is an online tool that can be used to support safe decision making to consume dietary supplements.

Recommendations

Recommendations for consumers

Consumers should put their safety first. Dangerous dietary supplements are still widely available and difficult to control. Therefore, researching carefully before deciding to purchase any dietary supplement is one method to secure the consumption and preventing potential adverse effects.

Recommendations for state authorities

Quality control of post-market products is a weak point of consumer protection in Thailand. Along with the limited government personnel, the problem of dietary supplements remains a public risk. The government sector should use technology to support efficient work. For example surveys of suspicious products based on keyword recognition, the use of Artificial Intelligence (AI) scanning

products’ information in online marketplaces, others. These technologies work with precision and reduce the limitations the limit on the number of officers.

Recommendations for entrepreneurs

The responsibility of the entrepreneurs greatly affects the safety of consumers, so it is important to inspect a product before selling it.

Further Research

Check4Safety is a tool that can be developed follows by the changing of technology trends and this tool will benefit consumers and consumer protection systems in the future. Check4Safety's capabilities should be developed in the field of data collection of consumer search about any dietary supplement products and reporting about consumption risks to the government. These recommendations will be beneficial to further proactive consumer protection.

REFERENCES

1. Department of Health Advisory Office, Ministry of Public Health. The 8th national economic and social development plan (1997 - 2001) [Internet]. [cited 2018 Jun 17]. Available from: http://advisor.anamai.moph.go.th/main.php?filename=plan1

2. Onpromme S. The important development of health promotion. 1st ed. Bangkok: Thana Press; 2013.

3. Food Industry Intelligence Center of Thailand. Market share of dietary supplements in Thailand [Internet]. 2016 [cited 2020 Dec 25]. Available from: http://fic.nfi.or.th/FoodMarketShareInThailandDetail.php?id=248

4. Benjawan S. The perspective of stakeholders towards the problems and solutions of health products available through social commerce in Thailand. Int J Manag Appl Sci. 2019;5(8):88–92.

5. Ministry of Public Health. Food Act B.E. 2522, with ministerial regulations and Ministry of Public Health announcements revised, B.E. 2562. Bangkok, Thailand; 2019. 369 p.

6. Detpraphatsorn N. Factors influencing decision to buy dietary supplements on the internet. Thammasat University; 2015.

7. The Food and Drug Administration. Announcements and news [Internet]. 2018. Available from: http://www.fda.moph.go.th/Pages/HomeP_D1.aspx

8. Siro I, Kapolna E, Kápolna B, Lugasi A. Functional food. Product development, marketing, and consumer acceptance—A review. appetite. 2008 Jul 1;51:456–67.

9. Bolotaeva V, Cata T. Marketing Opportunities with social networks. J Internet Soc Netw Virtual Communities. 2011 Jun 1;1–8.

10. Kamrath C, Bidkar S, Bröring S. Involvement and purchasing motives of dietary supplements: A consumer study from Germany. PharmaNutrition. 2019;

11. The Food and Drug Administration. Food and drug administration news [Internet]. 2020. Available from: https://www.fda.moph.go.th/SitePages/AllNews.aspx

12 Wahab MSA, Sakthong P, Winit-Watjana W. Qualitative exploration of pharmacist care for herbal and dietary supplement users in Thai community pharmacies. J Pharm Heal Serv Res [Internet]. 2019 Mar 1;10(1):57–66. Available from: https://doi.org/10.1111/jphs.12238

13. Products Complaint and Suppression Center for Health. 2020 Complaint action results. 2020.

14. Eliason BC, Kruger J, Mark D, Rasmann DN. Dietary supplement users: demographics, product use, and medical system interaction. J Am Board Fam Med. 1997;10:265–71.

15. Department of Medical Sciences, Ministry of Public Health. The health product contamination examination report. 2020.

16. Ministry of Public Health. Report of the complaint management regarding health products 2019. Bangkok; 2019.

17. Wangcharoen W, Amornlerdpison D, Mengumphan K. Factors influencing dietary supplement consumption: a case study in Chiang Mai, Thailand. Maejo Int J Sci Technol. 2013;7(1):155.

18. Songsin S. The prevalence of food products that illegally claim their properties on the label in Loei Province flea markets. Thai J Pharm Pract. 2019;11(1):151–9.

19. Karnwareetip S, Surawichai A, Ruanta Y. Health consumer protection officers' perspective toward the problems and the mechanism of consumer protection involving health products in upper northern Thailand. Mahidol Univ J Pharm Sci. 2016;43(2):63–7.

20. DeLorme DE, Huh J, Reid LN, An S. Dietary supplement advertising in the US. Int J Advert [Internet]. 2012 Jan 1;31(3):547–77. Available from: https://doi.org/10.2501/IJA-31-3-547-577

21. Ng JY, Zhang CJ, Ahmed S. Dietary and herbal supplements for fatigue: A quality assessment of online consumer health information. Integr Med Res [Internet]. 2021;10(4):100749. Available from: https://www.sciencedirect.com/science/article/pii/S2213422021000366

22. Caswell JA, Mojduszka EM. Using informational labeling to influence the market for quality in food products. Am J Agric Econ [Internet]. 1996 Aug 5;78(5):1248–53. Available from: http://www.jstor.org/stable/1243501

23. Chotthitaporn N, Klaewkla J, Sompopcharoen M. Factors affecting to purchasing decision on dietary supplement products for beauty through internet among professional nurses. Thai Red Cross Nurs J. 2019;12(2):151–64.

