FORMULATION OF KIMCHI FROM CHINESE MUSTARD (Juncea (L.). Czern)

BY
NATTHAWAT PRAKITIPONG
ID. 4716220

special project submitted to the Faculty of Biotechnology, Assumption University
in part fulfillment of the requirements for the degree of Bachelor of Science
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Title	: Formulation of kimchi from Chinese mustard (Juncea (L.) Czern)
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Abstract

The project aimed to develop new product from Chinese mustard by making kimchi, one of the famous Korea fermented foods around the world. Local herbs and spices in Thai were selected. This is an opportunity of Thai food producer to produce Kimchi which their taste and flavor for Thai people. The development of Chinese mustard Kimchi was divided into 6 experiments which starting from screening the three Kimchi formulas. First, the 1st Formula was chosen form three Kimchi formulas as a basic formula in this project. Second, Chinese cabbage and Chinese mustard were tested by varying 10 % and 15 % spices content and 5% and 10% cayenne pepper and evaluated by sensory evaluation. Chinese cabbage with 10 % spices was more accepted than 15 % spices. Tested panelists preferred less spices flavor. But Chinese mustard with 15 % spices had less bitterness than 10% spices because strong spice flavor masks bitterness and greeny flavor. Third, two types of chili were selected and varied into two samples, (1) 50% Cayenne pepper and (2) 25% cayenne and 25% bell pepper. Both cayenne and bell chili pepper provided reddish color and accepted by panelists. Forth, this experiment aimed to reduce bitterness and greeny flavor before studying the prototype formula of Chinese mustard Kimchi by varying salt content and soaking time of Chinese mustard. Chinese mustard which mixed with 10 % salt for 6 hrs could reduce bitterness and greeny odor and moderately saltiness. Fifth, Chinese mustard used as raw materials instead of Chinese was soaked with salt for 6 hr and varied types and amount of chili peppers in the ratio of Chinese cabbages and Chinese mustard from 100:0, 25:75, 50:50, 75:25 and 0:100, respectively. There was significant difference only in color attribute ($p<0.05$). Tested panelists preferred color from Bell pepper more than other samples. However, Panelists preferred 37.5% Bell pepper and 12.5 % more than other samples in other attributes. The last experiment, amount of garlic was varied from 9%, 12% and 15%, respectievly. There was significant difference only in sourness attribute ($p<0.05$). Panelists preferred 9% garlic in Chinese mustard Kimchi.

Acknowledgement

I would like to express my sincere gratitude to my advisor, A. Pornpen P. from the Faculty of Biotechnology, Assumption University, for her enthusiasm towards my research project and her encouragement, suggestion and patience and times which make project moving forward.

Special thanks to Mr. Kitikun Jaiyen, lovely senior who supplied me the Chinese mustard and help in information finding and gave me a suggestion.

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List of Content

List of Table

List of figure

Introduction

In present day, trend of Korea culture is worldwide in life style such as movie, music, custom, food, hair style, etc. With the success of the Korean drama *Daejanggeum* or *Jewel in the Palace* around Asia countries, these also introduced Korea food and Korea lifestyle.

A traditional Korean meal consists of a bowl of rice and side dishes. Koreans use a wide arrange of ingredients such as meat, fish, vegetables and seafood with unique seasonings. As there are many ways to cook these ingredients, Koreans have developed diverse kinds of cuisines. Every Korea food shop or restaurant around the world must have kimchi as Banchan which refers to small side dishes served along with cooked rice in Korean cuisine.

Kimchi represents Korea's best known food. Koreans serve *kimchi* at almost every meal. Although kimchi just only one of the side dishes in Korea food but it has the unique characteristic in color, flavor, odor, and taste. Kimchi can simply make by anyone and get different taste in different area depend on the recipes. Kimchi also can use in main food such as Kimchi stew (kimchi jjigae) and kimchi fried rice (kimchi bokkeumbap). Kimchi is one of preservation techniques that use fermentation method.

Korean Kimchi has widely types and characteristics. Kimchi products in Thai market have few brands. This could be the chance to develop Thai kimchi to get more variety of kimchi products in Thai market also add more value of the Thai vegetable by using Chinese mustard instead of Chinese cabbages. Chinese mustard is one kind of cabbages with hard texture, greeny flavor, and bitterness. These disadvantages of vegetable are the main causes that lead to the less varieties of products. The major product is fermented or pickling Chinese mustard in can. This project aimed to develop new products by using Chinese mustard to produce Kimchi for Thai people.

Chinese mustards used to study in this project were supported by Mr. Kitikun Jaiyen, Manager of R&D Food product Co., Ltd, Ratchaburi who want to create more variety of products from Chinese mustard.

Objectives

1. Screening the basic formula of Kimchi for this project.
2. Compare Kimchi by varied cabbages types and spices content.
3. To study the prototype of Chinese cabbages Kimchi by varied types and content of spices.
4. To study the optimum salt concentration and soaking time to reduce bitterness and greeny flavor of Chinese mustard.
5. To study the prototype of Chinese mustard by varying types and content of chili peppers, and garlic content.

Literature Review

1. Kimchi

Kimchi (Figure1) is the most relished food in Korea. In Korean food culture, no other food has the importance kimchi has. For instance, a meal without kimchi is considered to be lacking in style and grace.

Rice and kimchi constitute the basic meal for Koreans; the two alone suffice as a meal, along with soy sauce, soy bean paste and red chili pepper paste, kimchi is considered to have the most unique taste representing Korea. As is supported by much research, kimchi has had its place in the history of Korean food for quite a long time, and the methods of making it vary greatly.

Kimchi was also used to judge a woman's ability to make food. There is a saying that a good wife should be able to make twelve kinds of kimchi. Korean people believed that possessing the skill of making kimchi alone would guarantee the woman's ability as a cook, so Korean woman took pains to learn how to make good kimchi.

Kimchi was created because Korean winters are cold and harsh. It was hard to find vegetables of any sort long ago, and kimchi provided Koreans with the vitamin C (Table1) that was otherwise hard to get. Moreover, the freshness of the vegetables, the refreshing tastes of the organic acids from the fermenting nutritional value.

Kimchi become international food by introducing in year 1988 Seoul Olympics and 1998 world cup. Korea exports kimchi to more than 36 nations. Average Korean consumes kimchi about 100-150 g per day. So kimchi business will grow larger and larger in the near future. (Lee Chunja, 1998)

Figure1 Kimchi (http://en.wikipedia.text-writtenorg/wiki/Kimchi)

Kimchi is a traditional Korean fermented food and made from vegetables with various types of seasonings. Mainly vegetables are Chinese cabbage, ginger, green onion, chili and garlic, etc. Kimchi is a fermented product through lactic acid production at low temperatures to

ensure proper ripening and preservation. Kimchi tastes best and contains the most vitamins and nutrition when it is fermented at 2-7°C for 2 to 3 weeks.

Kimchi served as an appetizer and used as an ingredient in cooking such as kimchi soup, kimchi with steamed or fried rice, kimchi ramen, and kimchi pancakes. Kimchi can be tossed with diced tofu and heated or eaten cold for a fast breakfast or lunch. (http://findarticles.com/p/articles/mi_m0FDE/is_2_23/ai_n6021652/pg_2?tag=artBody;col1, November, 2008)

Table1 Composition of kimchi per 100g of edible portion

Moisture content (g)	88.4
Crude protein (g)	2
Crude lipid (g)	0.6
Total sugar (g)	1.3
Crude fiber (g)	7.2
Crude ash (g)	0.5
Calcium (mg)	28
Iron (mg)	trace
Vitamin A (IU)	492
Vitamin B1 (mg)	0.03
Vitamin B2 (mg)	0.06
Vitamin C (mg)	12
Niacin (mg)	2.1

Source: Lee Chunja,1998

2. History

Back to 2600-3000 years ago, the first evidence of existence of kimchi was found in Chinese poetry book, called "**Sikyeong".** In this book, kimchi was called "Ji" then in pre-modern time change to "Chimchae" (which means "soaked vegetables"). In the period of the Three Kingdoms of Korea (57B.C.-260A.D.), it was called as "Timchae". Then word then was modified into "Jimchi", and "Kimchi".

Kimchi in ancient times: It is difficult to identify the process of development of kimchi in ancient times, as historical records of the times are barely available. Koreans simply salted vegetables in order to keep them as long as possible.

Kimchi during the Goryeo Kingdom (918 - 1392): Although there are records that clearly indicate the root of kimchi's discovery, cabbage was first mentioned in an oriental medicine book titled 'Hanyakgugeupbang'. There were two types of kimchi - *jangajji* (sliced radish preserved in soy sauce) and *sunmu sogeumjeori* (salted radish). In this period, kimchi began to receive new attention as a processed food enjoyable regardless of season as well as storage food for winter. It is suspected that the development of seasonings at that time enabled spicy

kimchi to appear.

Kimchi in the Joseon Period (1392 - 1910). It was after foreign vegetables, in particular, cabbages (brassica) were introduced and used as the main ingredient that the current type of kimchi was formed. Hot red pepper was imported to Korea from Japan in the early 17th century (after the Japanese invasion of Korea in 1592), but it took roughly 200 years until it was actively used as an ingredient in kimchi. Therefore, it was only during the late Joseon period that kimchi became associated with its red color.

Kimchi in the Royal Court of Joseon: Normally three types of kimchi- whole-cabbage kimchi (*jeotgukji*), diced-radish kimchi (*kkakdugi*) and water kimchi, were served to the kings of Joseon. Jeotgukji for a good deal of pickled fish was added to the kimchi. A cooking book of Joseon (Joseon *massangsansik yorijebeop*) explains how to make *jeotgukj*i as follows:

1. Cut well-washed cabbages and radishes into small chunks and salt them.
2. Mix them with chopped hot red pepper, garlic, dropwort (*minari*), leaf mustards (*gat*) and some seaweed.
3. Boil fermented fish in some water and cool it.
4. Add it to the above mixture.
5. Store it in a pot and wait till it is fermented.

Even if the main ingredients of water kimchi (*dongchimi*) are radish and water, more garnishes were used to enhance the taste in the royal court of Joseon. The radishes used for water kimchi should be of a wholesome shape. In addition, they should be washed and salted for a day before being stored in a jar buried under ground. There is an anecdote that King Gojong, the second last king of the Joseon Kingdom, liked cold noodles in the *dongchimi* juice mixed with some beef juice as a winter-night-meal. Hence, special water kimchi was prepared with pears, which were exclusively used for the cold noodles.

