ALUMINIUM LEACHING INTO COOKED MEATS WRAPPED WITH ALUMINIUM FOIL AT DIFFERENT COOKING CONDITIONS

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Thesis
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ALUMINIUM LEACHING INTO COOKED MEATS WRAPPED WITH ALUMINIUM FOIL AT DIFFERENT COOKING CONDITIONS

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ABSTRACT

This research aimed to study aluminium contents leached into cooked meats (seabass fish, saba fish, chicken and beef) with and without seasoning, wrapped with brand 1 (a lower aluminium amount) or brand 2 (a higher aluminium amount) aluminium foil and heated by electric oven, electric grill stove or gas stove. The fat contents of each fresh meat, the aluminium contents in seasoning, and the initial aluminium amounts in aluminium foil were determined. The study was designed as a 4×2×2×3 factorial experiment. The analysis of variance and multiple comparisons were calculated in data analysis.

The results showed that kind of meat significantly affected leached aluminium content (p-value<0.05). The cooked meat with seasoning significantly effected higher leached aluminium contents than the cooked meat without seasoning (p-value<0.05). The cooked meat wrapped with brand 2 foil (the higher aluminium amount) significantly effected higher leached aluminium contents than the cooked meat wrapped with brand 1 foil (the lower aluminium amount) (p-value<0.05). Types of cooking significantly affected leached aluminium contents (p-value<0.05).

The most suitable cooking condition for each kind of meat was decided by the lowest aluminium content leached into the cooked meat, for consumer safety. The most suitable cooking condition for seabass fish, chicken and beef was cooking without seasoning, wrapped with brand 1 foil, and heated by electric oven or electric grill stove. The most suitable cooking condition for saba fish was cooking without seasoning, wrapped with brand 1 foil, and heated by electric oven. The meat cooked with seasoning, wrapped with brand 2 foil, and heated by gas stove contained the highest mean of leached aluminium content for all kinds of meat. This cooking condition should be avoided because it can contribute to aluminium accumulation in the human body and may cause impairment of consumer health.

The increased aluminium leaching in this research depends on various factors including kind of meat, use of seasoning, aluminium amount in aluminium foil and type of heat cooking.

KEY WORDS : ALUMINIUM / LEACHING / MEAT / ALUMINIUM FOIL / COOKING CONDITIONS

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การชะละลายของอะลูมิเนียมลงสู่อาหารประเภทเนื้อสัตว์ปรุงสุกซึ่งห่อหุ้มด้วยอะลูมิเนียมฟอยล์ที่สภาวะการปรุงต่างกัน
ALUMINIUM LEACHING INTO COOKED MEATS WRAPPED WITH ALUMINIUM FOIL AT DIFFERENT COOKING CONDITIONS

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บทคัดย่อ

งานวิจัยนี้มีวัตถุประสงค์เพื่อศึกษาปริมาณอะลูมิเนียมที่ชะละลายลงสู่อาหารประเภทเนื้อสัตว์ปรุงสุก (เนื้อปลากะพงขาว, เนื้อปลาซาบะ, เนื้อไก่ และ เนื้อวัว) ซึ่งเติมและไม่เติมเครื่องปรุงโดยการห่อหุ้มด้วยอะลูมิเนียมฟอยล์ ยี่ห้อที่ 1 (ปริมาณอะลูมิเนียมน้อยกว่า) หรือ ยี่ห้อที่ 2 (ปริมาณอะลูมิเนียมมากกว่า) และถูกปรุงร้อนด้วยเตาอบไฟฟ้า, เตาย่างไฟฟ้า หรือ เตาแก๊ส โดยศึกษาปริมาณไขมันในเนื้อสัตว์ดิบแต่ละชนิดและปริมาณอะลูมิเนียมเริ่มต้นในอะลูมิเนียมฟอยล์ด้วย การศึกษาเป็นการทดลองแบบแฟคทอเรียล 4×2×2×3 วิเคราะห์ผลการทดลองด้วยการวิเคราะห์ความแปรปรวนและการเปรียบเทียบความแตกต่าง

ผลการศึกษาพบว่า ชนิดของเนื้อสัตว์ มีผลต่อปริมาณอะลูมิเนียมที่ชะละลายออกมาแตกต่างกันอย่างมีนัยสำคัญทางสถิติ(p-value<0.05), การปรุงเนื้อสัตว์โดยการเติมเครื่องปรุง มีผลต่อปริมาณอะลูมิเนียมที่ชะละลายออกมามากกว่าการปรุงเนื้อสัตว์โดยไม่เติมเครื่องปรุงอย่างมีนัยสำคัญทางสถิติ(p-value<0.05), การปรุงเนื้อสัตว์โดยการห่อหุ้มด้วยฟอยล์ยี่ห้อที่ 2 (ปริมาณอะลูมิเนียมมากกว่า) มีผลต่อปริมาณอะลูมิเนียมที่ชะละลายออกมามากกว่าการปรุงเนื้อสัตว์โดยการห่อหุ้มด้วยฟอยล์ยี่ห้อที่ 1 (ปริมาณอะลูมิเนียมน้อยกว่า) อย่างมีนัยสำคัญทางสถิติ(p-value<0.05) และประเภทของอุปกรณ์ที่ใช้ปรุงอาหาร มีผลต่อปริมาณอะลูมิเนียมที่ชะละลายออกมาแตกต่างกันอย่างมีนัยสำคัญทางสถิติ(p-value<0.05)

สภาวะการปรุงที่เหมาะสมที่สุดสำหรับเนื้อสัตว์แต่ละชนิดพิจารณาจากปริมาณอะลูมิเนียมที่ชะละลายออกมาน้อยที่สุดเพื่อความปลอดภัยของผู้บริโภคสภาวะการปรุงที่เหมาะสมที่สุดสำหรับเนื้อปลากะพงขาว, เนื้อไก่ และ เนื้อวัวคือการปรุงโดยไม่เติมเครื่องปรุงที่ห่อหุ้มด้วยฟอยล์ยี่ห้อที่ 1 และถูกปรุงด้วยความร้อนโดยเตาอบไฟฟ้าหรือเตาย่างไฟฟ้า สภาวะการปรุงที่เหมาะสมที่สุดสำหรับเนื้อปลาซาบะคือการปรุงโดยไม่เติมเครื่องปรุงที่ห่อหุ้มด้วยฟอยล์ยี่ห้อที่ 1 และถูกปรุงด้วยความร้อนโดยเตาอบไฟฟ้า การปรุงเนื้อสัตว์โดยการเติมเครื่องปรุง ที่ห่อหุ้มด้วยฟอยล์ยี่ห้อที่2 และถูกปรุงด้วยความร้อนโดยเตาแก๊ส เป็นสภาวะการปรุงที่ให้ปริมาณอะลูมิเนียมที่ชะละลายออกมามากที่สุดในเนื้อสัตว์ทุกชนิด ดังนั้นจึงควรหลีกเลี่ยงการปรุงเนื้อสัตว์ที่สภาวะนี้เพราะจะนำไปสู่การสะสมของอะลูมิเนียมในร่างกายและอาจเป็นอันตรายต่อสุขภาพของผู้บริโภคได้

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CHAPTER I
INTRODUCTION

1.1 Rationale and Background

Nowadays, aluminium is widely used for manufacturing household utensils and packaging materials. Consumption of 28% for all aluminium in the United States is used for the purpose of packaging and 75% of packaging is aluminium foil for food packaging (e.g., drink cans and foil for pie plates and frozen foods) (1-2). Aluminium foil is very popular for packaging, storing, and cooking of various foods because it can prevent loss of valuable aromas and protect contents against light, oxygen, moisture and contamination. It guarantees product quality and protection against deterioration for sensitive and valuable products. Aluminium foil use is the common practice to wrap meat and fish prior to grill or cook in the oven in order to prevent loss of moisture and avoid direct heat that may result in a less appealing texture. The widespread uses of aluminium foil make it as a significant potential source of aluminium in food.

Aluminium is a non-essential metal which humans are frequently exposed (3-4). Human exposure mainly experienced through oral intake, and the major sources are drinking water, residues in foods, cooking utensils, food packaging, and aluminium containing medications (such as antacids and buffered aspirins). Aluminium sources in food come from natural sources, food additives (e.g., baking powder, anti-caking agent, sodium aluminosilicate) and food containers (e.g., cookware, utensils, cans and food wrappings) (2). Aluminium concentrations are less than 5 mg/kg in most unprocessed foods. The most consumption of aluminium ranged from 1 to 10 mg/person/day from natural dietary sources. Aluminium concentrations in foods generally ranged from less than 0.15 mg/kg in eggs, apples, raw cabbage, corn, and potatoes to 695 mg/kg in American cheese (5). Aluminium concentrations in Spain and the Mediterranean diet ranged from 3.74 mg/kg dry weight in cinnamon to 56.50 mg/kg dry weight in oregano (6). The high aluminium concentrations were found in some processed foods such as processed cheeses, baked goods, grain products, dairy product and grain based desserts (5, 7).

The effects of aluminium on human health have been extensively reviewed. It was found that aluminium is an etiologic factor in the origin of several illnesses (8). Aluminium toxicity has also been associated with neurological failures (Alzheimer's diseases), chronic renal failure, and osteomalacia (9-15). The toxic activity of aluminium is connected with its accumulation in human body, which can lead to the impairment or the destruction of tissue, organs, and nervous system (8). Although the kidney appears to be able to excrete aluminium in healthy persons, it is not known about the limit of elimination capacity and it is certain that people suffering from chronic renal failure do not possess the ability to excrete it (1, 16-17).

In recent years, the aluminium effects on human health interested many researchers. The association between aluminium in food and the mentioned above diseases was studied. Several studies were found that aluminium can be leached into foods which cooked or stored in aluminium containers. The increased aluminium leaching reported in these researches are dependent on various factors such as the composition of food, pH value, temperature, duration of contact or heating, presence of fluoride, sugar, salt, etc. The cooking of acidic and low acidic foods in aluminum utensils or storing in aluminum foil or cans results in the increase of aluminum concentrations in food (1, 17-23). Some studies showed that the presence of fluoride caused the leaching of aluminium from cookware (24-25). The increase of cooking temperature also results in the increase of aluminium in foods (22, 26-28).

Although aluminium foil and containers are widely used to cook, freeze, or wrap foods, the research information on leached aluminium concentrations in foodstuffs derived from Thai foods and from cooking utensils especially aluminium foil is scanty. Therefore this study was conducted to determine leached aluminium contents into meat wrapped with aluminium foil at different conditions. The various conditions about seasoning and types of heat cooking in each kind of meat will be studied. Kinds of meat and seasonings are popular for grill or bake in Thailand. The heats for cooking are electric oven, electric grill stove and gas stove. Moreover, aluminium amounts in aluminium foil are obtained. The interactions between various conditions will be studied. The study results can be applied as appropriate suggestion in using of aluminium foil.

1.2 Objectives of the Study

1.2.1 General objective

To study aluminium contents leached into cooked meats wrapped with aluminium foil at different cooking conditions.

1.2.2 Specific objective

1) To compare aluminium contents leached into cooked meats that wrapped with aluminium foil when using different kinds of meat.

2) To compare aluminium contents leached into cooked meats that wrapped with aluminium foil when use and non-use of seasoning.

3) To compare aluminium contents leached into cooked meats that wrapped with aluminium foil when using different aluminium amounts in aluminium foil.

4) To compare aluminium contents leached into cooked meats that wrapped with aluminium foil when using different types of heat cooking.

5) To compare aluminium contents leached into cooked meats that wrapped with aluminium foil when using different kinds of meat, use of seasoning, aluminium amounts in aluminium foil and types of heat cooking.

1.3 Hypothesis of the Study

1.3.1 The kinds of meat affect leached aluminium contents.

1.3.2 The meat cooked with seasonings affects higher leached aluminium contents than the meat cooked without seasoning.

1.3.3 The higher aluminium amount in aluminium foil affects leached aluminium contents higher than the lower aluminium amount in aluminium foil.

1.3.4 The types of heat cooking affect leached aluminium contents.

1.3.5 The kinds of meat, use of seasoning, aluminium amounts in aluminium foil and types of heat cooking affect leached aluminium contents.

1.4 Variables of the Study

1.4.1 Independent Variable

- Kinds of meat
- Use of seasoning
- Aluminium amounts in aluminium foil
- Types of heat cooking

1.4.2 Dependent Variable

- Leached aluminium contents into cooked meats (mg/kg)

1.4.3 Control Variable

- Size of meat
- Quantity of seasoning used for cooking each meat
- Cooking time and temperature
- Size of aluminium foil
- Brands of aluminium foil with lower and higher initial-aluminium amounts
- Method for wrapping meat with aluminium foil

1.5 Definitions of Terms

1.5.1 Leached aluminium contents into cooked meats (mg/kg): The amounts of aluminium in meat were measured by a flame atomic absorption spectrophotometer (FAAS) to find different aluminium contents before and after cooking. The value of aluminium content in meat was indicated by concentration value from the FAAS according to Standard methods for the examination of water and wastewater (29). The aluminium content in meat was expressed in mg/L then the value was transformed to mg/kg by the following equation.

$$\begin{pmatrix}\text{Aluminium content}\\ \text{in meat (mg/g)}\end{pmatrix} = \frac{\text{Aluminium concentration (mg/L)}}{\text{Weight of meat sample (g)}} \times 25\ \text{mL} \times \frac{1\ \text{L}}{10^3\ \text{mL}}$$

$$\begin{pmatrix}\text{Aluminium content}\\ \text{in meat (mg/kg)}\end{pmatrix} = \frac{\text{Aluminium concentration (mg/L)}}{\text{Weight of meat sample (g)}} \times (25 \times 10^{-3})\ \text{mL} \times \frac{10^3\ \text{g}}{1\ \text{kg}}$$

$$\text{Leached aluminium content into cooked meat (mg/kg)} = C_a - C_b$$

Where; C_a is aluminium content in cooked meat (after cooking).
C_b is aluminium content in fresh meat (before cooking).

1.5.2 The percentage of fat content (%): The percentage values of various crude fats and crude oils in meat (such as fats, oils, waxes, cholesterol, sterols, fat-soluble vitamins, monoglycerides, diglycerides, phospholipids and others) were measured by soxhlet extraction unit to find fat contents in meat. According to the Official Methods of Analysis of AOAC International (30), the percentage value of fat content was calculated by the following formula.

$$\text{Fat content (\%)} = \left(\frac{C - B}{A}\right) \times 100$$

Where; A is the weight of meat sample (g).
B is the weight of extraction cup (g).
C is the weight of extraction cup + residue (g).

1.5.3 Aluminium foil: The metal that made into very thin sheets was used for covering or wrapping food. Aluminium foils for this experiment were from two brands (i.e. the brands of aluminium foil with lower and higher initial aluminium amounts) that sold generally in Thailand. Size of aluminium foil was equal to 30 x 30 cm in every experiment. Contact areas of aluminium foil with meats were controlled by the same method for wrapping with aluminium foil in every experiment as shown in Chapter 3.

1.5.4 Kinds of meat: Meats in this experiment referred to the muscular part of animals used as human food. In this study, the used meats were seabass fish, saba fish, chicken and beef which each meat was classified by different kinds of meat and fat levels. The same size of each meat was used in every experiment (a whole fish per one treatment, and a piece of chicken or beef per one treatment). The breast chicken meat was used as a chicken meat representative and the round beef meat as a beef meat representative.

1.5.5 Seasoning: The substance used to add flavour to food. In this study, seasoning were composed of garlic, pepper, salt and soy sauce which were widely used in Thailand. The quantity of seasoning was the serving portion for specific dish, which was shown in chapter 3. The same quantities of seasoning were used in every experiment. Seasoning in this study were as follows:

Kinds of meat	Seasoning
Seabass fish and Saba fish	Salt and Soy sauce
Chicken and Beef	Garlic, Black pepper and Soy sauce

1.5.6 Types of heat cooking: The way for cooking meat which was the selected temperature and time that make meat just enough cooking and appetizing, which depends on the guideline of each type of heat cooking that it was actual cooking method. Types of heat cooking in this study were as follows:

Types of heat cooking	Temperature (°C)	Time (min.)
Electric oven	200	60
Electric grill stove	200	60
Gas stove	300	20

1.5.7 Aluminium amounts in aluminium foil: The percentage of aluminium in aluminium foil. The representative pieces of aluminium foil samples were randomly selected. The concentration of aluminium was measured by a flame atomic absorption spectrophotometer (FAAS). The aluminium amounts were expressed in mg/L then the value was transform as a percentage by weight of aluminium foil. Aluminium amount in aluminium foil (%) was calculated by the following formula (29).

$$\begin{pmatrix}\text{Aluminium concentration}\\ \text{in aluminium foil (mg/g)}\end{pmatrix} = \frac{\text{Aluminium concentration (mg/L)}}{\text{Weights of aluminium foil (g)}} \times 25\ \text{mL} \times \frac{1\ \text{L}}{10^3\ \text{mL}}$$

$$\begin{pmatrix}\text{Aluminium amounts}\\ \text{in aluminium foil (\%)}\end{pmatrix} = \begin{pmatrix}\text{Aluminium concentration}\\ \text{in aluminium foil (mg/g)}\end{pmatrix} \times \frac{1\ \text{g}}{1000\ \text{mg}} \times 100$$

1.5.8 Cooking conditions: The condition was used for cooking food. In this study, cooking conditions were composed of various conditions including the kinds of meat, the use of seasoning, the aluminium amounts of aluminium foil, and the types of heat cooking which were studied about their influence on aluminium leaching.

1.6 Scope of the Study

1.6.1 This study was not tested for every kinds of meat. The seabass fish, saba fish, chicken and beef were selected because they were usually as wrapped foods and sold in the markets.

1.6.2 Meat samples used in this study were purchased from a supermarket and cooked in laboratory, which were not collected from the raw-food markets.

1.6.3 Aluminium foils in this study included two brands, which were the products that generally sold in Bangkok, Thailand.

1.6.4 The seasoning used in this study were as the specific ingredients for specific dish, which selected to correspond with each kind of meat.

1.7 Limitation of the Study

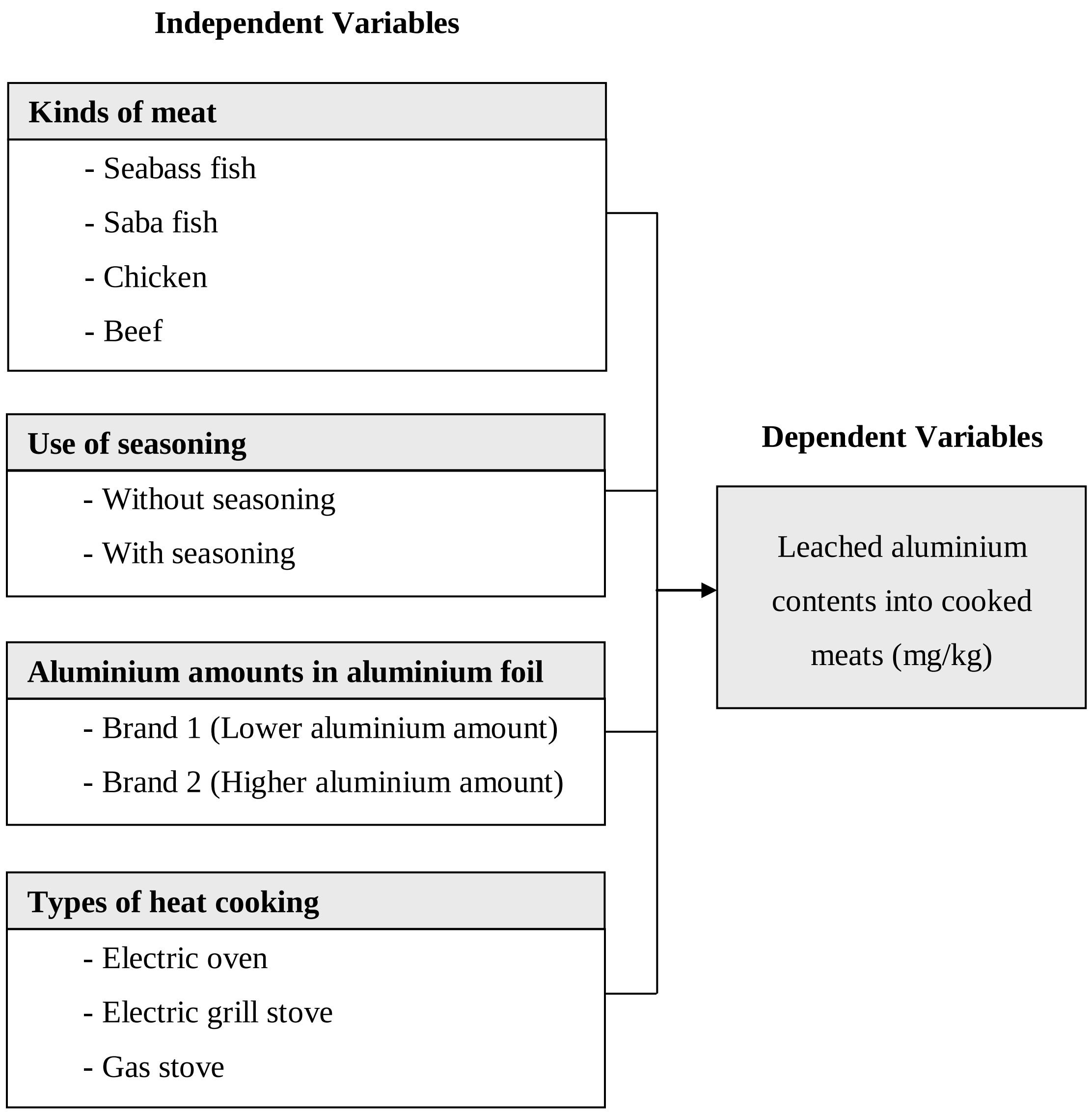
1.7.1 Aluminium foil used could not be tested for every brand. The brands of aluminium foil used in this study were two brands of aluminium foil which contained lower and higher initial aluminium amounts.

1.7.2 This study was not tested for every cooking temperature and time because types of heat cooking depended on the guideline of each heating equipment which its optimum cooking temperature and time would make different kinds of meat just enough cooking and appetizing.

1.8 Expected Outcome

The experimental results of this study indicated the factors affect the leaching of aluminium into meats that wrapped with aluminium foil. Moreover, they can be applied for the suggestion on appropriate use of aluminium foil and make consumers realize the accumulation effect that may happen from taking aluminium from the wrapped meats.

1.9 Conceptual Framework



CHAPTER II
LITERATURE REVIEW

2.1 Aluminium

Aluminium (Al) is metal occurs naturally in soil, clays, minerals, rocks, and even in water and food (1). Aluminium is widely used for manufacturing products in many industries because of its favorable physical characteristics and as a highly corrosion resistant metal. Sources to human exposure include air, food, water and soil. Generally, humans are exposed to aluminium by the ingestion of food and water. Aluminium-containing food ingredients are used mainly as preservatives, coloring agents, leavening agents, anti-caking agents, etc.

(a) 

(b) 

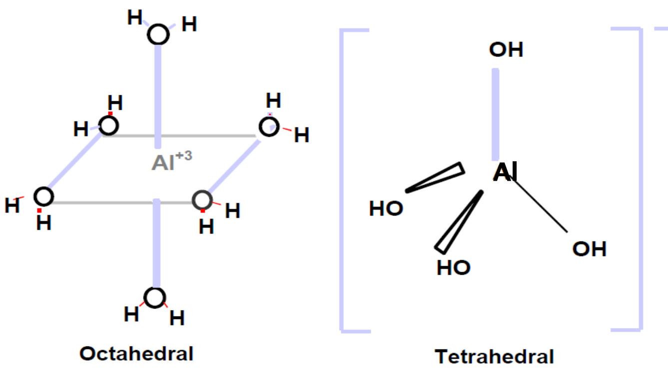
(c) 

Figure 2.1 (a) Aluminium; (b) Bauxite or Aluminium Ore; and (c) Configuration of soluble aluminium salts

2.1.1 Chemical and physical properties

Aluminium (atomic number of 13; atomic weight of 26.98; valence of 3; Density at 25°C of 2.70 g/cm^3) is a silvery-white, malleable, lightweight, and durable metal. Aluminium is shown in Figure 2.1 (a). Aluminium is a good conductor of heat and electricity, and is easily shaped by moulding and extruding. The melting point is 660ºC and the boiling point is 2467ºC at atmospheric pressure (1-2, 12, 16, 29) The physical and chemical properties of aluminium and some aluminium compounds are shown in Table 2.1.

Aluminium has two main advantages when compared with other metals. Firstly, it has a low density when comparing with iron and copper. Secondly, although it reacts rapidly with the oxygen in air, it forms a thin tough and impervious oxide layer which resists further oxidation. In addition, aluminium has a high corrosion resistance because of the tough oxide film always present on the surface of aluminium in the presence of air, water vapour, etc., and it has a strong affinity for oxygen (31).

Aluminum can exist as compounds that may be soluble or insoluble in water depending on the counter ion and solution pH. Aluminum ions, formed by the dissolution of soluble aluminum salts, exist as hexahydrate ions in an octahedral configuration as shown in Figure 2.1 (c). The high charge of aluminum ions results in the loss of hydration shell protons that produces a series of hydrolysis products. Aluminum induced hydrolysis produces acidic solutions for virtually all water-soluble salts. Aluminum exhibits a complex, pH-dependent chemistry in aqueous systems and the ability to produce important effects from either acidic or alkaline aluminum sources. Solutions of aluminum salts contain only $Al(H_2O)_6^{3+}$ at pH values below 3. When pH values are between three and five, aluminum species are distributed between a mixture of hydroxo species including $Al(OH)^{2+}$, $Al(OH)_2^+$, and various polynuclear (containing two or more aluminum atoms) cations. At pH values between 5 and 6, $Al(OH)_3$ appears. As the pH becomes more alkaline, $Al(OH)_4^-$ becomes dominant. Under appropriate conditions, aluminum forms an amphoteric hydroxide which at higher pH forms soluble tetrahydroxyaluminate anion. Aluminum hydroxides exist in several crystalline or amorphous forms. Wellbore stability is enhanced by precipitation of aluminum hydroxides within shale pore throats and micro-fractures (32, 33).

Table 2.1 Physical and Chemical Properties of Aluminum and Its Compounds

Compound	Molecular Weight	Physical State	Odor	Melting Point (°C)	Boiling Point (°C)	Density at 25°C	Solubility	
							Water at 25°C	Organic Solvents
Aluminum	26.98	Tin-white with bluish tint malleable, ductile metal; crystalline solid	Metallic odor when dust is inhaled	660	2327, 2450, 2467	2.70	Insoluble, rapidly oxidized at 180°C	Soluble in alkalies and acids
Aluminum aceglutamide	1084.98	no data available	no data available	no data available	no data available	no data available	no data available	no data available
Aluminum acetylaceto-mate	324.31	Colorless, monoclinic crystals	no data available	190-193	315	3.3	Practically insoluble	Very soluble in alcohol; soluble in ether and benzene
Aluminum carbonate	145.97	White lumps or powder	no data available	no data available	no data available	no data available	insoluble	dissolves in hot hydro-chloric or sulfuric acid
Aluminum chloride	133.34	White (when pure), ordinarily gray, or yellow to greenish crystals	Strong odor of hydro-chloric acid	Volatilizes without melting; 190 at 2.5 atm and 194 at 5.2 atm	182.7 at 752 mm Hg; sublimes readily at 178 or 181	2.44	Reacts explosively, evolving hydrogen chloride gas	Freely soluble in benzo-phenone, benzene, nitrobenzene, carbon tetra-chloride, chloroform; soluble in alcohol and ether
Aluminum chlorohydrate	174.46	Glassy solid	no data available	no data available	no data available	no data available	Dissolves, forming slightly turbid colloidal solutions (up to 55% w/w)	no data available
Aluminum fluoride	83.98	White, colorless, or triclinic hexagonal crystals	no data available	1291; sublimes at 1272 (760 mm Hg)	1276 (sublimation point)	2.88	0.559 g/100 mL	Sparingly soluble in acids and alkalies; insoluble in alcohol and acetone
Aluminum hydroxide	77.99	White bulky, amorphous powder	no data available	300	no data available	2.42	Practically insoluble; form gels on prolonged contact	Soluble in alkaline aqueous solutions or in hydro-chloric and sulfuric acid

Sources: Integrated Laboratory Systems (ILS), 2000 (2).

Table 2.1 Physical and Chemical Properties of Aluminum and Its Compounds (continue)

Compound	Molecular Weight	Physical State	Odor	Melting Point (°C)	Boiling Point (°C)	Density at 25°C	Solubility	
							Water at 25°C	Organic Solvents
Aluminum lactate	294.18	Colorless or white-yellowish powder	no data available	no data available	no data available	no data available	Freely soluble	no data available
Aluminum maltolate	402.18	no data available	no data available	no data available	no data available	no data available	no data available	no data available
Aluminum nitrate	213.00; 375.15 (hydrate)	White Nona hydrate, deliquescent crytals	Odorless	73	Decomposes at 135	1.72 (hydrate)	Very soluble (63.7 g/100 cc)	Very slightly soluble in acetone; almost insoluble in ethyl acetate and pyridine
Aluminum oxide	101.94	White crystalline powder	no data available	~2000, 2030, 2054	~3000	3.97	Practically insoluble in cold water (0.000098 g/100 cc; 980 ppb)	Slowly soluble in aqueous alkaline solution; practically insoluble in non-polar organic solvents
Aluminum palmitate	793.24	White to yellowish mass or powder	no data available	no data available	no data available	no data available	Practically insoluble	Practically insoluble in alcohol; when fresh, dissolves in petroleum ether or oil turpentine
Aluminum phosphate	121.95	White infusible powder or crystals	no data available	>1460	no data available	2.56 at 23°C	insoluble	Very slightly soluble in concentrated hydrochloric or nitric acid
Aluminum phosphide	57.96	Dark gray or dark yellow crystals	garlic odor	does not melt or decompose thermally at temperatures up to 1000	no data available	2.85 at 15°C	decomposes	no data available
Aluminum potassium sulfate	258.21	White powder	no data available	no data available	no data available	no data available	50 g/L	Insoluble in alcohol
Aluminum sulfate	342.14	White, lustrous crystals, pieces, granules, or powder	odorless	Decomposes at 770 or 1040	no data available	2.71	Soluble in 1 part water	Soluble in dilute acids; practically insoluble in alcohol
Dihydroxyaluminum sodium carbonate	144.00	Amorphous powder or poorly formed crystals	no data available	no data available	no data available	2.144	no data available	no data available

Sources: Integrated Laboratory Systems (ILS), 2000 (2).

2.1.2 Environmental Sources of Aluminium

a. Natural sources

Aluminium is the third most abundant element in the earth's crust, comprising about 8.8% of the earth's crust (1). Aluminum occurs in nature combination with silicon and oxygen (called aluminosilicates) to form feldspars, minerals corundum (Al_2O_3), diaspore ($Al_2O_3.H_2O$), gibbsite ($Al_2O_3.3H_2O$), and most commonly as bauxite ($Al_2O_3.2H_2O$) (4, 34-36). Bauxite or aluminium ore is shown in Figure 2.1 (b).

b. Anthropogenic sources

Direct anthropogenic releases of aluminum compounds are primarily into the atmosphere and are associated with industrial processes such as smelting. However, the use of aluminum and aluminum compounds in processing, packing, storage of food products, and as flocculants in the treatment of drinking water may contribute to its presence in food and drinking water (3).

2.1.3 Uses of Aluminium

Aluminum is a light, conductive, corrosion resistant metal with a strong affinity for oxygen. This combination of properties has made it a widely used material, with applications in the aerospace, architectural construction, marine industries, as well as many domestic uses (1, 31). The uses of aluminium compounds are shown in Table 2.2.

The major uses are in packaging (25% consumption; e.g., drink cans and foil for pie plates and frozen foods), building and construction (15%; siding and roofing, doors, and windows), transportation (34%; bodies, trim, and mechanical parts of cars, boats, and planes), and electrical applications (8%; overhead transmission lines, cable sheathing, and wiring) (1-2, 16).

Table 2.2 Uses of Aluminum Compounds

Compounds	Uses
alums*	as a hardening agent and setting accelerator for gypsum plaster; in tanning and dyeing; in styptic pencils (former use)
aluminas*	in water treatment; as an accelerator for concrete solidification (high alumina cements)
alkoxides*	in varnishes for textile impregnation; in cosmetics; as an intermediate in pharmaceutical production
borate*	in the production of glass and ceramics
carbonate*	in antacids
chlorides	anhydrous form: as an acid catalyst; as a chemical intermediate for other aluminum compounds; in the cracking of petroleum; in the manufacture of rubbers and lubricants; as an antiperspirant hexahydrate form: in the preservation of wood; in the disinfection of stables and slaughterhouses; in deodorants and antiperspirants; in cosmetics as an astringent; in the refinement of crude oil; in dyeing fabrics; in manufacture of parchment paper
chlorohydrate	as the active ingredient in many antiperspirants and deodorants
hydroxide	in stomach antacids (including Maaloxa, Mylantaa, and Delcida); as a desiccant powder; in antiperspirants and dentifricesa; in packaging materials; as a chemical intermediate; as a filler in plastics, rubber, cosmetics, and paper; as a soft abrasive for brass and plastics; as a glass additive to increase mechanical strength and resistance to thermal shock, weathering, and chemicals; in ceramics; to lower the plasma phosphorus levels of patients with renal failure
isopropoxide*	in the soap and paint industries; in waterproofing textiles
nitrate	in antiperspirants; for tanning leather; as a corrosion inhibitor; in the preparation of insulating papers; on transformer core laminates; in incandescent filaments; in cathode ray tube heating elements
oxide	in the production of aluminum; in the manufacture of abrasives, refractories, ceramics, electrical insulators, catalysts and catalyst supporters, paper, spark plugs, crucibles and laboratory works, adsorbent for gases and water vapors, chromatographic analysis, fluxes, light bulbs, artificial gems, heat resistant fibers, food additives (dispersing agent), and in hollow-fiber membrane units used in water desalination, industrial ultrafiltration, and hemodialysis; as a dosimeter for measuring personnel radiation exposure
phosphate	in over-the-counter stomach antacids
phosphide	as an insecticidal grain fumigant
silicate*	as a component of dental cement; in antacids and food additives
sulfate	as a flocculent for water purification systems and sewage treatment; in the paper and pulp industry; in fireproofing and waterproofing cloth; in clarifying oils and fats; in waterproofing concrete; in antiperspirants; in tanning leather; as a mordant in dyeing; in agricultural pesticides; as an intermediate in the manufacture of other chemicals; in cosmetics and soap; in the preparation of aluminum acetate ear drops Solutions containing 5-10% aluminum sulfate: as local applications to ulcers; to arrest foul discharges from mucous surfaces
trioxide*	as an absorbent, abrasive, and refractory material

Sources: ATSDR, 2006 (1); ILS, 2000 (2); and *IPCS, 1997 (16)

2.1.4 Manufacturing of Aluminium

Aluminum is produced from raw materials including bauxite (which contains 40 to 60% aluminum oxide [Al_2O_3]), cryolite (Na_3AlF_6), aluminum fluoride, fluorspar (CaF_2), corundum ($Al_2O_3 \cdot xH_2O$), and kaolin materials. Purified aluminum oxide is obtained from bauxite by the Bayer Process. Aluminum metal is produced in the Hall/Heroult reduction cell. In this process, Al_2O_3 is dissolved in a molten salt (cryolite—Na_3AlF_6) at temperatures of 900ºC to 1000ºC. Electric current is passed through the reduction cell which results in oxygen being released at the carbon anodes and molten aluminum being produced at the cathode, underneath the molten salt layer. The aluminum is virtually pure metal, having an aluminum content of 99.5% or more. The molten aluminum is drawn from the reduction cell and cast into billets, direct chill ingots or continuously cast into sheet (1-2, 35, 37).