24. Ministry of Public Health. Report of the complaint management regarding health products 2018. Bangkok; 2018.

25. Ministry of Public Health. Report of the complaint management regarding health products 2020. Bangkok; 2020.

26. Brown A. An overview of herb and dietary supplement efficacy, safety and government regulations in the United States with suggested improvements. Part 1 of 5 series. Food Chem Toxicol. 2016 Nov 1;107.

27. Ministry of Public Health. Warning for suppliers of dietary supplements the Magic Skins brand is guilty. 2018.

28. Ministry of Public Health. Don't be fooled by food products, diet claims, and cosmetics, exaggerating online media advertising. 2018.

29. Ministry of Public Health. Herbal Products Act B.E. 2562. 2019;

30. Nations F and AO of the U. General standard for the labeling of pre-packaged foods-CODEX STAN 1-1985 (Rev. 1-1991) [Internet]. 2018. Available from: http://www.fao.org/docrep/005/Y2770E/y2770e02.htm

31. Petroczi A, Taylor G, Naughton DP. Mission impossible? Regulatory and enforcement issues to ensure safety of dietary supplements. Food Chem Toxicol. 2011;

32. Harnett JE, Ung COL, Hu H, Sultani M, Desselle SP. Advancing the pharmacist's role in promoting the appropriate and safe use of dietary supplements. Complement Ther Med [Internet]. 2019;44(March):174–81. Available from: https://doi.org/10.1016/j.ctim.2019.04.018

33. Office of the Permanent Secretary, Ministry of Public Health. Report of research analysis related to public health consumer protection. 1997.

34. The Food and Drug Administration. Complaint guide (people's version). 1st ed. Bangkok; 2015.

35. Teerawattananon Y, Tangcharoensathien V, Tantivess S, Mills A. Health sector regulation in Thailand: recent progress and the future agenda. Health Policy (New York). 2003;63(3):323–38.

36. Kanjanarach T, Jaisa-Ard R, Poonaovarat N. Performance of health product risk management and surveillance conducted by health personnel at sub-district health promotion hospitals in the northeast region of Thailand. Risk Manag Healthc Policy. 2014;7:189.

37. Sriviriyanupap W. The development of prioritization method for consumer protection risk management of unsafe products. Thai J Pharm Sci. 2016;40.

38. van Waterschoot W, Van den Bulte C. The 4P classification of the marketing mix revisited. J Mark [Internet]. 1992 Oct 1;56(4):83–93. Available from: https://doi.org/10.1177/002224299205600407

39. Erasmus AC, Boshoff E, Rousseau GG. Consumer decision-making models within the discipline of consumer science: a critical approach. J Consum Sci. 2001;29.

40. Liu Y, Bi J-W, Fan Z-P. Ranking products through online reviews: a method based on sentiment analysis technique and intuitionistic fuzzy set theory. Inf Fusion. 2017 Jul 1;36:149–61.

41. Jolliffe IT, Cadima J. Principal component analysis: a review and recent developments. Philos Trans R Soc A Math Phys Eng Sci. 2016;374(2065):20150202.

42. Horel JD. Complex principal component analysis: theory and examples. J Clim Appl Meteorol [Internet]. 1984 Dec 1;23(12):1660–73. Available from: https://doi.org/10.1175/1520-0450(1984)023%3C1660:CPCATA%3E2.0.CO

43. Kolenikov S, Angeles G. The use of discrete data in PCA: theory, simulations, and applications to socioeconomic indices. Chapel Hill Carolina Popul Center, Univ North Carolina. 2004;20:1–59.

44. Athey S, Imbens GW. Machine learning methods that economists should know about. Annu Rev Econom. 2019;11:685–725.

45. Zheng Z, Kohavi R, Mason L. Real-world performance of association rule algorithms. In: Proceedings of the seventh ACM SIGKDD international conference on Knowledge discovery and data mining. 2001. p. 401–6.

46. Bhargava N, Sharma G, Bhargava R, Mathuria M. Decision tree analysis on j48 algorithm for data mining. Proc Int J Adv Res Comput Sci Softw Eng. 2013;3(6).

47. Singhal S, Jena M. A study on WEKA tool for data preprocessing, classification and clustering. Int J Innov Technol Explore Eng. 2013;2(6): 250–3.

48. Tomas S-. The use of PSPP software in learning statistics. Eur J Educ Res. 2019;8(4):1127–36.

49. Jazayeri M. Some trends in web application development. In: Future of Software Engineering (FOSE'07). IEEE; 2007. p. 199–213.

50. Nelson B. Getting to know Vue. js. Springer; 2018.

51. Hongsanun W. Development of the Thai Mobile Health Apps Rating Scale (THARS). Thai J Pharm Pract. 2019;1(1):182–93.

52. Institute for Population and Social Research, Mahidol University. Complimentary report of the research project on factors affecting the behavior change in health product consumption. 2016.

53. Electronic Transactions Development Agency (Public Organization), Ministry of Digital Economy and Society. Thailand Internet User Profile 2017. 2017.

54. Teas RK, Agarwal S. The effects of extrinsic product cues on consumers' perceptions of quality, sacrifice, and value. J Acad Mark Sci. 2000;28(2): 278–90.

VITA

NAME	Miss Sirikanlaya Benjawan
DATE OF BIRTH	28 April 1987
PLACE OF BIRTH	Nakhon Pathom, Thailand
INSTITUTIONS ATTENDED	- Bachelor of Pharmacy, Faculty of Pharmacy, Silpakorn University - Master of Pharmacy Informatics, Faculty of Pharmacy, Silpakorn University
HOME ADDRESS	83/1 M.6 Boophlub, Muang, Nakhon Pathom, Thailand 73000