Modern Kimchi: Kimchi has been scientifically proved to be highly nutritious and has been gaining popularity both at home and abroad. In fact, kimchi exports have risen sharply over recent years. Korean immigrants to China, Russia, Hawaii and Japan first introduced kimchi abroad, and have continued to eat kimchi as a side dish. It gradually gained popularity even among foreigners. Accordingly, kimchi may be found wherever Koreans live. In America and Japan especially, where relatively many Koreans live, packaged kimchi is easily available. In the past, the production and consumption of kimchi was confined to Korean societies, but nowadays it has become a globally recognized food.
(http://www.visitkorea.or.kr/ena/CU/CU_EN_8_1_1_2_1.jsp, November, 2008)

3. Type of Kimchi

Types of kimchi differ from region to region, depending on harvest and weather conditions. Each family also has its own recipe handed down from generation to generation. The number of specific kimchi types cannot be easily counted since Korean women can make kimchi out

of practically any edible material. However, the Korean Food Academy has categorized over 100 different types.

The flavor depends on ingredients, condiments, the amount of salt, and level of spice used in each region. Korea's various regions produce different types of agricultural products, and this is reflected in each region's type of *kimchi*. The Southern provinces (North-South Cholla Provinces and North-South Kyongsang Provinces) tend to use more salt and seafood so the taste is stronger and sweeter. To the north, *kimchi* tastes less salty and is very mild.

Kimchi can categorize by ingredients types in different recipes such as radish, carrots, broccolis, apples, pears, persimmons, pine nuts, and sesame seeds. Korean kimchi also often includes raw squid, shrimp, mussels or fish.

Commonly kimchi can be divided into two major types, region and season. Regions kimchi add different raw materials and fermentation temperatures according in each area. Season kimchi divides into four season base on Korea season because different vegetables can grow in some season and effect to fermentation temperature.

3.1 Classification of Kimchi by region

3.1.1 Seoul / Kyonggi Province

Kimchi in the capital city and the surrounding region features a variety of luxurious food and delicacies since it has diverse types of agricultural and seafood products, as well as being the center of commerce for Korea.

Name of kimchi: Undried *Insam* (ginseng) *Kimchi*, *Misam Kimchi*, *Hobak Mu-u* (pumpkin radish) *Kimchi*, *Sunmu* (turnip) *Kimchi*, *Chae Kimchi*, *Baech'u Kimchi*, *Mu-u Kimchi*, *Bae Kimchi*

Figure 2 Jang kimchi in royal palace

3.1.2 North and South Ch'ungch'ong Provinces

This area located in the middle of Korean Peninsula and has a moderate rainfall and enriched soil, producing a wealth of rice, vegetables, wild herbs, and greens. These people use fewer condiments since they enjoy the mild and soft taste.

Name of kimchi: *Gul Ggaktugi* (oyster and sliced radishes), *Hobak* (pumpkin) *Kimchi*, *Shigukch'i* (spinach) *Kimchi*, *Kaji* (eggplant) *Kimchi*, *Bae Kimchi*, *Sedum Kimchi*

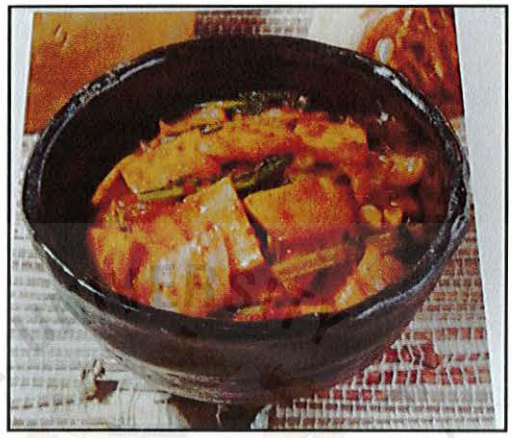


Figure 3 Pumpkin kimchi in Ch'ungch'ong Provinces

3.1.3 Kangwon Province

This area has good crop of grains and wild herbs, as well as a developed industry for seafood and processed fish products. Most of the local *kimchi* products feature seafood.

Name of kimchi: *Chanran* (fish paste and sliced radish) *kimchi*, *Sikhae*, *Ojingeo Mu-u* (squid radish) *Kimchi*

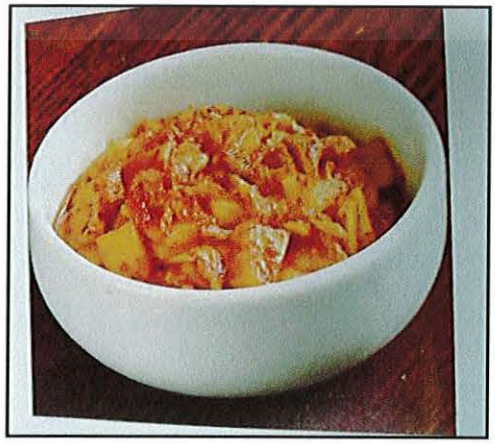


Figure 4 Kkakdugi using salted and fermented cod

3.1.4 North and South Cholla Provinces

No place in Korea has the natural source of food materials like crops, fishery, and wild vegetables more than the Cholla Provinces. The food culture here has been developed for many generations, and this area has become the homeland for traditional Korean food. This area's *kimchi* is stronger and spicier than other since it is mainly seasoned with pickled shellfish and salted anchovies.

Name of kimchi: *Baech'u Kimchi* with anchovies, *Yak* (medicine) *Kimchi*, *O-i* (cucumber) *Kimchi*, *Kaji Kimchi*, *Goguma* (sweet potato stem) *kimchi*, *Goch'u Ip'* (red pepper leaves) *Kimchi*, *Dolgat* (mustard leaf) *Kimchi*, *Goldulbagi* (Korean lettuce) *Kimchi*

Figure 5 Indian mustard kimchi in Cholla Provinces

3.1.5 North and South Kyongsang Provinces

This area located along South and West coasts, North and South Kyongsang Provinces are abundant with various types of seafood.

Name of kimchi: *K'ongnip* (bean leaf) *Kimchi*, *Ggaet'ip* (sesame leaf) *Kimchi*, *Goguma* (sweet potato stem) *Kimchi*, *Uong* (burdock) *Kimchi*, *Myeolch'i Baech'u* (cabbage with anchovies) *Kimchi*, *Manul Julgi* (garlic stem) *Kimchi*, *Gaji* (eggplant) *Kimchi*, *T'oran* (taro root) *Kimchi*, *Bak* (gourd) *Kimchi*, *Sseumbagwi* (lettuce) *Kimchi*, *Minari* (dropwort) *Kimchi*, *Gam* (parsimon) *Kimchi*, *Muumallaengi* (dried radish) *Kimchi*, *Ssuggat* (Korean lettuce) *Kimchi*

Figure 6 Wild leek kimchi in Kyongsang Provinces

3.1.6 Cheju Island

Cheju Island is located off the Southern tip of Korea, and is Korea's largest island. The area is unique and distinctive. The geographical characteristic of the island enables it to use rich and extensive seafood products to make *kimchi*.

Name of kimchi: *Jeonbok* (abalone) *kimchi*, *Haemul* (seafood) *kimchi*, *Nabak* (square cut radish) *kimchi*

Figure7 Abalon kimchi

3.1.7 Hwanghae Province (North Korea)

This area is known for its good quality of crops, fruits, and diverse kinds of seafood. The taste of the food is very mild, and the local people have a reputation for serving plenty of food.

Name of kimchi: *Naengmyeon Kyeoul Baech'u* (cold noodle winter cabbage) *Kimchi*, *Gabi* (eggplant) *Kimchi*, *Dongch'imi* (water radish)

Figure 8 Tongchimi

3.1.8 P'yongyang Province (North Korea)

P'yongyang Province has cold and long winters, and people here enjoy food made from meat, beans, and green peas to endure the long winter. The *kimchi* is mild and less salty than in other areas.

Figure 9 Cabbage kimchi and radish kimchi

3.1.9 Hamkyong Province (Northern Korea)

The *kimchi* from this area is mild, watery, and use less chili red pepper than other areas. It is also made with representative seafood products from this area.

Name of kimchi: *Dongch'imi* (water radish), *Bae* (white) *kimchi*, *Kongnamul* (bean sprout) *kimchi*, *Ssuk* (mugwort) *Kimchi*, Hamkyung Province *Daegu Ggaktugi* (cod with sliced radish)

Figure10. Water radish

(http://www.lifeinkorea.com/culture/kimchi/kimchi.cfm?xURL=types, 1998)
Picture source: (Lee chunja, 1998)

3.2 Classification of Kimchi by season

Kimchi usually consume at most of the meal. Thus kimchi production has occurred all the year. Each season have different temperatures that affect the fermentation rate. The modern kimchi use refrigerator instead which specifically designed to keep varieties of kimchi at optimal point of fermentation and extend shelf-life.

3.2.1 Spring: Vegetable grows well. This is a good time to produce the kimchi. This kimchi don't ferment for a long time and don't store for long time too. They usually consume in fresh form.

3.2.2 Summer: Radishes and cucumbers are popular more than summer vegetables so Koreans use them for extra ingredients. Brined fish or shellfish can be added and freshly ground dried chili peppers are often used.

3.3.3 Autumn: *Baechu kimchi* is the most common type of kimchi in the fall. It is prepared by inserting blended stuffing materials between layers of salted leaves of uncut in whole Chinese cabbage. This process called "*sok*". The ingredients of *sok* can vary; depend on the different regions and weather conditions. Generally, *Baechoo kimchi* used to have a strong salty flavor with a large amount of *myeolchijeot* (salted fermented dish) or *saeujeot* (salted fermented shrimp) had been used. It changed in the early of 1970s caused by *aekjeot* (Korean fish sauce) used instead of salted fish. However, low-sodium kimchi is preferably made both at household and factories.

3.4.4 Winter: Traditionally, the greatest varieties of kimchi were available during the winter. In preparation for the long winter months, many types of kimjang (winter kimchi) kimchi were prepared in early winter and stored in the ground in large kimchi pots. Nowadays, kimchi refrigerators which offering precise temperature controls are used to store kimjang kimchi. White kimchi (*baek kimchi*) is a common and popular kimchi to make during the wintertime. "Baechu kimchi" is made with salted baechu (a type of Chinese cabbage) filled with thin strips of radish, parsley, pine nuts, pears, chestnuts, shredded red pepper, manna lichen, garlic, and ginger.