Aluminium products are produced and sold in two major groups, that of purity grades and that of alloys (31). Most commercial uses of aluminium require special properties that the pure metal cannot provide. Therefore, alloying agents are added to impart strength, improve formability characteristics and influence corrosion characteristics. A wide range of aluminium alloys is commercially available for packaging applications, depending on the container design and fabrication method being used. The chemical composition and typical usage of some of the more commonly used aluminium alloys (the aluminium is at least 99% pure) (35). The common grades are comprised of major aluminium element and other elements (impurities), e.g. copper, manganese, silicon. The high purity grade of aluminium (99.95%) is typical used for producing extrusion joinery, electrical conductor, anodic trim and foil. At aluminium content of 99.80% is produced as plumbing reflectors, jewellery. At aluminium content of 99.50% is used for chemical plant, tanks, tubes, pots, pans, sheetmetal work (31).

Alloying is carried out by the addition of suitable quantities of the alloying element to molten aluminium in order to improve the properties in some way. This is done in a special holding furnace, usually by adding the element direct, e.g. magnesium, iron, silicon, or a master alloy or hardener (e.g., manganese as a 10% Mn - 90% Al hardener). Many alloys have been developed, the aim being to improve strength while retaining the desirable properties of aluminium, most notably its lightness and corrosion resistance. While the addition of an alloying element increases the strength, it reduces the resistance to corrosion, making a compromise of properties necessary. A possible exception to this is magnesium alloys, which have improved corrosion resistance in marine environments. Aluminium-copper alloys have very poor resistance to corrosion, and sheets are often produced in sandwich form with thin layers of pure corrosion resistant aluminium on the outside (31).

The alloys are identified by four-digit numbers where the value of the first digit indicates the alloy type and principal alloying ingredient. Commercially pure aluminium (Type 1100 and Type 1050) is used for the manufacture of foil and extruded containers since it is the least susceptible to work hardening. Aluminium foil is available in a variety of alloys, with the alloys 1100, 1145 and 1235 most commonly used in flexible packaging and 3003 when heavier gauges are required for stiffness. Type 5182 alloy contains 4 to 5 % magnesium and 0.35 % manganese, producing a very rigid material suitable for manufacturing beverage can ends (35). The general effect of several alloying elements on the corrosion behavior of aluminium and some typical uses are shown in Table 2.3.

Table 2.3 A summary of the effect on the aluminium corrosion behavior and some typical uses of alloys

Alloy element	General effect on the aluminium corrosion behavior*	Some typical uses
Copper	reduces the corrosion resistance of aluminium more than any other alloying element and leads to a higher rate of general corrosion	High strength aircraft parts
Manganese	slightly increases corrosion resistance	Sheetmetal work, pots, pans etc.
Silicon	slightly decreases corrosion resistance, depending on its form and location in the alloy microstructure	Motor parts, castings of all types
Magnesium	a beneficial influence and aluminium-magnesium alloys have good corrosion resistance	Marine uses, boats, fish boxes, beer can lids, etc.
Zinc	only a small influence on corrosion resistance in most environments, tending to reduce the resistance of alloys to acid media and increase their resistance to alkalis	High strength aircraft
Chromium	increases corrosion resistance in the usual amounts added to alloys	Easy-open beverage can ends
Iron	reduces corrosion resistance and is probably the most common cause of pitting in aluminium alloys; a high iron content increases the bursting strength but reduces the corrosion resistance	Beverage can ends and D&I can bodies
Titanium	little influence on corrosion resistance of aluminium alloys	Flexible tubes and foils

Sources: Grjotheim, K (31); and *Gordon L Robertson (35)

2.1.5 Environmental Transport, Distribution and Transformation

Aluminum is present ubiquitously in the form of silicates, oxides, and hydroxides, combined with other elements such as sodium and fluorine, and as complexes with organic matter. Aluminium is transported and distributed in the environment depend on its chemistry and the characteristics of the local environmental system (3). It is associated with both unavailable and available forms. Unavailable form of aluminium is largely associated with aluminosilicate minerals, most commonly as feldspars in non-weathered igneous rocks and as clay minerals in well-weathered soil. Available aluminium is nonsilicate-bound aluminium which occurred from crystalline aluminosilicate minerals, and this small fraction participates in biogeochemical processes (38). When crystalline aluminosilicate minerals occur from the well-weathering of metamorphic and igneous rocks, they are decomposed by carbonic acid and strong acid dissolution, and neutral hydrolysis and become available to participate in biogeochemical processes. The processes include biological assimilation associated with inorganic and organic ligands in water, followed by precipitation. Aluminium is also retained on the surfaces of charged soil or sediment associated with organic matter or clay minerals (39).

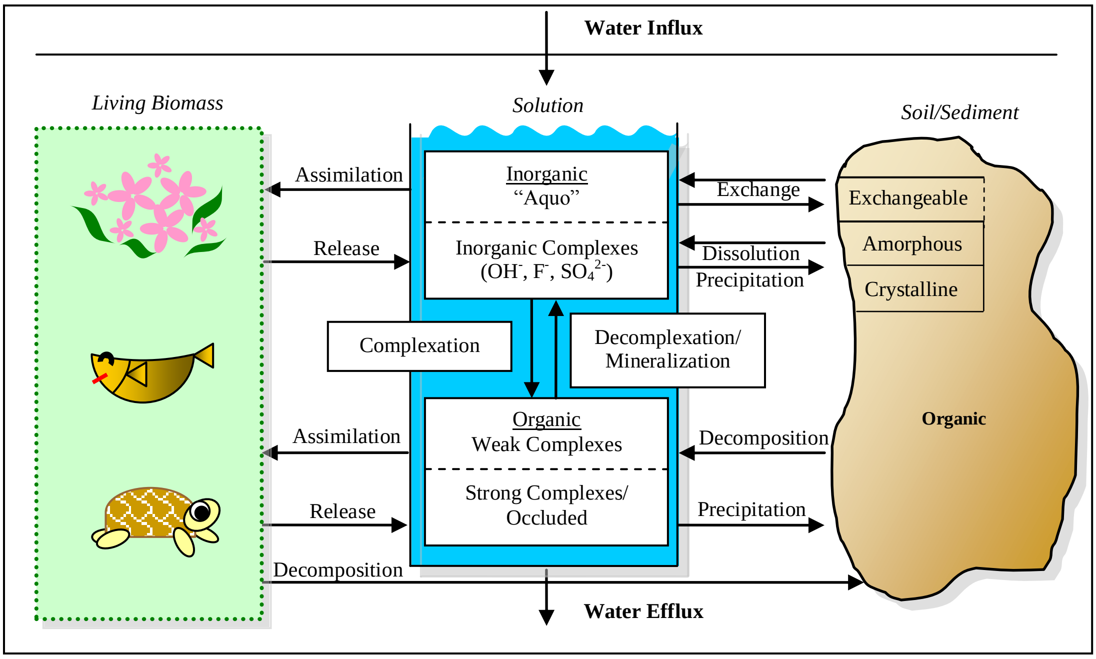


Figure 2.2 A schematic representation of the aluminium cycle (39)

Finally, decomposition and transformation of aluminium occur by microbial and plants. However, aqueous aluminium is derived largely from free soil pools than the release of aluminium from highly crystalline minerals (34-35, 39). The schematic representation of the aluminium cycle is shown in Figure 2.2.

On acidification of soils, aluminum can be released into solution for transport to streams. Several investigators studied the concentration of aluminum in sediments from different countries. Mean aluminum concentration in sediments from different countries ranges from 20,000 to 80,000 mg/kg (3). Elevated aluminium concentration is often toxic to the variety of organisms; they can not survive large intracellular accumulation. Therefore, living biomass is generally assumed to be a minor pathway. Nevertheless, some plants are capable of accumulating high concentrations of aluminium (39).

2.1.6 Sources of Aluminium to Human Expose

Aluminium is ubiquitous in the environment and is used in a variety of products. Exposure of the general population to aluminium is inevitable. The sources inevitably of exposure of human to aluminium include water, food, cookware, soil, and medicines.

a. Water

Aluminium in natural waters is mainly derived from weathering of aluminium-containing rocks and minerals (1). Aluminium levels in surface waters are also affected directly or indirectly by human activity through industrial and municipal discharges, surface run-off, tributary inflow, groundwater seepage, and wet/dry atmospheric deposition (2). Analytical data from drinking water in the United States suggested that the aluminium content of raw surface water is higher than that of raw ground water. Additionally, aluminium concentrations were greater than 0.05 mg/L in 55% of the raw surface water samples and in only 4% of the raw groundwater samples (40). Aluminium levels in water vary with pH and the humic-derived acid content of the water (1-2). At pH less than 5, the aluminium concentration is high. Levels up to 269 mg/L were found in surface water samples contaminated with acidic mine drainage (pH range from 2.1 to 3.4) and collected at seven different locations in the vicinity of abandoned coal mines in west-central

Indiana (2). Between pH 6 and 8, aluminum is only sparingly soluble. Concentration of dissolved aluminium in raw water near pH 7 is typically between 1 and 50 μg/L while it can increase from 500 to 1000 μg/L in acidified water (40). Humic acid content plays a role on aluminium levels in natural waters. In lakes at neutral pH levels, the high dissolved aluminum levels were found with a high humic acid content (2).

Aluminium also is present in drinking water owing to the use of aluminum salts (alum or aluminum sulfate) as coagulants to remove color and turbidity in water treatment processes (41). Typical coagulant doses are 2–5 mg Al/L. Aluminium sulfate is frequently added as a coagulant to flocculate the organic matter and to clarify the water in water treatment plant (33). Drinking water contributes only about 3% of total daily intake of aluminum. According to the estimates of World Health Organization/International Program on Chemical Safety (16), drinking water may contribute around 0.4 mg daily at present international guidelines values, but the amount is more likely to be around 0.2 mg per day.

b. Food

Food is the main source of aluminium intake. Aluminum in foods comes from natural sources, water used in food preparation, and food additives. Aluminium in food varies widely, depending upon the plant varieties, and soil conditions (3). Unprocessed foods typically contain less than 5 ppm. The aluminium levels in beverages ranged 0.02-4.3 ppm (fruit juices, soft drinks, instant and whole coffee, etc.); animal products 0.06-14.10 ppm (cooked beef, cheese, milk, etc.); fruits (apples, peaches, dried raisins, etc.) 0.05-3.1 ppm; grains (bread, cereal, rice, spaghetti, etc.) 0.040-400 ppm; vegetables and legumes (corn, peanut butter, potatoes, etc.) 0.1-25.2 ppm; and dried herbs and spices (basil, cinnamon, thyme, etc.) 82-3,082 ppm (2). Recently, World Health Organization/International Program on Chemical Safety (16) summarized the total intake of aluminum from food and beverages (excluding drinking water) from several countries. The estimates of aluminum intake from different countries studied are less than 15 mg/day (range 0.03-11.5). In another estimate on the consumption of aluminum from food, Pennington and Schoen, 1995 (42) calculated the daily intake of aluminum, based on the FDA Total Diet Study dietary exposure method. Estimates of aluminum intake ranged from 0.7 mg/day for 6- to 11-month old infants to 11.5 mg/day for 14- to 16-year-old males. Average intakes for adult men and women were 8–9 and 7 mg/day, respectively.

Other sources of aluminium in foods come from food additives which is the major contributors to daily intake. Food additives are aluminium-containing compounds used mainly as preservatives, coloring agents, leavening agents, etc (3). The most commonly used aluminum-containing food additives are acidic sodium aluminum phosphate (leavening agent in baked goods); the basic form of sodium aluminum phosphate (emulsifying agent in processed cheese); aluminum sulfates (acidifying agents); bentonite (materials handling aid); aluminum lakes of various food dyes and colors; and aluminum silicates (anticaking agent) (2-3).

c. Cookware and Containers

In addition to one of the potential sources of additional dietary aluminium come from cooking, packaging, handling of food in aluminium containers or cookware. The use of aluminium skillets, pressure cookers, roasting pans, pots, saucepans, frozen dinner trays, foils and wrappers can increase the amounts of aluminium in foods. Aluminium is also widely used for packaging of foodstuffs such as pan masala, pan mixtures, beverages, tea, toothpaste, snacks, hot food served in trains and aircraft (2, 33).

Probably the leaching of aluminium depends on various factors such as the type of aluminium utensils; previous use of the utensils; pH of the food and/or cooking medium; form and composition of food; duration of contact/cooking; and presence of salt, sugar, and other ions (F, Cl, CO_3), etc (1, 33). Use of aluminium utensils significantly contributes aluminium to total daily intakes through foods in India. Based on food consumption data by India populations, the total daily intakes of aluminium was estimated to be 9.6, 14.2 and 18.2 mg/day in urban populations when the foods were cooked in stainless steel, old aluminium vessels (age 10 years) and new aluminium vessels (age 1 to 15 days), respectively. These data suggest that daily use of an aluminium vessel may lead to an increased exposure of around 7 mg/day (19). The migration of aluminium from aluminium-containing cookware and utensils into food was found to be high if acidic foods (tomato sauces, sauerkraut) are cooked in uncoated aluminium containers. The highest rate of migration is found when aluminium utensils are used for acid foods (20), which similar to other researches that the cooking of acidic foods in aluminium utensils (17-18, 21-23) or storing in aluminium containers (43-44) results in the increasing of aluminium contents in food. The temperature of cooking results in the leaching of aluminium. The study on various foods was cooked under different cooking temperature that is aluminium contents increased at higher temperature (22). The use of aluminium foil for baking and grilling fish filled that grilling method was higher temperature than baking method. The aluminium contents of grilled fillets were higher than those of baked fillets (28). Leaching of aluminium from utensils made from various metals (aluminium, indalium, stainless steel and hard anodized aluminium) was studied under different boiling time, found to be the highest during first-time preparation of all foods as compared with second-and third-time preparations using the same utensils (23).

d. Soil

Aluminum, found in soil complexed with electron-rich species such as fluoride, sulfate, and phosphate, is released to soil by the weathering of aluminum-containing rocks and minerals and as a constituent of many mining wastes and solid wastes from coal combustion, aluminum reduction, and other metal processing operations (1). Its concentration in soils varies widely, ranging from about 700 mg/kg to over 100,000 mg/kg. Varying concentrations can be found in different soil samples taken from the same area. For example, in different soils of Missouri, aluminum concentrations ranged from 4,800 to 58,000 mg/kg, while in Hawaii, aluminum contents were much higher with concentrations ranging from 79,000 to 317,000 mg/kg. In cultivated and uncultivated soil samples collected during a number of field studies, levels ranged from 7,000 mg/kg to over 100,000 mg/kg (mean of 33,000 mg/kg) for subsurface soils in the eastern United States, from 5,000 mg/kg to over 100,000 mg/kg (mean of 54,000 mg/kg) for subsurface soils in the western United States, and from 13,000 to 76,000 mg/kg (mean of 57,000 mg/kg) for surface horizon soils in Colorado. Aluminum levels in soil also vary with different vegetation types (1-2). The concentration of aluminium in soil is the factors responsible for the elevated concentration of aluminium found in vegetables and plants. Certain plants absorb more aluminium from the environment (33). For example, concentrations in the soils of coniferous forests are often higher than in soils of beech forests (2).

e. Medicines

The typical quantities of aluminum consumed in foods and beverages amounts to less than 1% of the quantities that can be consumed in pharmaceutical products. The use of aluminum-containing medications such as antacids, buffered aspirins, kaolin-based antidiarrheal agents, and anti-ulcerative drugs, may result in large intakes of aluminum into the body far in excess of that normally consumed in food (1, 45). It is estimated that from 126 to 5000 mg of aluminum are consumed, which is 6 to 250 times greater than that from food (1). Aluminium contents per dose range from 840 to 5000 for antacids, 130 to 730 mg/day for buffered analgesics, 36 to 1450 mg for anti-diarrheal drugs, and 207 mg for an anti-ulcerative drug (1, 45). Other sources of pharmaceutical aluminum are also used in the manufacture of cosmetics (e.g., aluminum hexahydrate in deodorants) (1, 3).

2.1.7 Toxic effect of Aluminium

a. Death

There are no deaths from aluminium exposure in humans (1-2). No available studies indicate that aluminium related death. Data in some animal case, acute lethality of ingested aluminium, a single gavage exposure to 540 mg Al/kg as aluminium lactate was fatal to all 5 lactating female New Zealand rabbits tested. Time to death was reported as 8-48 hr. Intermediate-duration oral exposure, mortality occurred in female Swiss Webster mice exposed to aluminium lactate in the diet for 42 days throughout gestation and lactation at doses of 184 or 280 mg Al/kg per day by the same group of investigators. Severe signs of neurotoxicity (ataxia, paralysis) prior to the deaths related to semi-purified diet composition (1).

b. Respiratory Effects

Respiratory diseases have been observed primarily in workers in the aluminium industry (e.g., pulmonary fibrosis, occupational or potroom asthma, and chronic bronchitis). Occupational asthma has been reported in aluminium potroom workers; there is some debate whether the asthma is related to exposure to respiratory irritants, such as hydrogen fluoride and chlorine, or due to aluminium exposure. Case reports provide suggestive evidence that chronic exposure to aluminium may cause occupational asthma. Pulmonary fibrosis is the most commonly reported respiratory effect observed in workers exposed to fine aluminium dust and alumina. In some of the cases, the fibrosis was attributed to concomitant exposure to other chemicals. There is also some evidence suggesting aluminium-induced pneumoconiosis, interstitial pneumonia, and granulomas; however, these reports are based on a small number of cases, which limits their interpretation (1-2).

Respiratory effects typically associated with inhalation of particulates and lung overload have been observed in animals. In rats exposed to aluminium flakes for 5 days, there were alterations in the cytological (increase in the number of polymorphonuclear neutrophils [PMNs]) and enzymatic (increased activity of alkaline phosphatase and lactate dehydrogenase) content of the lavage fluid at ≥50 mg Al/m^3 and multifocal microgranulomas in the lungs and hilar lymph nodes at ≥100 mg Al/m^3. The enzymatic changes in the lavage fluid probably resulted from the presence of PMNs, increased phagocytosis of alveolar macrophages, and Type II cell hyperplasia. Similar pulmonary effects were observed in animals following intermediate-duration exposure. Some of one suggestive evidence of alveolar macrophage damage was observed in rats following a 5-month exposure (6 hours/day, 5 days/week) to either aluminium chloride (0.37 mg Al/m^3) or aluminium fluoride (0.41 mg Al/m^3); increases in lysozyme levels, protein levels (aluminium chloride only), and alkaline phosphatase (aluminium chloride only) were observed in the lavage fluid. Chronic exposure studies, there are limited data on the pulmonary toxicity of aluminium in animals (1).

c. Cardiovascular Effects

No studies were regarding cardiovascular effects. There are no available reports in deaths related to cardiovascular disease (1).

d. Hematological Effects

There are no studies regarding hematological effects from aluminium exposure in humans (1). In some evidence in animal cases, aluminium may affect iron levels in blood; however, this study results are not available. Several studies in animal cases have shown that aluminium can adversely affect erythropoeisis. Intermediate-duration exposure has been associated with significant inhibition of colony forming units-erythroid development in bone marrow of mice exposed to 13 mg Al/kg as aluminium citrate or aluminium chloride administered via gavage 5 days/week for 2 or 22 weeks, rats exposed to 27 mg Al/kg as aluminium citrate administered via gavage 5 days/week for 15 weeks, rats exposed to 420 mg Al/kg/day as aluminium citrate in drinking water for 15 weeks, and rats exposed to 230 mg Al/kg/day as aluminium citrate in drinking water for 8 months (1).

e. Musculoskeletal Effects

Osteomalacia has been observed in healthy individuals following long-term use of aluminium-containing antacids and in individuals with kidney disease. There are numerous case reports of osteomalacia and rickets in otherwise healthy infants and adults using aluminium-containing antacids for the treatment of gastrointestinal illnesses (1). The aluminium in the antacids binds with dietary phosphorus and prevents its absorption resulting in hypophosphatemia and phosphate depletion. Osteomalacia, characterized by a softening of the bone and resulting in increased spontaneous fractures and pain, has been documented in dialyzed uremic adults and children exposed to aluminium-contaminated dialysate or orally administered aluminium-containing phosphate-binding agents. Decreased aluminium urinary excretion caused by impaired renal function and possibly an increase in gastrointestinal absorption of aluminium results in increased aluminium body burden leading to markedly increased bone aluminium levels and the presence of aluminium between the junction of calcified and non-calcified bone (46). Although long-term oral exposure to aluminium results in an increase in aluminium levels in the bone, there is no histological evidence that under normal physiological conditions that the accumulation of aluminium alters the bone structure (1).

Dermal exposure studies, there is limited to a case report of a woman reporting bone pain after a 4-year exposure to aluminium chlorhydrate in antiperspirant (47). No osseous abnormalities were detected via radiography, and C-reactive protein levels and bone-specific serum parameters were within reference ranges. However, plasma aluminium levels were approximately 10 times higher than reference levels. Termination of aluminium exposure resulted in decreases in plasma aluminium levels and a disappearance of bone pain.

f. Renal Effects

Several intermediate- or chronic-duration studies examined for possible effects on the kidneys; most studies did not find any adverse effects. Mild tubular "glomerularnephritis" was observed in dogs exposed to 75 mg Al/kg/day as sodium aluminium phosphate in the diet for 26 weeks (48). However, the study investigators did not consider this effect to be adverse because it was not accompanied by clinical evidence of kidney dysfunction. The effect may have been secondary to the drastic reduction in feed intake and decreased body weight also observed in these dogs. According to ATSDR (1), found that no alterations in kidney histopathology when observed in all case of animal studies.

g. Immunological Effects

No immunotoxicity studies are available in humans. However, few cases reported about hypersensitivity to aluminium following dermal application or parenteral administration (2). According to ATSDR (1), there are very few animal studies that examined the potential immunotoxicity of aluminium. Intermediate-duration exposure of mice to 13 mg Al/kg/day as aluminium citrate administered via gavage 5 days/week for 22 weeks resulted in a significantly higher proliferation of lymph node cells and had no effect on spleen cell proliferation. This suggests that while aluminium might induce alterations in cell immune response, the stimulating or suppressing effects could depend on the dose, route of administration, exposure duration, or cell population. There is some evidence that developmental exposure to aluminium may adversely affect the immune system in young animals.

h. Reproductive Effects

According to Agency for Toxic Substances and Diseases Registry (1), there are no studies and no reports regarding reproductive effects in humans. Several studies evaluated reproductive effects of acute-duration oral exposure to aluminium in animals. Reproductive effects observed in male mice, rats, or dogs given aluminium compounds orally included repressed sexual behavior, decreased spermatogenesis, or other effects on the testes, sperm duct, and/or epididymis. In a study of female reproductive system development (49), offspring of rats that were gavage with aluminium lactate on gestation days 5–15 showed a transient irregularity of the estrus cycle at 250 mg Al/kg/day; doses as high as 1,000 mg Al/kg/day did not affect other end points (gonad weights, anogenital distance, time to puberty, duration of induced pseudopregnancy, or numbers of superovulated oocytes).

i. Developmental Effects

Developmental effects such as encephalopathy, bone disease, microcytic anemia, and rickets, have occurred in premature infants with reduced or failed renal function receiving aluminium-containing treatment and in non-uremic infants receiving parenteral nutrition with aluminium-containing fluids or high doses of aluminium antacids (2). There are no adequate studies in the long-term effects of aluminium exposure on brain development and skeletal maturation.

j. Neurological Effects

Aluminium is a potent neurotoxic agent in humans. Numerous studies and epidemiological studies have examined the possible role of aluminium in Alzheimer's disease, other dementias, and cognitive dysfunction (2). Case study of aluminium dust in workers (retired for at least 10 years) found some impairment in some tests of cognitive function; the investigators raised the possibility that cognitive impairment may be a pre-clinical indicator of Alzheimer’s disease (13). In a case-control study, the association between Alzheimer’s disease and the use of aluminium-containing antiperspirants was examined (50). No association was found between Alzheimer’s disease and antiperspirant/deodorant use, regardless of aluminium content (odds ratio of 1.2; 95% confidence interval of 0.6–2.4). When only users of aluminium-containing antiperspirants/deodorants were examined, the adjusted odds ratio was 1.6 (95% confidence interval of 1.04-2.4). A trend toward a higher risk of Alzheimer’s with increasing use of aluminium-containing antiperspirants/ deodorants was also found.

In addition, there are studies that examined the possible association between Alzheimer’s disease and ingestion of aluminium from sources other than drinking water, especially tea and antacids. The aluminium levels in tea are typically 10–50 times higher than levels found in drinking water. The aluminium levels in antacids are very high compared to drinking water levels. No significant associations between tea consumption or antacid use and Alzheimer’s disease have been found (1). A small scale study did find a significant relationship between consumption of food containing aluminium additives and the risk of Alzheimer’s disease. However, this was based on a very small number of cases. The contrast between the results of the drinking water studies, many of which found a weak association between living in areas with high aluminium levels in drinking water and Alzheimer’s disease, and the tea and antacid studies may be due to the difference in aluminium bioavailability. Although the aluminium speciation does not provided in most drinking water studies, organic monomeric aluminium was the only aluminium species significantly associated with Alzheimer’s disease (9). The available data suggest that aluminium is not likely the causative agent in the development of Alzheimer’s disease. Aluminium may play a role in the disease development by acting as a cofactor in the chain of pathological events resulting in Alzheimer’s disease (51).

Numerous animal studies, particularly orally studies in mice and rats, show that aluminium compounds are neurotoxic, but species variation exist. The toxicity is characterized by progressive neurological impairment leading to death associated with repeated seizures. Morphologically, the progressive encephalopathy, associated with neurofibrillary pathology in neurons mostly in the spinal cord, brain stem, and the hippocampus and cingulated gyrus of the cortex, has been induced by aluminium in susceptible animals such as the rabbit, cat, guinea pig, and ferret when given as intrathecal, intracerebral, and subcutaneous injections (2). For example, case study in mice and rats found various neurotoxic effects in exposed adults and developing offspring, and another case in mouse dams exposed to 200 mg Al/kg/day as aluminium lactate during gestation and lactation resulted in impairment (ataxia, splaying and dragging of hindlimbs, and paralysis) (1).

k. Carcinogenicity

The available carcinogenicity studies do not indicate that aluminium is carcinogenic. No initiation/promotion studies or anticarcinogenicity studies were available (1-2).

2.2 Aluminium foil

Aluminium foil is very thin sheet of aluminium with a thickness less than 0.2 mm (200 μm), commonly used only 0.006 mm thickness in packaging laminates (52). Aluminium foil is made from an aluminium alloy which contains between 92 and 99 percent aluminium (53). Aluminium foil is sometimes known as al-foil or alu-foil. It is often called tinfoil or silver paper, although it is not made from tin or silver (54).

Aluminium foil has been extensively used as packaging and household foils to protect foods from environmental effects (55).

2.2.1 History of aluminium foil

Aluminum foils were first produced in the late 1940's for the packaging of bakery products. During the 1950's there were many innovations and many new uses for formed containers. Thus, the industry prospered. By 1960, nearly 50 million pounds of aluminum were being used to produce formed aluminum containers. In the decade from 1960 to 1970, usage grew to 140 million pounds and by 2002 over 250 million pounds of aluminum were used to manufacture over 7 billion containers in North America. World wide numbers had total over 12 billion containers and over 400 million pounds. The growth of the aluminum foil container is due to its many advantages. The natural qualities of aluminum, its impermeability and barrier properties, provide real benefits for consumers. Aluminium foils also come in a variety of colors and special purpose coatings. They are used to prepare, freeze, store, transport, cook and serve a variety of foods (37).

2.2.2 Characteristic of Aluminium Foil

Aluminium foil (Specific weight of 6.35 μm foil weighs 17.2 g/m^2; Density of 2.70) is thin sheet of aluminium that is impermeable to light, gases and water vapor. The electrical conductivity is 64.94% and the electrical resistivity is 26.5 nΩm. Aluminium foil has a high thermal conductivity (235 W/m K); it reduces the energy required for sealing and sterilization. Heat exchangers make full use of this valuable property (52). The physical and mechanical properties of aluminium foil are shown in Table 2.4 and 2.5, respectively.

Aluminium foil prevents loss of valuable aromas and protects against light, oxygen, moisture and contamination, the production process of aluminium foil may be the cause of slightly permeable due to minute pinholes (55).

Table 2.4 Physical properties of aluminium foil (52)

Impermeability	The crystalline structure of the metal provides a high performance barrier even at thicknesses under 6.5µm (common in liquid cartons). At its lower thicknesses, aluminium foil is normally used with a supporting laminate of film and/or paper to further enhance the strength and barrier performance of the metal layer. The introduction of a high barrier aluminium foil layer enables significant reductions in the thickness of other substrates in a flexible packaging complex otherwise needed to achieve a given barrier performance.
Opacity	Foil is a solid metal. It is a total barrier to light including the UV spectrum.
Non-reactive	Non-reactive except to substances of high acidity or alkalinity. Resistant to most common compounds in solution.
Non-absorbency	Non-absorbent and proof against grease, oil, water and other liquids.
Hygiene and safety	At the end of its production process, aluminium foil is sterile. It can therefore be delivered to a high level of sterility. Foil is safe for use in contact with foodstuffs, does not harbour or promote the growth of bacteria and is an ideal protection against product tampering.
Food contact	Euronorm EN602 specifies the aluminium foil alloy for food contact. Aluminium is commonly used for food, drugs and cosmetics packaging. In the majority of applications, polymer coatings separate the metal from the product itself.
Taste, odour	Tasteless and odour-free, aluminium foil imparts no detectable taste or odour to foodstuffs.
Non-magnetic	Aluminium is insignificantly magnetic and provides excellent electrical shielding.
Recyclability	Aluminium can be repeatedly recycled without loss of quality. Modern separation techniques allow aluminium foil in household waste to be extracted and recycled.
Energy recovery	In thicknesses below 50 µm and where the metal is uneconomic to recover directly, its energy content can be efficiently recovered in the form of heat with a calorific gain of 25 MJ/kg.

Table 2.5 Mechanical properties of aluminium foil (52)

Dead fold	When fully annealed, aluminium foil retains no 'temper' and therefore retains its shape when deformed.
Formability	Aluminium is very malleable and can be easily deformed to a large degree without losing its barrier integrity.
Corrosion Resistance	The naturally occurring surface oxide on all aluminium in the presence of atmospheric oxygen acts as a shield and renders foil substantially corrosion resistant. Aluminium is also resistant to substances in the pH range 4 to 9.
Reflectivity	Reflects approximately 98% of radiant heat and light. There is no difference between the reflectivity of a bright and a matte foil surface.
Surface finish	The foil rolling process creates a highly polished finish. To produce thin foil economically, however, two layers are normally rolled together and then separated, the 'inner' surfaces taking on a matte finish. The thickness below which double rolling is done (typically about 50µm) varies according to the individual manufacturer. Single rolled aluminium foil can also be made in thinner gauges and produces a bright finish on both sides. A variety of embossed or textured surface finishes can also be produced.

Aluminium foil typically has a highly reflective side and a more matte side. This difference in the finish has led to the perception that favoring side has an effect when cooking. While many believe that the shiny side's reflective properties keep heat in when wrapped on the interior and keep heat out when facing exterior, the actual difference is imperceptible without instrumentation (56). The reflectivity of bright aluminium foil is 88% while dull embossed foil is about 80% (54).

Moreover, Aluminium foils can recycle to makes aluminum one of the most environment friendly materials on earth, a key advantage for planet conscious consumers and local governments. Additionally, recycled aluminum saves more than 95% of the energy necessary to produce new primary aluminum (37).

2.2.3 Manufacturing Aluminium Foil

Aluminium foil has different thicknesses ranging from about 0.006 mm to the upper ISO defined limit of 0.2 mm (35, 52). Aluminium foil is produced by two methods. The first method, rolling sheet ingots (hot rolling) cast from molten aluminium then rolling the foil to the required foil thickness. The second method, continuous casting is much less energy intensive and has become the preferred process (35, 37). This method bypasses the ingot stage and converts molten metal directly into a thick strip which is immediately rolled as the roll of aluminium foil. In the production process, two layers are usually put together and rolled simultaneously that help control the thickness, reduce tearing and increase production rates. The double roll results in the difference between the two surfaces which occurs foil with one bright side and one matte side (35, 52).

Aluminium alloys are classified by chemical compositions and typical usage such as 1xxx, 3xxx, 8xxx series alloys are typical for foil productions. In case of 1xxx and 8xxx series have iron and silicon as major alloying elements, which 1xxx series alloys is mostly used for foil or flexible tubes, and 8xxx series alloys is suitable for beverage can ends. While 3xxx series alloys has manganese as major element which are mostly used for container foils, beverage can ends and can bodies (35).

2.2.4 Uses of Aluminium Foil for Cooking and Food Packaging

Millions of tons of aluminium foil are produced annually, with production of approximately 800,000 tons in Europe (52) and 600,000 tons (1.3 billion lbs) in the USA in 2003 (53). Approximately 75% is used for packaging and household foil and 25% is used industrially: heat exchangers, e.g. in cars, thermal insulation for buildings, pipework, aerospace, cables and in the electronics industry (52).

Aluminum foil commonly used in packaging laminates, can keep sensitive foodstuffs fresh for months without refrigeration. It offers many packaged goods absolute barrier properties. It prevents the loss of valuable aromas and protects contents against light, oxygen, moisture and contamination. It guarantees quality and the best protection against deterioration for sensitive and valuable products (52, 55) . As aluminium foil acts as a complete barrier to light and oxygen (which cause fats to oxidize or become rancid), odors and flavour, moisture, and bacteria, it is used extensively in food and pharmaceutical packaging. Aluminium foil is used to make long life packs (aseptic packaging) for drinks and dairy products which enables storage without refrigeration. Aluminium foil laminates are also used to package many other oxygen or moisture sensitive foods, in the form of pouches, sachets and tubes, and as tamper evident closures. Aluminium foil containers and trays are used to bake pies and to pack takeaway meals, ready snacks and long life pet foods (52). There are many applications of foils such as aluminium-lined beverage catons, sachets, preserved foods in pouches and cartons, yoghurt pot lids and wrappers for butter or cheese, confectionery wraps, pharmaceutical blister and strip packs, foil containers for baked products, ready meals, pet foods, etc.

Aluminium foil can be converted into a wide range of shapes and products including semi-rigid containers with formed foil lids, caps and cap liners, composite cans and containers, laminates containing plastic and sometimes paper or paperboard where it acts as a gas and light barrier and foil lidding, the latter being sealed using inductive sealing. Processes involved may include converting, forming, laminating, coloring, printing and coating. It can also be embossed to provide textured surfaces (35). Aluminium foil is widely sold in the consumer market, usually in rolls of around 50 centimetres width and several metres in length. It is used for wrapping food in order to preserve it, for example when storing leftover food in a refrigerator (where it serves the additional purpose of preventing odor exchange), when taking sandwiches on a journey, or when selling some kinds of take-away or fast food. Aluminium foil is also used for barbecuing more delicate foods such as mushrooms and vegetables; food is wrapped in foil then placed on the grill, preventing loss of moisture that may result in a more appealing texture (35, 52-53, 57-58).

2.3 Overview of Corrosion

Corrosion is the chemical or electrochemical reaction between a material (usually as metal) and its environment. Corrosion is a deterioration of the material and its properties, and corrosion of most metals (and many materials for that matter) is inevitable (59). Most metals corrode on contact with water (and moisture in the air), acids, bases, salts, oils, aggressive metal polishes, and other solid and liquid chemicals. Metals are also corroded when exposed to gaseous materials like acid vapors, formaldehyde gas, ammonia gas, and sulfur containing gases (60).

2.3.1 Forms of Corrosion

Corrosion can be classified into several categories by using different characteristics, such as by mechanism of corrosion, by physical characteristics of corrosion and by the influence factor on corrosion, etc. Corrosion is also classified by use of materials such as atmospheric corrosion, microbial corrosion, corrosion of implant materials, corrosion in petroleum and petrochemical industry (60-61). Traditionally, corrosion is classified into eight categories based on the morphology of the attack as follows (59-61).

a. *Uniform corrosion* also called *general corrosion*. The surface effect produced by most direct chemical attacks (e.g., as by acid) is a uniform etching of metal.

b. *Galvanic corrosion* is an electrochemical action of two dissimilar metals in the presence of an electrolyte and an electron conductive path. It occurs when dissimilar metals are in contact.

c. *Pitting corrosion* is localized corrosion that occurs at microscopic defects on a metal surface. The pits are often found underneath surface deposits caused by corrosion product accumulation.

d. *Intergranular corrosion* is an attack on or adjacent to the grain boundaries of a metal or alloy. A highly magnified cross section of most commercial alloys will show its granular structure. This structure consists of quantities of individual grains, and each of these tiny grains has a clearly defined boundary that chemically differs from the metal within the grain center.

e. *Crevice or contact corrosion* is the corrosion produced at the region of contact of metals with metals or metals with nonmetals. It may occur at washers, under barnacles, at sand grains, under applied protective films, and at pockets formed by threaded joints.

f. *Erosion corrosion* is the result of a combination of an aggressive chemical environment and high fluid-surface velocities.

g. *Stress corrosion* is caused by the simultaneous effects of tensile stress and a specific corrosive environment. Stresses may be due to applied loads, residual stresses from the manufacturing process, or a combination of both.

h. *Fretting Corrosion* is the rapid corrosion that occurs at the interface between contacting, highly loaded metal surfaces when subjected to slight vibratory motions. This type of corrosion is most common in bearing surfaces in machinery, such as connecting rods, splined shafts, and bearing supports, and often causes a fatigue failure.

2.3.2 Factors Affect Corrosion Rate

a. *Polarization of the electrodes*

Consequently, the potential difference between the anode and the cathode decrease until a steady state is reached when corrosion proceeds at a constant rate. Thus, the corrosion current and the corrosion rate will be affected by anything that affected the polarization of the electrodes. The dominant polarization term controlling the corrosion rate of many metals in deaerated water is the hydrogen overpotential at cathodic areas of metal (35).

b. *Supply of oxygen*

The rate at which oxygen is supplied largely governs the rate of corrosion, because corrosion by oxygen reduction requires the presence of oxygen for the cathodic reaction to proceed. The rate of supply is proportional to the rate at which oxygen diffuses to the metal surface, and this depends on the concentration of dissolved oxygen in solution. This is further justification for the practice of attempting to remove all the oxygen from canned foods prior to seaming on the can end (35).

c. *Temperature*

The rate of corrosion generally increases with increase in temperature, as more reactant molecules or ions are activated and are able to cross over the energy barrier. Furthermore, increasing the temperature tends to increase the rate of diffusion of molecules or ions in a solution, although the solubility of oxygen in water decreases with increasing temperature (35).

2.3.3 Corrosion of Aluminium

Aluminium has a natural corrosion protection from its oxide layer, but if exposed to aggressive environments it may corrode (35, 62). Highly pure aluminium is quite resistant to acids and is best attacked by hydrochloric acid containing a little cupric chloride or in contact with platinum, some hydrogen peroxide also being added during the dissolution (63). In oxygen containing environment (air, water), aluminium is rapidly covered with a dense oxide layer. The oxide layer is essentially inert and prevents corrosion. The thickness of oxide layer may vary as a function of temperature, environment and alloy elements. At the room temperature, oxide layer formed in air are 2-3 nm thick on pure aluminium. If the oxide layer is damaged, new oxide will immediately form on the bare metal (62).

This oxide layer consists mainly of amorphous Al_2O_3 and aluminium oxide hydrate (AlOOH) and some physically and chemically bound water, depends on the moisture content of the air.

$$4Al + 3O_2 \text{ ------------> } 2Al_2O_3$$

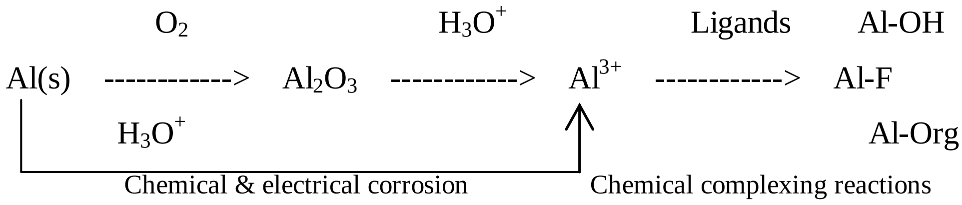
The oxide layer is the reason for the favorable behavior of aluminium when exposed to weather and for its corrosion resistance against many inorganic and organic substances in the pH range of 4 to 9. The oxide layer is not stable in strong acid (pH below 4) or alkaline (pH above 9) environments (33, 62). Aluminium oxide is amphoteric as the result of it will dissolve in acid or alkali to give the soluble aluminium cation or anion.

$$Al_2O_3 + 6H^+ \text{ ------------> } 2Al^{3+} + 3H_2O$$

$$Al_2O_3 + 2OH^- \text{ ------------> } 2AlO_2^- + H_2O$$

Although no foods have a pH greater than 8, cleaning solutions used in food processing plants frequently have pH value of 13. It is therefore important that these solutions do not come into contact with aluminium packaging materials, and that any package-contact surfaces cleaned with these solutions are thoroughly rinsed with water afterwards (35).

According to Shuping Bi (64) the aluminium leaching processes can be explained by the following chemical reaction.



Where, Al_2O_3 is a protective film. The free aluminium in solutions reacts with organic acids found in food, like citric, oxalic and acetic acid, and other complexing ligands like fluoride ion and hydroxyl. These reactions may take place simultaneously and promote each other (64).

Having a strongly negative electrode potential (E_H = -1.66), aluminium is liable to undergo severe corrosion if brought into metallic contact with copper, iron or other more positive metals in the presence of an electrolyte (35).

The aggressive ions (e.g., chloride, fluoride) also affect the corrosion potential of aluminium. Chloride ions migrate into the pit to form aluminium chloride ($AlCl_3$) which dissolves in the solution. Because of the low pH the aluminium may also corrode with the evolution of hydrogen (65).

$$2Al + 6H^+ \text{ ------------> } 3H_2 + 2Al^{3+}$$

There is equilibrium between the formation of aluminium oxide and $AlCl_3$, at the interfacial region (the area between the metal and the corrosive medium).

$$Al_2O_3 + 6H^+ + 6Cl^- \text{ ------------> } 2AlCl_3 + 3H_2O$$

When aluminium chloride is formed a pit develops and when alumina (Al_2O_3) forms the pit will passivate. The chloride ions directly after the corrosion potential of aluminium in fresh water. The higher concentration of chloride ions is the corrosion potential and the faster metal will corrode (in the absence of complicating factors). Chloride ions accelelate the corrosion process but whether this is dur to oxide film breakdown or assisting the anodic reaction is not known (35, 65).

Products containing brine should not be packed in aluminium as they can produce rapid and dramatic corrosion, such corrosion becoming apparent in the form of container or end perforation within 24 hours (35). Some investigation (66) was found the state of corrosion differs in relation to the concentration of chloride ions, temperature and time in the high salt content foods. Such as the vinegar used for sushi that contains 5 to 9% salt causes pitting and crevice corrosion and stress corrosion cracking is sometimes found when extracting essence at high temperature in the manufacture of soup containing about 5 to 10% salt. Additionally, soy sauce, dressing, and dripping, all contain about 15% salt, which cause pitting and crevice corrosion in the processes of brewing and storage for a long period of time. The process of heat treatment is subjected to the severest corrosion environment in which pitting, crevice corrosion, and stress corrosion cracking tend to occur (66).

Pitting corrosion in aluminium is most commonly produced by halide ions of which the chloride ion is most frequently encountered. Pitting of aluminium in halide solutions open to air, occurs because in the presence of oxygen, the metal is readily polarized to its pitting potential. Corrosion takes place with high chloride content products such as tomato and vegetable juices, and is accelerated when the end is used with a tinplated can body. This is because the aluminium end is anodic to the can body. This problem can be overcome by reapplying enamel to the end after scoring (33, 35, 67).

Moreover, the presence of some elements (Ga, Ti, In, Sn, Pb) may affect the stability of the aluminium oxide and thereby cause corrosion (62, 67). Another investigation (68) reported the low quality (Al-Pb alloy) utensils with the high fluoride concentrations and low pH were enhancing the leaching of aluminium more than the high quality (Al-Mn alloy) utensils with the low fluoride concentrations and high pH.

Most commercial alloys contain several types of intermetallic phases. Corrosion on aluminium alloys is essentially a microgalvanic process between these phases and the matrix alloy. While the phases often act as local cathodes because of their Fe content, the surrounding aluminium matrix undergoes localized attack (62).

In addition the typical phenomena may become important; including an active phase may corrode preferentially. A corroding phase may serve as a sacrificial anode and provide cathodic protection to the surrounding material. Due to the electrochemical reactions at the corroding sites and the cathodes, the composition and pH of the electrolyte adjacent to the reaction sites may become different from the bulk electrolyte. Active components of the matrix alloy and the intermetallic phases may corrode selectively (dealloying), resulting in changed corrosion properties (62).

2.4 Cooking

2.4.1 The definition of cooking

Cooking is the process of preparing food for producing safe and edible food (69). Food is cooked to make it more appetizing and digestible, add flavour, make it safe to eat, improve the aesthetic appeal and add variety to the diet. The cooking of food involves heating it in variety of ways to make it more palatable. The heat to cook the food comes from a variety of sources, including electric elements or hotplates; gas flame from a stove or barbecue; the heat from a conventional oven; and heat generated by a microwave oven. The basis of all cooking is the application of heat, which may be transferred to food by the processes of convection, conduction and radiation. Heat is transferred to the food and cooking medium (the fat, water, stock or milk) by means of convection, conduction and radiation (70). It must be remembered that most foods are cooked by a combination of at least two of the processes of transferring heat, not just one. For example, a baked butter cake will be cooked by heat directly reflecting from the oven walls (radiation), heat circulating in the air of the oven (convection), and heat transferred from the cake pan to the cake mixture (conduction).

2.4.2 History of cooking

There is not clear evidence as to when cooking was invented. Evidence of fire is inconclusive as wildfires started by lightning-strikes are still common in East Africa and other wild areas, and it is difficult to determine as to when fire was used for cooking, as opposed to just being used for warmth or for keeping predators away. Most anthropologists believe that cooking fires first developed around 250,000 years ago. The development of agriculture and trade across civilizations offered cooks many new ingredients. New inventions and technologies, such as pottery for holding and boiling water, expanded cooking techniques. Some modern cooks apply advanced scientific techniques to food preparation (71).

2.4.3 The principle of cooking

There are two basic methods for cooking meats: dry heat and moist heat method. Generally, dry heat methods are best applied to naturally tender cuts of meat. Moist heat methods tenderize less-tender cuts (70).

Moist heat methods: Moist heat methods of cooking use a liquid cooking medium, usually stock, water, milk or fruit juice. The liquid cooking medium transfers the heat to the food, and cooks the food by convection. Methods of cooking with moist heat include boiling, poaching, steaming, braising and stewing.

Dry heat methods: Dry heat methods of cooking use no liquid as a cooking medium. Heat is transferred by direct contact (conduction), rays going straight through the food (radiation), or heat moving through the air (convection). The dry heat methods of cooking include deep frying, shallow frying, baking, roasting and grilling.

The cooking of food involves heating it in a variety of ways to make it more palatable. The heat to cook the food comes from a variety of sources, including electric elements or hotplates; gas flame from a stove or barbecue; the heat from a conventional oven; and heat generated by a microwave oven. Heat is transferred to the food and cooking medium by means of convection, conduction and radiation. It must be remembered that most foods are cooked by a combination of at least two of the processes of transferring heat, not just one (70). For example, a baked butter cake will be cooked by heat directly reflecting from the oven walls (radiation), heat circulating in the air of the oven (convection), and heat transferred from the cake pan to the cake mixture (conduction).

a. Convection

When food is cooked through the convention process, the heat passes through another medium—either liquid or gas. When liquids or gases are heated, the heat is distributed throughout the cooking medium and food by convection currents. For example, in baking, the air in the oven gradually heats up until the heat is transferred to the product being baked. When food is boiled, the water (the cooking medium) is gradually heated by the process of convection. Once the water is heated, it transfers the heat to the food. The same principle applies to deep frying, except that oil is the cooking medium. Cooking equipment that uses the process of convection to cook food includes deep fryers, stockpots, steamers, boilers, poachers, cooking pots and ovens. Methods of cooking by convection include poaching, boiling, stewing, braising, baking and roasting (70).

b. Conduction

Conduction is the process in which heat is transferred to the food by direct contact with the cooking vessel (e.g., pot, pan, barbecue, and hotplate). The heat passes through a solid or from one solid to another. For food to be cooked by conduction, it must be in direct contact with a heated item. This process relies on the use of good conductors, which allow the heat to transfer through them to the food. Metals are generally good conductors of heat, which is why the cooking equipment in a commercial kitchen is mostly metallic. Cooking equipment that uses the process of conduction to cook food includes bratt pans, barbecues, woks, crêpe pans, solid grill plates and stove hotplates. Methods of cooking by conduction include stir frying, shallow frying and sautéing (70).

c. Radiation

Radiation is the process of heat transference directly onto the food being cooked. The heat is transferred by electromagnetic waves, such as microwaves and infrared waves. These waves go directly to the food being cooked, and any object in the path of the rays will also become hot, such as a grill plate. When food is microwaved, the cooking process is due to the action of electromagnetic waves produced from the magnetron in the microwave oven. Infrared waves are produced from the grill. These waves cause the food, which is located close to the heat source, to first heat then cook the food. Cooking equipment that uses the process of radiation to cook food includes microwaves, salamanders, grillers and toasters. Methods of cooking by radiation include grilling, toasting, baking and microwaving. Moist heat or dry heat can be used to cook food in this way. The decision of which cooking method to choose depends on the desired end result of the cooked product. For example, a boneless chicken breast fillet will taste and appear very different if it is poached in chicken stock, rather than being char-grilled, or crumbed and shallow fried (70).

2.4.4 Cooking Methods

There are very many methods of cooking, most of which have been known since antiquity. The basic methods of cooking include boiling, steaming, simmering, frying, baking, roasting, grilling. Various methods use differing levels of heat and moisture and vary in cooking time. The method chosen affects the end result of food. Some foods are more appropriate to some methods than others. In addition, this item is described several methods for cooking, especially roasting and grilling method that are used in this study as follows.

a. Boiling

Boiling is the method of cooking in which food is immersed in a liquid and cooked at 100°C. In boiling, air bubbles rise to the surface of the water and break. Foods are fully immersed in boiling water, and then the water is returned to a rapid boil. Sometimes it is necessary to reduce the temperature a little and maintain it at the simmering point in order to keep the water moving. Potatoes and vegetables are often boiled in a sauce pan over a burner (72).

b. Steaming

Steaming is cooking food in steam. It is used mostly to cook vegetables. Foods place on a rack or perforated pan in a saucepan and add water to the saucepan. The water collects below the rack or perforated pan, and the food remain above and out of the liquid. Cover the saucepan and heat it on a burner until the water boils and forms steam, which surrounds and cooks the vegetables. Steaming takes longer than boiling. Food is cooked in the steam produced by a boiling liquid. It is used mostly to cook vegetables (72).

c. Simmering

Simmering is cooking food in water that is just below the boiling point. Cooked often use covered saucepans to simmer foods. Slow cookers are electric appliances that simmer foods at low temperatures for 4 to 12 hr. A cook puts the food and some water in a slow cooker and sets the temperature. Such foods as eggs and meats should be simmered rather than boiled (72).

d. Frying

Frying is the cooking of food in fat, such as butter or vegetable oil. Frying adds fat and calories to food because the food absorbs some of the fat in the pan (72).

e. Baking

Baking is the cooking of food by dry heat, in an oven. It is a popular method of cooking, as it not only makes food more palatable and digestible, it results in food having a more pleasing texture, color and appearance. In most cases, the oven temperature ranges from 300 to 450ºF (149 to 232ºC). The word baking usually refers to the cooking of foods made from a batter or dough. Such foods include breads, cakes, cookies, and pastries (70).

f. Roasting

Roasting is cooking food uncovered in hot air. The term usually refers to the cooking of meat. The meat is usually placed on a rack in a shallow pan and cooked uncovered in an oven. The temperature usually ranges from 300 to 350ºF (149 to 177ºC). Roasting is a dry heat method of cooking using the heat of the oven (70, 72).

g. Grilling

Grilling (called broiling in North America) is a form of cooking that involves dry heat applied to the surface of food, commonly food is cooked over or under heat source. Heat may occasionally come from both top and bottom, or from the sides, in the case of a vertical grill. Food to be grilled is cooked on a grill (an open with a heat source above or below), or a grill pan (similar to a frying pan, but with raised lid.). The grill may be heated by electricity, gas, wood or charcoal. The speed at which the food is cooked depends upon the type of food being used. The grill temperature may be controlled, and the tray containing the food may be moved closer to, or further away from, the food (70).

g-1 Direct heat method

Grilling with direct heat method is similar to broiling; food is cooked directly over the heat source at a high heat for a short time. Use the direct method takes less than 25 minutes to cook. This is the way to grill small or thin pieces of food, such as chicken breasts, fish fillets, steaks, etc. Direct heat cooking is also necessary to sear meats. Searing creates wonderful crisp, caramelized texture where the food hits the grate. Its also adds nice grill marks and flavor to the entire food surface.

g-2 Indirect heat method

Indirect heat method is similar to roasting, is done next to, not over the heat source. Use the direct method requires 25 minutes or more of grilling time. Indirect method is used for large or tough cuts pieces of meat, like whole chickens, turkeys, briskets, thick steaks, and whole fish. In this method, the food is cooked just off the heat at about 350ºF (175ºC). The lid is closed and the cooking times are somewhat longer. Traditional barbeque is a form of indirect heat using very low temperatures over long periods of time.

2.4.5 Heat transfer and Cooking burner

Heat transfer is the transition of thermal energy from a hotter mass to a cooler mass. When an object is a different temperature than its surroundings or another object, transfer of thermal energy, also known as heat transfer or heat exchange (73). In cooking, there are several cooking equipment which is burner such as electric coil, gas, charcoal, ceramic cooking surface, infrared cooking surface, ultra modern burner, oven, microwaves, etc. Particularly, the detail of cooking burners for cooking meats are described, including oven and gas stove.

a. Oven

In cooking, the conventional oven is a kitchen appliance and is used for roasting and heating. Modern ovens are fueled by gas or electricity. When an oven is contained in a complete stove, the fuel used for the oven may be the same as or different from the fuel used for the burners on top of the stove. The most common may be to heat the oven from below. This is commonly used for baking and roasting. The oven may also be able to heat from the top to provide broiling.

The heat transfer form of oven is primarily convection from the hot air in the oven and radiation from the heat being emitted from the hot walls of the oven (74). Oven roasting relies on the radiated heat reflected from the surface of the oven to cook the surface of the food. Conducted heat is transferred to the food from underneath. Circulating air transfers heat by convection. The outside of the meat is sealed, and the moisture is retained inside (70). A convection oven will heat the cooking utensils faster than a conventional oven because the air in the convection oven is circulated forcefully past the cooking utensil, whereas in the conventional oven, the air is allowed to circulate by means of the natural currents established in the heated environment. Although, there is a radiant component to the energy that is absorbed by ingredients in the oven, much of the energy comes from the air flowing around the ingredients. The fan in a convection oven forces the hot air inside the oven to circulate at a higher speed than a conventional oven without the fan (74).

The ingredients generally require some means of support in an oven, such as a baking sheet or roasting pan, the support mechanism is also heated during the cooking process. Over time, the support can heat to near the temperature of oven. The parts of the food being cooked that are in contact with the support mechanism become more cooked than the parts which are not in contact. Conduction is a more effective way to transfer heat than convection. To prevent the parts in contact from burning, it is common to set the item supporting the ingredients being cooked into another container filled with water (74).

b. Gas

In cooking, a gas stove is a cooker which uses natural gas, propane, butane, liquefied petroleum gas or other flammable gas as a fuel source. Gas stoves today use two basic types of ignition sources, standing pilot and electric. A stove with a standing pilot has a small, continuously burning gas flame under the cooktop. The flame is between the front and back burners. When the stove is turned on, this flame lights the gas flowing out of the burners. Most of heat transfer is by means of convection where the burning, high temperature gas flows along the bottom of the cooking utensil. There are also smaller contributions from the burning gas producing electromagnetic radiation in both the visible and infrared spectrums and conduction from the hot metal prongs that support the cooking utensils (74).

2.5 Meats

Meat is the flesh of slaughter animals that is used as food such as buffalo, cattle, goat, sheep, pig, chicken, duck, rabbit, etc (69). Other edible parts of the slaughtered animal are organs, livers, skin, brains, bone marrow, kidneys, or lung (75).

2.5.1 Types of meat

a. Red meat

Red meat is dark brown in color when it has been cooked, such as beef, lamb and veal (69). Red meat in culinary terminology refers to meat which is red-colored when raw. It is darker-colored than other meats and contrasted with white meat. Red meat does not refer to how well a piece of meat is cooked or its coloration after cooking. The main determinant of the color of meat is the concentration of myoglobin. Red meat is a significant source of high-quality protein, providing all the essential amino acids. Raw red meat contains protein around 20-25g/100g (76). Red meat is one of the richest sources of iron. It also contains creatine, vitamins (such as niacin, B12, thiamin, riboflavin) and minerals (such as zinc, phosphorus) (77).

b. Poultry/White meat

White meat is pale in color when it has been cooked (69). White meat or poultry meat refers to any lighter-colored meat, often contrasted with red meat, including chicken, duck, goose, turkey and ostrich.

There are two types of poultry meats - white and dark. The different colors are based on the different locations and uses of the muscles (78). Dark meats simply have more myoglobin proteins, the magic stuff that ships oxygen to the muscle cells. Dark meats must use myoglobins as they transfer oxygen more efficiently to the muscles than glycogen. Dark meats occur in the legs, which are used more frequently, get to be dark. When dark meat is cooked it turns the myoglobins to metmyoglobins, which is brown/gray. Metmyoglobins are very high in iron. In contrast the white meat, generally found within the breasts. It is used for quick bursts of power which requires little of the meat-darkening myoglobin. Dark meats tend to contain more zinc, riboflavin, niacin, thiamin, vitamins B6 and B12, amino acids, iron than white meat. Dark beef meat contains about 11 times more zinc than tuna, and about 3 times as much iron than raw spinach. Chicken dark meat contain vitamins A, K, B6, B12, niacin, folate, pantothenic acid, minerals as selenium, phosphorus and zinc. Even the fats in most of the dark meats have healthy parts; contain Omega-3, and Omega-6 fatty acids, and other healthy fats. It is the saturated fat content which lowers the true quality of dark meat (78).

c. Aquatic meat

Aquatic meats refers to tissue of animals that live in freshwater, saltwater or brackish water, include fish crabs, shrimp, shellfish and other aquatic animals (69).

d. Game meat

Game meat refers to tissue of wild animals that people hunt for human consumption or a leisure sports, including deer, wild pig (69).

2.5.2 Meats used in this study

In this study, meats used to cook including aquatic meats (seabass fish and saba fish), poultry meat (chicken), and red meat (beef) that are described as follows.

a. Seabass Fish

The Asian Seabass, Seabass Fish, *Lates calcarifer,* a fish of the family Centropomidae, has always been found as an occasional component in the harvest from extensive brackish water ponds in Asia. Asian seabass is widely cultured in sea cages in Malaysia and other Southeast Asian countries, similar to the European seabass which is widely cultured in cages in southern Europe and the Mediterranean. It has considerable potential as an easily grown species tolerant of a wide range of salinities and water quality. It is a high-value food fish that supports a growing aquaculture industry. The popularity of seabass stems from its fast growth and palatability. Because fishery harvests are low, most of the commercial supply comes from aquaculture (79).

b. Saba Fish

The blue mackerel, Japanese mackerel, Pacific mackerel, slimy mackerel, or spotted chub mackerel, *Scomber australasicus*, a fish of the family Scombridae (80), is found in tropical and subtropical waters of the Pacific Ocean, the Red Sea, the Gulf of Oman and the Gulf of Aden, in surface waters down to 200 m. In Japanese, it is known as Goma Saba or sesame mackerel. Its length is between range 30 to 55 cm and weight over a kilogram (2 lbs) (81). Mackerel are often used as sushi "Saba", they are a strong tasting meat which is best for consumption if smoked, barbecued, or boiled.

c. Chicken

Chicken is the meat derived from chicken (*Gallus gallus domesticus*) (69). It is the most common type of poultry on earth (82) and is prepared as food in a wide variety of ways, varying by region and culture throughout the world. Chicken was widely believed to be easily digested and considered to be one of the most neutral foodstuffs. Typically, the muscle tissue (breast, legs, thigh, etc), liver, heart, and gizzard are processed for food. Chicken was eaten over most of the Eastern hemisphere and a number of different kinds of chicken such as capons, pullets and hens were eaten. Chicken consumption in the US increased during World War II due to a shortage of beef and pork (83).

d. Beef

Beef is meat comes from a cow (69). Beef is the culinary name for meat from bovines, especially domestic cattle (cows). Beef is one of the principal meats used in the cuisine of Australia, Europe and America, and is also important in Africa, East Asia, and Southeast Asia. Beef is one of red meat which is good source of vitamin B and minerals such as iron, zinc, phosphorus, is the most significant dietary source of carnitine and like any other meat or fish (84). Beef is considered a taboo food in some cultures: especially in Hinduism although not strictly forbidden, as bovines are revered; it is also discouraged among some Buddhists. Beef muscle can be cut into steak, roasts or short ribs. Some cuts are processed (corned beef or beef jerky), and trimmings, usually mixed with meat from older, leaner cattle, are ground, minced or used in sausages. The blood is used in some varieties of blood sausage. Other parts that are eaten include the oxtail, tongue, tripe from the reticulum or rumen, gland (particularly the pancreas and thymus) referred to as sweetbread, the heart, the brain, the liver, the kidneys, and the tender testicles of the bull (85).

2.5.3 Nutrients in meats

Meat is a rich source of many essential nutrients for health growth and development in children, as well as for good health and well-being in adults. Generally, meat is composed of water, fat, protein, minerals and a small proportion of carbohydrate.

The most valuable component from the nutritional and processing point of view is protein include amino acids required for the human diet. In contrast, vegetables and fruits are usually lacking several essential amino acids (75). Essential nutrients in various types of meat include macronutrients (protein and fat) and micronutrients (vitamins and minerals) as follows.

a. Proteins

Protein is a natural substance found in meat, eggs, fish, some vegetables, etc. There are many different proteins and they are an essential part of what humans and animals eat to help them grow and stay health (69). The nutritional value of meat is essentially related to the content of high quality protein. High quality proteins are characterized by the content of essential amino acids which cannot be synthesized by body but must be supplied through food (86).

Protein in fish is highly digestible protein. On a fresh weight basis, fish contains a good quantity of protein, about 18-20%, and contains all the eight essential amino acids including the sulphur-containing lysine, methionine, and cysteine (87). Fish contain 20 to 25 g of protein per 4 ounces of edible portion (75).

Chicken is a good source of protein and low in carbohydrate. Chicken also contains amino acids that can produce serotonin (the hormone that helps to feel happy) (88). Chicken breast contained 28 g of protein per 4 ounces of edible portion (75).

Protein in beef is a complete, high quality protein which it supplied all of the essential amino acids. The human body needs protein to build, maintain and repair body tissue. Muscles also form hormones and enzymes, and increase resistance to infection and disease. A growing body of scientific evidence suggests that eating more protein can benefit weight loss, muscle mass maintenance, cholesterol and triglyceride levels and satiety (84, 89). The protein of beef (top round) steak and beef (T-bone) steak were 36 and 25 g per 4 ounces of edible portion (75).

b. Fats

Fat is a white or yellow substance in the bodies of animals and humans that it becomes pure for use in cooking (69). Fats also referred to as lipids, are compound that do not dissolve in water. Fats terms include saturated fatty acids, monounsaturated fatty acids, polyunsaturated fatty acids, omega-3 fatty acids, trans fatty acids, triglycerides, and cholesterol (90). Meats include triglycerides (the predominant type of fat), followed by smaller amounts of phospholipids and glycolipids, cholesterol, cholesterol esters and waxes (91). The fat content of meat can vary widely depending on the species and the breed of animal, the way in which the animal was raised, including what it was fed, the anatomical part of the body, and the methods of butchering and cooking (75).

The fat content of fish depends on the fish species, the season, the condition and the feed of fish. Generally, fish have less fat than red meats (D M Chilima). The pelagic species of fish contain higher levels of fat content than the demersal species (92). The fat content of fish ranges from 0.2 to 25%. Lawrie R A et al (75) showed fish contain range 1 to 5 g of fat per 4 ounces of edible portion. However, fats from fatty fish species contain the polyunsaturated fatty acids (PUFAs) namely EPA (eicosapentaenoic acid) and DHA (docosahexaenoic acid) (omega 3 fatty acids) (D M Chilima). The fish is classified by the fat content in the body, including lean fish and fatty fish. Lean fish (e.g., cod, coley, halibut, seabass, skate, tilapia, etc.) have less than 5% (5g/100g) fat in their flesh. While fatty fish have more than 5% fat in their fresh, such as anchovies, eel, herring, mackerel, salmon, sardines, trout, tuna, etc (93).

The fat content of chicken is low. Chicken breast without the skin has the lowest fat content of any part of the chicken and the same amount of sirloin steak, beef tenderloin, pork chop, or salmon. Chicken has only one gram of saturated fat, so it is an ideal meat for any weight loss diet (94). According to USDA (Nutrition facts serving size 3 ounces cooked chicken without skin), chicken have about 11% of total fat (95). While Lawrie RA et al (75) showed 7 g of fat in chicken per 4 ounces of edible portion.

Beef ranged 7 to 35 g of fat per 4 ounces of edible portion (75). The study nutritional composition of beef per 100g has about 2.8g of total fat (84). According to USDA (Nutrition facts serving 3 ounces of lean beef and cooked trimmed), chicken have 9.91 g of total fat (95).

Beef, pork and lamb are similar in cholesterol content to other foods of animal origin, such as chicken and turkey and many types of fish. Three ounces of lean beef and lean pork contain 73 mg and 72 mg of cholesterol, respectively, while a 3-ounce serving of chicken (skin removed), contain 76 mg of cholesterol. Fish vary widely in cholesterol content, from approximately 17 to 140 mg per 3-ounce serving (91).

c. Vitamins

Vitamin is a natural substance found in food that is an essential part of what humans and animals eat to help them grow and stay healthy. There are many different vitamins (69). Meat is excellent sources of the B-complex vitamins. The daily requirement for humans of this rarely occurring vitamin is 1-1.5 mg. Plant food has no vitamin B12; hence meat is a good source of this vitamin for children, as in their organisms deposits of B12 have to be established (86).

Fish is a rich source of vitamins, particularly vitamins A and D from fatty species, as well as thiamin, riboflavin and niacin (vitamins B_1, B_2 and B_3). Vitamin A from fish is more readily available to the body than from plant foods. Vitamin A is required for normal vision and for bone growth. Fatty fish contains more vitamin A than lean species. Vitamin D present in fish liver and oils is crucial for bone growth since it is essential for the absorption and metabolism of calcium. Thiamin, niacin and riboflavin are important for energy metabolism. If eaten fresh, fish also contains a little vitamin C which is important for proper healing of wounds, normal health of body tissues and aids in the absorption of iron in the human body (87).

Chicken is rich in vitamins, especially vitamin B3, but only trace amounts of vitamin B12. A raw chicken breast (per 100 gram edible portion) contains: 2 mg vitamin A, 0.06 mg vitamin B1, 0.12 mg vitamin B2, and 7.5 mg Niacin (94).