4. Benefits

Kimchi is made of various vegetables and contains a high concentration of dietary fiber and low calories. One serving also provides up to 80% of the daily required amount of vitamin C and carotene. Most types of kimchi contain onions, garlic, and peppers, all of these materials are health benefits. Kimchi is rich in vitamin A, thiamine (B1), riboflavin (B2), calcium, and iron, and contains lactic acid bacteria, the typical species *Lactobacillus kimchii*. (http://www.treelight.com/health/nutrition/KimchiHealthy.html, November 2008)

4.1. Anti-cancer Effects and Heavy Metal Detoxification

A. Professor Miri Kim (Food Nutrition Department, Chungnam National University) found that the bio-chemicals (isocyanate and sulfide) contained in vegetables such as Chinese cabbage and radish are effective in preventing cancer and detoxifying heavy metals in liver, kidney, and small intestine.

B. Professor Kun Yung Park (Department of Food & Nutrition, Pusan National University) found that:

- The red hot pepper powder (full of vitamin A and C) contained in Kimchi suppresses the growth of cancer cells.
- Fibers in Kimchi detoxify toxins that cause cancer and prevent constipation.
- The organic acid, lactobacilli, and lactic acid--which are produced during the fermentation of Kimchi--suppress harmful bacteria and stimulate beneficial bacteria, prevent constipation, clean intestines and prevent colon cancer.

C. Professor Chajun Chang (Department of Pathology, Seoul National University College of Medicine) found that:

Capsaicin, which is contained in the red hot pepper powder of Kimchi, helps reduce the chance of developing lung cancer. Allicin, chemical contained in garlic, helps reduce the chance of developing liver, stomach, and thyroid cancer. In addition, the Indole-3-Carbinol contained in Chinese cabbage helps reduce the chance of developing stomach cancer.

D. Based on his research, Professor Ahn Sik Chung (Department of Biology at KAIST, Korea Advanced Institute of Science and Technology) found that Chlorophyll in Kimchi helps prevent cells from absorbing carcinogen.

- Garlic and red hot pepper powder in Kimchi kill bacteria that cause gastritis, such as Helicobacter Pylori.
- There is no proof that the spicy substances in Kimchi aggravate ulcer and gastritis: Jung Kwon Lee, M.D. Department of Family Medicine, Samsung Hospital

4.2. Increasing Immunity & Anti-Cancer Effect

A. Research from Kimchi Research Institute at Pusan National University regarding the Activity of Immune Cells

The experiment tested immune system by measuring number of antibodies in different diets of mouse. The result was showed in the table below.

Table2. Experiment with Mice (Four Weeks)

High Cholesterol Diet	High Cholesterol Diet + Red Hot Pepper powder	Normal Diet	High Cholesterol Diet + Kimchi
55%	67%	68%	75%

B. Professor Rina Yu (Food and Nutrition Department, University of Ulsan) found that eating Kimchi made immune cells become more active and increased the number of antibodies.

C. Transplantation of cancer cell (Observation for 3 weeks)

The experiment was test with a mouse by test weight of cancer in a normal mouse, and mouse fed with kimchi extract. The result was showed in the table below.

Table3. Effect of treated mouse with kimchi to cancer

A normal mouse	Weight of cancer cell 4.32g
A mouse fed with Kimchi extract	Weight of cancer cell 1.98g

The result showed that weight of cancer cell was reducing in a mouse that fed with kimchi.

4.3. Helps Prevent Cardiovascular Disease, Myocardial Infarction and Hardening of the Arteries

A. The researchers at Family Medicine Department of Seoul Asian Medical Center found that eating Kimchi lowers homocysteine in blood that causes blood vessel diseases, such as stricture of the heart and stroke.

*The blood test results from 670 people who visited Seoul Asan Medical Center revealed that people who ate Kimchi twice or three times a day had lower chances of having a heart attack.

B. Research team of Professor Young Sun Song (Food and Nutrition Department, Inje University)

The experiment test with mice by feed normal food, normal food+3% kimchi, normal food+5% kimchi. The result was showed in the table below.

Table4. Experiment with Mice

	Normal Food	Normal Food plus 3% of Kimchi	Normal Food plus 5% of Kimchi
Level of Cholesterol	88mg	74mg	67mg

Kimchi remarkably decreased the cholesterol level, which helped prevent the hardening of arteries.

D. When a rabbit with hardened arteries was fed with garlic from Kimchi for three months, its cholesterol level decreased from 70.5 mg to 25mg.
F. Kimchi also inhibited the formation of blood clots which, in turn, helps prevent myocardial infarction.

4.4. Slowing Down the Aging Process

A. Dr. Gab Soon Moon and Professor Young Soo Chun (Kimchi Research Institute at Pusan National University) discovered that Kimchi, after two weeks of fermentation, is abundant in anti-oxidation substances that slow down the aging of skin. Also, Kimchi inhibits oxidation of cells that occurs as a result of stress.

B. The researchers at Food and Nutrition Departments from Inje University, Pusan Women's College and Kyung Hee University found that Vitamin C, chlorophyll and β-Carotene in Kimchi prevent dry flaky skin, relieve the cell toxicity, protect the skin by protecting skin cells, and slow down the aging process for skin.

4.5. Diet effect & Prevent overweight

Professor Kon Young Choi (Food and Nutrition Department at Pusan National University) experimented the effect of Kimchi in preventing fatty liver and on weight loss.

Table 5 Testing with mice for a month

	Normal Diet	High Cholesterol Diet	High Cholesterol Diet + 5 % Red Hot Pepper Powder	High Cholesterol Diet + Kimchi
Weight	302g	338g	311g	302g
Weight of liver	3.79g	4.39g	4.01g	3.69g

4.6. Usually, 1 g of well-fermented Kimchi produces more than 8 hundred million lactobacilli (4 times of lactobacilli from Yogurt.) These lactobacilli accelerate the activity of colon. They not only clean colon, but also prevent constipation, the inflammation of intestines, and colonitis.

4.7. Kimchi provides a variety of nutrition: Inorganic nitrogenous compounds such as calcium, copper, phosphor and iron. It is also rich in Vitamins, such as Vitamin A, C, B1 and

B2

4.8. Kimchi is the alkaline food that prevents acidosis, acid blood due to the over-ingestion of meat and/or acidic food.

4.9. Kimchi helps lower cholesterol, thereby preventing diseases such as high blood pressure and diabetes.

4.10. Kimchi adjusts body rhythm and is beneficial while recovering from diseases.

4.11. Because Kimchi is fermented food, it is easy to digest and its nutritions are easily absorbed.

4.12. Since it is fermented, Kimchi has no harmful side effects because it is fermented. It may be helpful in preventing or fighting cancer.

Some research focused on high-sodium dietary dependence has found overconsumption of kimchi and doenjang (soy bean paste) to be a risk factor in gastric cancer.

Major ingredients

The major ingredients of kimchi are list below.

1. Chinese cabbages
2. Salt
3. Chili
4. Garlic
5. Ginger
6. Green onion

Raw materials

Chinese cabbage

Figure11. Chinese cabbage (http://en.wikipedia.org/wiki/Cabbage, November 2008)

Chinese cabbage *(Brassica campestris)* is a vegetable that people in East-Asia usually plant and consume. Chinese cabbage has been grown in Asia since the 5th century and in North America 100 years ago. All types of Chinese cabbage used in both fresh and cooking such as boiling, frying, stir-frying. Kimchi pickled it in salt solution and fermented Chinese cabbage.

Chinese cabbage has many varieties and the famous on for making kimchi is Napa cabbage. Napa cabbage was group in species of *Brassica rapa* and had lighter color than ordinary Chinese cabbage. (http://www.treelight.com/health/nutrition/KimchiHealthy.html, November, 2008)

Chinese mustard

Figure12. Chinese mustard (http://www.evergreenseeds.com/headtypnapca.html, November 2008)

Chinese mustard (*Brassica juncea* (L.) Czern or called mustard green, Indian mustard has dark green leaves with broad and thick petioles are very tender and crispy, very popular in China. Chinese mustard has a peppery taste actually uses seed for making mustard. For the leaf, it uses whole cabbage to make pickle. In leaf part will contain more bitterness than stem part. (http://www.evergreenseeds.com/headtypnapca.html, November 2008)

Table6. Composition of vegetables per 100g.

Composition	Cabbage	Mustard
Energy (Kcal)	26	13
Water	90.1	95.3
Protein (g)	1.7	1.6
Fat (g)	0.4	0.6
Carbohydrate (g)	4.1	0.4
Total sugar	4	0.4
Calcium (mg)	52	50
Phosphorus (mg)	41	33
Thiamin (B1) (mg)	0.15	0.04
Riboflavin (B2) (mg)	0.02	0.04
Niacin (mg)	0.5	1.0
Vitamin C (mg)	49	33
Fiber (g)	2.9	3.3

Source: McCance,**1991**

Salt

Salt, Sodium chloride, can divide into two categories that are unrefined salt and refined salt. Overconsumption of salt increases the risk of health problems, including high blood pressure. 8-10% of salt concentration is use in normal kimchi.

The role of salt in salted vegetables began when mankind discovered salt and used it to preserve vegetables. The salting process is essential for producing kimchi. It works on the taste and quality of kimchi, as well as the storage of kimchi through preservative action against putrefaction.

When vegetables are soaked with salt, salt penetrates the vegetables by osmosis; water removed from intracellular of cabbage out and softens the cabbage. Microorganisms in vegetables cease their activity through the osmotic action of salt and are destroyed through dehydration or lost their enzymatic ability. Salt also work as a preservative, kill some microbes that can't withstand the salt on the surface of cabbage. (Lee chunja, 1998)

Chili

Chili or chili pepper is the fruits from the plant in genus of *Capsicum*, which are members of the family, *Solanaceae*. Its popularity has seen it adopted into many countries around the World. Chili has also become a part of the Korean, Indian, Indonesian, Szechuan and Thailand. Chili can be eaten in raw or cooked form.

The major heat substance is capsaicin (8-methyl-*N*-vanillyl-6-nonenamide). The stem end of

the pod has highest gland to produce capsaicin. Removing the seeds and inner membranes is thus effective at reducing the heat of a pod.

In Korea's kimchi usually use red chili peppers. Red chilies contain high amounts of vitamin C and carotene (Table7.). Yellow and green chilies contain a considerably lower amount of both substances. In addition, peppers are a good source of most B vitamins, and vitamin B6 in particular. They are very high in potassium and high in magnesium and iron.

Cayenne chili pepper (Figure13.)

Figure13. Cayenne chili pepper

Cayenne chili is labeling in market as red chili pepper, very spicy use for dry chili. Immature cayenne chili has green color, mature red color.