Beef contains several vitamin B including vitamin B6 and B12, niacin and riboflavin. Beef is an excellent source of vitamin B12, which is needed for normal functioning of body cells and of the nervous system. Lean beef is a good source of vitamin B6, which is important for a healthy nervous system and helps the body fight infection. In addition, both vitamins B12 and B6 play important roles in lowering blood levels of homocysteine, an amino acid that increases risk for heart disease and dementia. Beef is a good source of niacin, which promotes healthy skin and nerves, aids digestion, and fosters normal appetite; and is also a good source of riboflavin, which helps the body use energy and promotes healthy skin and good vision (84, 89).

d. Minerals

Mineral is a substance that is naturally present in the earth and is not formed from animal or vegetable matter, for example gold and salt. Some minerals are also present in food and drink and in the human body. There are essential for good health (69). The mineral contents of meat include calcium, phosphorus, sodium, potassium, chlorine and magnesium with the level of each of these minerals above 0.1%, and trace elements such as iron, copper, zinc and many others. Blood, liver, kidney, other red organs and to a lesser extent lean meat, in particular beef are good sources of iron. Iron intake is important to combat anaemia, which particularly in developing countries is still widespread amongst children and pregnant women (86).

The minerals present in fish include iron, calcium, zinc, iodine (from marine fish), phosphorus, selenium and fluorine. These minerals are highly ‘bioavailable’ meaning that they are easily absorbed by the body (87).

Chicken is good source of minerals. Raw chicken breast (per 100 gram edible portion) contains: 6 mg calcium, 192 mg phosphorus, 0.8 mg iron, 99 mg sodium, 191 mg potassium, 0.07 mg copper, and 0.4 mg zinc (94).

Beef contains several minerals including iron, zinc, calcium, phosphorus, sodium, potassium and copper. Beef is a good source of iron, and unlike plant proteins, beef is the food supply’s most readily available and easily absorbed source of iron. Iron not only helps red blood cells carry oxygen to body tissue, it also plays an important role in cognitive health, including memory, ability to learn and reasoning. Beef is an excellent source of zinc, which is an essential nutrient that fuels thousands of bodily processes, including building muscles and healing wounds, maintaining the immune system, and contributing to cognitive health (84, 89).

2.6 Seasonings

Seasonings are ingredients or substances which added to food (69). Seasonings also play important role to enhance flavoring. They have several types of seasoning such as spices or herbs, salt, acids, sugar, etc. there are also ingredients and derivatives of various natural and synthetic products such as flavorings, hydrolysates, glutamates, extractives, or encapsulates. Seasonings are added to food before it is ready for serving, either during its manufacture or in its preparation. They may contain ingredients that have little or no effect on the flavor of a food but provide another advantage such as physical stability, antimicrobial preservation or nutritional value. So, seasonings used to add in foods for acceptance by the consumer (96). Seasonings used in this study include garlic, peppers, salt, and soy sauce which are described as follows.

2.6.1 Garlic

Garlic or *Allium sativum* is a spice in the onion family Alliaceae and a cousin to onions, leeks, chives, and shallots. It used as a vegetable, flavoring agent and as a condiment (97). Garlic plays an important role in the everyday cooking of many geographical locations such as southern Europe, the middle and Far East, Africa, the West Indies, Mexico and South America (96).

Garlic has a characteristic pungent and spicy flavor, thus it is often used in small quantities. Garlic improves an enormous amount of dishes and blends well with all meat, game, fish, shellfish, and most vegetables and herbs. It is the primary flavoring of popular recipes such as Caesar salad, pesto, garlic bread and teriyaki (96).

Moreover, garlic is also known for its medicinal properties. It contains antiseptic substances that tone the digestive system. Garlic has been known to reduce blood pressure, and has been effective against several viruses and bacteria. It is also claimed to help prevent heart disease, atherosclerosis, high cholesterol, and cancer (96, 98).

2.6.2 Peppers

Pepper is a spice or vegetable in the genus *Piper* of the pepper family Piperaceae. Pepper used as a condiment that has become increasingly popular. There are two different families of peppers: vine peppers (*Piperaceae*) and capsicum peppers (*Anacardiaceae*) (96).

Pepper comes from several species of a vinous plant, the spice being the fruit, called peppercorns. The many distinct varieties of pepper vary in aroma, pungency, size, and color of peppercorn, and are often called after their place of origin (Malabar for Indian, Lampong for Indonesian, Saigon for Vietnamese, Ceylon, Sarawak, and Brazilian) (96).

Black pepper is the dried, unripe berry. The corns are wrinkled and spherical, about 5 mm (1/8 in) in diameter. Malabar and Tellicherry pepper are both considered top quality due to size and maturity, with only 10% of the largest corns being graded as Tellicherry. Black pepper has become so basic to most countries in their cooking that being without it with would be almost like being without salt. It contains piperine, which stimulates the flow of saliva and gastric juices to aid digestion. Black pepper is very pungent and fiery. The flavor bite is due to a non-volatile resinous substance. Black pepper tastes strongest when freshly ground, although pre-ground pepper is often used in seasonings as a convenience (96). Black pepper is produced from the still-green unripe berries of the pepper plant. The berries are cooked briefly in hot water, both to clean them and to prepare them for drying. The heat ruptures cell walls in the pepper, speeding the work of browning enzymes during drying. The berries are dried in the sun or by machine for several days, during which the pepper around the seed shrinks and darkens into a thin, wrinkled black layer. Once dried, the spice is called black peppercorn (99).

White pepper is derived from the same plant as black pepper but the berries are allowed to ripen instead of being picked green. The outer shell is then removed by soaking the berries in water until the shell falls off, or are held under flowing spring water, yielding a whiter, cleaner pepper. White pepper is less aromatic and crude than black pepper, and is used mainly in white sauces (96). White pepper consists of the seed only, with the skin of the pepper removed. This is usually accomplished by a process known as retting, where fully ripe peppers are soaked in water for about a week, during which the flesh of the pepper softens and decomposes. Rubbing then removes what remains of the fruit, and the naked seed is dried. Alternative processes are used for removing the outer pepper from the seed, including decortication, the removal of the outer layer from black pepper from small peppers through mechanical, chemical or biological methods (100). White pepper is sometimes used in dishes like light-colored sauces or mashed potatoes, where ground black pepper would visibly stand out. There is disagreement regarding which is generally spicier. They have differing flavor due to the presence of certain compounds in the outer fruit layer of the berry that are not found in the seed.

Green pepper is from the same fruit but is harvested before they mature. Green pepper is milder with a cleaner, fresher flavour. Green pepper, like black, is made from the unripe berries. It has a fresh flavor that is less pungent than the berry in its other forms. Dried green peppercorns are treated in a manner that retains the green colour, such as treatment with sulfur dioxide or freeze-drying. Pickled peppercorns, also green, are unripe berries preserved in brine or vinegar. Fresh, unpreserved green pepper berries, largely unknown in the West, are used in some Asian cuisines, particularly Thai cuisine. Their flavor has been described as piquant and fresh, with a bright aroma (101).

Pink pepper is not true peppercorns but actually the dried berries from the *Baies* rose plant. It comes from the French island of Reunion which is not a vinous pepper. Pink peppercorns have a brittle, papery pink skin enclosing a hard, irregular seed, much smaller than the whole fruit. These rose-hued berries are pungent and slightly sweet. Pink peppers are used as colorful, flavorful additions to a variety of sauces and meat and fish dishes. Though there was once widespread debate regarding their safety, pink peppercorns have now been approved by the Food and Drug Administration (101).

2.6.3 Salt

Salt is a white substance that is added to food for give a better flavor or to preserve food (69). Salt normally obtained from sea water or rock deposits. Salt for human consumption is produced in different forms: unrefined salt (sea salt), refined salt (table salt), and iodized salt (102). Salt is a flavor enhancer that is added to a food product to supplement or intensify its original flavor. Salt is the most fundamental of all tastes in food, used not only as a flavor or flavor enhancer but also playing an essential role in food processing (96).

Salt controls yeast activity in the fermentation of bread dough, sauerkraut, pickles, soy sauce and other condiments. It is a basis ingredient in all processed meats and dairy products such as butter and cheese. Salt acts as a preservative by lowering water activity (A_w) and limiting microbial growth in meat, fish, bacon, vegetables and other foods. Salt may also be used as a carrier in flavor compounds by selecting an appropriate crystalline structure to entrap the flavor material such as used to coat snack foods (96). Salt contains sodium and chloride ions which are essential for survival of all known living creatures, including humans (102). Salt is involved in regulating the fluid balance of the body. Too much or too little salt in the diet can lead to muscle cramps, dizziness, or electrolyte disturbance, which can cause neurological problems, or be fatal (103).

2.6.4 Soy sauce

Soy sauce, soya sauce or shoyu is produced by fermenting soybeans with the molds Aspergillus oryzae and Aspergillus soyae along roasted grain, water, and salt (104). Soy sauce originated in China, where it has been used as a condiment. It is widely used in East and Southeast Asian cuisines and increasingly appears in western cuisine and prepared foods (105). Soy sauce can help prevent cardiovascular diseases and it contains the antioxidants. Soy sauce is rich in lactic acid bacteria and of excellent anti-allergic potential (106).

Soy sauce can also be very salty, having a salt content of between 14-18%, so it may not be a suitable condiment for people on a low sodium diet. Low-sodium soy sauce is produced, but it is difficult to make soy sauce without using some quantity of salt as an antimicrobial agent (107).

2.7 Related Researches

2.7.1 Aluminium contents in some raw and cooked foods

According to Madhussudan GS et al (3) that summarized from the literature researches about aluminium concentration in some foods found various sources of aluminium intake. Cooked cod fish contain 0.04 mg Al per 100 g. Aluminium concentrations in black pepper and salt with aluminium additives contain 14.30 and 16.60 mg per 100 g. Moreover, the estimated average daily dietary intake of aluminium range around 25 mg/day. Average aluminium intake from meat, fish, and poultry; salt; and herbs and peppers are around 0.1, 0.6, and 0.5 mg/day, respectively.

Ščančar J et al (20) determined the concentration of aluminium in various Slovenian foodstuffs. The results indicated that the concentration of aluminium in foodstuffs (dry weight) was in general below 30 mg/kg while in total diet ranged from 3 to 6 mg/kg. High aluminium concentrations were found in mussels (300 mg/kg), parsley leave (282 mg/kg), and lamb's lettuce (413 mg/kg). Onion and chives contained about 6.7 and 76 mg/kg of aluminium, respectively. Aluminium concentrations in fish including gilthead bream, golden grey mullet, anchovy and trout contained about 1.5, 1.5, 2.0, and 1.7 mg/kg, respectively.

The study of Anil DS et al (23) determined aluminium content of various foodstuffs and spices. Cereals contribute a smaller amount of aluminium to the total daily intake than legumes. Spices contained high amounts of aluminium. Most of the spices contained 0.45-1.6 mg/kg of aluminium, except pepper (3.2 mg/kg). Onion and garlic contained 0.8 and 1.1 mg/kg of aluminium. The differences of aluminium contents in foods depended on variations in soils and growing conditions. The low acidity of soils and water and a lower incidence of acid rain in India may be resulted in low contents of aluminium in Indian foods.

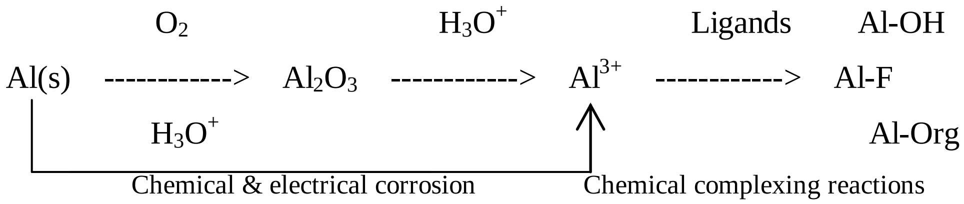
Onianwa PC et al (108) determined aluminium contents in various raw and processed foods from Nigerian market. Generally, aluminium contents in processed foods were higher that that in raw foods. The values of aluminium content in meat (raw foods) including beef and fish contain: 1.1 and 1.7 μg/g, respectively. Moreover, aluminium contents in Nigerian foods were not different from those in other countries.

Müller M et al (109) investigated aluminium in foodstuffs and carried out the food assortment. Most investigated foodstuffs contained less than 5 μg Al per gram fresh matter. For summary survey, highest aluminium contents were found in the cocoa/cocoa product (33μg/g), spices (145μg/g), and black tea leaves (899μg/g). However, spices are not importance to food intake in human; generally contain high amounts of aluminium. The differences occurred with the aluminium content in spices among 1988 and 1991, may resulted in harvest sites of spices. The fact that table salt from 1991 (15μg/g) contained up to 10 times of 1988 (1.4μg/g), while, aluminium in pepper from 1988 (288μg/g) contained up to 6 times of 1991(44μg/g) is also noteworthy. In addition, the observed aluminium contents in meat found that there were high aluminium concentrations in entrails such as liver and kidney. Beef, pork and chicken, which are popular consumed in large quantities, containing 3.6, 3.8 and 3.5 μg/g, respectively. From different kinds of sausage investigated that the aluminium content of meat was lower than that of sausage when related to fresh matter basis. However, related to dry matter basis, this tendency disappeared. So the addition of spices during sausage production had no effect on the aluminium content of sausages when compared with its raw material meat. Moreover, aluminium contents in fish was found that the aluminium range from 1.2 (rosefish fillet) to 5.5 (sardine) μg/g in fresh matter. For trout (trout, fresh), mackerel (mackerel fillet) and herring (herring fillet) contain 3.5, 4.2 and 4.9 μg/g, respectively. In the case of smoked trout, there was not significant effect on its aluminium concentration.

2.7.2 Leaching of aluminium from aluminium cookware, containers and foils

The studies about the leaching of aluminium from aluminium cookware or containers were carried out in many researches. Several researches reported about probable cause of the leaching of aluminium depends on various factors such as type of utensils, pH of the food, composition of food, duration of cooking or contact food, and presence of salt, sugar, fluoride, organic acid etc.

The study of Shuping Bi (64) set up a simple model based on the thermodynamic equilibrium and describes the complexing effect in the aluminium leaching from cooking utensils, which demonstrated that the complexing effect take a very important role in the process of aluminium released from cooking utensils. In addition to postulate the aluminium leaching from cooking utensils are expressed by the mechanism illustrated in the follow diagram.



The result indicated that increased concentrations of complexing ions (organic acids, fluoride ion, OH^-, etc.) significantly enhance the release of aluminium. Furthermore, the model suggested that in the neutral pH range (pH 4-8) of most food, aluminium present is predominantly in the form of aluminium organic complexes, which is very harmful to humans.

KS Jagannatha Rao et al (68) studied aluminium leaching from low quality (Al-Pb alloy) and high quality (Al-Mn alloy) utensils by water under different conditions of pH, boiling time and NaF concentrations. The results found that the quality of vessels, duration of boiling and pH have very highly significant effects on aluminium leaching. The low quality utensils with the high fluoride concentrations and low pH were enhancing the leaching of aluminium more than the high quality utensils with the low fluoride concentrations and high pH. Therefore, the utensils and packaging materials made of Al-Pb alloy are not safe for cooking and storage of acid foods.

Tennakone K (24) found the enhancementof the leaching of aluminium by fluoride, even under conditions of neutral pH. It was suggested that the ingestion of fluoride containing water boiled in aluminium utensils may contribute to cumulative aluminium toxicity. Similar to the study results of Baxter M (110), it was clearly that 1 mg/kg of fluoride enhanced aluminium dissolution by 2-3 mg/kg. This effect was observed on boiling with citric acid solution and was not detectable when acidic foodstuffs, such as rhubarb and tomatoes were cooked.

Layla A (4) studied leaching of aluminium from aluminium cookware in some meat extracts and liquid milk. It was found that corrosion rate of aluminium in 30% meat extract ranged from $2.65x10^{-2}$ to $4.25x10^{-2}$ mg/cm^2.hr while in 30% milk ranged from $2.12x10^{-2}$ to $4.08x10^{-2}$ mg/cm^2.hr. In addition surface of aluminium alloy was studied by SEM and EDX after the leaching experiment for 1 hour in 30% milk extract and 90ºC. It is clearly showed the holed in aluminium alloy due to dissolution of aluminium by milk solution.

The study of Ščančar J et al (20), sauerkraut and sour turnip were cooked in aluminium cookware in order to estimate the extent of aluminium leaching from utensils. The results indicated that the concentration of aluminium before cooking in sauerkraut and sour turnip was 2.2 and 1.5 mg/kg, respectively. The concentration of aluminium after cooking sauerkraut and sour turnip in aluminium utensil was increased as 313 and 260 mg/kg, respectively. Therefore the cookware usage is not recommended for acidic foods.

R Karbouj (111) studied leaching of aluminium by using chelating agents as the compositions of food including lactic acid, oxalic acid and citric acid. These acids are commonly found in foods and beverages. These three chelating agents were test acids, sodium, potassium and lithium salts. The three selected concentrations are the lower, median and higher levels of those substances that are commonly found in foods (such as the lowest citrate is found in lettuce and the highest citrate is found in lemon). The results found that the variation of aluminium leaching depends on the chemical form of chelating agent and the temperature. Aluminium leaching at the boiling temperature is significantly higher than that at the ambient temperature. Besides, the salty form for the composition releases more aluminium than the acidic form.

Marta IS Veríssimo et al (17) studied red cabbage samples cooked with different acidic additives (lemon juice, wine vinegar and cider apple vinegar). It was showed that low pH values increased leaching of aluminium. Red cabbage cooked with lemon juice at pH 2.6 showed 5.1 mg aluminium per 100 g red cabbage. The preparing tomato sauce with white sugar also decreased aluminium leaching, therefore the sugar presence helps to decrease aluminium intake from food. Tomato sauce cooked with and without sugar, showed 2.7 and 4.9 mg aluminium per 100 g tomato sauce, respectively. The same samples, stored acidic food in aluminium containers for 48 hr. in a refrigerator showed 2.8 and 5.0 mg aluminium per 100 g tomato sauce, respectively. So, the keeping acid food stored in aluminium containers for 48 hr. in a refrigerator, not leads to significantly increase aluminium leaching into foods.

Fimreite N et al (21) studied aluminium concentrations in selected acid foods and tea cooked in aluminium cookware. It was found that the aluminium concentrations in black currant juice and stewed rhubarb prepared in aluminium cookware increased with the cooking time. Investigation the aluminium concentrations derived from cooking with different volume and age of cooking pots, indicated that there were differences among the aluminium pots as the oldest one (30 years) released more aluminium than the others, but no appreciable difference was observed between the 10 years old pot and the new pot. Moreover, it was reported that cooking black currant juice and postulated a possible explanation for sugar role. Since sugar has no alkaline or acid neutralization properties, a possible explanation can be that the sugar may have formed a sort of coating that reduce the contact between the acids in the juice and the aluminium surface.

Neelam et al (19) determined aluminium contents of cooked foods to evaluate its daily burden in the Indian population. The results showed that major contributions of aluminium from Indian food are derived through consumption of vegetables, spices and pulses, especially green leafy vegetables and pulse preparations that contribute greatly to total daily aluminium intakes. Spices contain high amounts of aluminium. It was found pepper contained aluminium 3.45 mg/100 g, and asafetida had the highest content of aluminium (15.10 mg/100g). Use of aluminium utensils for cooking foods contributes a significant amount of aluminium. The difference in the extent of migration of aluminium between new and old vessels clearly showed that new vessels are more easily attacked by foods and the extent of migration of aluminium from vessels gradually declines with use. Storage of food in aluminium vessels also increased aluminium content significantly. In addition, it was found total intake of aluminium in Indian population groups, who regularly use aluminium cookware and storage utensils, may be higher than that reported elsewhere.

Piyasatidtham W (22) studied the leaching of aluminium from aluminium cooking utensils into cooked food. The factors on various cooking conditions were studied including pH of food, salinities of food, cooking times and cooking temperatures. Stainless steel cooking utensils were used as control units. It was found that the levels of pH and cooking temperatures affected the amount of aluminium leaching from the aluminium cooking utensils into foods. That is aluminium contents increased at lower pH values or higher temperatures. In contrast, the levels of salinity and cooking times did not affect the aluminium contents leaching from the aluminium cooking utensils into foods.

The study of Anil DS et al (23) studied leaching of aluminium from utensils made of aluminium, indalium (alloy of aluminium), stainless steel and hard anodised aluminium under different conditions of pH and boiling time. Low pH was found to enhance leaching of aluminium from the utensils. The leaching was found to be the highest during first-time preparation (new utensils) of all the foods as compared with second-and third-time preparations using the same utensils. Leaching of aluminium during the preparation of various traditional Indian foods was found to be negligible in hard anodised aluminium utensils, indicating the advantage of using such vessels for food preparation over simple aluminium and indalium utensils.

Yaman M et al (43) determined aluminium concentrations in Turkish meals in new and old aluminium and the various other cooking utensils (clay, foil, steel, teflon, boron glass and tinned copper). In addition, aluminium amounts leached from yogurt fermented in various containers made from new and old aluminium, steel and boron glass were determined at the soured and fresh (non-soured) conditions. It was found that the aluminium concentrations of Turkish meals cooked in old aluminium utensil were significantly higher than these cooked in other utensils. In the case of yogurt fermented in the new aluminium container, aluminium concentrations in soured yogurt are two times higher than that of the fresh yogurt. Aluminium concentration in the soured yogurt in old aluminium container is excessively higher than that of fresh yogurt that it is dangerous for health.

Müller JP et al (44) determined migration of aluminium from packaging materials and cooking utensils into foods and beverages at intervals during cooking or during storage. It was found that high amounts of aluminium migrated into acidic products such as mashed tomatoes during normal processing in normal, non-coated aluminium pans. Aluminium content in tomato sauce ranged from 10 to15 mg/kg after cooking for 60 min. Aluminium content in aluminium pans was also increased up to 2.6 mg/L after boiling tap water for 15 min. Storage of Coca-Cola in internally lacquered aluminium cans resulted in aluminium contents below 0.25 mg/L. In contrast, non-coated aluminium camping bottles containing lime blossom tea acidified with lemon juice released up to 7 mg/L of aluminium within 5 days. The aluminium content in coffee was lower than that of the tap water used in its preparation, even it prepared in aluminium heaters.

In the case study of cooking by wrapping foods with aluminium foil, Boonyanan S (26) determined the amounts of aluminium released from aluminium foil wrapped meat into baked meat including fish, chicken and beef after baking with different cooking times (20, 30 and 40 minutes) and temperatures (200°C, 225°C, 250°C, and 275°C). The results found that aluminium release increased with an increase in baking time and temperature. In contrast, the kinds of meat had not significant effect on aluminium leaching.

Takeda et al (112) studied dissolution of aluminium from aluminium foil into foods and effect of food component on dissolution, it was found that aluminium migration from aluminium foil depend on pH value cause to aluminium contaminate into foods.

Sadettin T (27) studied aluminium contents in baked meats (beef, water buffalo, mutton, chicken and turkey) wrapped in aluminium foil in various cooking treatments (60 min at 150°C, 40 min at 200°C, and 20 min at 250°C). It was found that cooking increased the aluminium concentration of both the white and red meats. The increase was 89–378% in red meats and 76–215% in poultry. The least increase (76–115%) was observed in the samples baked for 60 min at 150°C, while the highest increase (153–378%) was in samples baked for 20 min at 250°C. These results observed that cooking temperature is more important in aluminium leaching than cooking time. It was also found that raw chicken and turkey breast meat contained higher amounts of aluminium than the raw chicken and turkey leg meat, respectively. Therefore, fat content of meat affected to the increase of aluminium.

The study of Ranau R et al (28) determined the aluminium contents of grilled and baked fish (cod, saithe, ocean perch and mackerel) fillets with and without ingredients wrapped in aluminium foil. The selected fish species were mackerel (a fatty species), ocean perch (a medium fatty species) and cod and saithe (two lean fish species). The wrapped fish fillets were added ingredients (vinegar and sodium chloride) or not added them and baked in an oven. In another part of fish fillets were added ingredients (onion rings and mixed spices) or not added its and grilled over charcoal. The ingredients were added in order to get a lower pH value and simulate the normal human eating habits. All aluminium contents of both baked and grilled fillets wrapped in aluminium foil increased during cooking. The increase in aluminium concentration ranged from a factor of 2 (baked saithe fillets without ingredients from 0.10 up to 0.21 mg/kg) to a factor of 68 (grilled mackerel fillets with ingredients from 0.07 up to 5.04 mg/kg). The aluminium contents of grilled fillets were higher than those of baked fillets. Higher temperature in preparation of grilled fillets is higher than the preparation temperature (200ºC) of baked fillets and that the high temperature promoted stronger aluminium leaching from aluminium foil into fillets. In addition, the results clearly showed that fat content of fillets had an influence on the aluminium increase. Another possible reason could be that the high aluminium content in mixed spices (63.5 mg Al/kg) may be taken up by the grilled fillets.

CHAPTER III
MATERIALS AND METHODS

3.1 Research Design

This study was designed as an experimental research to find leached aluminium contents into cooked meats from wrapping with aluminium foil. The experimental research was a 4 x 2 x 2 x 3 factorial design with 3 replications, which consists of 4 factors, i.e., kinds of meat (seabass fish, saba fish, chicken, and beef), use of seasonings (without and with seasoning), aluminium amounts in aluminium foil (brand 1 - lower aluminium amount - and brand 2 - higher aluminium amount - of aluminium foil) and types of heat cooking (electric oven, electric grill stove and gas stove) for finding the conditions to be suggested for appropriate use of aluminium foil.

3.2 Places of the Study

1) The experiment was carried at the environmental health laboratory, the Department of Environmental Health Sciences, Faculty of Public Health, Mahidol University, Bangkok, Thailand.

2) The fat content was investigated using the Soxhlet Extraction Apparatus at the nutrition laboratory, the Department of Nutrition, Faculty of Public Health, Mahidol University, Bangkok, Thailand.

3) The samples were digested by using the Microwave Digestion System at the Department of Agro-Industrial Technology, Faculty of Applied Science, King Mongkut’s University of Technology North Bangkok, Bangkok, Thailand.

4) Aluminium contents was investigated using the Flame Atomic Absorption Spectrophotometer (FAAS) at the Center of Excellence on Environmental Health, Toxicology and Management of Chemicals, Toxicology, Faculty of Science, Mahidol University, Bangkok, Thailand.

3.3 Materials, Equipments, Glasswares and Chemicals used

3.3.1 Materials used

The materials were used in this study as follows:

1. Distilled water
2. Deionized water
3. Filter paper No.40 and No.42, ∅ 110 mm, Whatman, England
4. Cellulose Extraction Thimble, 22 mm x 80 mm, Whatman, England
5. Polyethylene bag
6. Cotton wool
7. Aluminium foil
8. Meat samples (seabass fish, saba fish, chicken and beef)
9. Seasonings (garlic, black pepper, table salt, soy sauce)

3.3.2 Equipments used

The equipments were used in this study as follows:

1. Analytical Balance: Mettler-Toledo, Model AB204-S, Max 220 g and Min 10 mg, Switzerland
2. Balance: Zepper, Kitchen Scale, KCC2000, Max 2000 g and Min 10 g, Thailand
3. Soxhlet Extraction Apparatus
4. Clamp holder
5. Desiccator: Patron Dry-Cabinet, Model 010600/5, Taiwan
6. Thermocouple: Yokogawa, Model 2455, Japan
7. Blender: Philips, Model HR2068 (600W, 2 L), Indonesia
8. Flame Atomic Absorption Spectrophotometer (FAAS): Varian, SpectrAA 220FS, Australia
9. Microwave digestion system: Milestone, Model MLS-1200 MEGA, Italy
10. Water bath: Memmert, Model WB-14, Germany
11. Hot Air Oven: Memmert, Model UNE400,Germany
12. pH meter: Hach Sension 1, U.S.A

13. Micropipette: 1, 5 and 10 mL, LIO LAB, Model LP-1000A., U.S.A
14. Pipette tip: 1, 5 and 10 mL
15. Teaspoon, Knife, Scissors and Chopping block
16. Stop watch
17. Electric oven: EOV-19RC, 1380 W, Alfa Kitch, China
18. Electric grill stove: 150-OAP, 1500 W, Kuma Denki, Thailand
19. Gas stove: Marritaa, Thailand

3.3.3 Glasswares used

The glasswares were used in this study as follows:

1. Volumetric flask: 25, 50, and 100 mL
2. Beaker 50, 100, and 250 mL
3. Flat Bottom Flask 250 mL
4. Cylinder 100 mL
5. Glass funnel
6. Glass bead
7. Dropper
8. Stirring rod

3.3.4 Chemicals used

The chemical reagents in this study were used of analytical reagent grade (p.a.) as follow:

1. Standard Stock Solution of Aluminium: Aluminium Nitrate Standard Solution for AAS, 1000 ppm, Ajax Finechem, Australia.
2. Nitric acid (65% HNO_3), Merck, Germany.
3. Hydrogen peroxide, 100 volumes > 30% w/v, Fisher Scientific, UK.
4. Petroleum Ether 35-60°C, J.T. Baker, U.S.A

3.4 Experimental Procedure

3.4.1 Sample Preparation and Cooking Method

a. Sample preparation

Meat samples in this experiment (seabass fish, saba fish, chicken, and beef) were purchased from a supermarket in Bangkok, Thailand. Saba fish and seabass fish approximately weigh 800-1000 g of a whole fish. They were washed with tap water, removed fish scale, removed entrails and cut off fish's head. A whole fish was analyzed for one condition. Chicken (breast chicken meat) and beef (round beef meat) meat approximately weighed 400-600 g per piece. They were washed with tap water, trimmed to remove bones, skin and most of the surface fat, and then cut into pieces with size of 10 cm x 10 cm and a thickness of 1 cm. They approximately weighed 180-200 g/piece. One piece of chicken or beef meat was analyzed for one condition. All of meat was determined aluminium contents in fresh meat before cooking for background data of aluminium in meat, as shown in Item 3.4.7 and Figure 3.2, similar to determination of aluminium concentration in cooked meat. Fat content of each fresh meat was analyzed as explained in Item 3.4.5.

Aluminium foils (two brands of aluminium foil for covering or wrapping food) in this experiment were purchased from a supermarket. Size of aluminium foil was equal to 30 cm x 30 cm for each piece of sample. The same method for wrapping with aluminium foil was performed for every experiment as shown in Item 3.4.2 and Figure 3.5. The amount of aluminium in aluminium foil was analyzed by FAAS and the analytical method to determine aluminium amount in aluminium foil sample was shown in Figure 3.4.

Regarding seasonings use of this study, saba fish and seabass fish were mixed with salt (iodized table salt) and soy sauce. Garlic (crushed garlic), pepper (black pepper), and soy sauce were mixed with chicken and beef meat. The quantities of them were shown in Table 3.1. The seasonings were added in order to simulate the normal human eating habits. The amount of aluminium in seasonings was analyzed by FAAS. All meat were mixed with seasonings and chilled in the refrigerator at 3-5 °C for 1 hour before cooking as each testing condition.

b. Cooking Method

1. Mixed all ingredients (both meat and seasonings) together in a glass bowl (e.g., breast chicken, garlic, pepper, soy sauce) and chilled in the refrigerator at 3-5 °C for 1 hr.

2. The prepared meat sample was wrapped with the prepared aluminium foil. The wrapping method was shown in Item 3.4.2 and Figure 3.5.

3. The wrapped meat sample was cooked as three types of heat cooking shown in Table 3.1.

4. Completely cooked, waited for cooling meat sample about 10 min and remove aluminium foil from cooked meat sample.

5. The cooked meat was sampled and digested as described in Item 3.4.4 and then analyzed for aluminium content by FAAS as shown in Item 3.4.7.

In addition, cooking method (cooking time and cooking temperature) in each meat depended on the guideline of each heating equipment, which was the selected cooking temperature and time that could make meat just enough cooked and appetizing. They are shown in Table 3.1.

Table 3.1 Seasonings use, cooking time, and cooking temperature for each meat

Kinds of Meat	Seasonings	Types of cooking heat		
		Equipment	**Cooking Temperature (°C)**	**Cooking Time (min)**
Seabass fish (800-1000 g/fish)	- 1/2 tsp salt - 2 tsp soy sauce	Electric oven	200	60
		Electric grill stove	200	60
		Gas stove	300	20
Saba fish (800-1000 g/fish)	- 1/2 tsp salt - 2 tsp soy sauce	Electric oven	200	60
		Electric grill stove	200	60
		Gas stove	300	20
Chicken (180-200 g/piece)	- 5 g garlic, crushed - 1/2 tsp black pepper - 2 tsp soy sauce	Electric oven	200	60
		Electric grill stove	200	60
		Gas stove	300	20
Beef (180-200 g/piece)	- 5 g garlic, crushed - 1/2 tsp black pepper - 2 tsp soy sauce	Electric oven	200	60
		Electric grill stove	200	60
		Gas stove	300	20

3.4.2 Meat Wrapping Method with Aluminium Foil

First step, a piece of meat or a fish was placed on aluminium foil. Folded two sides of aluminium foil so that the meat or fish was placed in the center. Took the overlapping foil and folded into half to form a seal foil that ran along the piece of meat. Folded again into half in the same direction to be under double seal. Flattened the open ends to form two flaps. Folded each flap into half and did once again to seal the ends. Aluminium foil was made to fit tightly against the meat. Meat wrapping method with aluminium foil is shown in Figure 3.5.

3.4.3 Cleaning of Laboratory Glass and Plastic ware (29)

Laboratory glass and plastic wares in the experiment were as follows.

a. For Glass and Plastic wares

After cleaning with tap water and detergent, all glass and plastic ware were soaked in 20% HNO_3 at least 24 hr. Before use, they were washed in tap water and rinsed with distilled water.

b. For Digestion Vessels

First step washed the vessels with water and detergent. Rinsed with tap water, followed by deionized water and kept vessels covered with 5% HNO_3 for 1 hr. After that rinsed with deionized water and let vessels dry.

3.4.4 Sampling and Digestion method

a. Sampling method

The raw and cooked samples were ground in a blender to ensure homogeneity and representative samples for further analysis. The homogeneity sample of each piece of meat was drawn to analyze in three repeated values which those were calculated as one replication. The result of three replications was calculated as the mean value. Meat sample used for aluminium determination was accurately 1 g of fresh matter. The meat sample for determination of fat content was approximately 5 g of fresh matter as shown in Item 3.4.5 and Figure 3.3.

b. Procedure for microwave digestion system

1. Placed a vessel on the balance and set zero. Meat sample accurately weighed and placed 1 g of fresh matter on vessel.

2. Added reagents (6 mL of 65% HNO_3, 1 mL of 30% H_2O_2).

3. Assembled the vessel in the polypropylene rotor body and tightened the screw in the upper part of the rotor body. Placed into the microwave cavity.

4. Recalled a stored program. Run the program settings for digesting of animal tissue and started digestion.

5. After complete digestion program, took the rotor body with vessels and protection ring inside the cooling system for approximately 10 min. Moved the rotor body from the cooling system to the work station, preferably located under the fume-hood.

6. Carefully loosened the screw in the upper part of the rotor body, using the capping tool or the tension wrench and waited till pressure was completely released.

7. Repeated the same operation with all vessels in the rotor. Removed the external protection ring. Took the vessels out of the rotor body. Carefully took up the vessel cover, together with the protection ring.

8. Rinsed the lower part of the cover, collecting the solution inside the vessel with deionized water.

9. Filtered the cooled solution through Whatman filter paper (No.42) and washed repeatedly the inside of vessel with deionized water.

10. Made up to 25 mL with deionized water in a volumetric flask. The clear solution was analyzed for aluminium by FAAS showed in Item 3.4.7.

3.4.5 Fat content analysis in fresh meat by Soxhlet extraction (30)

1. Weighed about 5-6 g of fresh matter and dried in oven at 103°C for 2 hr.

2. Accurately weighted 2 g of dry matter (A) on Whatman filter paper (No.40).

3. Completely wrapped up the paper before putting in thimble and placed cotton wool in the top of the thimble. Inserted the thimble in a Soxhlet extractor (Figure C-3 in Appendix C).

4. Dried a clean extraction flask containing a few glass beads in oven at 103°C for 2 hr. Removed, cooled the flask in a desiccator and accurately weighed the extraction flask (B).

5. Added petroleum ether about 150 mL in extraction flask.

6. Assembled a soxhlet extraction apparatus as shown in Figure 3.4 and placed the extraction unit over an electric heating mantle.

7. Heated the solvent in the flask until it boiled. Adjusted the heat source so that solvent dripped from the condenser into the sample chamber at the rate about 6 drops per second and continued the extraction for 8 hr.

8. After completion of extraction, closed condenser valves and removed the extraction unit from the heat source. Detached the extractor and condenser. Replaced the flask on the heat source and evaporated off the solvent.

9. Placed the flask in oven at 103°C and dried until a constant weight was reached (1-2 hr). Cooled the flask in desiccator and weighed extraction flask (C).

10. The fat content was calculated as fat content (%) by the following equation (30).

$$\text{Fat content (\%)} = \left(\frac{C - B}{A}\right) \times 100$$

Where; A was the weight of meat sample (g).
B was the weight of extraction flask (g).
C was the weight of extraction flask + residue (g).

3.4.6 Preparation of Standard Solutions

A standard stock solution of aluminium (1000 ppm) was prepared. Further solutions were prepared by dilution of aluminium stock solution with deionized water and the volumes adjusted to 25 mL. Thus, solution concentrations of 0, 0.1, 0.5, 1.0, 2.0, and 4.0 mg/L were obtained. Each solution was then analyzed by the Flame Atomic Adsorption Spectrophotometer (FAAS) to set up a standard curve (29).

3.4.7 Aluminium analysis for Flame Atomic Absorption Spectrometry

1. After digestion, the aluminium concentrations in each digested sample were analyzed by using the Flame Atomic Absorption Spectrophotometer (FAAS). Set FAAS according to manufacturer's recommendations. The operating conditions of FAAS for aluminium measurement were listed below.

Element:	Al
Wavelength:	309.3 nm
Lamp current:	10.0 mA
Slit width:	0.5 nm
Flame type:	N_2O/Acetylene

2. Set up a aluminium standard curve of 0, 0.1, 0.5, 1.0, 2.0, and 4.0 mg/L

3. Analyzed the clear sample solutions for aluminium by FAAS and read aluminium concentration of sample (mg/L)

4. Calculated for change the data to leached aluminium contents into meat wrapped with aluminium foil (mg/kg) by the following equation (29).

$$\begin{pmatrix}\text{Aluminium content}\\ \text{in meat (mg/g)}\end{pmatrix} = \frac{\text{Aluminium concentration (mg/L)}}{\text{Weight of meat sample (g)}} \times 25\ \text{mL} \times \frac{1\ \text{L}}{10^3\ \text{mL}}$$

$$\begin{pmatrix}\text{Aluminium content}\\ \text{in meat (mg/kg)}\end{pmatrix} = \frac{\text{Aluminium concentration (mg/L)}}{\text{Weight of meat sample (g)}} \times (25 \times 10^{-3})\ \text{mL} \times \frac{10^3\ \text{g}}{1\ \text{kg}}$$

$$\text{Leached aluminium content into cooked meat (mg/kg)} = C_a - C_b$$

Where; C_a is aluminium contents in cooked meat (after cooking).
C_b is aluminium contents in fresh meat (before cooking).

For determination of aluminium amount in aluminium foil (%) can be calculate by the following equation (29).

$$\begin{pmatrix}\text{Aluminium content}\\ \text{in meat (mg/g)}\end{pmatrix} = \frac{\text{Aluminium concentration (mg/L)}}{\text{Weight of meat sample (g)}} \times 25\ \text{mL} \times \frac{1\ \text{L}}{10^3\ \text{mL}}$$

$$\begin{pmatrix}\text{Aluminium amounts}\\ \text{in aluminium foil (\%)}\end{pmatrix} = \begin{pmatrix}\text{Aluminium concentration}\\ \text{in aluminium foil (mg/g)}\end{pmatrix} \times \frac{1\ \text{g}}{1000\ \text{mg}} \times 100$$

3.5 Flow Diagram

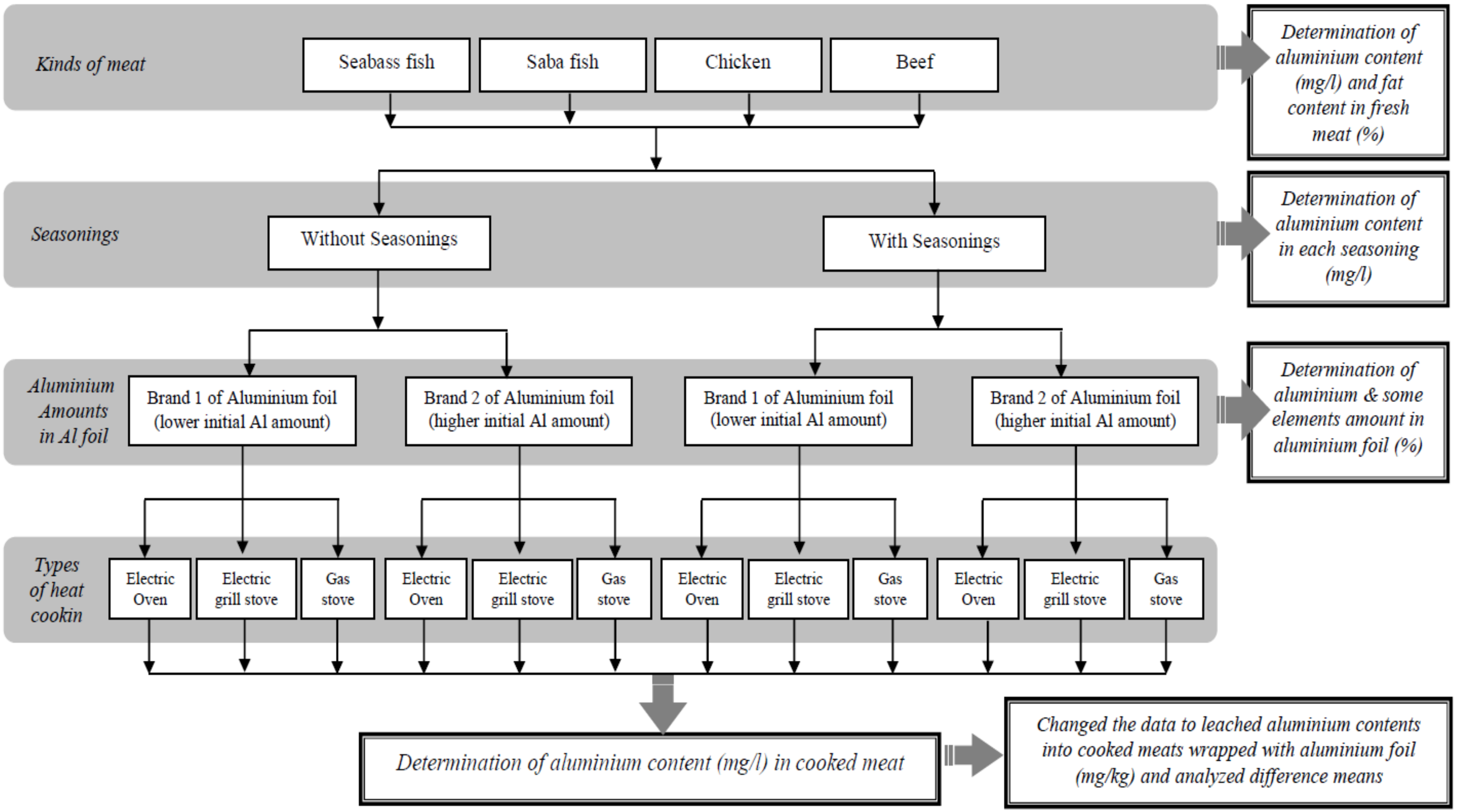


Figure 3.1 Flow diagram of the experiment of leached aluminium contents into meat wrapped with aluminium foil (Thesis Flow Chart)

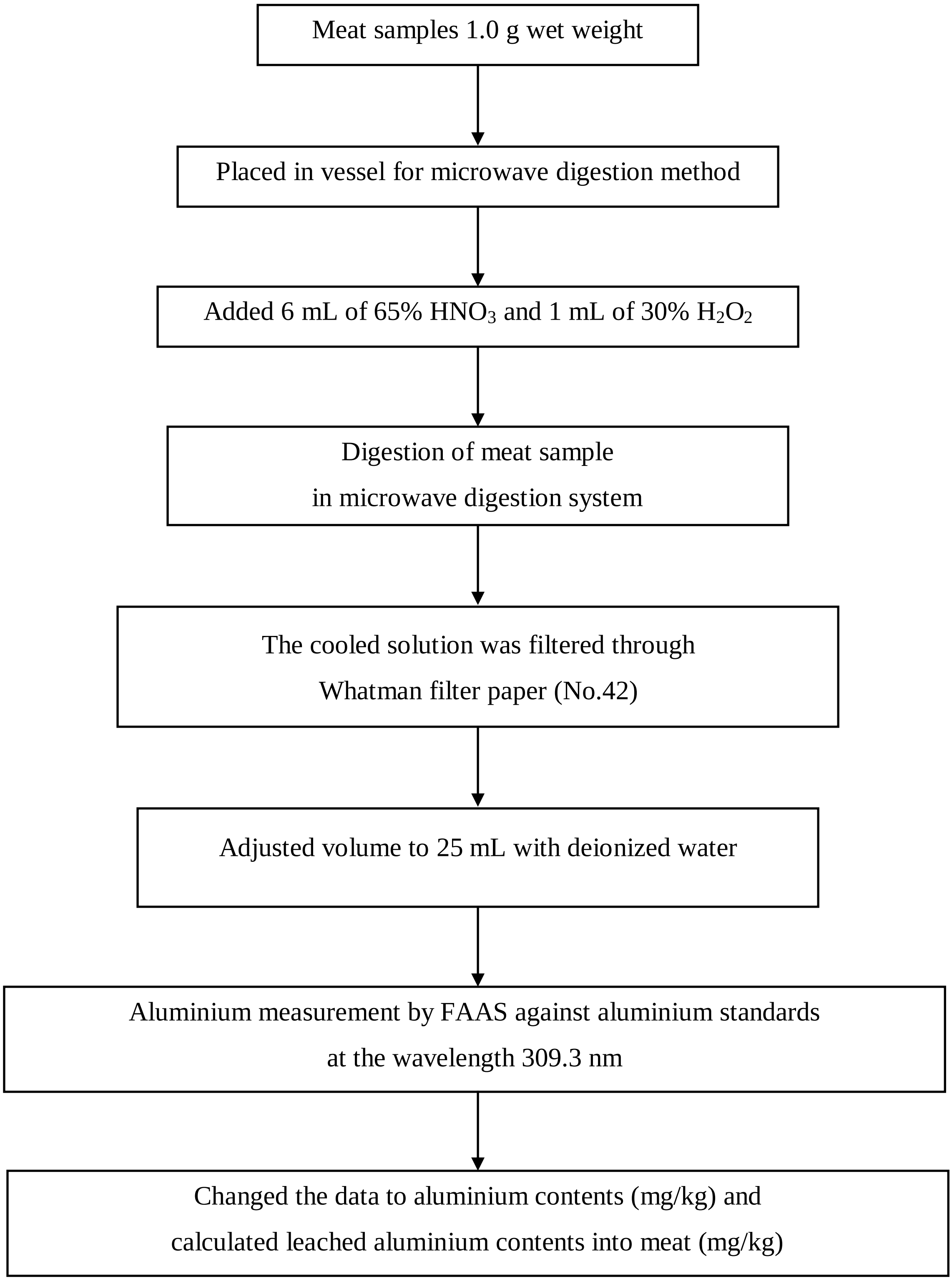


Figure 3.2 Flow diagram for aluminium analysis in meat samples

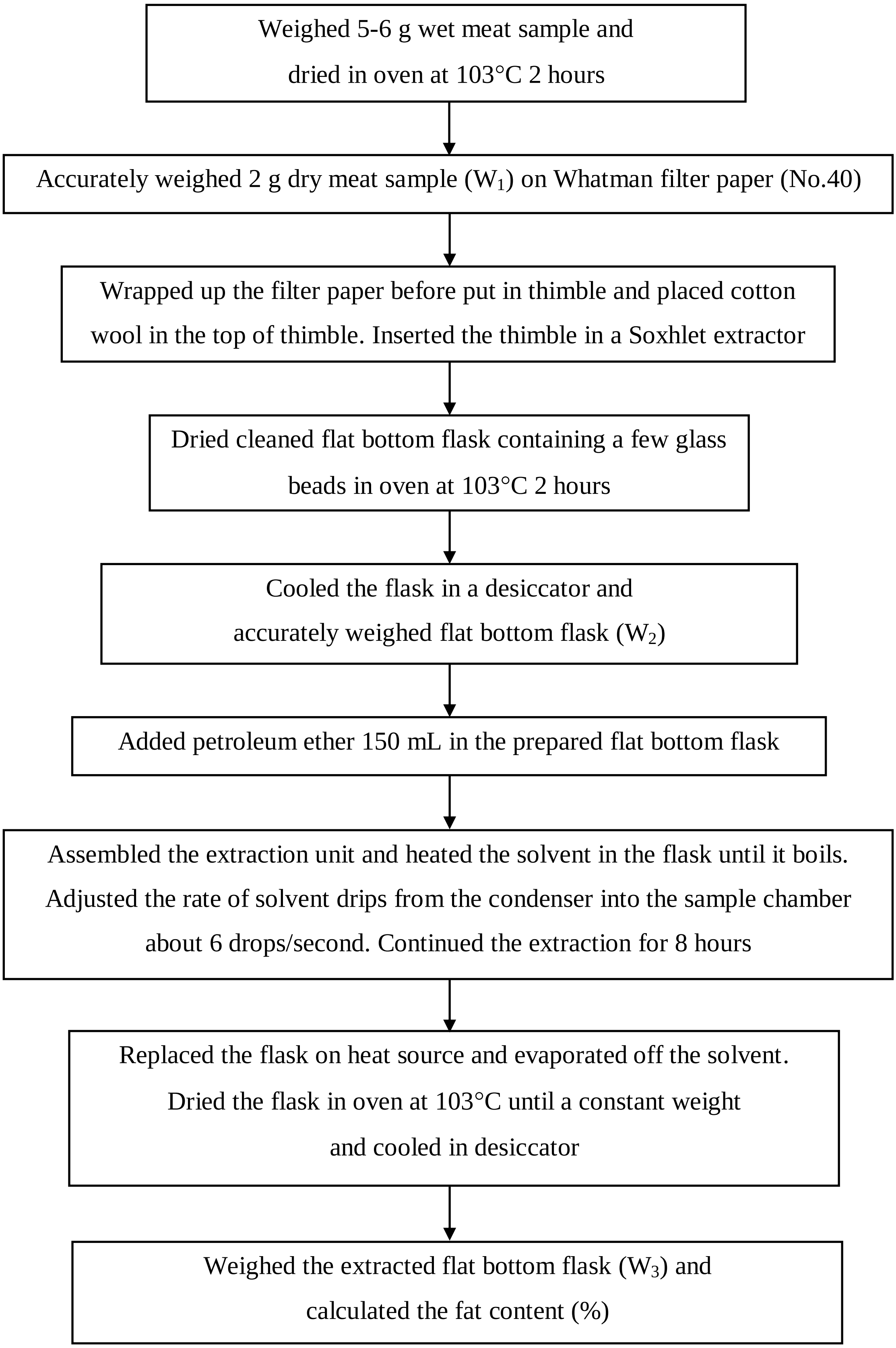


Figure 3.3 Flow diagram of fat analysis for soxhlet extraction method

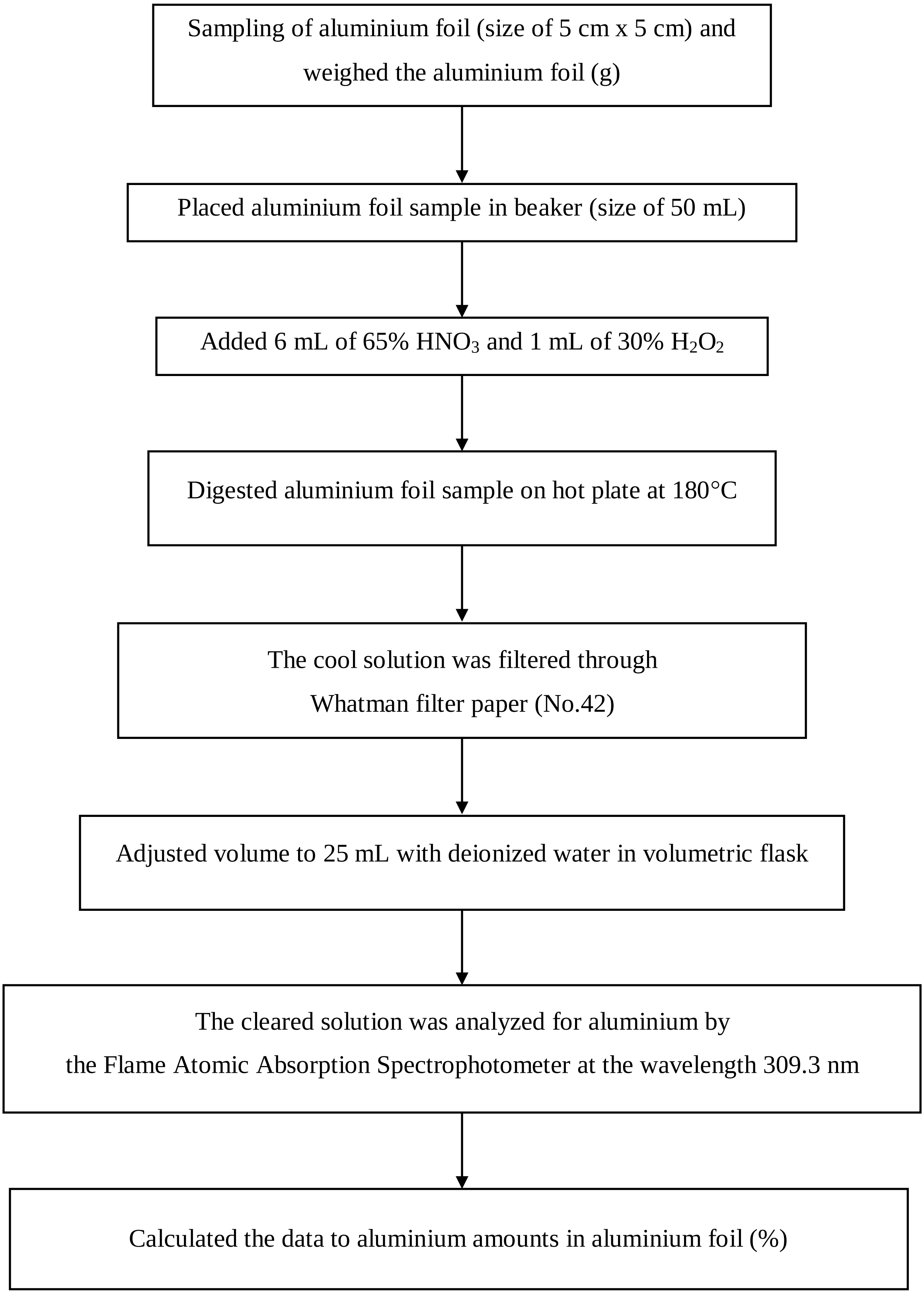


Figure 3.4 Flow diagram for determination of aluminium amount in aluminium foil (%)

Placed meat sample on aluminium foil (size of 30 cm x 30 cm) and fold two sides over so the sample was placed in the center.

Took the overlapping foil and folded into half to form a seal that ran along the piece of meat. Folded again into half in the same direction to be under double seal.

Flattened the open ends to form two flaps. Folded each flap into half and once did once again to seal the ends. Aluminium foil was made to fit tightly against the meat.

Figure 3.5 Meat wrapping method with aluminium foil

3.6 Statistical Analysis

3.6.1 Descriptive Statistics

The data of leached aluminium contents into meat was analyzed and illustrated as the mean and standard deviation for each of four factors consisted of 4 x 2 x 2 x 3 conditions - i.e. kinds of meat (seabass fish, saba fish, chicken, and beef), use of seasonings (without and with seasonings), aluminium amount in aluminium foil (brand 1 - lower aluminium amount and brand 2 - higher aluminium amount), types of heat cooking (electric oven, electric grill stove and gas stove) and their combination of kinds of meat, use of seasonings, aluminium amount in aluminium foil and types of heat cooking.

3.6.2 Analytical Statistics

The analysis of variance (ANOVA) was performed for the factorial experiment with 4 factors - i.e. kinds of meat (seabass fish, saba fish, chicken, and beef), use of seasonings (with and without seasonings), aluminium amounts in aluminium foil (brand 1 - lower aluminium amount and brand 2 - higher aluminium amount) and types of heat cooking (electric oven, electric grill stove and gas stove). The results of ANOVA table were assigned at α level of 0.05. The multiple comparisons for testing significant differences between every pair of treatments were performed.

CHAPTER IV
RESULTS

The results of this study were presented in this chapter. The results emphasized aluminium content leached into cooked meats wrapped with aluminium foil. This study was performed as the laboratory experiment; the samples were collected and taken for analysis at the laboratory. The study consisted of four influencing factors: kinds of meat, use of seasoning, aluminium amounts in aluminium foil and types of heat cooking. The raw data, statistical analysis and photographs of the experiment are shown in Appendix A, B and C respectively.

4.1 Descriptive Statistical Results

This study was conducted to determine leached aluminium content into cooked meats wrapped with aluminium foil at different cooking conditions. Leached aluminium content into cooked meats (mg/kg) was calculated by aluminium content in meat between before and after cooking. The raw data of aluminium content in meat at different kinds of meat, use of seasoning, aluminium amounts in aluminium foil and types of heat cooking are shown in Appendix A.

The study results indicated that aluminium content leached into cooked meats by wrapping with aluminium foil were between 0.149 to 8.573 mg/kg, which depended on the influencing factors (kinds of meat, use of seasoning, aluminium amounts in aluminium foil and types of heat cooking) and the overall of total mean was 2.214 mg/kg. The results are presented in Table 4.1.

The total mean of leached aluminium content was 1.634 mg/kg when using seabass fish. The mean values of leached aluminium content by using seabass fish were 0.541 and 2.726 mg/kg when cooking without and with seasoning respectively; 1.050 and 2.217 mg/kg when wrapping with brand 1 (lower aluminium amount) and brand 2 (higher aluminium amount) of aluminium foil respectively; and 1.274, 1.662 and 1.965 mg/kg when using electric oven, electric grill stove and gas stove respectively.

The total mean of leached aluminium content was 1.973 mg/kg when using saba fish. The mean values of leached aluminium content by using saba fish were 0.611 and 3.335 mg/kg when cooking without and with seasoning respectively; 1.174 and 2.771 mg/kg when wrapping with brand 1 (lower aluminium amount) and brand 2 (higher aluminium amount) of aluminium foil respectively; and 1.393, 2.115 and 2.411 mg/kg when using electric oven, electric grill stove and gas stove respectively.

The total mean of leached aluminium content was 2.197 mg/kg when using chicken. The mean values of leached aluminium content by using chicken were 0.875 and 3.518 mg/kg when cooking without and with seasoning respectively; 1.299 and 3.094 mg/kg when wrapping with brand 1 (lower aluminium amount) and brand 2 (higher aluminium amount) of aluminium foil respectively; and 1.572, 2.316 and 2.702 mg/kg when using electric oven, electric grill stove and gas stove respectively.

The total mean of leached aluminium content was 3.052 mg/kg when using beef. The mean values of leached aluminium content by using beef were 1.263 and 4.842 mg/kg when cooking without and with seasoning respectively; 1.837 and 4.268 mg/kg when wrapping with brand 1 (lower aluminium amount) and brand 2 (higher aluminium amount) of aluminium foil respectively; and 2.139, 3.106 and 3.912 mg/kg when using electric oven, electric grill stove and gas stove respectively.

As shown in Table 4.1, they indicated that cooking of beef with seasoning, wrapping with brand 2 (higher aluminium amount) of aluminium foil and using gas stove gave the highest leached aluminium content (8.573 mg/kg) and cooking of seabass fish without seasoning, wrapping with brand 1 (lower aluminium amount) of aluminium foil and using electric oven gave the lowest leached aluminium content (0.149 mg/kg). The results are also presented in Table 4.1 and Figure 4.1.

Table 4.1 Mean values of leached aluminium content into cooked meats (mg/kg) wrapped with aluminium foil at different cooking conditions (kinds of meat, use of seasoning, aluminium amounts in aluminium foil and types of heat cooking)

Type of heat cooking	Aluminium amounts in Al foil	Kinds of meat														
		Seabass fish			Saba fish			Chicken			Beef			Total		
		Without seasoning	With seasoning	Total mean (SD)	Without seasoning	With seasoning	Total mean (SD)	Without seasoning	With seasoning	Total mean (SD)	Without seasoning	With seasoning	Total mean (SD)	Without seasoning	With seasoning	Total mean (SD)
Electric oven	**Brand 1** (lower Al amount)	0.149 (0.129)	1.412 (0.020)	0.780 (0.656)	0.188 (0.139)	1.657 (0.010)	0.923 (0.762)	0.315 (0.013)	1.886 (0.004)	1.101 (0.808)	0.407 (0.011)	2.407 (0.039)	1.407 (1.029)	0.265 (0.138)	1.840 (0.373)	1.053 (0.841)
	Brand 2 (higher Al amount)	0.635 (0.118)	2.900 (0.106)	1.768 (1.170)	0.808 (0.012)	2.917 (0.017)	1.862 (1.085)	0.927 (0.008)	3.160 (0.008)	2.043 (1.149)	1.307 (0.010)	4.436 (0.009)	2.871 1.610)	0.919 (0.257)	3.353 (0.644)	2.136 (1.319)
	Total mean (SD)	0.392 (0.278)	2.156 (0.769)	1.274 (1.061)	0.498 (0.333)	2.287 (0.648)	1.393 (1.040)	0.621 (0.315)	2.523 (0.655)	1.572 (1.090)	0.857 (0.463)	3.421 (1.044)	2.139 (1.525)	0.592 (0.388)	2.597 (0.924)	**1.594 (1.229)**
Electric grill stove	**Brand 1** (lower Al amount)	0.193 (0.153)	2.031 (0.135)	1.112 (0.956)	0.284 (0.018)	2.138 (0.024)	1.211 (0.954)	0.349 (0.028)	2.195 (0.008)	1.272 (0.950)	0.459 (0.009)	3.000 (0.005)	1.729 (1.307)	0.321 (0.124)	2.341 (0.396)	1.331 (1.058)
	Brand 2 (higher Al amount)	0.719 (0.123)	3.705 (0.258)	2.212 (1.549)	0.948 (0.025)	5.090 (0.011)	3.019 (2.131)	1.438 (0.010)	5.281 (0.010)	3.360 (1.977)	2.013 (0.009)	6.951 (0.009)	4.482 (2.540)	1.280 (0.508)	5.257 (1.174)	3.268 (2.195)
	Total mean (SD)	0.456 (0.302)	2.868 (0.884)	1.662 (1.386)	0.616 (0.343)	3.614 (1.519)	2.115 (1.868)	0.893 (0.561)	3.738 (1.588)	2.316 (1.860)	1.236 (0.800)	4.975 (2.033)	3.106 (2.432)	0.800 (0.606)	3.799 (1.707)	**2.300 (1.973)**
Gas stove	**Brand 1** (lower Al amount)	0.301 (0.031)	2.215 (0.126)	1.258 (0.989)	0.313 (0.029)	2.466 (0.012)	1.389 (1.108)	0.484 (0.008)	2.567 (0.008)	1.526 (1.072)	1.065 (0.008)	3.683 (0.007)	2.374 (1.347)	0.541 (0.317)	2.733 (0.575)	1.637 (1.196)
	Brand 2 (higher Al amount)	1.249 (0.157)	4.093 (0.181)	2.671 (1.473)	1.126 (0.103)	5.739 (0.004)	3.432 (2.374)	1.738 (0.006)	6.018 (0.005)	3.878 (2.202)	2.325 (0.007)	8.573 (0.005)	5.449 (3.215)	1.609 (0.487)	6.106 (1.628)	3.858 (2.559)
	Total mean (SD)	0.775 (0.500)	3.154 (0.978)	1.965 (1.429)	0.719 (0.425)	4.103 (1.684)	2.411 (2.100)	1.111 (0.645)	4.292 (1.775)	2.702 (2.082)	1.695 (0.648)	6.128 (2.516)	3.912 (2.886)	1.075 (0.675)	4.419 (2.087)	**2.747 (2.281)**
Total	**Brand 1** (lower Al amount)	0.214 (0.130)	1.886 (0.365)	1.050 (0.886)	0.262 (0.096)	2.087 (0.339)	1.174 (0.954)	0.383 (0.076)	2.216 (0.284)	1.299 (0.948)	0.644 (0.305)	3.030 (0.532)	1.837 (1.279)	0.376 (0.241)	2.305 (0.583)	1.340 (1.064)
	Brand 2 (higher Al amount)	0.868 (0.305)	3.566 (0.539)	2.217 (1.429)	0.961 (0.145)	4.582 (1.230)	2.771 (2.023)	1.368 (0.341)	4.820 (1.234)	3.094 (1.960)	1.882 (0.434)	6.653 (1.735)	4.268 (2.714)	1.269 (0.514)	4.905 (1.671)	3.087 (2.200)
	Total mean (SD)	0.541 (0.403)	2.726 (0.963)	**1.634 (1.321)**	0.611 (0.373)	3.335 (1.544)	**1.973 (1.767)**	0.875 (0.554)	3.518 (1.585)	**2.197 (1.778)**	1.263 (0.727)	4.842 (2.227)	**3.052 (2.439)**	0.822 (0.601)	3.605 (1.805)	**2.214 (1.935)**

Different values out the parenthesis indicate the mean of leached aluminium content into cooked meat.
Different values in the parenthesis indicate the standard deviation of leached aluminium content into cooked meat.
The overall of total mean is 2.214 ± 1.935.

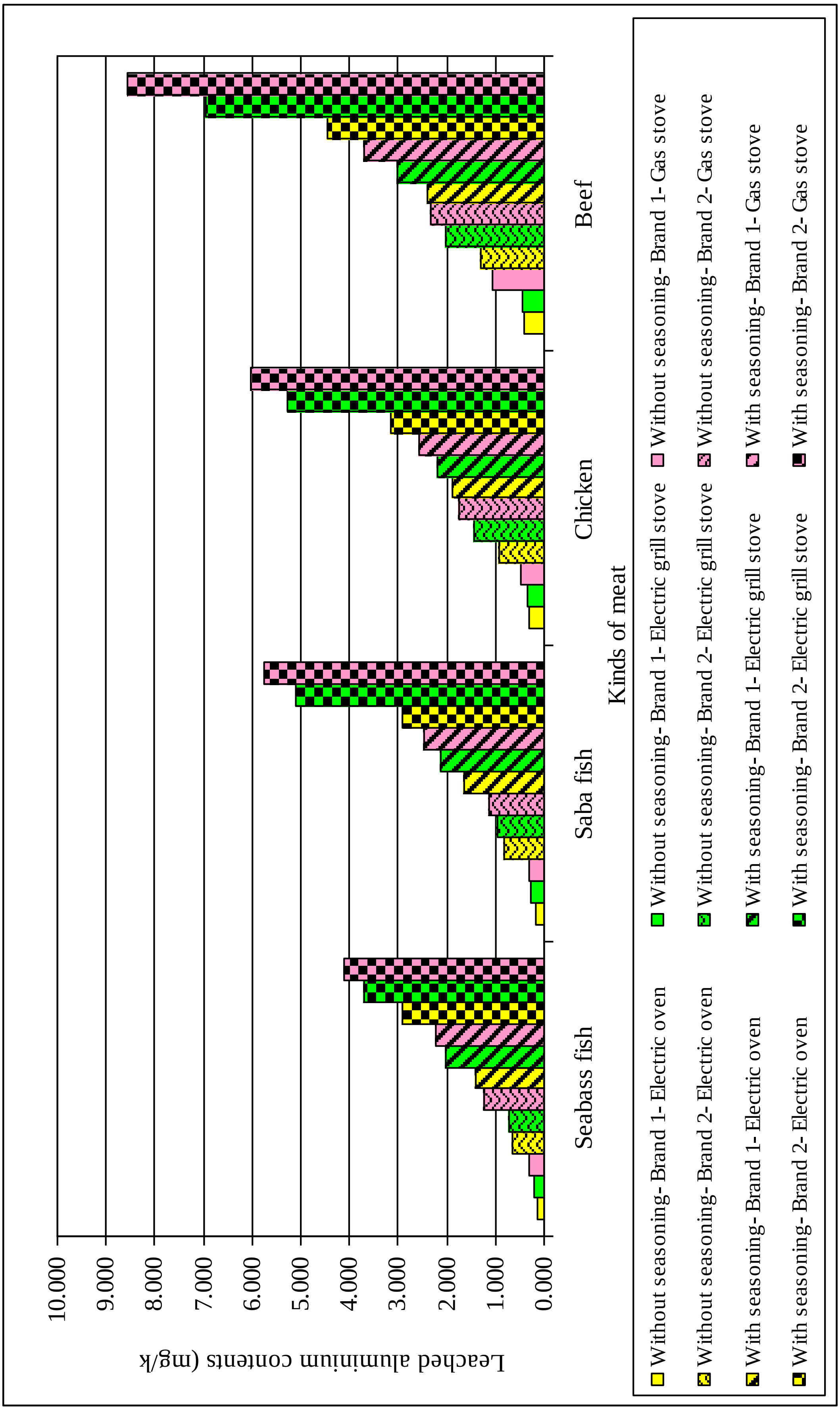


Figure 4.1 Mean values of leached aluminium contents into cooked meats (mg/kg) wrapped with aluminium foil at different cooking conditions (kinds of meat, use of seasoning, aluminium amounts in aluminium foil and types of heat cooking)

4.1.1 Leached aluminium content into cooked meats (mg/kg) wrapped with aluminium foil by using different kinds of meat

Leached aluminium content into cooked meat (mg/kg) was studied by using four kinds of meat which were seabass fish, saba fish, chicken and beef. The results are presented in Figure 4.2, it showed that the total mean values of leached aluminium content into cooked meat (mg/kg) were 1.634, 1.973, 2.197 and 3.052 when using seabass fish, saba fish, chicken and beef respectively. The aluminium contents were different when using different kinds of meat.