Bird chili (Figure14.)

Figure14. Bird chili

Usually call bird eye's chili came from the appearance that looks like mynah bird. Bird is very spicy, use for fresh in most of Thai food or dry. Immature bird chili has green color, mature red color.

Bell chili pepper (Figure15.)

Figure15. Bell chili pepper Source: Jenni fleet wood, 2002

Bell chili has label as not spicy or no spicy, use in salad or pizza and many foods for decoration. Immature bell chili has green color, mature red color. In the book of kimchi mentioned about reddish color came from cockscomb flower.

Table7. Chemical composition of chili each type in 100g

Composition	Bell pepper	Cayenne pepper	Bird chili
Energy (Kcal)	26	53	68
Protein (g)	1.3	3	4.1
Fat (g)	-	1.1	2
Carbohydrate (g)	-	8	8.4
Calcium (mg)	12	14	76
Phosphorus (mg)	-	75	82
Iron (mg)	0.9	1.1	1.6
Thiamin (B1) (mg)	0.07	0.11	0.28
Riboflavin (B2) (mg)	0.08	0.01	0.15
Niacin (mg)	0.8	-	-
Vitamin C (mg)	103	90	87
Beta-carotene (RE)	1.8	31.09	140
Fiber (g)	1.4	-	9.9

Source: Dr. Susheela Techawongstean (ดร. สุชีลา เตชะวงค์เสถียร) 2549

Garlic

Garlic (*Allium sativum*), it is a root crop, with the bulb growing underground. Head of garlic is composed of smaller cloves. Garlic is one of the famous spice widely and use as a main ingredient in many recipes in the world. Garlic has been used as both food and medicine for thousands years. It was used to protect against plague by monks in the middle Ages. Garlic is claimed to help prevent heart disease including atherosclerosis, high cholesterol, high blood pressure, and cancer. Studies have shown garlic can suppress the growth of tumors,

and is a potent antioxidant good for cardiovascular health.

Garlic provides good smell in the food. The garlic odor come when cells have been ruptured by cutting or pressing, they release an enzyme called *allinaise*. This enzyme chemically changes the inherent *alliin* into *allicin,* a sulfur-containing molecule. These sulphur molecules are absorbed into the bloodstream and lungs, escaping through exhaled air and perspiration. (http://homecooking.about.com/od/cookingfaqs/f/faqgarlic.htm)

Ginger

Ginger (*Zingiber officinale*) was group in the family of *Zingiberaceae*. Ginger is commonly used as a cooking spice throughout the world. Although often called "ginger root" it is actually a rhizome. Ginger has been important in Chinese medicine for many centuries, and is mentioned in the writings of Confucius.

Ginger is most commonly known for its effectiveness as a digestive aid. By increasing the production of digestive fluids and saliva, Ginger helps relieve indigestion, gas pains, diarrhea and stomach cramping. Ginger's therapeutic properties effectively stimulate circulation of the blood, removing toxins from the body, cleaning the bowels and kidneys, and nourishing the skin. Ginger Root can use in the treatment of asthma, bronchitis and other respiratory problems by loosening and expelling phlegm from the lungs. Ginger Root may also be used to help break fevers by warming the body and increasing perspiration. (http://www.theepicentre.com/Spices/ginger.html, November 2008)

Green onion (Green Shallot, *Alliumcepa var. aggregatum*)

Green shallot is closely related to multiplier onions, but smaller. Sometimes labeled in supermarkets as shallots (eschalots) and also referred to as spring onions or scallions, green shallots have edible hollow tube-like leaves and white bulbs. Green shallots have a delicate onion flavor; white parts have a stronger onion flavor. In kimchi, green onion use only leaf part not bulbs. Green onion provide color for decorate. (http://en.wikipedia.org/wiki/Greenonion, December 2008)

Fermentation of Kimchi

After pass salting part, lactic acid bacteria, which can grow in 3% brine, play the most active role in the kimchi fermentation; it suppresses the growth of other bacteria which could grow under such conditions.

Among the 200 bacteria isolated form *kimchi*, the important microorganisms in *kimchi* fermentation are known to be *Lactobacillus plantarum, L. Brevis, Streptococcus faecalis, Leuconostoc mesenteroides,* and *Pediococcus pentosaceus*.

The changes start with reducing of sugar content. Natural sugars that present in all

vegetables have been transformed by lactic acid bacterial ferment into lactic acid. The pH of kimchi is getting lower to around 4.2-3.8. Lactic acid is a preservative and the inhibitor for other decay processes. Vegetables already soften by salt and in fermentation process; enzyme pectinesterase will activate and soften vegetables more.

The number of aerobes increased in the early stage of kimchi fermentation and then decreased, while the number of anaerobes continued to increase during the middle stage. A rapid increase of aerobes in the late stage was due to the growth of film-forming yeasts.

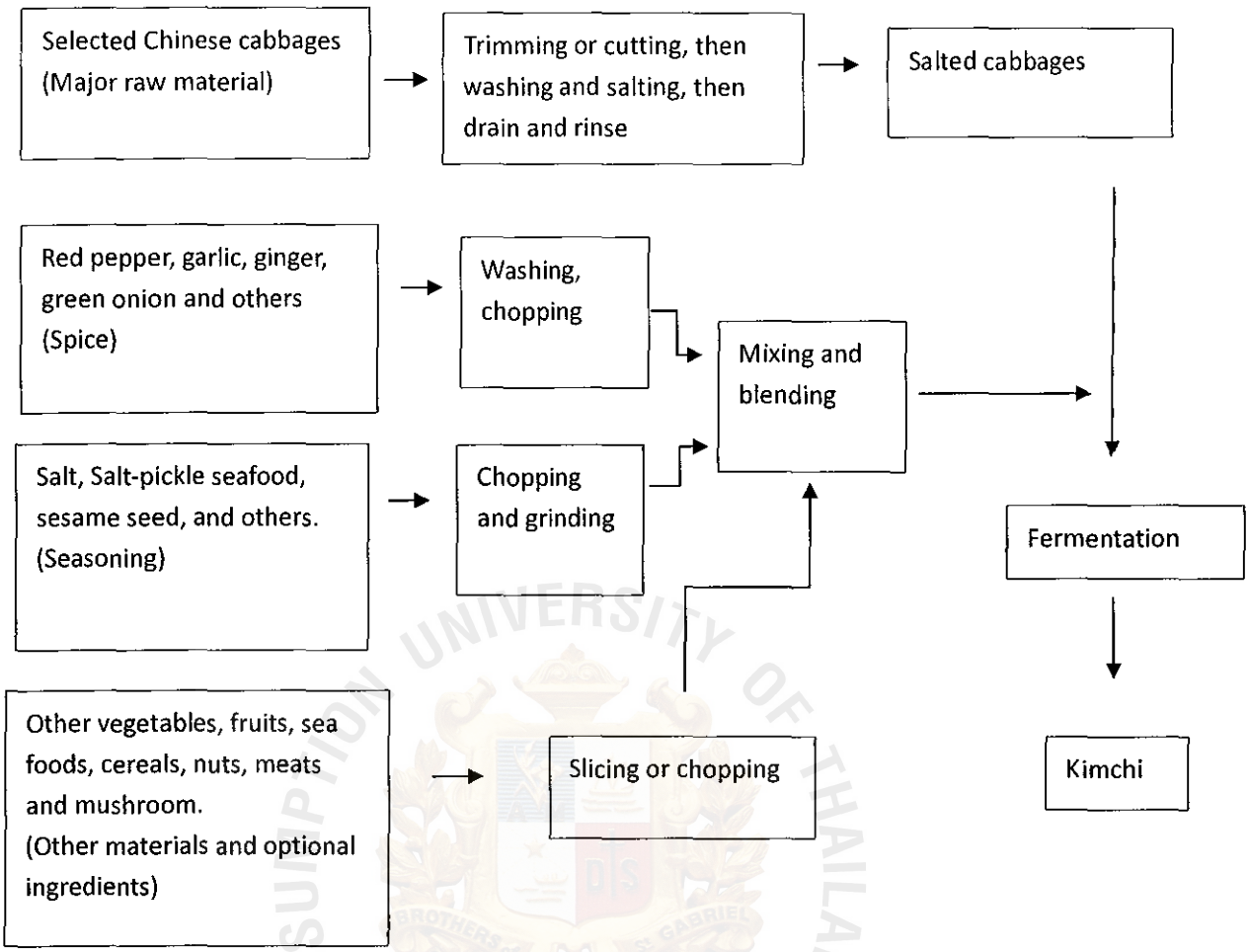
Leu. mesenteroides actively grows in the early stage of kimchi fermentation, thereby producing lactic acid and carbon dioxide which could acidify kimchi and create an anaerobic state to suppress the growth of aerobes. *Streptococcus* actively grows in the early stage of fermentation, *Pediococcus* in the mid-stage, and *L. plantarum* and *L. brevis* in the late stage, which could affect the ripening of kimchi.

In the process of fermentation, if there is oxygen in the jar, the cabbage will be contaminated by mold. Lactic acid bacteria produce lactic acid with CO_2, is heavier than air and it will fill the jar and force the oxygen out.

Processing

In common process of kimchi, cabbages and other ingredients were prepared. Cabbages used as major raw material. Chinese cabbages were processed by trimming or cutting then washing and salting, then draining to be get salted cabbages. Red pepper, garlic, ginger, and others used as spice, process by washing and chopping. Salt, salted-pickle, and others used as seasoning, processed by chopping and grinding. Other vegetables, fruits and others used as optional ingredients, processed by slicing or chopping. Mixing and blending the prepared spice, seasoning and optional ingredients, then mixed with salted cabbages and fermented about 2-3days..

Fig16. Common process form kimchi production



(Lee chunja, 1998)

Kimchi packing

In the old time, kimchi was pack in the jars and kept it underground at the backyard of the house. When the time change, kimchi getting famous and been one of the exporting product of Korea so new technology of packaging coming in the way to global export. There are currently three basic packs of kimchi products in modern super markets: 1) Freshly-packed items of salad type kimchi 2) refrigerated items of pickled kimchi 3) Pasteurized items of shelf stable kimchi. These kimchi products are produced on an industrial scale in modern facilities in response to increasing consumer demand in both domestic and foreign markets. (http://www.asianinfo.org/asianinfo/korea/food.htm, November 2008)

Right now, kimchi pack in flexible pouches or rigid plastic tray with film lids. For flexible pouches packages, laminated multiply film structures containing nylon or aluminum layer are usually used. Due to such advantages as an aroma barrier, the capability of trap printing, and stiffness which are especially required for standing pouch types. The packages are often vacuumized prior to sealing.