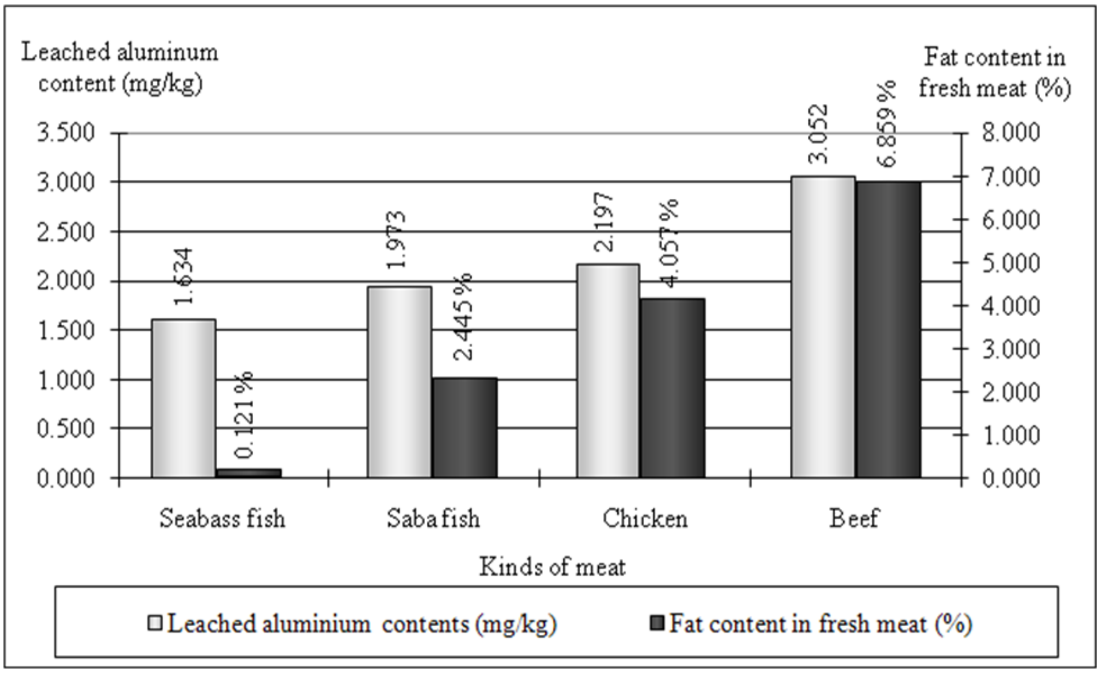


Figure 4.2 The total mean of leached aluminium content into cooked meats (mg/kg) wrapped with aluminium foil and the percentages of fat content in different kinds of fresh meat

Moreover, fat content of these meats had been analyzed before cooking (fresh meat). The results are presented in Figure 4.2 which was shown that the percentages of fat content in fresh meat (%) were 0.121, 2.445, 4.057 and 6.859 for seabass fish, saba fish, chicken and beef respectively. The results indicated that different kinds of fresh meat had different fat contents. Besides, these results obviously showed that fat content of fresh meat influenced on the increasing of leached aluminium content into cooked meats wrapped with aluminium foil.

In addition to pH values of these fresh meats had also been measured before and after cooking. The results showed that pH value in various fresh meats range between 5.60 and 6.07, which were acidic. After cooking, each meat was measured the pH value again, they were between 5.72 and 6.28. The pH value was slightly increased but the value was not less than 4.00 and not more than 9.00.

The result in Figure 4.3 showed the interaction between kinds of meat and use of seasonings. It was found that the mean values of leached aluminium content into cooked meat (mg/kg) without seasonings were 0.541, 0.611, 0.875 and 1.263 when using seabass fish, saba fish, chicken and beef respectively. The mean values of leached aluminium content into cooked meat (mg/kg) with seasonings were 2.726, 3.335, 3.518 and 4.842 when using seabass fish, saba fish, chicken and beef respectively.

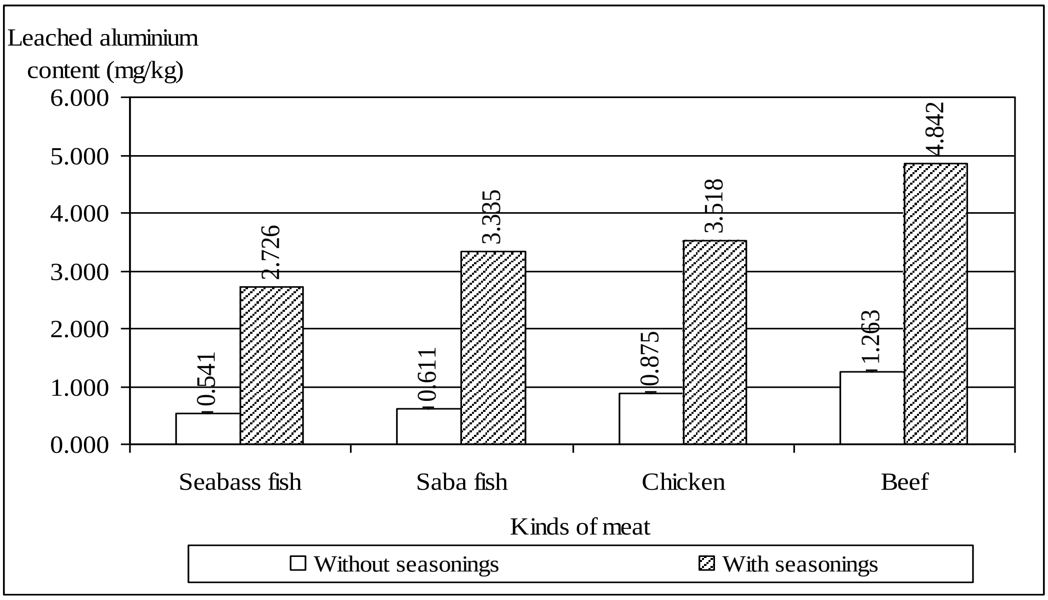


Figure 4.3 The mean values of leached aluminium content into cooked meats (mg/kg) wrapped with aluminium foil when using different kinds of meat and use of seasonings

The results showed that the mean of leached aluminium content into cooked meat (mg/kg) was the highest value (4.842 mg/kg) when using beef and cooked with seasonings, while it was the lowest value (0.541 mg/kg) when using seabass fish and cooked without seasonings.

The results indicated that leached aluminium content into cooked meat (mg/kg) - by using seabass fish, saba fish, chicken and beef - increased when cooking either with or without seasonings. The results also revealed that leached aluminium content into cooked meat (mg/kg) wrapped with aluminium foil by cooking with seasonings was higher than by cooking without seasonings.

The interaction between kinds of meat and aluminium amounts in aluminium foil is presented in Figure 4.4. The results showed that the mean values of leached aluminium content into cooked meat (mg/kg) wrapped with brand 1 (lower aluminium amount) of aluminium foil were 1.050, 1.174, 1.299 and 1.837 when using seabass fish, saba fish, chicken and beef respectively. The mean values of leached aluminium content into cooked meat (mg/kg) wrapped with brand 2 (higher aluminium amount) of aluminium foil were 2.217, 2.771, 3.094 and 4.268 when using seabass fish, saba fish, chicken and beef respectively.

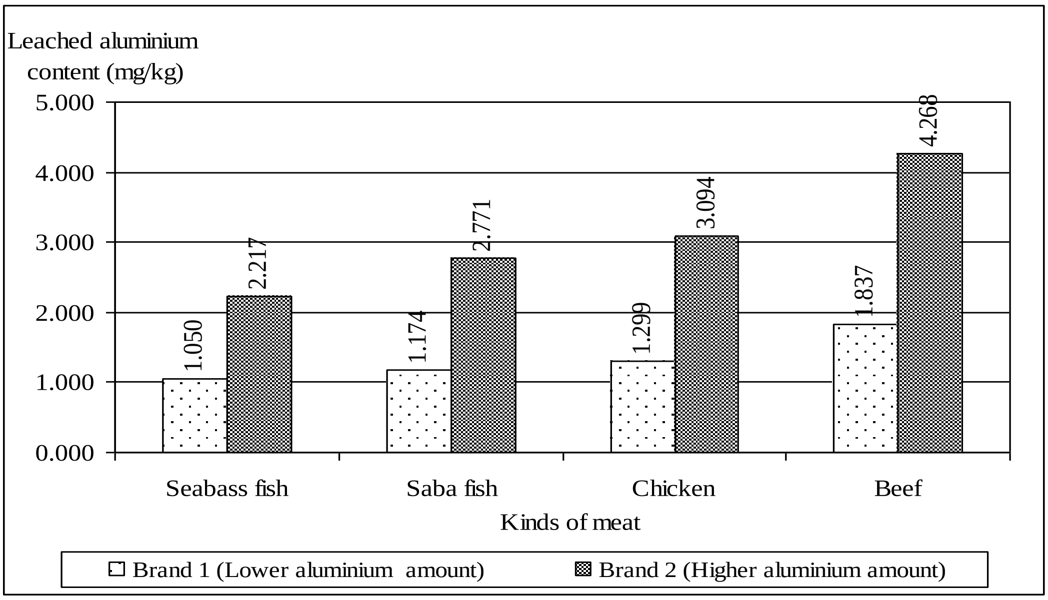


Figure 4.4 The mean values of leached aluminium content into cooked meats (mg/kg) wrapped with aluminium foil when using different kinds of meat and aluminium amounts in aluminium foil

It was found that the mean of leached aluminium content into cooked meat (mg/kg) was the highest value (4.268 mg/kg) when using beef and wrapped with brand 2 (higher aluminium amount) of aluminium foil, while it was the lowest value (1.050

mg/kg) when using seabass fish and wrapped with brand 1 (lower aluminium amount) of aluminium foil.

The results showed that leached aluminium content into cooked meat (mg/kg) - by using seabass fish, saba fish, chicken and beef - increased when wrapping with each brand of aluminium foil. The results indicated that leached aluminium content into cooked meat (mg/kg) wrapped with brand 2 (higher aluminium amount) of aluminium foil was higher than wrapped with brand 1 (lower aluminium amount) of aluminium foil.

The interaction between kinds of meat and aluminium amounts in aluminium foil is presented in Figure 4.5. The results showed that the mean values of leached aluminium content into cooked meat (mg/kg) by using electric oven were 1.274, 1.393, 1.572 and 2.139 in seabass fish, saba fish, chicken and beef respectively; by using electric grill stove were 1.662, 2.115, 2.316 and 3.106 in seabass fish, saba fish, chicken and beef respectively; and by using gas stove were 1.965, 2.411, 2.702 and 3.912 in seabass fish, saba fish, chicken and beef respectively.

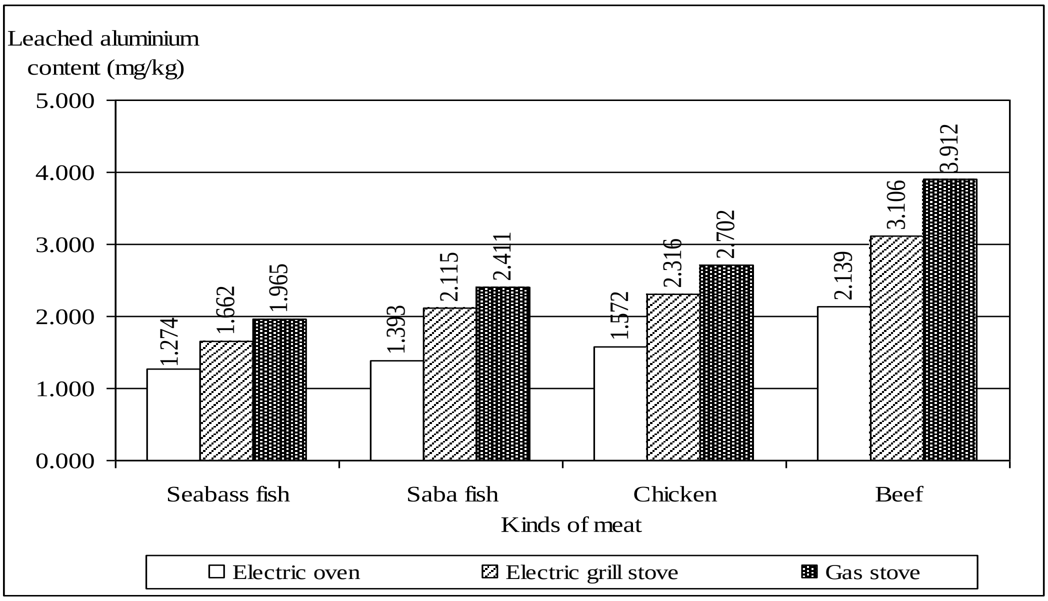


Figure 4.5 The mean values of leached aluminium content into cooked meats (mg/kg) wrapped with aluminium foil when using different kinds of meat and types of heat cooking

It was found that the mean of leached aluminium content into cooked meat (mg/kg) was the highest value (3.912 mg/kg) when using beef and cooked by gas stove, while it was the lowest value (1.274 mg/kg) when using seabass fish and cooked by electric oven.

The results indicated that leached aluminium content into cooked meat (mg/kg) - by using seabass fish, saba fish, chicken and beef - increased when using each type of heat cooking. The results also showed that cooking by using gas stove gave higher leached aluminium content than cooking by other types of heat cooking (gas stove, electric grill stove and electric oven gave the highest, lower and lowest level of leached aluminium content into cooked meat respectively).

4.1.2 Leached aluminium content (mg/kg) into cooked meats wrapped with aluminium foil by cooking with and without seasonings

The study was performed by cooking with and without seasonings. The results are shown in Figure 4.6 according to use of seasonings and leached aluminium content into cooked meats. They indicated that the total mean values of leached aluminium content into cooked meat (mg/kg) were 0.822 and 3.605 when cooking without and with seasonings respectively.

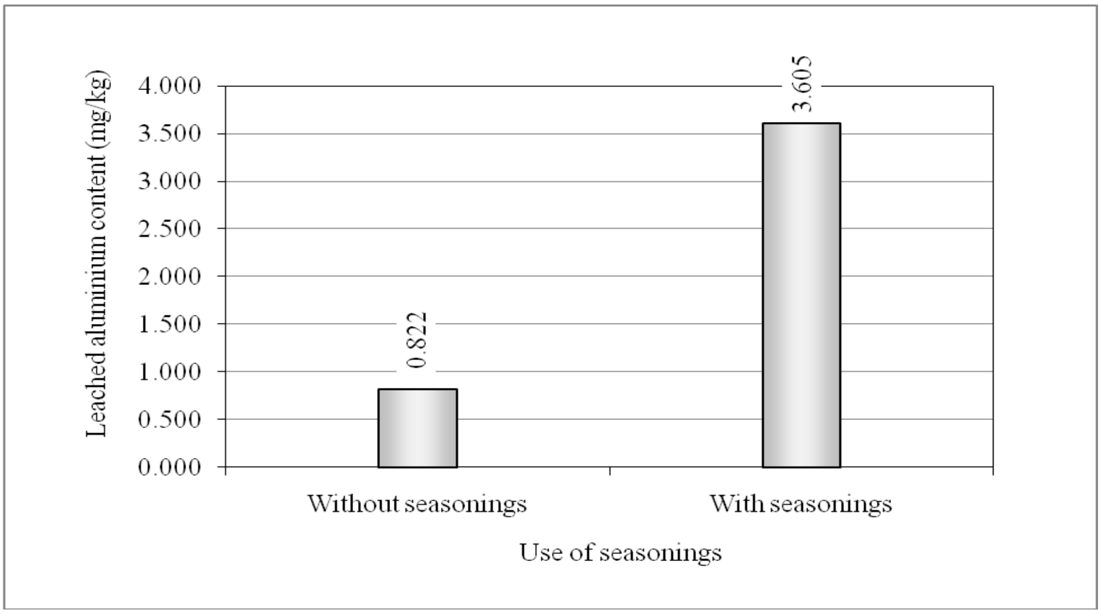


Figure 4.6 The total mean of leached aluminium content into cooked meats (mg/kg) wrapped with aluminium foil when cooking with and without seasonings

The results showed that cooking with seasonings had an influence on the increasing of leached aluminium content into cooked meat. It was found that leached aluminium content into cooked meat (mg/kg) when cooking with seasonings was higher than cooking without seasonings.

Figure 4.7 showed the interaction between use of seasonings and kinds of meat. The results showed that the mean values of leached aluminium content into cooked meat (mg/kg) were 0.541 and 2.726 when using seabass fish and cooked without and with seasonings respectively; 0.611 and 3.335 when using saba fish and cooked without and with seasonings respectively; 0.875 and 3.518 when using chicken and cooked without and with seasonings respectively; and 1.263 and 4.842 when using beef and cooked without and with seasonings respectively.

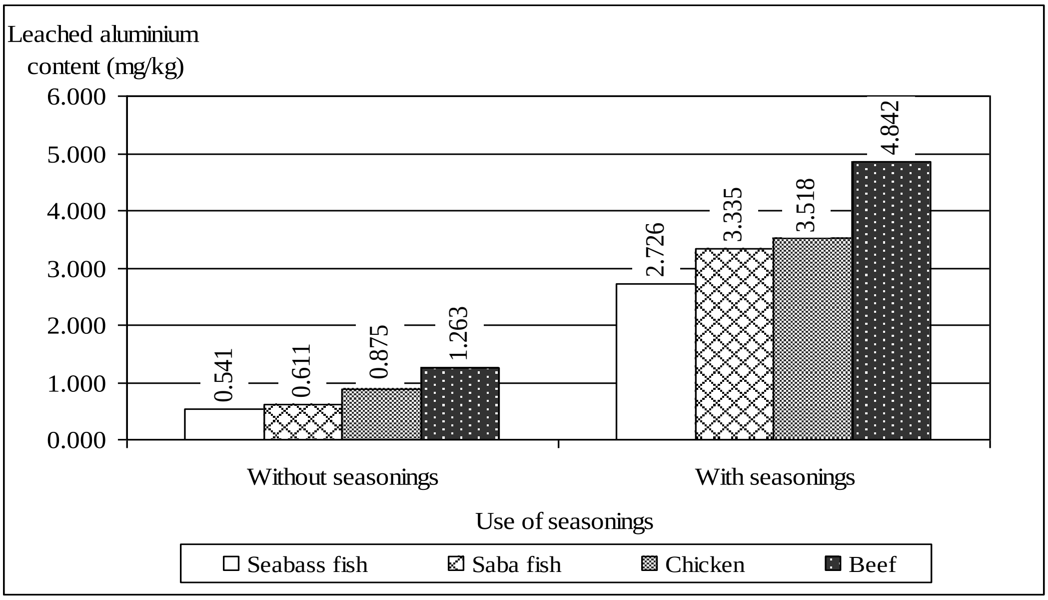


Figure 4.7 The mean values of leached aluminium content into cooked meats (mg/kg) wrapped with aluminium foil when cooking with and without seasonings and different kinds of meat

It was found that the mean of leached aluminium content into cooked meat (mg/kg) was the highest value (4.842 mg/kg) when cooking beef and with seasonings, while it was the lowest value (0.541 mg/kg) when cooking seabass fish and without seasonings.

The results indicated that leached aluminium content into cooked meat (mg/kg) - at with and without seasonings - increased when using each kind of meat. The results also showed that the highest to lowest levels of leached aluminium content into cooked meat were beef, chicken, saba fish and seabass fish respectively.

The interaction between use of seasonings and aluminium amounts in aluminium foil is presented in Figure 4.8. The results showed that the mean values of leached aluminium content into cooked meat (mg/kg) by wrapping with brand 1 (lower aluminium amount) of aluminium foil were 0.376 and 2.305 when cooking without and with seasonings respectively. The mean values of leached aluminium content into cooked meat (mg/kg) by wrapping with brand 2 (higher aluminium amount) of aluminium foil were 1.269 and 4.905 when cooking without and with seasonings respectively.

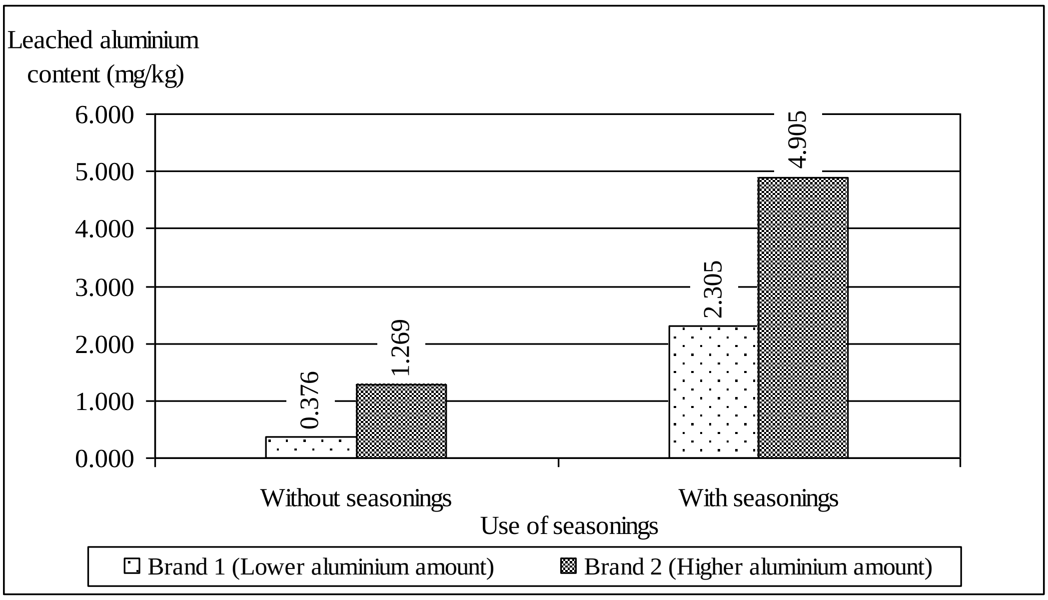


Figure 4.8 The mean values of leached aluminium content into cooked meats (mg/kg) wrapped with aluminium foil when cooking with and without seasonings and different aluminium amounts in aluminium foil

It was found that the mean of leached aluminium content into cooked meat (mg/kg) was the highest value (4.905 mg/kg) when cooking with seasonings and wrapped with brand 2 (higher aluminium amount) of aluminium foil, while it was the lowest value (0.376 mg/kg) when cooking without seasonings and wrapped with brand 1 (lower aluminium amount) of aluminium foil.

The results showed that leached aluminium content into cooked meat (mg/kg) - at with and without seasonings - increased when wrapping with each brand of aluminium foil. The results indicated that leached aluminium content into cooked meat (mg/kg) wrapped with brand 2 (higher aluminium amount) of aluminium foil was higher than wrapped with brand 1 (lower aluminium amount) of aluminium foil.

The interaction between use of seasonings and types of heat cooking is presented in Figure 4.9. The results showed that the mean values of leached aluminium content into cooked meat (mg/kg) were 0.592 and 2.597 when cooking without and with seasonings by electric oven respectively; 0.800 and 3.799 when cooking without and with seasonings by electric grill stove respectively; and 1.075 and 4.419 when cooking without and with seasonings by gas stove respectively.

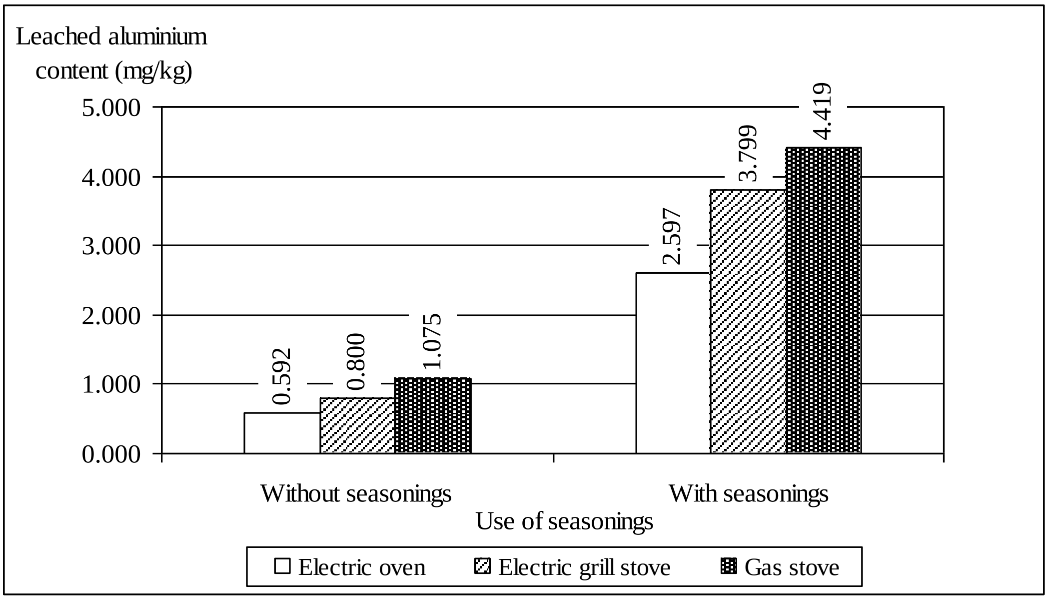


Figure 4.9 The mean values of leached aluminium content into cooked meats (mg/kg) wrapped with aluminium foil when cooking with and without seasonings and different types of heat cooking

It was found that the mean of leached aluminium content into cooked meat (mg/kg) was the highest value (4.419 mg/kg) when cooking with seasonings and using gas stove, while it was the lowest value (0.592 mg/kg) when cooking without seasonings and using electric oven.

The results indicated that leached aluminium content into cooked meat (mg/kg) - at with and without seasonings - increased when using each type of heat cooking. There was difference in the mean values of leached aluminium content into cooked meat (mg/kg) between cooking without and with seasonings. Furthermore, when cooking by gas stove (first level) gave higher leached aluminium contents than cooking by electric grill stove (second level) and electric oven (third level).

4.1.3 Leached aluminium content into cooked meats (mg/kg) wrapped with aluminium foil by using different aluminium amount in aluminium foil

Aluminium foil used for this experiment, included two brands of aluminium foil for food wrapping: brand 1 (lower initial aluminium amount) and brand 2 (higher initial aluminium amount) of aluminium foil. Two brands of aluminium foil were analyzed to determine the percentage of aluminium amounts in aluminium foil. These results are presented in Table A-8 (Appendix A).

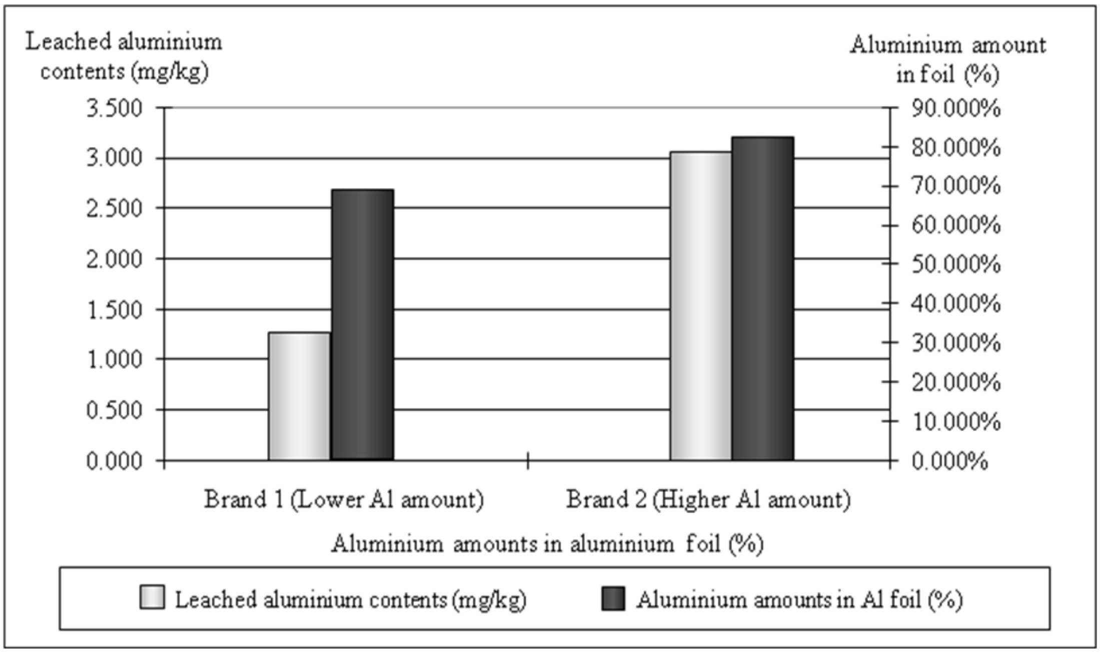


Figure 4.10 The total mean of leached aluminium content into cooked meats (mg/kg) wrapped with aluminium foil at different aluminium amounts in aluminium foil

It was found that aluminium amounts in brand 1 and brand 2 of aluminium foil were 69.483% and 83.419% respectively. The difference of leached aluminium contents into cooked meat while using aluminium foil with different amounts of aluminium are shown in Figure 4.10. The total mean values of leached aluminium content into cooked meat (mg/kg) were 1.340 and 3.087 when wrapping with brand 1 (lower aluminium amount) and brand 2 (higher aluminium amount) of aluminium foil respectively.

There was difference of leached aluminium content into cooked meat (mg/kg) at different aluminium amounts in aluminium foil. Leached aluminium content into cooked meat (mg/kg) when wrapping with brand 2 (higher aluminium amount) of aluminium foil was higher than brand 1 (lower aluminium amount) of aluminium foil.

The interaction between aluminium amounts in aluminium foil and kinds of meat is presented in Figure 4.11. The results showed that the mean values of leached aluminium content into cooked meat (mg/kg) were 1.050 and 2.217 when using seabass fish wrapped with brand 1 (lower aluminium amount) and brand 2 (higher aluminium amount) of aluminium foil respectively; 1.174 and 2.771 when using saba fish wrapped with brand 1 (lower aluminium amount) and brand 2 (higher aluminium amount) of aluminium foil respectively; 1.299 and 3.094 when using chicken wrapped with brand 1 (lower aluminium amount) and brand 2 (higher aluminium amount) of aluminium foil respectively; and 1.837 and 4.268 when using beef wrapped with brand 1 (lower aluminium amount) and brand 2 (higher aluminium amount) of aluminium foil respectively.

It was found that the mean of leached aluminium content into cooked meat (mg/kg) was the highest value (4.268 mg/kg) when using beef and wrapped with brand 2 (higher aluminium amount) of aluminium foil, while it was the lowest value (1.050 mg/kg) when using seabass fish and wrapped with brand 1 (lower aluminium amount) of aluminium foil.

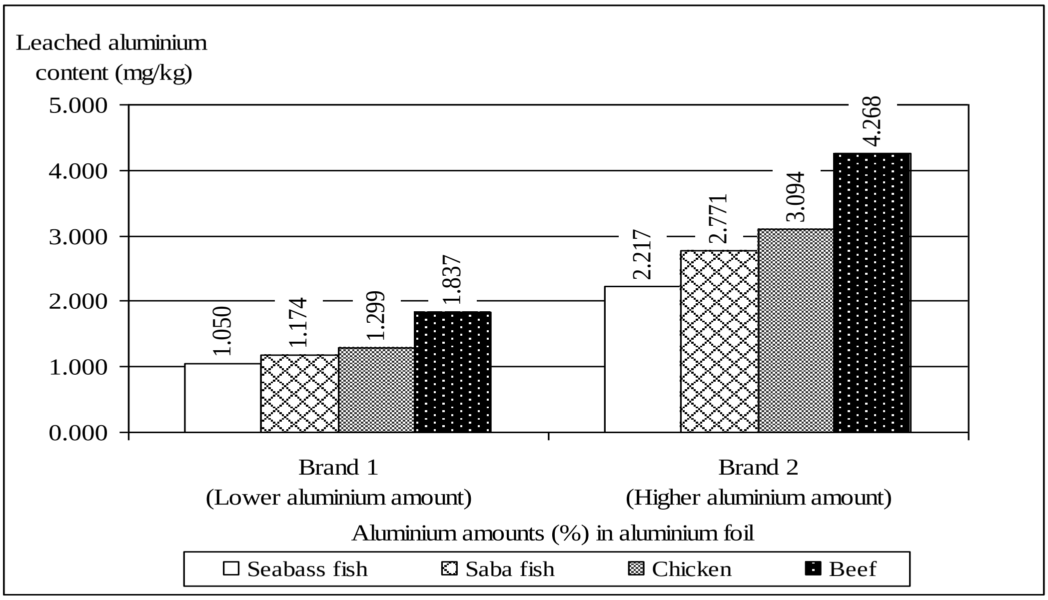


Figure 4.11 The mean values of leached aluminium content into cooked meats (mg/kg) wrapped with aluminium foil at different aluminium amounts in aluminium foil and kinds of meat

The results indicated that leached aluminium content into cooked meat (mg/kg) - by wrapping with brand 1 (lower aluminium amount) and brand 2 (higher aluminium amount) of aluminium foil - increased when using each kind of meat. It was shown that leached aluminium content into cooked meat (mg/kg) at different aluminium amounts in aluminium foil differed. Moreover, when cooking by beef (highest level) gave higher leached aluminium contents than cooking by chicken, saba fish and seabass fish.

The interaction between aluminium amounts in aluminium foil and use of seasonings is presented in Figure 4.12. The results showed that the mean values of leached aluminium content into cooked meat (mg/kg) were 0.376 and 1.269 when cooking without seasonings and wrapped with brand 1 (lower aluminium amount) and brand 2 (higher aluminium amount) of aluminium foil respectively. The mean values of leached aluminium content into cooked meat (mg/kg) were 2.305 and 4.905 when cooking with seasonings and wrapped with brand 1 (lower aluminium amount) and brand 2 (higher aluminium amount) of aluminium foil respectively.

It was found that the mean of leached aluminium content into cooked meat (mg/kg) was the highest value (4.905 mg/kg) when cooking with seasonings and wrapping with brand 2 (higher aluminium amount) of aluminium foil, while it was the lowest value (0.376 mg/kg) when cooking without seasonings and wrapping with brand 1 (lower aluminium amount) of aluminium foil.

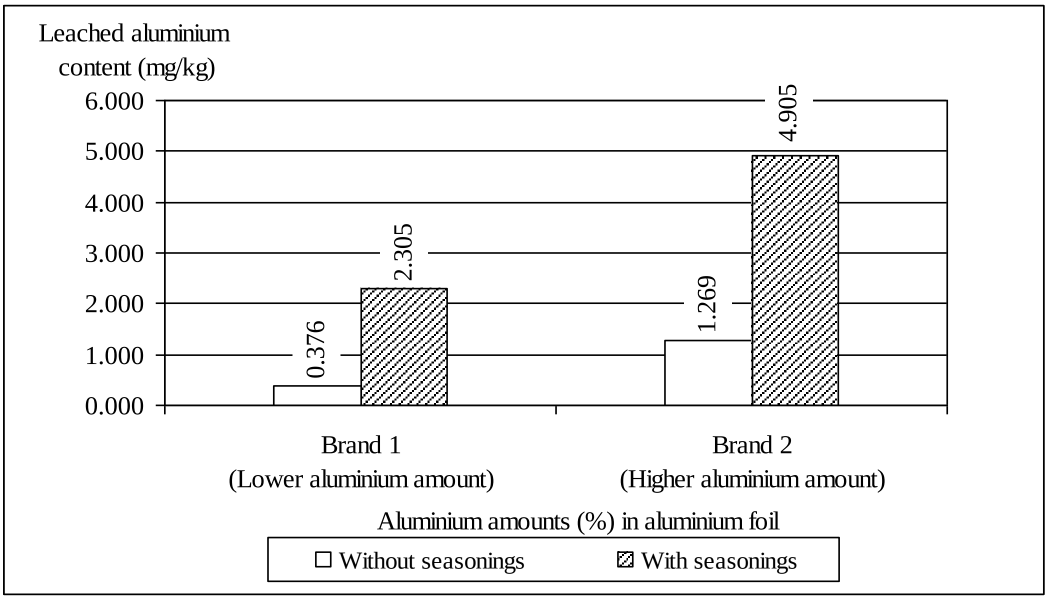


Figure 4.12 The mean values of leached aluminium content into cooked meats (mg/kg) wrapped with aluminium foil at different aluminium amounts in aluminium foil and use of seasonings

The results indicated that leached aluminium content into cooked meat (mg/kg) - by wrapping with brand 1 (lower aluminium amount) and brand 2 (higher aluminium amount) of aluminium foil - increased when cooking either with or without seasonings. It was shown that cooking with seasonings gave higher leached aluminium contents than cooking without seasonings.

The interaction between aluminium amounts in aluminium foil and types of heat cooking is presented in Figure 4.13. The results showed that the mean values of leached aluminium content into cooked meat (mg/kg) were 1.053 and 2.136 when wrapping with brand 1 (lower aluminium amount) and brand 2 (higher aluminium amount) of aluminium foil by using electric oven respectively; 1.331 and 3.268 when wrapping with brand 1 (lower aluminium amount) and brand 2 (higher aluminium amount) of aluminium foil by using electric grill stove respectively; and 1.637 and

3.858 when wrapping with brand 1 (lower aluminium amount) and brand 2 (higher aluminium amount) of aluminium foil by using gas stove respectively.

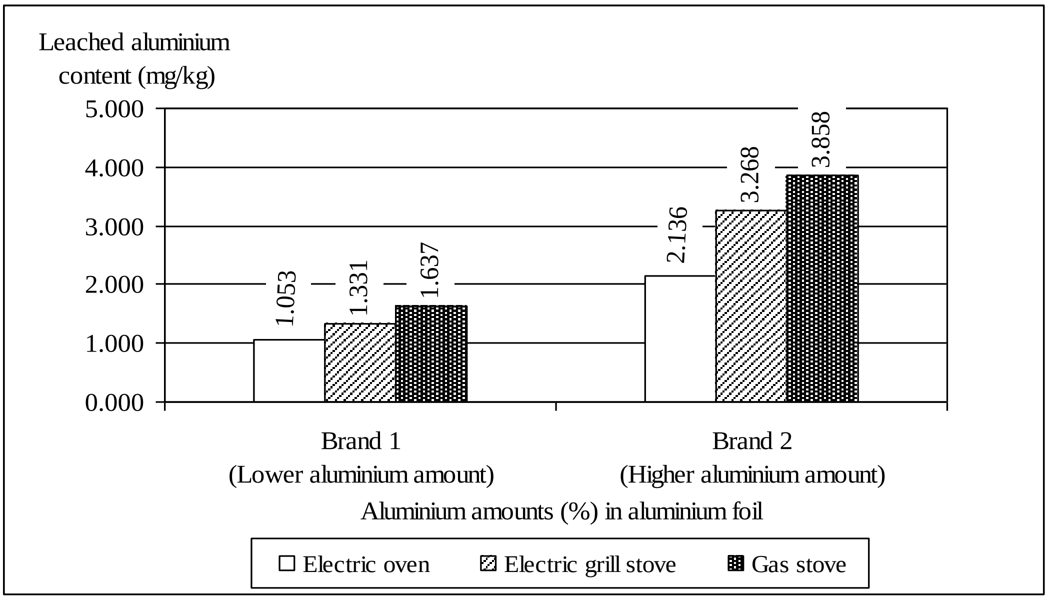


Figure 4.13 The mean values of leached aluminium content into cooked meats (mg/kg) wrapped with aluminium foil at different aluminium amounts in aluminium foil and types of heat cooking

The results showed that the mean of leached aluminium content into cooked meat (mg/kg) was the highest value (3.858 mg/kg) when wrapping with brand 2 (higher aluminium amount) of aluminium foil and using gas stove, while it was the lowest value (1.053 mg/kg) when wrapping with brand 1 (lower aluminium amount) of aluminium foil and using electric oven.

The results indicated that leached aluminium content into cooked meat (mg/kg) - by wrapping with brand 1 (lower aluminium amount) and brand 2 (higher aluminium amount) of aluminium foil - increased when using each type of heat cooking. There was difference in leached aluminium content into cooked meat (mg/kg) at different aluminium amounts in aluminium foil. Moreover, the results also showed that cooking by gas stove (highest level) gave higher leached aluminium contents into cooked meat than cooking by electric grill stove (lower level) and electric oven (lowest level).

4.1.4 Leached aluminium contents into cooked meats (mg/kg) wrapped with aluminium foil by using different types of heat cooking

This study was tested on three types of heat cooking, including electric oven, electric grill stove and gas stove. Cooking temperatures and times of these types of heat cooking were selected conditions to make meat just enough cooking and appetizing, which they were different in each type of heat cooking (electric oven at 200ºC 60 min; electric grill stove at 200ºC 60 min; and gas stove at 300ºC 20 min). The results are presented in Figure 4.14. The total mean values of leached aluminium content into cooked meat (mg/kg) were 1.594, 2.300 and 2.747 when using electric oven, electric grill stove and gas stove respectively.

The results showed that different types of heat cooking gave different leached aluminium content into cooked meat. They also indicated that cooking by gas stove gave higher leached aluminium contents than cooking by electric grill stove and electric oven.

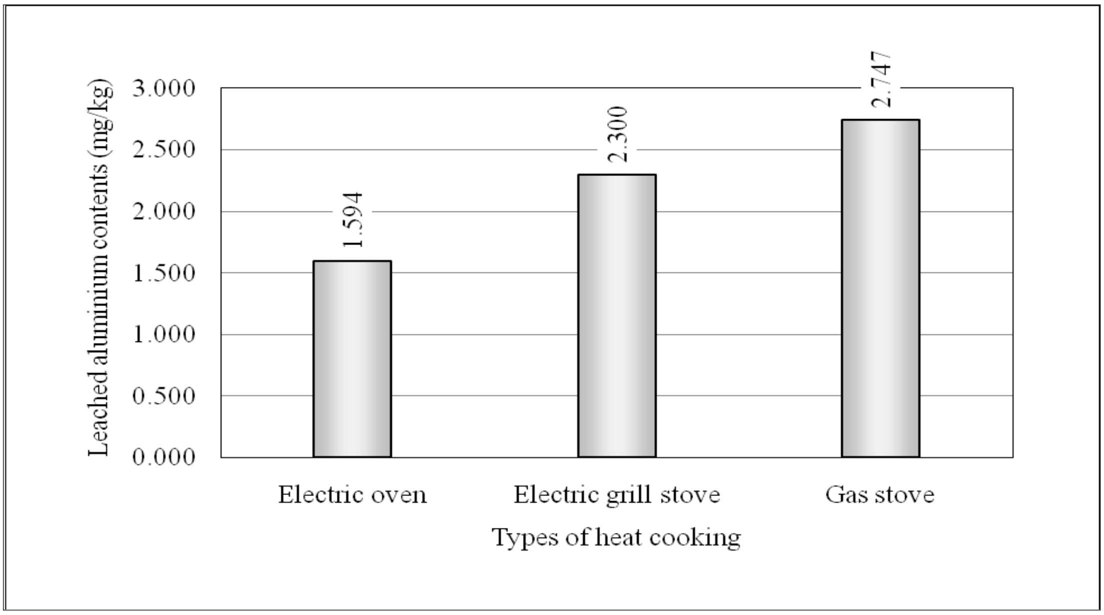


Figure 4.14 The total mean of leached aluminium content into cooked meats (mg/kg) wrapped with aluminium foil at different types of heat cooking

The interaction between types of heat cooking and kinds of meat is presented in Figure 4.15. The results showed that the mean values of leached aluminium content into cooked meat (mg/kg) were 1.274, 1.662 and 1.965 when cooking seabass fish by electric oven, electric grill stove and gas stove respectively; 1.393, 2.115 and 2.411 when cooking saba fish by electric oven, electric grill stove and gas stove respectively; 1.572, 2.316 and 2.702 when cooking chicken by electric oven, electric grill stove and gas stove respectively; and 2.139, 3.106 and 3.912 when cooking beef by electric oven, electric grill stove and gas stove respectively.

It was found that the mean of leached aluminium content into cooked meat (mg/kg) was the highest value (3.912 mg/kg) when cooking beef and using gas stove, while it was the lowest value (1.274 mg/kg) when cooking seabass fish and using electric oven.

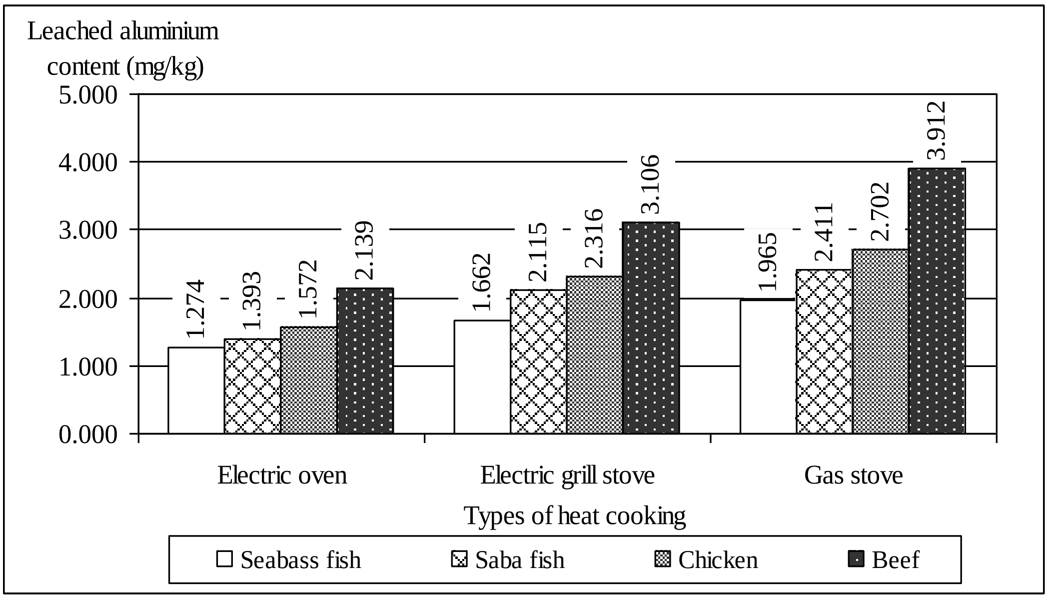


Figure 4.15 The mean values of leached aluminium content into cooked meats (mg/kg) wrapped with aluminium foil at different types of heat cooking and kinds of meat

The results indicated that leached aluminium content into cooked meat (mg/kg) - by using electric oven, electric grill stove and gas stove - increased when using each kind of meat. There was difference in leached aluminium content into cooked meat (mg/kg) at different types of heat cooking. Furthermore, leached aluminium content into cooked meat by using beef (highest level) was higher than those of chicken, saba fish and seabass fish.

The interaction between types of heat cooking and use of seasonings is presented in Figure 4.16. The results showed that the mean values of leached aluminium content into cooked meat (mg/kg) without seasonings were 0.592, 0.800 and 1.075 when cooking by electric oven, electric grill stove and gas stove respectively. The mean values of leached aluminium content into cooked meat (mg/kg) with seasonings were 2.597, 3.799 and 4.419 when cooking by electric oven, electric grill stove and gas stove respectively.

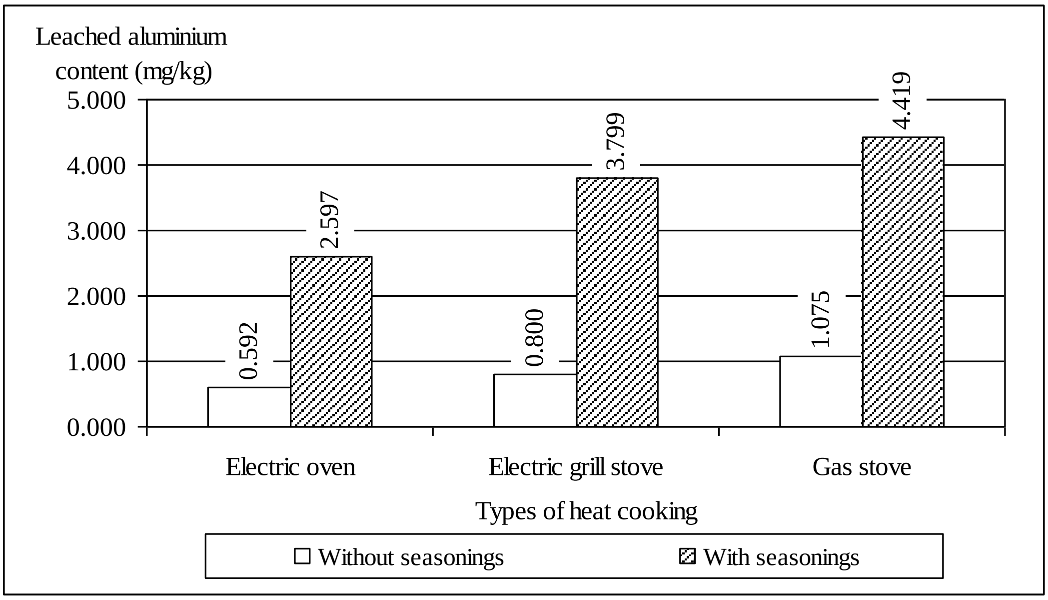


Figure 4.16 The mean values of leached aluminium content into cooked meats (mg/kg) wrapped with aluminium foil at different types of heat cooking and use of seasonings

It was found that the mean of leached aluminium content into cooked meat (mg/kg) was the highest value (4.419 mg/kg) when cooking with seasonings and using gas stove, while it was the lowest value (0.592 mg/kg) when cooking without seasonings and using electric oven.

The results indicated that leached aluminium content into cooked meat (mg/kg) - by using electric oven, electric grill stove and gas stove - increased when cooking either with or without seasonings. The results revealed that leached aluminium content into cooked meat (mg/kg) wrapped with aluminium foil by cooking with seasonings was higher than cooking without seasonings.

The interaction between types of heat cooking and aluminium amounts in aluminium foil is presented in Figure 4.17.

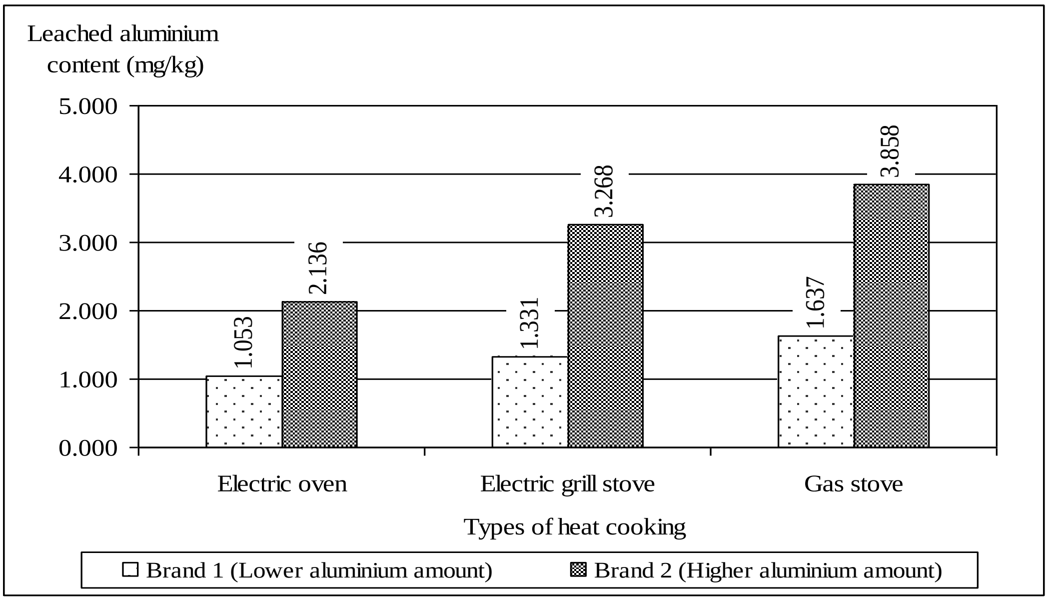


Figure 4.17 The mean values of leached aluminium content into cooked meats (mg/kg) wrapped with aluminium foil at different types of heat cooking and aluminium amounts in aluminium foil

The results showed that the mean values of leached aluminium content into cooked meat (mg/kg) were 1.053, 1.331 and 1.637 when wrapping with brand 1 (lower aluminium amount) of aluminium foil by using electric oven, electric grill stove and gas stove respectively. The mean values of leached aluminium content into cooked meat (mg/kg) were 2.136, 3.268 and 3.858 when wrapping with brand 2 (higher aluminium amount) of aluminium foil by using electric oven, electric grill stove and gas stove respectively.

It was found that the mean of leached aluminium content into cooked meat (mg/kg) was the highest value (3.858 mg/kg) when wrapping with brand 2 (higher aluminium amount) of aluminium foil and using gas stove, while it was the lowest value (1.053 mg/kg) when wrapping with brand 1 (lower aluminium amount) of aluminium foil and using electric oven.

The results indicated that leached aluminium content into cooked meat (mg/kg) - by using electric oven, electric grill stove and gas stove - increased when wrapping with each brand of aluminium foil. The results also showed that leached aluminium content into cooked meat (mg/kg) wrapped with brand 2 (higher aluminium amount) of aluminium foil was higher than wrapped with brand 1 (lower aluminium amount) of aluminium foil.

4.2 Inferential Statistical Results

This study was analyzed by analysis of variance (ANOVA) in 4x2x2x3 factorial experiment with 3 replications at a significance level of 0.05. The ANOVA result with full interaction model is presented in Table 4.2.

Table 4.2 The ANOVA result of leached aluminium content into cooked meat at different cooking conditions

Source of variation	*df*	*p-value*
Kind of meat	3	< .0001
Seasoning	1	< .0001
Aluminium in foil	1	< .0001
Type of heat cooking	2	< .0001
Kind of meat * Seasoning	3	< .0001
Kind of meat * Aluminium in foil	3	< .0001
Kind of meat * Type of heat cooking	6	< .0001
Seasoning * Aluminium in foil	1	< .0001
Seasoning * Type of heat cooking	2	< .0001
Aluminium in foil * Type of heat cooking	2	< .0001
Kind of meat * Seasoning * Aluminium in foil	3	< .0001
Kind of meat * Seasoning * Type of heat cooking	6	< .0001
Kind of meat * Aluminium in foil * Type of heat cooking	6	< .0001
Seasoning * Aluminium in foil * Type of heat cooking	2	< .0001
Kind of meat * Seasoning * Aluminium in foil * Type of heat cooking	6	< .0001

a. R Squared = .999 (Adjusted R Squared = .998)
b. Computed using a significance level of 0.05

There was the significant difference in the mean of leached aluminium content into cooked meat (mg/kg) at each cooking condition (kinds of meat, seasoning, aluminium amounts in aluminium foil and types of heat cooking). The interaction effects between all factors were significantly different. There were also significant differences in two-factor, three-factor and four-factor interactions. Moreover, the multiple comparisons of the significant main and interaction effects were analyzed to determine the difference by pair between the individual means - by using the Duncan's Multiple Range test at a significance level of 0.05.

4.2.1 The comparison of leached aluminium content into cooked meats wrapped with aluminium foil by using different kinds of meat

The results were analyzed by factorial analysis of variance (ANOVA) and the difference by pair between the individual mean values of the kind of meat was compared by using the Duncan's Multiple Range test at α level of 0.05. The statistical analysis showed that there was significant difference of the aluminium content (p-value < 0.05) among different kinds of meat. So, the results indicated that cooking by different kinds of meat gave different leached aluminium contents into cooked meat. The results are shown in Table 4.3.

Table 4.3 The comparisons of leached aluminium content (number in the parenthesis) into cooked meat at different kinds of meat

Source of variation	***p-value***
Seabass fish * Saba fish (1.634, 1.973)	< .0001
Seabass fish * Chicken (1.634, 2.197)	< .0001
Seabass fish * Beef (1.634, 3.052)	< .0001
Saba fish * Chicken (1.973, 2.197)	< .0001
Saba fish * Beef (1.973, 3.052)	< .0001
Chicken * Beef (1.973, 3.052)	< .0001

4.2.2 The comparison of leached aluminium content into cooked meats wrapped with aluminium foil between cooking with and without seasonings

The factor on use of seasonings between with and without seasonings was analyzed in terms of the difference between the individual mean values by the Independent Samples T-test at α level of 0.05. The statistical analysis showed that there was significant difference of the aluminium content (p-value < 0.05) between different uses of seasonings. The results indicated that cooking with seasonings gave higher leached aluminium contents into cooked meat than cooking without seasonings. The results are shown in Table 4.4

Table 4.4 The comparison of leached aluminium content (number in the parenthesis) into cooked meat at different use of seasonings

Source of variation	*p-value*
Without seasonings * With seasonings (0.822, 3.605)	< .0001

4.2.3 The comparison of leached aluminium content into cooked meat wrapped with aluminium foil by using different aluminium amounts in aluminium foil

The factor on aluminium amounts in aluminium foil was analyzed in terms of the difference between the individual mean values by the Independent Samples T-test at α level of 0.05. The statistical analysis showed that there was significant difference of the aluminium content (p-value < 0.05) between different amounts of aluminium in aluminium foil. The results indicated that cooking by wrapping with brand 2 (higher aluminium amount) of aluminium foil gave higher leached aluminium contents into cooked meat than cooking by wrapping with brand 1 (lower aluminium amount) of aluminium foil. The results are shown in Table 4.5.

Table 4.5 The comparison of leached aluminium content (number in the parenthesis) into cooked meat at different aluminium amounts in aluminium foil

Source of variation	*p-value*
Brand 1 of Al foil * Brand 2 of Al foil (1.340, 3.087)	< .0001

4.2.4 The comparison of leached aluminium content into cooked meats wrapped with aluminium foil by using different types of heat cooking

The difference between the individual mean values of the factor on types of heat cooking was compared by using the Duncan's Multiple Range test at α level of 0.05. The statistical analysis showed that there was significant difference of the aluminium content among different types of heat cooking (p-value < 0.05). The results indicated that cooking by different types of heat cooking gave different leached aluminium contents into cooked meat. The results are shown in Table 4.6.

Table 4.6 The comparisons of leached aluminium content (number in the parenthesis) into cooked meat at different types of heat cooking

Source of Variable	***p-value***
Electric oven * Electric grill stove (1.594, 2.300)	< .0001
Electric oven * Gas stove (1.594, 2.747)	< .0001
Electric grill stove * Gas stove (2.300, 2.747)	< .0001

4.2.5 The comparison of leached aluminium content into cooked meats from interaction effect between different kinds of meat and use of seasonings

The multiple comparisons at α level of 0.05 of leached aluminium content into cooked meats from the interaction effect between the different kinds of meat and use of seasonings mostly showed significant difference. Except the mean of leached aluminium content into cooked meat when cooking by using seabass fish - without seasonings was not significantly different from cooking by using saba fish - without seasonings and chicken - without seasonings. The mean of leached aluminium content into cooked meat when cooking by using saba fish - without seasonings was not significantly different from cooking by using chicken - without seasonings. The mean of leached aluminium content into cooked meat when cooking by using saba fish - with seasonings was not significantly different from cooking by using chicken - with seasonings. The mean of leached aluminium content into cooked meat when cooking by using chicken - without seasonings was not significantly different from cooking by using beef - without seasonings.

Therefore, the statistical results showed that most of the effects were significant difference of the aluminium content (p-value < 0.05) between different kinds of meat and use of seasonings. The results are shown in Table 4.7.

As shown in Table 4.1 and Figure 4.3, the mean of leached aluminium content into cooked meat (mg/kg) when cooking by using beef - with seasonings was the highest value (4.842 mg/kg) and the mean of leached aluminium content into cooked meat (mg/kg) when cooking by using seabass fish - without seasonings was the lowest value (0.541 mg/kg). Moreover, the multiple comparison results were found that the highest mean of leached aluminium content into cooked meat when cooking by using beef - with seasonings (4.842 mg/kg) was significantly different from others at α level of 0.05. However, the lowest mean of leached aluminium content into cooked meat when cooking by using seabass - without seasonings (0.541 mg/kg) was not significantly different from cooking by using saba fish - without seasoning (0.611 mg/kg) and chicken - without seasoning (0.875 mg/kg) at α level of 0.05.

Table 4.7 The multiple comparisons of leached aluminium content into cooked meat at different kinds of meat and use of seasonings

Kinds of meat - Use of seasonings	Seabass fish - W/O seasonings	Seabass fish - W/ seasonings	Saba fish - W/O seasonings	Saba fish - W/ seasonings	Chicken - W/O seasonings	Chicken - W/ seasonings	Beef - W/O seasonings	Beef - W/ seasonings
Seabass fish - W/O seasonings								
Seabass fish - W/ seasonings	+							
Saba fish - W/O seasonings	0	+						
Saba fish - W/ seasonings	+	+	+					
Chicken - W/O seasonings	0	+	0	+				
Chicken - W/ seasonings	+	+	+	0	+			
Beef - W/O seasonings	+	+	+	+	0	+		
Beef - W/ seasonings	+	+	+	+	+	+	+	

Note: + = significantly different at the significance level of 0.05
0 = non- significantly different at the significance level of 0.05
W/O seasonings = Cooking without seasonings; W/ seasonings = Cooking with seasonings

4.2.6 The comparison of leached aluminium content into cooked meats from interaction effect between different kinds of meat and aluminium amounts in aluminium foil

The multiple comparisons at α level of 0.05 of leached aluminium content into cooked meats from the interaction effect between the different kinds of meat and aluminium amounts in aluminium foil mostly showed significant difference. Except the mean of leached aluminium content into cooked meat when cooking by using seabass fish - wrapped with brand 1 (lower aluminium amount) of aluminium foil was not significantly different from cooking by using saba fish - wrapped with brand 1 (lower aluminium amount) of aluminium foil and chicken - wrapped with brand 1 (lower aluminium amount) of aluminium foil.

The mean of leached aluminium content into cooked meat when cooking by using seabass fish - wrapped with brand 2 (higher aluminium amount) of aluminium foil was not significantly different from cooking by using saba fish - wrapped with brand 2 (higher aluminium amount) of aluminium foil and beef - wrapped with brand 1 (lower aluminium amount) of aluminium foil.

The mean of leached aluminium content into cooked meat when cooking by using saba fish - wrapped with brand 1 (lower aluminium amount) of aluminium foil was not significantly different from cooking by using chicken - wrapped with brand 1 (lower aluminium amount) of aluminium foil.

The mean of leached aluminium content into cooked meat when cooking by using saba fish - wrapped with brand 2 (higher aluminium amount) of aluminium foil was not significantly different from cooking by using chicken - wrapped with brand 2 (higher aluminium amount) of aluminium foil.

The mean of leached aluminium content into cooked meat when cooking by using chicken - wrapped with brand 1 (lower aluminium amount) of aluminium foil was not significantly different from cooking by using beef - wrapped with brand 1 (lower aluminium amount) of aluminium foil.

Therefore, the statistical results showed that most of the effects were significant difference of the aluminium content (p-value < 0.05) between different kinds of meat and aluminium amounts of aluminium foil. The results are shown in Table 4.8.

As shown in Table 4.1 and Figure 4.4, the mean of leached aluminium content into cooked meat (mg/kg) when cooking by using beef – wrapped with brand 2 (higher aluminium amount) of aluminium foil was the highest value (4.268 mg/kg) and the mean of leached aluminium content into cooked meat (mg/kg) when cooking by using seabass fish – wrapped with brand 1 (lower aluminium amount) of aluminium foil was the lowest value (1.050 mg/kg). Moreover, the multiple comparison results were found that the highest mean of leached aluminium content into cooked meat when cooking by using beef – wrapped with brand 2 (higher aluminium amount) of aluminium foil (4.268 mg/kg) was significantly different from others at α level of 0.05. However, the lowest mean of leached aluminium content into cooked meat when cooking by using seabass fish – wrapped with brand 1 (lower aluminium amount) of aluminium foil (1.050 mg/kg) was not significantly different from cooking by using saba fish – wrapped with brand 1 (lower aluminium amount) of aluminium foil (1.174 mg/kg) and chicken – wrapped with brand 1 (lower aluminium amount) of aluminium foil (1.299 mg/kg) at α level of 0.05.

Table 4.8 The multiple comparisons of leached aluminium content into cooked meat at different kinds of meat and aluminium amounts in aluminium foil

Kinds of meat - Aluminium amounts in aluminium foil	Seabass fish - Brand 1	Seabass fish - Brand 2	Saba fish - Brand 1	Saba fish - Brand 2	Chicken - Brand 1	Chicken - Brand 2	Beef - Brand 1	Beef - Brand 2
Seabass fish - Brand 1								
Seabass fish - Brand 2	+							
Saba fish - Brand 1	0	+						
Saba fish - Brand 2	+	0	+					
Chicken - Brand 1	0	+	0	+				
Chicken - Brand 2	+	+	+	0	+			
Beef - Brand 1	+	0	+	+	0	+		
Beef - Brand 2	+	+	+	+	+	+	+	

Note: + = significantly different at the significance level of 0.05
0 = non- significantly different at the significance level of 0.05
Brand 1 = brand 1 (lower aluminium amount) of aluminium foil;
Brand 2 = brand 2 (higher aluminium amount) of aluminium foil

4.2.7 The comparison of leached aluminium content into cooked meats from interaction effect between different kinds of meat and types of heat cooking

The multiple comparisons of leached aluminium content into cooked meats from the interaction effect between the different kinds of meat and types of heat cooking showed that there were both significantly and non-significantly different at α level of 0.05. The results are shown in Table 4.9.

As shown in Table 4.1 and Figure 4.5, the mean of leached aluminium content into cooked meat (mg/kg) when cooking by using beef – with gas stove was the highest value (3.912 mg/kg) and the mean of leached aluminium content into cooked meat (mg/kg) when cooking by using seabass fish – with electric oven was the lowest value (1.274 mg/kg). Furthermore, the multiple comparison results showed that the highest mean of leached aluminium content into cooked meat when cooking by using beef – with gas stove (3.912 mg/kg) was significantly different from others at α level of 0.05 except it was not significantly different from cooking by using beef – with electric grill stove (3.106 mg/kg) (p-value > 0.05). However, the lowest mean of leached aluminium content into cooked meat when cooking by using seabass fish – with electric oven (1.274 mg/kg) was not significantly different from cooking by using seabass fish – with electric grill stove (1.662 mg/kg), seabass fish – with gas stove (1.965 mg/kg), saba fish – with electric oven (1.393 mg/kg), saba fish – with electric grill stove (2.115 mg/kg), chicken – with electric oven (1.572 mg/kg) and beef – with electric oven (2.139 mg/kg) at α level of 0.05.

Table 4.9 The multiple comparisons of leached aluminium content into cooked meat at different kinds of meat and types of heat cooking

Kinds of meat - Types of heat cooking	Seabass fish - Electric oven	Seabass fish - Electric grill stove	Seabass fish - Gas stove	Saba fish - Electric oven	Saba fish - Electric grill stove	Saba fish - Gas stove	Chicken - Electric oven	Chicken - Electric grill stove	Chicken - Gas stove	Beef - Electric oven	Beef - Electric grill stove	Beef - Gas stove
Seabass fish - Electric oven												
Seabass fish - Electric grill stove	0											
Seabass fish - Gas stove	0	0										
Saba fish - Electric oven	0	0	0									
Saba fish - Electric grill stove	0	0	0	0								
Saba fish - Gas stove	+	0	0	+	0							
Chicken - Electric oven	0	0	0	0	0	0						
Chicken - Electric grill stove	+	0	0	0	0	0	0					
Chicken - Gas stove	+	+	0	+	0	0	+	0				
Beef - Electric oven	0	0	0	0	0	0	0	0	0			
Beef - Electric grill stove	+	+	+	+	+	0	+	0	0	+		
Beef - Gas stove	+	+	+	+	+	+	+	+	+	+	0	

Note: + = significantly different at the significance level of 0.05
0 = non- significantly different at the significance level of 0.05

4.2.8 The comparison of leached aluminium content into cooked meats from interaction effect between different use of seasonings and aluminium amounts in aluminium foil

The multiple comparisons of leached aluminium content into cooked meats showed that all interaction effects were significant difference (p-value < 0.05) between different use of seasonings and aluminium amounts in aluminium foil at α level of 0.05. The results are shown in Table 4.10.