Because of CO_2 production inside package, films with high gas transmission rates such as polyethylene or polypropylene was used. An amorphous nylon laminate film has developed to control relatively high ration of CO_2 and permeability of O_2. It control strong aroma to not contaminate the other products on the shelf. (Jeewon lim)

Quality of kimchi

As 40 countries including Japan are becoming interested in Kimchi and consuming it, Codex international food standard of kimchi was established to smooth the exchange between countries. On March, 1996, the 10^{th} codex coordinating committee for Asia (CCASIA) suggested Codex standard for Korean kimchi. Through 8-step discussion in CCASIA, codex standard was selected on July 2001 on the basis of cabbage kimchi of Korea.

CODEX set the standard that lactic acid and set to lower than 1.0% to apply over-ripen kimchi and give the best taste at 0.6~0.8% acidity. Salinity set about 1-4% for proper fermentation for lactic acid bacteria. Color should be red, being originated from red chilly. Taste should contain hot and salty taste and also sour. Texture should be properly hard and crispy

Table8. CODEX standard of kimchi.
(http://www.kimchi.or.kr/eng/about/codex/1177884_3955.html, November 2008)

Total acid rate	As for the total acid rate of Kimchi, main fermentation is lactic acid fermentation, it is indicated as lactic acid and set to lower than 1.0% to apply over-ripen kimchi to various kinds of food, including 0.6~0.8%, the state of best taste, as kimchi can be eaten right after being made.
Salinity (contents of sodium chlorine)	set to 1~4%, the proper density of fermentation of lactic acid
Color	It should be red, being originated from red chilly
Taste	It should contain hot and salty taste and also sour
Texture	It should be properly hard and crispy

Materials and Methods

Raw materials

- Chinese cabbages
- Chinese mustard (**R&D Food product Co.,Ltd, Ratchaburi**)
- Salt
- Gingers
- Garlic
- Green onions
- Onions
- Chili paste
- Sugar
- Carrots
- Radishes
- Kapi paste
- Cayenne Pepper
- Bell pepper
- Bird Chili

Equipment & Chemical Reagents

- Blender SHARP EM-11
- Digital balance Mettler PJ300
- pH meter Hanna HI222
- 0.1N NaOH
- 0.1N Silver nitrate

Methods

1. **Screening the basic formula of kimchi**

The objective of this experiment was studied the appropriate basic Kimchi formula for this project by screening the three formulas. (Table9.) Each formula was processed and packed in jar for 3 days at room temperature. After fermentation, each Kimchi sample was measured pH and % acidity (lactic acid). Kimchi was cooked via microwave for 2 min. and evaluated by sensory with test panelists. The most acceptance formula was chosen to be a basic formula in the next experiment.

Table 9: The three formulas of Kimchi

Ingredients	Formula		
	1st Formula*	2nd Formula**	3rd Formula**
Cabbage	1kg	1kg	1kg
Onion	100g	100g	200g
Chili paste	20g	100g	200g
Garlic	100g	100g	200g
Sugar	20g	-	-
Salt	-	50g	-
Ginger	10g	-	200g
Carrot	-	-	200g
Radish	-	-	200g
Kapi paste	-	-	100g

Source:

* 1st Formula, (http://Kimchi.pyongyang-metro.com/)

** 2nd Formula (http://www.jasonunbound.com/Kimchi.html)

*** 3rd Formula "Making kimchi" provided by Mr. Kitikun Jaiyen

2. **Compare types of Cabbages and vary spices content (Chinese cabbage and Chinese mustard)**

According to the previous experiment, the 1st formula was selected as a basic formula in this project. This step replaced chili paste with fresh chili because color of chili paste Kimchi was poor. Cayenne Pepper and Bird chili were selected in this experiment because they were common chilies in Thailand. This experiment was compared two types of cabbage (Chinese cabbage and Chinese mustard) in order to evaluate Kimchi products and improve in the further steps. It also compared amounts of onion (10 and 15%), garlic (10 and 15%), ginger (10 and 15%), and cayenne pepper (5 and 10%). (Table 11) Each formula was processed and packed in jar for 3 days at room temperature. After fermentation, each Kimchi sample was

measured pH and % acidity (lactic acid). Kimchi was cooked via microwave for 2 min. and tested by sensory evaluation method with test panelists.

Table10: The comparison between Chinese cabbage and Chinese mustard and varying percent of onion, garlic, ginger and cayenne pepper

Ingredients	Percent			
	CB I	CB II	CM III	CM IV
Chinese cabbage	100%	100%	-	-
Chinese mustard	-	-	100%	100%
Onion	10%	15%	10%	15%
Green onion	5%	5%	5%	5%
Garlic	10%	15%	10%	15%
Ginger	10%	15%	10%	15%
Bird Chili	5%	5%	5%	5%
Cayenne Pepper	5%	10%	5%	10%

CB I refer to Chinese cabbage sample 1
CB II refer to Chinese cabbage sample 2
CM III refer to Chinese mustard sample 3
CM IV refer to Chinese mustard sample 4

3. Variation types and content of chili (Chinese cabbage as raw material)

According to the previous experiment, the Chinese mustard Kimchi was too bitter. This project was divided into two sections, the first section was studied the optimum formula of Chinese cabbage Kimchi. The second section was studied on the optimum formula of Chinese cabbage Kimchi. The objective of this experiment was studied the optimum contents and types of pepper in order to improve Kimchi in juice color and taste. Bell pepper and Cayenne chili were selected. The 1st sample, 50 CP: 0 BP, added 250g Cayenne pepper or 50 % Kimchi and the 2nd sample, 25CP:25BP, added 125g (25% Kimchi) cayenne pepper with 125g (25 % Kimchi) bell pepper in the ratio 1:1. Each formula was processed and packed in jar for 3 days at room temperature. After fermentation, each Kimchi sample was measured pH and % acidity (lactic acid). Kimchi was cooked via microwave for 2 min. and tested by sensory evaluation method with test panelists.

4. Remove greeny odor and bitter flavor from Chinese mustard

The objective of this experiment was studied optimum soaking time and salt concentration of salting period to reduce bitterness and unpleasant odor. Salt concentration was varied from 10, 12.5, 15, 17.5, and 20 percent of Cabbages and collected each concentration at 3, 4, 5 and 6 hours. Salted Chinese mustard was washed, boiled and tested by sensory evaluation method with test panelists. Samples also measured salt concentration.

5. **Use Chinese mustard as a raw material in CB and vary amount of chili in different ratio**

This experiment was studied the optimum formula of Chinese mustard Kimchi by varying types and percent of the pepper. The ratio of Cayenne pepper: Bell pepper was varied from 100:0, 75:25, 50:50, 25:75 and 0:100. Chinese mustard was mixed with 10% salt concentration for 6 hours and washed with tap water for 5 minutes. Each formula was processed and packed in jar for 10 days at room temperature. After 3, 6, 9 days of fermentation, each sample were collected to measure pH and % acidity. After 10 days of fermentation, Kimchi was cooked via microwave for 2 min. and tested by 9-Hedonic scale preference method with 30 untrained panelists (Appendix B1.).

6. **Variation of garlic in selected formula**

The objective of this experiment was studied the optimum garlic content by varying from 9%, 12% and 15%. Each formula was processed and packed in jar for 10 days at room temperature. After fermentation, Kimchi was cooked via microwave for 2 min. and tested by 9-Hedonic scale preference with 26 untrained panelists (Appendix B2.).

7. **Experimental location**

   a. Pilot plant, E-Building, Faculty of Biotechnology, Assumption University

   b. E81 laboratory, Faculty of Biotechnology, Assumption University

8. **Time planning and research place**

The project was planning to discuss with advisor in June about 2 weeks. Then made a research information on the related research took around 1 month. Next, find basic formula took about 2 weeks. Adjust formula with Chinese mustard took about 2 months. Develop taste and quality took about 3 months. Write down report on October. Prepare for presentation and approval from advisor at third week of November. The last was presentation on December. (Table11.)

Table 11: Job description timeline

Job	Description
1	Discuss with advisor
2	Research information on the related research
3	Find basic formula
4	Adjust formula with Chinese mustard
5	Develop taste and quality
6	Write down report
7	Prepare for presentation and approval from advisor
8	Presentation

The following Grant chart (Table12.) shows the schedule of each task and its planned completion period. The plan is constructed in order to complete the job description follow the time line.

Table12. Product Development Time Line in 2008

Task	June		July		August		September		October		November		December	
1														
2														
3														
4														
5														
6														
7														
8														

Result and discussion

1. Screening the basic Kimchi formula

A B C

Figure17. Three Kimchi formulas

A refer to formula1 (Table9)
B refer to formula2 (Table9)
C refer to formula3 (Table9)

Table13. pH and % acidity (lactic acid) of each formula after 3days fermentation

Formula	pH	% acidity (lactic acid)
1	3.5	2.16
2	4.6	0.54
3	3.8	1.98

The first formula (Table.9&Fig.17A), was too strong sour (pH 3.5 and 2.16% acidity (lactic acid) and crunchy vegetable texture but juice color looked fade or pale due to lower chili pepper content (only 2% Kimchi). From table 10, %acidity at 2.16 was too high for kimchi comparing with standard CODEX (Table8) which has only 0.6-0.8%. Therefore it needs more fermented time to reduce % acidity.

The second formula (Table.9&Fig.17B), the juice color look like reddish, but did not like commercial Kimchi. The cabbage leaf color didn't look like fresh or green as the same as the first formula. The taste was too strong salty because of addition salt in formula. Due to pH 4.6 and 0.54% acidity (lactic acid), it might be the higher salt content and lead to low fermentation rate because high salt concentration inhibit microorganism growth. pH of Kimchi should be between 4.2-3.8. This formula should reduce salt content and extent fermentation time to increase acidity content.

The third formula, (Table.9&Fig.17C), the color of juice was turbid because of additional kapi paste. The taste had strong sour (pH 3.8 and 1.98% acidity (lactic acid), and salty

because of kapi paste. The third formula liked some traditional Korean Kimchi which fermented squid or shrimp in the formula. The fermentation rates of the first and third formulas were not much different. Kapi paste content should adjust to reduce sourness.

This project was chosen the first formula as the basic formula in this experiment because of its taste and fresh vegetable color. This formula should modify to produce Kimchi which accepted by Thai people. Garlic and ginger provided the strong odor and flavor but it should be blended instead of mashing technique. Carrots and radishes were optional ingredients, so both of them would be remove from formula. They would be adding to provide specific and unique characteristic of Kimchi later after Chinese mustard Kimchi was succeed.

2. Compare types of Cabbages and vary spices content

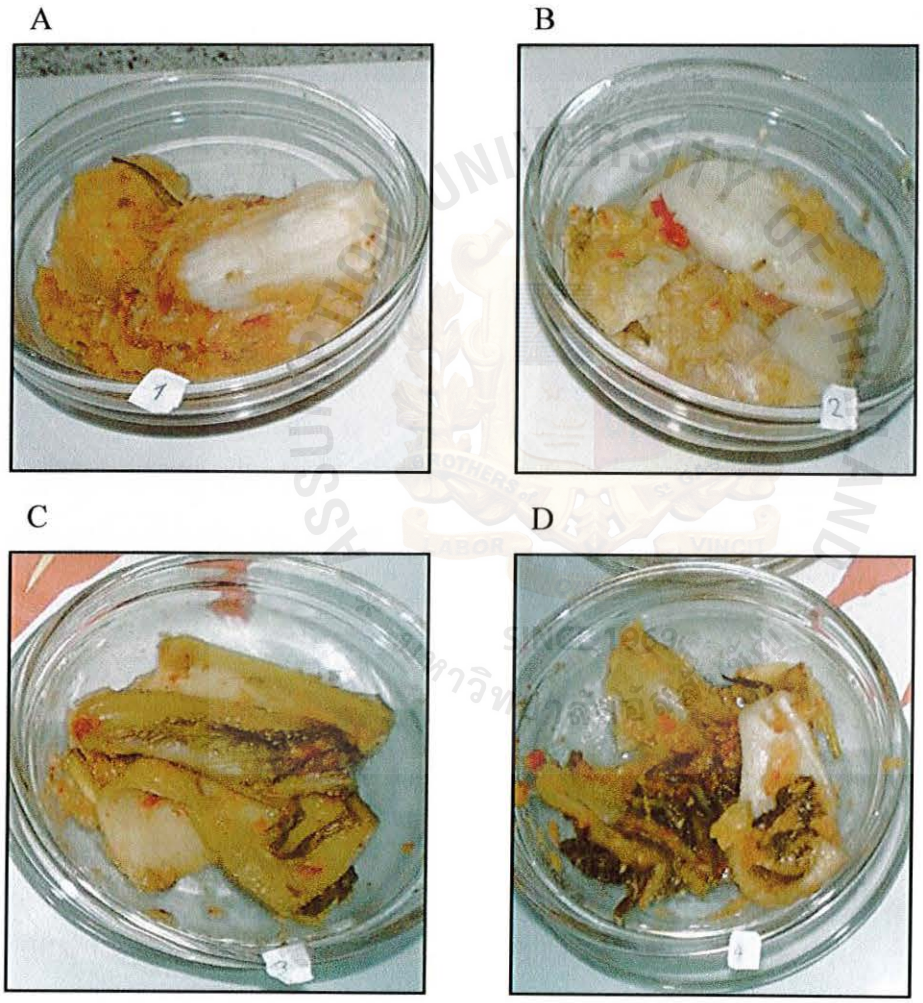


Figure18. Compare Chinese cabbage and Chinese mustard Kimchi by varying spices content

A refer to Chinese cabbage sample 1 with 10% spices and 5% cayenne chili
B refer to Chinese cabbage sample 2 with 15% spices and 10% cayenne chili
C refer to Chinese mustard sample 3 with 10% spices and 5% cayenne chili
D refer to Chinese mustard sample 4 with 15% spices and 10% cayenne chili

Table14. pH and % acidity (lactic acid) of Chinese cabbage and Chinese mustard Kimchi by varying spices content after 3 days of fermentation

Formula	pH	% acidity (lactic acid)
1	3.7	1.32
2	3.8	1.23
3	4.7	0.68
4	4.8	0.6

This experiment was studied the effect of Chinese cabbage and Chinese mustard in the basic formula of Kimchi. The content of spices were varies to study the optimum content and the effects of bird chili to improve hot and spicy flavor.

Pepper had been changed from chili paste to fresh chili because commercial Kimchi had very reddish color but did not strong spice. It did not like Thai pepper that provide strong red color and very hot and spicy flavor. The project was studied by adding the bird chili to provide spicy flavor while cayenne pepper without seed to provide reddish color.

Color of cabbage in CB I (Fig.18A) was more reddish because pepper was added up to 50g (10%of kimchi) instead of basic formula in the first experiment, The first formula (Table9.) used only 20g (2% of kimchi). Its red color did not like commercial Kimchi. The taste was strong sour, hot and spicy, resulting by adding bird chili, it's tasted like tom-yum, Thai style food.

CB II, (Fig.18B), which added high pepper, but its color was pale. It might be the poor milling of chili. The taste was too sour, hot and spicy. Test panelists commented that the hot degree of CB II was close to CB I. Cayenne pepper without seed also contained capsaicin and cause hot and spicy flavor. Texture of CB I and CB II was acceptable.

CB II contained more ginger, onion, garlic and cayenne pepper content than CB I and had more herb flavor. But other attribute such as sourness, spiciness, crispness were closed to CB II. Test panelists preferred CB I more than CB II.

For CM III and CM IV Chinese mustard had been use in the process. CM III (Fig.18C) and CM IV (Fig.18D) gave strong stink odor and strong bitter taste that made test panelists could not detect other attributes in Chinese mustard Kimchi. Hard texture stem was found. However, the taste of CM IV was better than CM III because the additional of herbs and spices helped to mask some bitterness and greeny flavor.

At the same amount of ingredients, Chinese cabbage provided hot and spicy flavor while Chinese mustard provided bitterness and greeny odor. The spicy taste, like tom-yum, was more preferred and accepted by test panelists. The texture of Chinese cabbage and Chinese mustard were different because the intracellular structures were different. Chinese mustard

has harder texture comparing with Chinese cabbage that has softer texture. Test panelist preferred bright green color of Chinese cabbage and disliked Chinese mustard that provided dark green color. The odor of Chinese mustard was not preferred by test panelist and it should be improved in the formula.

Chinese cabbage is the suitable raw material in Kimchi production when comparing with others. Improvements of Chinese mustard Kimchi were required. The next experiment was studied on the optimum formula of Chinese cabbage Kimchi and followed by studying on the optimum formula of Chinese mustard Kimchi by using the Chinese cabbages Kimchi formula. Bird chili was not suitable for making Kimchi because it's too hot and spicy like tom-yum flavor but did not like Kimchi style. The project was plan by studying the optimum Chinese cabbage and reducing bitterness and greeny odor. Finally, study on the prototype formula of Chinese mustard kimchi.

3. Variation types and content of chili (Chinese cabbage as raw material)

The amount of ginger was reduced from 50g (10%) in experiment 2 (Table 10.) to 25g (5%) because test panelists complained on too strong ginger flavor in all samples.

The major problems in this project to improve Kimchi color but should to maintain spiciness. This experiment varied between Bell pepper and Cayenne pepper in difference ratio. The chili amount was increased up to from 5 % to 50 % of kimchi. Cayenne and bell pepper provided strong red color and looked like commercial kimchi. (Fig.19A) Cayenne pepper without seed provided red color with a little bit of spiciness but bell pepper gave some sweetness.

A B

Figure19. 50% Cayenne pepper Kimchi and 25% Cayenne pepper + 25% Bell pepper Kimchi
A refer to Chinese cabbage with 50% Cayenne pepper
B refer to Chinese cabbage with 25% Cayenne pepper + 25% Bell pepper

Test panelists evaluated samples after 3 days of fermentation, and commented that 50CP:0BP (Fig.19A) had only strong sourness and look like Kimchi. Both samples had same odor because chili didn't provide odor. 25CP:25BP (Fig.19B) had sourness, sweetness and had some flavor more than 50CP. Some test panelists preferred 50CP:0BP because they preferred strong sourness while the other preferred 25CP:25BP more because they like some flavors in this sample. After a week, test panelists tested again and commented that two samples gave more aroma of Kimchi. Both samples had same reddish color, and also crunchiness of vegetable. Bell pepper was more soften texture because of higher moisture content. After blending into paste, bell pepper had a little bit more volume. In this step was hardly concluded that which formula was more acceptable. Therefore, the next was varied Cayenne and Bell pepper in different ratio and using many untrained panelists to evaluate them.

4. Remove greeny odor and bitter flavor from Chinese mustard

This experiment changed raw material from Chinese cabbage to Chinese mustard. But the greeny odor and bitterness should be solved before studing on the optimum formula of Chinese mustard Kimchi. There were many ways to remove greeny odor and bitterness. Green mustard was soaked in brine solution for many days or boiled in hot water or directly kneaded with salt and washed. Chinese mustard was pickled in brine solution for a month. This could be reduced bitterness. But this method took long time and made too salty product. Boiling made vegetable too soft. This project should study on the Kimchi process which directly mixed with salt. Salt concentration and soaking time were varied.

Table15. Bitterness acceptation in different salt concentration and time

Salt concentration (%)	Bitterness acceptation after 3-6 hours passed				Salt concentration after 6 hours (%)
	3	4	5	6	
10	+++	+++	++	-	1.68
12.5	+++	+++	++	-	2.22
15	+++	+++	++	-	2.36
17.5	+++	++	+	-	2.73
20	+++	++	+	-	3.02

+++ refer to very high bitter taste
++ refer to high bitter taste
+ refer to bitter taste
- refer to less bitter taste at acceptable level

Base on experiment 2 which soaked CM with salt for 2-3 hours but could not remove bitterness. After 3-4 hrs of soaking time, all samples still remained high bitterness and unacceptable. After 5 hrs of soaking time, the bitterness of 10-15 % salt were slightly reduced while bitterness of 17.5-20 % salt was reduced but still unacceptable. After 6 hrs of

soaking time, all sample had less bitterness, still remain little bitterness and acceptable. Base on result, higher concentration could remove bitterness faster because of higher rate transfer of water out of the cell. With higher salt concentration, the osmotic pressure of the extracellular fluids became lower than inside cells. Since water passed from a region of higher to lower region of osmotic pressure, water flowed out of the cells into the extracellular to balance the pressure. Bitter tasted cause by phenolic or other compounds that contained inside the plants cells. These compounded may be water or salt soluble substrate, thus when water moved off the cells these compound also came out with the water. Salting method could use to reduce the bitterness.

At 6 hours passed, 10% salt was selected because higher salt concentration was too salty. Higher concentration was lower the bitterness but also increased the saltiness.

5. Use Chinese mustard as a raw material in CB and vary amount of chili in different ratio

Table16. 9-Hedonic scale of cayenne: bell pepper in different ratio

Attribute	Sample amount of cayenne pepper : bell pepper				
	100:0	75:25	50:50	25:75	0:100
Color	6.43±1.3^{ab}	5.9±1.56^{a}	6.53±1.19^{ab}	6.4±1.37^{ab}	**6.73±1.1**^{b}
Flavor	5.6±1.67	5.53±1.92	5.73±1.57	**6±1.4**	5.76±1.38
Sweetness	5.33±1.44	5.3±1.57	**5.73±1.25**	5.63±1.58	5.3±1.44
Bitterness	5.16±1.62	5.5±1.57	5.56±1.59	**5.66±1.68**	5.5±1.65
Sourness	5.5±1.4	5.53±1.96	5.7±1.72	**6±1.44**	5.6±1.76
Spiciness	5.6±1.42	5.53±1.52	5.5±1.45	**5.7±1.44**	5.66±1.53
Crispness	5.96±1.32	6.23±1.22	6.06±1.2	**6.4±1.27**	5.8±1.37
Overall	5.53±1.25	5.7±1.48	5.76±1.35	**5.9±1.26**	5.73±1.38

Table17. Change of pH and %acidity after 3, 6 and 9 days of fermentation

Days	Sample amount cayenne pepper : bell pepper									
	100:0		75:25		50:50		25:75		0:100	
	pH	%acidity	pH	%acidity	pH	%acidity	pH	%acidity	pH	%acidity
3	4.5	0.3	4.5	0.55	4.5	0.36	4.5	0.35	4.7	0.23
6	4.5	0.67	4.4	0.64	4.4	0.77	4.4	0.48	4.7	0.43
9	4.6	0.22	4.4	0.37	4.3	0.26	4.5	0.23	4.5	0.17

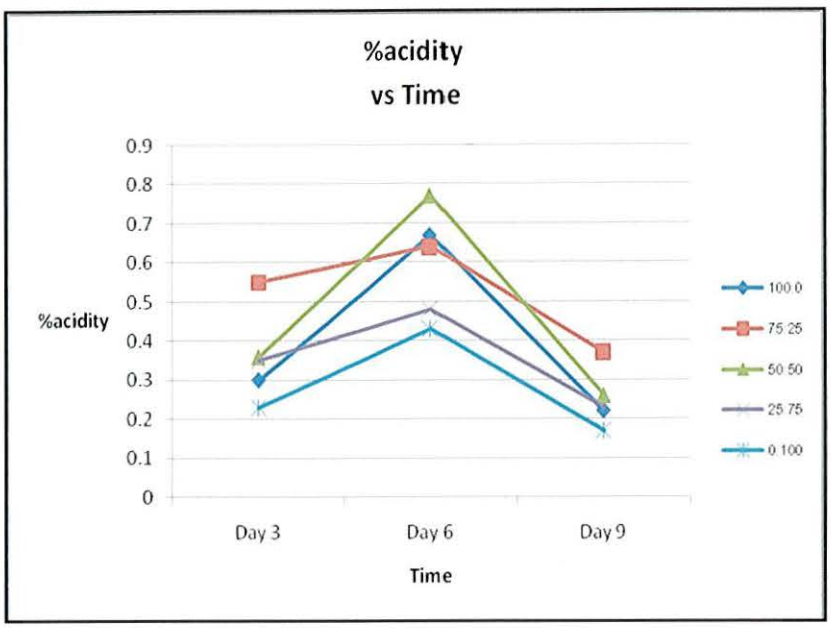


Figure20. %acidity of Chinese mustard by varying the time and % chilies

After 10 days fermentation, 30 untrained panelists were tested with the 9-hedonic scale preference test. (Table 17) There are slightly significant difference only in color attributes in all samples ($P<0.05$). Focus on most of attributes, untrained panelists preferred 25CP: 75BP. Other attributes were not significant different in all samples ($P<0.05$). The result was similar to the previous experiment. Untrained panelists preferred in any chili types. But some trend was found in each attributes. The higher score zone of each attributes was found in CP: BP from 50:50, 25:75 and 0:100 while the lower score zone was found in CP: BP from 100:0 to 75:25. It's seemed to be more preference in high level of pepper and less preference in high cayenne pepper content.

The pattern of acidity formation of all samples was the same (Tables18 and Figure20). Acid production would rapidly increase in first 6 days and reduce at day9. In first period, sugar changed into lactic acid so pH started to increase. After reach the highest point of fermentation, lactic acid was change into some others compound so it causes the pH drop.

According to CODEX (table8) showed that properly pH about 4.2-3.8 and % acidity of Kimchi should not over 1 %. Hand carried pH meter was used and result in slightly pH change. This affected to the result that % acidity change but pH still the same.

The formula that contained cayenne: bell pepper 25:75 was selected for the further experiment because this sample got the highest score from 9-Hedonic scale test.

6. Variation of garlic in selected formula

Table18. 9-Hedonic scale preference test of variation of garlic content

Attribute	Garlic content (%)		
	9	12	15
sweetness	5.0 ± 1. 8	**5.3±1.5**	5.1±1.8
Flavor	5.6 ± 1.6	**5.7±1.5**	5.6±1.6
Sourness	5.2^{ab} ±1.6	**$5.8±1.4^{b}$**	$4.9±1.6^{a}$
Crispness	5.7±1.3	**6.1±1.2**	6.0±1.2
Overall	5.3±1.5	**5.8±1.3**	5.5±1.6

Table19. pH and % acidity (lactic acid) of variation of Garlic content

Formula	pH	% acidity (lactic acid)
9%	3.69	0.29
12%	3.84	0.31
15%	3.58	0.4

Some untrained panelists complained on too much garlic flavor. This experiment was varied garlic content from 9%, 12% and 15% Cabbages. After fermented for 10 days, 26 untrained panelists were tested with 9-hedonic scale preference test. There was significant different only in sourness attributes among samples ($P<0.05$). Most of untrained panelists preferred 12% garlic. Reducing of garlic should cause a significant different in flavor attribute but it was found in sourness. The reason of this should be instability of fermentation like wine production which can't exactly foretold that the product will come out good or not.

Garlic contained amount of organosulfur, antimicrobials, should be affect to the fermentation rate of Chinese mustard kimchi. Change of garlic could affect on flavor which it will be more or less.

All samples provided the lower pH but % acidity was poor. Untrained panelist commented that Kimchi was too sour. Kimchi should serve with rice, like tradition in Korea. The plain taste of rice will reduce the sour taste of Kimchi in the range of good taste. After all experiments, the formula was shown at the table below. (Table21.)

Table20. Prototype of Chinese mustard Kimchi

Ingredient	Amount	Percentage
Cabbage	500g	100
Garlic	60g	12
Green onion	25g	5
sugar	12.5g	2.5
ginger	25g	5
Bell pepper	187.5g	37.5
Cayenne Pepper	62.5g	12.5

In further experiment, specific cultures that isolated from commercial Kimchi, which Thai people prefer, inoculated in this formula. The experiment can't further continue because isolated cultures were kept for a long time and contaminated with other organisms.

Conclusion

- The 1st Formula used as a basic formula in this project
- Chinese cabbage with 10 % spices and 5 % cayenne was more accepted than 15 % spices and 10 % cayenne. Chinese mustard with 15 % spices had less bitterness than 10% spices.
- Both cayenne and bell chili pepper provided reddish color.
- Chinese mustard mixed with 10 % salt content for 6 hr was reduced bitterness and green odor with less saltiness.
- Untrained panelists preferred 37.5% Bell pepper and 12.5 % more than other sample.
- Untrained panelists preferred 9% garlic in Chinese mustard kimchi.

Recommendation

Chinese mustard Kimchi should further develop and the recommend was show below

- To improve flavors, specific starter culture should be used to control the fermentation process by isolating from commercial Kimchi.
- To improve the varieties of Kimchi or the uniqueness, different kinds of vegetable should add.
- To improve more safety and quality of Kimchi, pasteurization can be used to kill microorganism and inhibit the fermentation for extending shelf-life.

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Appendix A

Analysis of acid solution

Procedure

1. Transfer acid solution 10 ml into 125ml Erlenmeyer flask
2. Add phenolphthalein 2-3 drops
3. Titrate with standard NaOH to the end point, turn to pink color
4. Calculate % acidity

$$\%\text{acidity} = \frac{\text{mol NaOH x V NaoH x MW x 100}}{\text{1000 x V sample}}$$

mol NaOH = 0.1 N
V NaoH = depend on result
MW lactic acid = 90.08
V sample = 10ml

Determination of salt content

Procedure

1. Weigh accurately 25 g of sample into a 400-ml beaker
2. Add 200 ml hot boiled water and stir for 60 mins.
3. Filter through the glass wool. Collect the filtrate in a 250-mL volumetric flask. Make up to the volume and shake well.
4. Transfer 10 ml filtrate with bulb pipette into 100 ml conical flask. Add 50 ml distilled water using the measuring cylinder and 1 ml of K_2CrO_4 indicator.
5. Titrate with 0.1 N $AgNO_3$ (as S ml). At the end point, the color changes from yellow to brownish red.
6. Carry out a blank determination using 60 ml distilled water and 1 ml K_2CrO_4 indicator (B ml).

$$\text{Salt (\%)} = \frac{\text{250 ml} \times \text{(S-B)} \times \text{F} \times \text{100}}{\text{10 ml} \times \text{25 g}}$$

S = Titration volume of sample (ml)
B = Titration volume of blank (ml)
F = Conversion factor of 1 ml 0.1 N $AgNO_3$ to 0.005844 g NaCl

Appendix B

B1. Use Chinese mustard as a raw material in CB and vary amount of chili in different ratio

Hedonic Preferences Test

Thai style kimchi

Name: Date: .

Instruction

1. Please rinse your month with water before starting.
2. Please taste the samples in the order presented, from the left to right.
3. Give the preference mark for each attributes and overall of sample.

1 = dislike extremely
2 = dislike very much
3 = dislike moderately
4 = dislike slightly
5 = neither like nor dislike
6 = like slightly
7 = like moderately
8 = like very much
9 = like extremely

Attributes \ Sample					
Kimchi color					
Kimchi flavor					
Sweetness					
Bitterness					
Sourness					
Spiciness					
Crispness					
Overall					

Comment

_____

_____

Thank you for your cooperation

B2. Variation of garlic in selected formula

Hedonic Preferences Test

Thai style kimchi

Name: Date: .

Instruction

1. Please rinse your month with water before starting.
2. Please taste the samples in the order presented, from the left to right.
3. Give the preference mark for each attributes and overall of sample.

1 = dislike extremely	6 = like slightly
2 = dislike very much	7 = like moderately
3 = dislike moderately	8 = like very much
4 = dislike slightly	9 = like extremely
5 = neither like nor dislike	

Attributes \ Sample			
Kimchi flavor			
Sweetness			
Sourness			
Crispness			
Overall			

Comment

_____

_____

Thank you for your cooperation

Appendix C

C1. Statistic analysis of use Chinese mustard as a raw material in CB and vary amount of chili in different ratio

Univariate Analysis of Variance Between-Subjects Factors

		Value Label	N
trt	1.00	145	30
	2.00	537	30
	3.00	545	30
	4.00	071	30
	5.00	207	30

Descriptive Statistics

Dependent Variable: color

trt	Mean	Std. Deviation	N
145	6.4333	1.30472	30
537	5.9000	1.56139	30
545	6.5333	1.19578	30
071	6.4000	1.37966	30
207	6.7333	1.11211	30
Total	6.4000	1.33109	150

Homogeneous Subsets

Color

Duncan

	N	Subset	
trt	1	2	1
537	30	5.9000	
071	30	6.4000	6.4000
145	30	6.4333	6.4333
545	30	6.5333	6.5333
207	30		6.7333
Sig.		.092	.380

Means for groups in homogeneous subsets are displayed.

Based on Type III Sum of Squares

The error term is Mean Square(Error) = 1.742.

a Uses Harmonic Mean Sample Size = 30.000.

b Alpha = .05

Descriptive Statistics

Dependent Variable: flavor

trt	Mean	Std. Deviation	N
145	5.6000	1.67332	30
537	5.5333	1.92503	30
545	5.7333	1.57422	30
071	6.0000	1.46217	30
207	5.7667	1.38174	30
Total	5.7267	1.60074	150

Flavor

Duncan

	N	Subset
trt	1	1
537	30	5.5333
145	30	5.6000
545	30	5.7333
207	30	5.7667
071	30	6.0000
Sig.		.328

Means for groups in homogeneous subsets are displayed.
Based on Type III Sum of Squares
The error term is Mean Square(Error) = 2.606.
a Uses Harmonic Mean Sample Size = 30.000.
b Alpha = .05.

Descriptive Statistics

Dependent Variable: sweet

trt	Mean	Std. Deviation	N
145	5.3333	1.44636	30
537	5.3000	1.57896	30
545	5.7333	1.25762	30
071	5.6333	1.58622	30
207	5.3000	1.44198	30
Total	5.4600	1.45920	150

Sweetness

Duncan

	N	Subset
trt	1	1
537	30	5.3000
207	30	5.3000
145	30	5.3333
071	30	5.6333
545	30	5.7333
Sig.		.317

Means for groups in homogeneous subsets are displayed.
Based on Type III Sum of Squares
The error term is Mean Square(Error) = 2.152.
a Uses Harmonic Mean Sample Size = 30.000.
b Alpha = .05.

Descriptive Statistics

Dependent Variable: bitter

trt	Mean	Std. Deviation	N
145	5.1667	1.62063	30
537	5.5000	1.47975	30
545	5.5667	1.59056	30
071	5.6667	1.68836	30
207	5.5000	1.65571	30
Total	5.4800	1.59580	150

Bitterness

Duncan

	N	Subset
trt	1	1
145	30	5.1667
207	30	5.5000
537	30	5.5000
545	30	5.5667
071	30	5.6667
Sig.		.292

Means for groups in homogeneous subsets are displayed.
Based on Type III Sum of Squares
The error term is Mean Square(Error) = 2.588.

a Uses Harmonic Mean Sample Size = 30.000.
b Alpha = .05.

Descriptive Statistics

Dependent Variable: sour

trt	Mean	Std. Deviation	N
145	5.5000	1.40810	30
537	5.5333	1.96053	30
545	5.7000	1.72507	30
071	6.0333	1.44993	30
207	5.6667	1.76817	30
Total	5.6867	1.66341	150

Sourness

Duncan

	N	Subset
trt	1	1
145	30	5.5000
537	30	5.5333
207	30	5.6667
545	30	5.7000
071	30	6.0333
Sig.		.281

Means for groups in homogeneous subsets are displayed.
Based on Type III Sum of Squares
The error term is Mean Square(Error) = 2.806.
a Uses Harmonic Mean Sample Size = 30.000.
b Alpha = .05.

Descriptive Statistics

Dependent Variable: spice

trt	Mean	Std. Deviation	N
145	5.6333	1.42595	30
537	5.5333	1.52527	30
545	5.5000	1.45626	30
071	5.7000	1.44198	30
207	5.6667	1.53877	30
Total	5.6067	1.46042	150

spice

Duncan

trt	N	Subset 1
	1	
545	30	5.5000
537	30	5.5333
145	30	5.6333
207	30	5.6667
071	30	5.7000
Sig.		.649

Means for groups in homogeneous subsets are displayed.
Based on Type III Sum of Squares
The error term is Mean Square(Error) = 2.186.
a Uses Harmonic Mean Sample Size = 30.000.
b Alpha = .05.

Descriptive Statistics

Dependent Variable: crisp

trt	Mean	Std. Deviation	N
145	5.9667	1.32570	30
537	6.2333	1.22287	30
545	6.0667	1.20153	30
071	6.4000	1.27577	30
207	5.8000	1.37465	30
Total	6.0933	1.28150	150

Crispness

Duncan

trt	N	Subset 1
	1	
207	30	5.8000
145	30	5.9667
545	30	6.0667
537	30	6.2333
071	30	6.4000
Sig.		.109

Means for groups in homogeneous subsets are displayed.
Based on Type III Sum of Squares
The error term is Mean Square(Error) = 1.643.

a Uses Harmonic Mean Sample Size = 30.000.
b Alpha = .05.

Descriptive Statistics

Dependent Variable: overall

trt	Mean	Std. Deviation	N
145	5.5333	1.25212	30
537	5.7000	1.48904	30
545	5.7667	1.35655	30
071	5.9000	1.26899	30
207	5.7333	1.38796	30
Total	5.7267	1.34062	150

Overall

Duncan

	N	Subset
trt	1	1
145	30	5.5333
537	30	5.7000
207	30	5.7333
545	30	5.7667
071	30	5.9000
Sig.		.360

Means for groups in homogeneous subsets are displayed.
Based on Type III Sum of Squares
The error term is Mean Square(Error) = 1.832.
a Uses Harmonic Mean Sample Size = 30.000.
b Alpha = .05.

C2. Statistic analysis of variation of garlic in selected formula

Univariate Analysis of Variance

Between-Subjects Factors

		Value Label	N
trt	1.00	224	26
	2.00	108	26
	3.00	148	26

Descriptive Statistics

Dependent Variable: flavor

trt	Mean	Std. Deviation	N
224	5.6154	1.62670	26
108	5.7308	1.48479	26
148	5.6154	1.60192	26
Total	5.6538	1.55277	78

Homogeneous Subsets

Descriptive Statistics

Dependent Variable: flavor

trt	Mean	Std. Deviation	N
224	5.6154	1.62670	26
108	5.7308	1.48479	26
148	5.6154	1.60192	26
Total	5.6538	1.55277	78

Flavor

Duncan

	N	Subset
trt	1	1
224	26	5.6154
148	26	5.6154
108	26	5.7308
Sig.		.805

Means for groups in homogeneous subsets are displayed.
Based on Type III Sum of Squares

The error term is Mean Square(Error) = 2.472.
a Uses Harmonic Mean Sample Size = 26.000.
b Alpha = .05.

Descriptive Statistics

Dependent Variable: sweetness

trt	Mean	Std. Deviation	N
224	5.0769	1.83135	26
108	5.3077	1.49048	26
148	5.0000	1.78885	26
Total	5.1282	1.69306	78

Sweetness

Duncan

	N	Subset
trt	1	1
148	26	5.0000
224	26	5.0769
108	26	5.3077
Sig.		.546

Means for groups in homogeneous subsets are displayed.
Based on Type III Sum of Squares
The error term is Mean Square(Error) = 2.925.
a Uses Harmonic Mean Sample Size = 26.000.
b Alpha = .05.

Descriptive Statistics

Dependent Variable: sour

trt	Mean	Std. Deviation	N
224	4.8846	1.60815	26
108	5.8462	1.43366	26
148	5.2308	1.63236	26
Total	5.3205	1.59132	78

Sourness

Duncan

	N	Subset	
trt	1	2	1
224	26	4.8846	
148	26	5.2308	5.2308
108	26		5.8462
Sig.		.426	.159

Means for groups in homogeneous subsets are displayed.
Based on Type III Sum of Squares
The error term is Mean Square(Error) = 2.435.
a Uses Harmonic Mean Sample Size = 26.000.
b Alpha = .05.

Sourness

Duncan

	N	Subset	
trt	1	2	1
224	26	4.8846	
148	26	5.2308	5.2308
108	26		5.8462
Sig.		.426	.159

Means for groups in homogeneous subsets are displayed.
Based on Type III Sum of Squares
The error term is Mean Square(Error) = 2.435.
a Uses Harmonic Mean Sample Size = 26.000.
b Alpha = .05.

Descriptive Statistics

Dependent Variable: crisp

trt	Mean	Std. Deviation	N
224	6.0385	1.21592	26
108	6.1154	1.17735	26
148	5.7308	1.28243	26
Total	5.9615	1.22148	78

Crispness

Duncan

trt	N	Subset
	1	1
148	26	5.7308
224	26	6.0385
108	26	6.1154
Sig.		.292

Means for groups in homogeneous subsets are displayed.
Based on Type III Sum of Squares
The error term is Mean Square(Error) = 1.503.
a Uses Harmonic Mean Sample Size = 26.000.
b Alpha = .05.

Descriptive Statistics

Dependent Variable: overall

trt	Mean	Std. Deviation	N
224	5.5000	1.60624	26
108	5.8077	1.29674	26
148	5.3462	1.52164	26
Total	5.5513	1.47399	78

Overall

Duncan

trt	N	Subset
	1	1
148	26	5.3462
224	26	5.5000
108	26	5.8077
Sig.		.295

Means for groups in homogeneous subsets are displayed.
Based on Type III Sum of Squares
The error term is Mean Square(Error) = 2.192.
a Uses Harmonic Mean Sample Size = 26.000.
b Alpha = .05.