Table 4.10 The multiple comparisons of leached aluminium content into cooked meat at different use of seasonings and aluminium amounts in aluminium foil

Use of seasonings - Aluminium amounts in aluminium foil	W/O seasonings - Brand 1	W/O seasonings - Brand 2	W/ seasonings - Brand 1	W/ seasonings - Brand 2
W/O seasonings - Brand 1				
W/O seasonings - Brand 2	+			
W/ seasonings - Brand 1	+	+		
W/ seasonings - Brand 2	+	+	+	

Note: + = significantly different at the significance level of 0.05
0 = non- significantly different at the significance level of 0.05
W/O seasonings = Cooking without seasonings; W/ seasonings = Cooking with seasonings
Brand 1 = brand 1 (lower aluminium amount) of aluminium foil;
Brand 2 = brand 2 (higher aluminium amount) of aluminium foil

As shown in Table 4.1 and Figure 4.8, the mean of leached aluminium content into cooked meat (mg/kg) when cooking with seasonings – wrapped with brand 2 (higher aluminium amount) of aluminium foil was the highest value (4.905 mg/kg) and the mean of leached aluminium content into cooked meat (mg/kg) when cooking without seasonings – wrapped with brand 1 (lower aluminium amount) of aluminium foil was the lowest value (0.376 mg/kg). Furthermore, the multiple comparisons results showed that the highest mean of leached aluminium content into cooked meat when cooking with seasonings – wrapped with brand 2 (higher aluminium amount) of aluminium foil (4.905 mg/kg) was significantly different from others at α level of 0.05. However, the lowest mean of leached aluminium content into cooked meat when cooking without seasonings – wrapped with brand 1 (lower aluminium amount) of aluminium foil (0.376 mg/kg) was significantly different from others at α level of 0.05.

4.2.9 The comparison of leached aluminium content into cooked meats from interaction effect between different use of seasonings and types of heat cooking

The multiple comparisons at α level of 0.05 of leached aluminium content into cooked meats from the interaction effect between the different use of seasonings and types of heat cooking mostly showed significant difference except the mean of leached aluminium content into cooked meat when cooking without seasonings – by electric oven was not significantly different from cooking without seasonings – by electric grill stove. Besides, the mean of leached aluminium content into cooked meat when cooking without seasonings – by electric grill stove was not significantly different from cooking without seasonings – by gas stove.

Therefore, the statistical results showed that most of the effects were significant difference of the aluminium content (p-value < 0.05) between different use of seasonings and types of heat cooking. The results are shown in Table 4.11.

As shown in Table 4.1 and Figure 4.9, the mean of leached aluminium content into cooked meat (mg/kg) when cooking with seasonings – by gas stove was the highest value (4.419 mg/kg) and the mean of leached aluminium content into cooked meat (mg/kg) when cooking without seasonings – by electric oven was the lowest value (0.592 mg/kg). Moreover, the multiple comparisons results indicated that the highest mean of leached aluminium content into cooked meat when cooking with seasonings – by gas stove (4.419 mg/kg) was significantly different from others at α level of 0.05. However, the lowest mean of leached aluminium content into cooked meat when cooking without seasonings – by electric oven (0.592 mg/kg) was not significantly different from cooking without seasonings – by electric grill stove (0.800 mg/kg) at α level of 0.05.

Table 4.11 The multiple comparisons of leached aluminium content into cooked meat at different use of seasonings and types of heat cooking

Use of seasonings - Types of heat cooking	W/O seasonings - Electric oven	W/O seasonings - Electric grill stove	W/O seasonings - Gas stove	W/ seasonings - Electric oven	W/ seasonings - Electric grill stove	W/ seasonings - Gas stove
W/O seasonings - Electric oven						
W/O seasonings - Electric grill stove	0					
W/O seasonings - Gas stove	+	0				
W/ seasonings - Electric oven	+	+	+			
W/ seasonings - Electric grill stove	+	+	+	+		
W/ seasonings - Gas stove	+	+	+	+	+	

Note: + = significantly different at the significance level of 0.05
0 = non- significantly different at the significance level of 0.05
W/O seasonings = Cooking without seasonings; W/ seasonings = Cooking with seasonings

4.2.10 The comparison of leached aluminium content into cooked meats from interaction effect between different aluminium amounts in aluminium foil and types of heat cooking

The multiple comparisons at α level of 0.05 of leached aluminium content into cooked meats from the interaction effect between the different aluminium amounts of aluminium foil and types of heat cooking showed significant difference except the mean of leached aluminium content into cooked meat when cooking by wrapping with brand 1 (lower aluminium amount) of aluminium foil – by electric oven was not significantly different from cooking by wrapping with brand 1 (lower aluminium amount) of aluminium foil – by electric grill stove. The mean of leached aluminium content into cooked meat when cooking by wrapping with brand 1 (lower aluminium amount) of aluminium foil – by electric grill stove was not significantly different from cooking by wrapping with brand 1 (lower aluminium amount) of aluminium foil – by gas stove. The mean of leached aluminium content into cooked meat when cooking by wrapping with brand 1 (lower aluminium amount) of aluminium foil – by gas stove was not significantly different from cooking by wrapping with brand 2 (higher aluminium amount) of aluminium foil – by electric oven.

Therefore, the statistical results showed that most of the effects were significant difference of the aluminium content (p-value < 0.05) between different aluminium amounts of aluminium foil and types of heat cooking. The results are shown in Table 4.12.

Table 4.12 The multiple comparisons of leached aluminium content into cooked meat at different aluminium amounts in aluminium foil and types of heat cooking

Aluminium amounts in aluminium foil - Types of heat cooking	Brand 1 - Electric oven	Brand 1 - Electric grill stove	Brand 1 - Gas stove	Brand 2 - Electric oven	Brand 2 - Electric grill stove	Brand 2 - Gas stove
Brand 1 - Electric oven						
Brand 1 - Electric grill stove	0					
Brand 1 - Gas stove	+	0				
Brand 2 - Electric oven	+	+	0			
Brand 2 - Electric grill stove	+	+	+	+		
Brand 2 - Gas stove	+	+	+	+	+	

Note: + = significantly different at the significance level of 0.05
0 = non- significantly different at the significance level of 0.05

As shown in Table 4.1 and Figure 4.13, the mean of leached aluminium content into cooked meat (mg/kg) when cooking by wrapping with brand 2 (higher aluminium amount) of aluminium foil – by gas stove was the highest value (3.858 mg/kg) and the mean of leached aluminium content into cooked meat (mg/kg) when cooking by wrapping with brand 1 (lower aluminium amount) of aluminium foil – by electric oven was the lowest value (1.053 mg/kg). Moreover, the multiple comparisons results indicated that the highest mean of leached aluminium content into cooked meat when cooking by wrapping with brand 2 (higher aluminium amount) of aluminium foil

– by gas stove (3.858 mg/kg) was significantly different from others at α level of 0.05. However, the lowest mean of leached aluminium content into cooked meat when cooking by wrapping with brand 1 (lower aluminium amount) of aluminium foil – by electric oven (1.053 mg/kg) was not significantly different from cooking by wrapping with brand 1 (lower aluminium amount) of aluminium foil – by electric grill stove (1.331 mg/kg) at α level of 0.05.

4.2.11 The comparison of leached aluminium content into cooked meats from interaction effect among different kinds of meat, use of seasonings and aluminium amounts in aluminium foil

The multiple comparisons of the three-factor interaction among different kinds of meat, use of seasonings and aluminium amounts in aluminium foil were analyzed at α level of 0.05. The statistical results showed that most of the effects were significant difference (p-value < 0.05). The results are shown in Table 4.13.

As shown in Table 4.1, the mean of leached aluminium content into cooked meat (mg/kg) when cooking by using beef - with seasonings - wrapped with brand 2 (higher aluminium amount) of aluminium foil was the highest value (6.653 mg/kg) and the mean of leached aluminium content into cooked meat (mg/kg) when cooking by using seabass fish - without seasonings - wrapped with brand 1 (lower aluminium amount) of aluminium foil was the lowest value (0.214 mg/kg).

Moreover, the multiple comparisons results also revealed that the highest mean of leached aluminium content into cooked meat when cooking by using beef - with seasonings - wrapped with brand 2 (higher aluminium amount) of aluminium foil (6.653 mg/kg) was significantly different from others at α level of 0.05. However, the lowest mean of leached aluminium content into cooked meat when cooking by using seabass fish - without seasonings - wrapped with brand 1 (lower aluminium amount) of aluminium foil (0.214 mg/kg) was not significantly different from cooking by using saba fish - without seasonings - wrapped with brand 1 (lower aluminium amount) of aluminium foil (0.262 mg/kg) and chicken - without seasonings - wrapped with brand 1 (lower aluminium amount) of aluminium foil (0.383 mg/kg) at α level of 0.05.

Table 4.13 The multiple comparisons of leached aluminium content into cooked meat at different kinds of meat, use of seasonings and aluminium amounts in aluminium foil

Kinds of meat - Use of seasonings - Aluminium amounts in aluminium foil	Seabass fish - W/O seasonings - Brand 1	Seabass fish - W/O seasonings - Brand 2	Seabass fish - W/ seasonings - Brand 1	Seabass fish - W/ seasonings - Brand 2	Saba fish - W/O seasonings - Brand 1	Saba fish - W/O seasonings - Brand 2	Saba fish - W/ seasonings - Brand 1	Saba fish - W/ seasonings - Brand 2	Chicken - W/O seasonings - Brand 1	Chicken - W/O seasonings - Brand 2	Chicken - W/ seasonings - Brand 1	Chicken - W/ seasonings - Brand 2	Beef - W/O seasonings - Brand 1	Beef - W/O seasonings - Brand 2	Beef - W/ seasonings - Brand 1	Beef - W/ seasonings - Brand 2
Seabass fish - W/O seasonings - Brand 1																
Seabass fish - W/O seasonings - Brand 2	+															
Seabass fish - W/ seasonings - Brand 1	+	+														
Seabass fish - W/ seasonings - Brand 2	+	+	+													
Saba fish - W/O seasonings - Brand 1	0	+	+	+												
Saba fish - W/O seasonings - Brand 2	+	0	+	+	+											
Saba fish - W/ seasonings - Brand 1	+	+	0	+	+	+										
Saba fish - W/ seasonings - Brand 2	+	+	+	+	+	+	+									
Chicken - W/O seasonings - Brand 1	0	+	+	+	0	+	+	+								
Chicken - W/O seasonings - Brand 2	+	+	+	+	+	+	+	+	+							
Chicken - W/ seasonings - Brand 1	+	+	0	+	+	+	0	+	+	+						
Chicken - W/ seasonings - Brand 2	+	+	+	+	+	+	+	0	+	+	+					
Beef - W/O seasonings - Brand 1	+	0	+	+	0	0	+	+	0	+	+	+				
Beef - W/O seasonings - Brand 2	+	+	0	+	+	+	0	+	+	+	0	+	+			
Beef - W/ seasonings - Brand 1	+	+	+	+	+	+	+	+	+	+	+	+	+	+		
Beef - W/ seasonings - Brand 2	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	

Note: + = significantly different at the significance level of 0.05
0 = non- significantly different at the significance level of 0.05
W/O seasonings = Cooking without seasonings; W/ seasonings = Cooking with seasonings
Oven = electric oven; Grill stove = electric grill stove; Gas stove = gas stove
Brand 1 = brand 1 (lower aluminium amount) of aluminium foil;
Brand 2 = brand 2 (higher aluminium amount) of aluminium foil

4.2.12 The comparison of leached aluminium content into cooked meats from interaction effect among different kinds of meat, use of seasonings and types of heat cooking

The multiple comparisons of the three-factor interaction among different kinds of meat, use of seasonings and types of heat cooking were analyzed at α level of 0.05. The statistical results showed that most of the effects were significant difference (p-value < 0.05). The results are shown in Table 4.14.

Table 4.14 The multiple comparison of leached aluminium content into cooked meat at different kinds of meat, use of seasonings and types of heat cooking

Kinds of meat - Use of seasonings - Types of heat cooking	Seabass fish - W/O - Oven	Seabass fish -W/O- Grill stove	Seabass fish - W/O- Gas stove	Seabass fish - W/ - Oven	Seabass fish - W/ - Grill stove	Seabass fish - W/ - Gas stove	Saba fish - W/O - Oven	Saba fish - W/O - Grill stove	Saba fish - W/O - Gas stove	Saba fish - W/ - Oven	Saba fish - W/ - Grill stove	Saba fish - W/ - Gas stove	Chicken - W/O - Oven	Chicken - W/O - Grill stove	Chicken - W/O - Gas stove	Chicken - W/ - Oven	Chicken - W/ - Grill stove	Chicken - W/ - Gas stove	Beef - W/O - Oven	Beef - W/O - Grill stove	Beef - W/O - Gas stove	Beef - W/ - Oven	Beef - W/ - Grill stove	Beef - W/ - Gas stove
Seabass fish - W/O - Oven																								
Seabass fish - W/O -Grill stove	0																							
Seabass fish - W/O - Gas stove	0	0																						
Seabass fish - W/ - Oven	+	+	+																					
Seabass fish - W/ - Grill stove	+	+	+	0																				
Seabass fish - W/ - Gas stove	+	+	+	+	0																			
Saba fish - W/O - Oven	0	0	0	+	+	+																		
Saba fish - W/O - Grill stove	0	0	0	+	+	+	0																	
Saba fish - W/O - Gas stove	0	0	0	+	+	+	0	0																
Saba fish - W/ - Oven	+	+	+	0	0	+	+	+	+															
Saba fish - W/ - Grill stove	+	+	+	+	0	0	+	+	+	+														
Saba fish - W/ - Gas stove	+	+	+	+	+	+	+	+	+	+	0													
Chicken - W/O - Oven	0	0	0	+	+	+	0	0	0	+	+	+												
Chicken - W/O - Grill stove	0	0	0	+	+	+	0	0	0	+	+	+	0											
Chicken - W/O - Gas stove	0	0	0	+	+	+	0	0	0	+	+	+	0	0										
Chicken - W/ - Oven	+	+	+	0	0	0	+	+	+	0	+	+	+	+	+									
Chicken - W/ - Grill stove	+	+	+	+	+	0	+	+	+	+	0	0	+	+	+	+								
Chicken - W/ - Gas stove	+	+	+	+	+	+	+	+	+	+	0	0	+	+	+	+	0							
Beef - W/O - Oven	0	0	0	+	+	+	0	0	0	+	+	+	0	0	0	+	+	+						
Beef - W/O - Grill stove	0	0	0	+	+	+	0	0	0	+	+	+	0	0	0	+	+	+	0					
Beef - W/O - Gas stove	+	+	+	0	+	+	+	+	+	0	+	+	+	+	0	+	+	+	+	0				
Beef - W/ - Oven	+	+	+	+	0	0	+	+	+	+	0	0	+	+	+	+	0	+	+	+	+			
Beef - W/ - Grill stove	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	0	+	+	+	+		
Beef - W/ - Gas stove	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	

Note: + = significantly different at the significance level of 0.05
0 = non- significantly different at the significance level of 0.05
W/O seasonings = Cooking without seasonings; W/ seasonings = Cooking with seasonings
Oven = electric oven; Grill stove = electric grill stove; Gas stove = gas stove

As shown in Table 4.1, the mean of leached aluminium content into cooked meat (mg/kg) when cooking by using beef - with seasonings - by gas stove was the highest value (6.128 mg/kg) and the mean of leached aluminium content into cooked meat (mg/kg) when cooking by using seabass fish - without seasonings - by electric oven was the lowest value (0.392 mg/kg).

Moreover, the multiple comparisons results also revealed that the highest mean of leached aluminium content into cooked meat when cooking by using beef -

with seasonings - by gas stove (6.128 mg/kg) was significantly different from others at α level of 0.05. However, the lowest mean of leached aluminium content into cooked meat when cooking by using seabass fish - without seasonings - by electric oven (0.392 mg/kg) was not significantly different from cooking by using seabass fish – without seasonings – by electric grill stove (0.456 mg/kg), seabass fish - without seasonings - gas stove (0.775 mg/kg), saba fish - without seasonings – electric oven (0.498 mg/kg), saba fish - without seasonings – electric grill stove (0.616 mg/kg), saba fish - without seasonings - gas stove (0.719 mg/kg), chicken - without seasonings – electric oven (0.621 mg/kg), chicken - without seasonings - electric grill stove (0.893 mg/kg), chicken – without seasonings – gas stove (1.111 mg/kg), beef – without seasonings – electric oven (0.857 mg/kg), beef – without seasonings – electric grill stove (1.236 mg/kg) at α level of 0.05.

4.2.13 The comparison of leached aluminium content into cooked meats from interaction effect among different kinds of meat, aluminium amounts in aluminium foil and types of heat cooking

The multiple comparisons of the three-factor interaction among different kinds of meat, aluminium amounts in aluminium foil and types of heat cooking were analyzed by statistic at α level of 0.05. The statistical results showed that there were both significantly and non-significantly different which most of the effects were not significantly different (p-value > 0.05). The results are shown in Table 4.15.

As shown in Table 4.1, the mean of leached aluminium content into cooked meat (mg/kg) when cooking by using beef – wrapped with brand 2 (higher aluminium amount) of aluminium foil – by gas stove was the highest value (5.449 mg/kg) and the mean of leached aluminium content into cooked meat (mg/kg) when cooking by using seabass fish – wrapped with brand 1 (lower aluminium amount) of aluminium foil – by electric oven was the lowest value (0.780 mg/kg). Moreover, the multiple comparisons results also revealed that the highest mean of leached aluminium content into cooked meat when cooking by using beef - wrapped with brand 2 (higher aluminium amount) of aluminium foil – by gas stove (5.449 mg/kg) was not significantly different from cooking beef – wrapped with brand 2 (higher aluminium amount) of aluminium foil – by electric grill stove (4.482 mg/kg) at α level of 0.05.

Table 4.15 The multiple comparison of leached aluminium content into cooked meat at different kinds of meat, aluminium amounts in aluminium foil and types of heat cooking

Kinds of meat - Aluminium amounts in aluminium foil - Types of heat cooking	Seabass fish - Brand 1 - Oven	Seabass fish -Brand 1- Grill stove	Seabass fish -Brand 1- Gas stove	Seabass fish - Brand 2 - Oven	Seabass fish -Brand 2- Grill stove	Seabass fish -Brand 2- Gas stove	Saba fish - Brand 1 - Oven	Saba fish - Brand 1 - Grill stove	Saba fish - Brand 1 - Gas stove	Saba fish - Brand 2 - Oven	Saba fish - Brand 2 - Grill stove	Saba fish - Brand 2 - Gas stove	Chicken - Brand 1 - Oven	Chicken - Brand 1 - Grill stove	Chicken - Brand 1 - Gas stove	Chicken - Brand 2 - Oven	Chicken - Brand 2 - Grill stove	Chicken - Brand 2 - Gas stove	Beef - Brand 1 - Oven	Beef - Brand 1 - Grill stove	Beef - Brand 1 - Gas stove	Beef - Brand 2 - Oven	Beef - Brand 2 - Grill stove	Beef - Brand 2 - Gas stove
Seabass fish - Brand 1 - Oven																								
Seabass fish - Brand 1- Grill stove	0																							
Seabass fish - Brand 1 - Gas stove	0	0																						
Seabass fish - Brand 2 - Oven	0	0	0																					
Seabass fish - Brand 2- Grill stove	+	0	0	0																				
Seabass fish - Brand 2- Gas stove	+	+	+	0	0																			
Saba fish - Brand 1 - Oven	0	0	0	0	+	+																		
Saba fish - Brand 1 - Grill stove	0	0	0	0	0	+	0																	
Saba fish - Brand 1 - Gas stove	0	0	0	0	0	+	0	0																
Saba fish - Brand 2 - Oven	0	0	0	0	0	0	0	0	0															
Saba fish - Brand 2 - Grill stove	+	+	+	+	0	0	+	+	+	0														
Saba fish - Brand 2 - Gas stove	+	+	+	+	+	0	+	+	+	+	0													
Chicken - Brand 1 - Oven	0	0	0	0	0	+	0	0	0	0	+	+												
Chicken - Brand 1 - Grill stove	0	0	0	0	0	+	0	0	0	0	+	+	0											
Chicken - Brand 1 - Gas stove	0	0	0	0	0	0	0	0	0	0	+	+	0	0										
Chicken - Brand 2 - Oven	+	0	0	0	0	0	0	0	0	0	0	+	0	0	0									
Chicken - Brand 2 - Grill stove	+	+	+	+	0	0	+	+	+	+	0	0	+	+	+	+								
Chicken - Brand 2 - Gas stove	+	+	+	+	+	+	+	+	+	+	0	0	+	+	+	+	0							
Beef - Brand 1 - Oven	0	0	0	0	0	+	0	0	0	0	+	+	0	0	0	0	+	+						
Beef - Brand 1 - Grill stove	0	0	0	0	0	0	0	0	0	0	+	+	0	0	0	0	+	+	0					
Beef - Brand 1 - Gas stove	+	+	0	0	0	0	+	0	0	0	0	0	+	0	0	0	0	+	0	0				
Beef - Brand 2 - Oven	+	+	+	0	0	0	+	+	+	0	0	0	+	+	+	0	0	0	+	0	0			
Beef - Brand 2 - Grill stove	+	+	+	+	+	+	+	+	+	+	+	0	+	+	+	+	+	0	+	+	+	+		
Beef - Brand 2 - Gas stove	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	0	

Note: + = significantly different at the significance level of 0.05
0 = non- significantly different at the significance level of 0.05
Oven = electric oven; Grill stove = electric grill stove; Gas stove = gas stove
Brand 1 = brand 1 (lower aluminium amount) of aluminium foil;
Brand 2 = brand 2 (higher aluminium amount) of aluminium foil

However, the lowest mean of leached aluminium content into cooked meat when cooking by using seabass fish – wrapped with brand 1 (lower aluminium amount) of aluminium foil – by electric oven (0.780 mg/kg) was not significantly different from cooking by using seabass fish – wrapped with brand 1 (lower aluminium amount) of aluminium foil – by electric grill stove (1.112 mg/kg), seabass fish – wrapped with brand 1 (lower aluminium amount) of aluminium foil – gas stove (1.258 mg/kg), seabass fish – wrapped with brand 2 (higher aluminium amount) of aluminium foil – electric oven (1.768 mg/kg), saba fish – wrapped with brand 1 (lower aluminium amount) of aluminium foil – electric oven (0.923 mg/kg), saba fish – wrapped with brand 1 (lower aluminium amount) of aluminium foil – electric grill stove (1.211 mg/kg), saba fish – wrapped with brand 1 (lower aluminium amount) of aluminium foil – gas stove (1.389 mg/kg), saba fish – wrapped with brand 2 (higher aluminium amount) of aluminium foil – electric oven (1.862 mg/kg), chicken – wrapped with brand 1 (lower aluminium amount) of aluminium foil – electric oven (1.101 mg/kg), chicken – wrapped with brand 1 (lower aluminium amount) of aluminium foil – electric grill stove (1.272 mg/kg), chicken – wrapped with brand 1 (lower aluminium amount) of aluminium foil – gas stove (1.526 mg/kg), beef – wrapped with brand 1 (lower aluminium amount) of aluminium foil – electric oven (1.407 mg/kg), beef – wrapped with brand 1 (lower aluminium amount) of aluminium foil – electric grill stove (1.729 mg/kg) at α level of 0.05.

4.2.14 The comparison of leached aluminium content into cooked meats from interaction effect among different use of seasonings, aluminium amounts in aluminium foil and types of heat cooking

The multiple comparisons of the three-factor interaction among different use of seasonings, aluminium amounts in aluminium foil and types of heat cooking were analyzed by statistic at α level of 0.05. The statistical results showed that most of the effects were significant difference (p-value < 0.05). The results are shown in Table 4.16.

As shown in Table 4.1, the mean of leached aluminium content into cooked meat (mg/kg) when cooking with seasonings - wrapped with brand 2 (higher aluminium amount) of aluminium foil - by gas stove was the highest value (6.106 mg/kg) and the mean of leached aluminium content into cooked meat (mg/kg) when cooking without seasonings - wrapped with brand 1 (lower aluminium amount) of aluminium foil - by electric oven was the lowest value (0.265 mg/kg).

Table 4.16 The multiple comparisons of leached aluminium content into cooked meat at different use of seasonings, aluminium amounts in aluminium foil and types of heat cooking

Use of seasonings - Aluminium amounts in aluminium foil - Types of heat cooking	W/O seasonings -Brand 1- Oven	W/O seasonings -Brand 1- Grill stove	W/O seasonings -Brand 1- Gas stove	W/O seasonings - Brand 2 - Oven	W/O seasonings - Brand 2 - Grill stove	W/O seasonings - Brand 2 - Gas stove	W/ seasonings - Brand 1 - Oven	W/ seasonings - Brand 1 - Grill stove	W/ seasonings - Brand 1 - Gas stove	W/ seasonings - Brand 2 - Oven	W/ seasonings - Brand 2 - Grill stove	W/ seasonings - Brand 2 - Gas stove
W/O seasonings - Brand 1 - Oven												
W/O seasonings - Brand 1 - Grill stove	0											
W/O seasonings - Brand 1 - Gas stove	0	0										
W/O seasonings - Brand 2 - Oven	+	+	+									
W/O seasonings - Brand 2 - Grill stove	+	+	+	+								
W/O seasonings - Brand 2 - Gas stove	+	+	+	+	+							
W/ seasonings - Brand 1 - Oven	+	+	+	+	+	0						
W/ seasonings - Brand 1 - Grill stove	+	+	+	+	+	+	+					
W/ seasonings - Brand 1 - Gas stove	+	+	+	+	+	+	+	+				
W/ seasonings - Brand 2 - Oven	+	+	+	+	+	+	+	+	+			
W/ seasonings - Brand 2 - Grill stove	+	+	+	+	+	+	+	+	+	+		
W/ seasonings - Brand 2 - Gas stove	+	+	+	+	+	+	+	+	+	+	+	

Note: + = significantly different at the significance level of 0.05
0 = non- significantly different at the significance level of 0.05
W/O seasonings = Cooking without seasonings; W/ seasonings = Cooking with seasonings
Oven = electric oven; Grill stove = electric grill stove; Gas stove = gas stove
Brand 1 = brand 1 (lower aluminium amount) of aluminium foil;
Brand 2 = brand 2 (higher aluminium amount) of aluminium foil

Moreover, the multiple comparisons results also revealed that the highest mean of leached aluminium content into cooked meat when cooking with seasonings - wrapped with brand 2 (higher aluminium amount) of aluminium foil - by gas stove (6.106 mg/kg) was significantly different from others at α level of 0.05. However, the lowest mean of leached aluminium content into cooked meat when cooking without seasonings - wrapped with brand 1 (lower aluminium amount) of aluminium foil - by electric oven (0.265 mg/kg) was not significantly different from cooking without seasonings - wrapped with brand 1 (lower aluminium amount) of aluminium foil - by electric grill stove (0.321 mg/kg) and cooking without seasonings - wrapped with brand 1 (lower aluminium amount) of aluminium foil - by gas stove (0.541 mg/kg) at α level of 0.05.

4.2.15 The comparison of leached aluminium content into cooked meat from interaction effect among different kinds of meat, use of seasonings, aluminium amounts in aluminium foil and types of heat cooking

Leached aluminium contents into cooked meat at different cooking conditions (kinds of meat, use of seasonings, aluminium amounts in aluminium foil and types of heat cooking) were statistical analyzed by using factorial ANOVA at α level of 0.05. It was found that there were significant differences between the mean of leached aluminium content for all of main effects. The interaction effects of two-factor, three-factor and four-factor were also significantly different. The statistical result is shown in Table 4.2.

As the multiple comparisons results, it was found that the mean of leached aluminium content into cooked meat (mg/kg) when cooking by using beef - with seasonings - wrapped with brand 2 (higher aluminium amount) of aluminium foil cooked - by gas stove was the highest value (8.573 mg/kg) and significantly different form others at α level of 0.05. However, the mean of leached aluminium content into cooked meat (mg/kg) when cooking by using seabass fish - without seasonings - wrapped with brand 1 (lower aluminium amount) of aluminium foil cooked - by electric oven was the lowest value (0.149 mg/kg) and non-significantly different from the mean of leached aluminium content into cooked meat (mg/kg) when cooking by using seabass fish - without seasonings - wrapped with brand 1 (lower aluminium amount) of aluminium foil cooked - by electric grill stove (0.193 mg/kg) and cooking by using saba fish - without seasonings - wrapped with brand 1 (lower aluminium amount) of aluminium foil cooked - by electric oven (0.188 mg/kg) at α level of 0.05. The results are shown in Table 4.17.

Furthermore, this study could be concluded the condition for appropriate use of aluminium foil for each kind of meat. The most suitable condition in this study was considered from use of seasonings, aluminium amounts in aluminium foil and types of heat cooking which gave the lowest of leached aluminium content into cooked meat in order to safety of consumer. Considering the highest - lowest mean values of leached aluminium content into cooked meats wrapped with aluminium foil and statistical difference of all factors interaction in each kind of meat, it was concluded the suitable condition as follows.

Cooking by using seabass fish - with seasonings - wrapped with brand 2 (higher aluminium amount) of aluminium foil - by gas stove gave the highest of leached aluminium content into cooked meat (4.093 mg/kg) and significantly different from others at α level of 0.05. While cooking by using seabass fish - without seasonings - wrapped with brand 1 (lower aluminium amount) of aluminium foil - by electric oven gave the lowest of leached aluminium content into cooked meat (0.149 mg/kg) and non-significantly different from the mean of leached aluminium content into cooked meat (mg/kg) when cooking by using seabass fish - without seasonings - wrapped with brand 1 (lower aluminium amount) of aluminium foil - by electric grill stove (0.193 mg/kg) and cooking by using saba fish - without seasonings - wrapped with brand 1 (lower aluminium amount) of aluminium foil - by electric oven (0.188 mg/kg) at α level of 0.05. The results are shown in Table 4.1 and Table 4.17. Therefore, the most suitable cooking condition for seabass fish was the cooking without seasonings - wrapped with brand 1 (lower aluminium amount) of aluminium foil - by electric oven or electric grill stove.

Cooking by using saba fish - with seasonings - wrapped with brand 2 (higher aluminium amount) of aluminium foil - by gas stove gave the highest of leached aluminium content into cooked meat (5.739 mg/kg) and significantly different from others at α level of 0.05. While cooking by using saba fish - without seasonings - wrapped with brand 1 (lower aluminium amount) of aluminium foil - by electric oven gave the lowest of leached aluminium content into cooked meat (0.188 mg/kg) and significantly different from others at α level of 0.05. The results are shown in Table 4.1 and Table 4.17. Therefore, the most suitable cooking condition for saba fish was the cooking without seasonings - wrapped with brand 1 (lower aluminium amount) of aluminium foil - by electric oven.

Cooking by using chicken - with seasonings - wrapped with brand 2 (higher aluminium amount) of aluminium foil - by gas stove gave the highest of leached aluminium content into cooked meat (6.018 mg/kg) and significantly different from others at α level of 0.05. While cooking by using chicken - without seasonings -

wrapped with brand 1 (lower aluminium amount) of aluminium foil - by electric oven gave the lowest of leached aluminium content into cooked meat (0.315 mg/kg) and non-significantly different from the mean of leached aluminium content into cooked meat (mg/kg) when cooking by using chicken - without seasonings - wrapped with brand 1 (lower aluminium amount) of aluminium foil - by electric grill stove (0.349 mg/kg) at α level of 0.05. The results are shown in Table 4.1 and Table 4.17. Therefore, the most suitable cooking condition for chicken was the cooking without seasonings - wrapped with brand 1 (lower aluminium amount) of aluminium foil - by electric oven or electric grill stove.

Cooking by using beef - with seasonings - wrapped with brand 2 (higher aluminium amount) of aluminium foil - by gas stove gave the highest of leached aluminium content into cooked meat (8.573 mg/kg) and significantly different from others at α level of 0.05. While cooking by using beef - without seasonings - wrapped with brand 1 (lower aluminium amount) of aluminium foil - by electric oven gave the lowest of leached aluminium content into cooked meat (0.407 mg/kg) and non-significantly different from the mean of leached aluminium content into cooked meat (mg/kg) when cooking by using beef - without seasonings - wrapped with brand 1 (lower aluminium amount) of aluminium foil - by electric grill stove (0.459 mg/kg) at α level of 0.05. The results are shown in Table 4.1 and Table 4.17. Therefore, the most suitable cooking condition for beef was the cooking without seasonings - wrapped with brand 1 (lower aluminium amount) of aluminium foil - by electric oven or electric grill stove.

Table 4.17 The multiple comparisons of leached aluminium content into cooked meat at different kinds of meat, seasoning, aluminium amount in aluminium foil and types of heat cooking

				Seabass fish												Saba fish												Chicken												Beef											
				Without seasoning						With seasoning						Without seasoning						With seasoning						Without seasoning						With seasoning						Without seasoning						With seasoning					
				Brand 1			Brand 2			Brand 1			Brand 2			Brand 1			Brand 2			Brand 1			Brand 2			Brand 1			Brand 2			Brand 1			Brand 2			Brand 1			Brand 2			Brand 1			Brand 2		
				oven	grill	gas	oven	grill	gas	oven	grill	gas	oven	grill	gas	oven	grill	gas	oven	grill	gas	oven	grill	gas	oven	grill	gas	oven	grill	gas	oven	grill	gas	oven	grill	gas	oven	grill	gas	oven	grill	gas	oven	grill	gas	oven	grill	gas	oven	grill	gas
Seabass fish	Without seasoning	Brand 1	oven																																																
			grill	0																																															
			gas	+	+																																														
		Brand 2	oven	+	+	+																																													
			grill	+	+	+	+																																												
			gas	+	+	+	+	+																																											
	With seasoning	Brand 1	oven	+	+	+	+	+	+																																										
			grill	+	+	+	+	+	+	+																																									
			gas	+	+	+	+	+	+	+	+																																								
		Brand 2	oven	+	+	+	+	+	+	+	+	+																																							
			grill	+	+	+	+	+	+	+	+	+	+																																						
			gas	+	+	+	+	+	+	+	+	+	+	+																																					
Saba fish	Without seasoning	Brand 1	oven	0	0	+	+	+	+	+	+	+	+	+	+																																		
			grill	+	+	0	+	+	+	+	+	+	+	+	+	+																																	
			gas	+	+	0	+	+	+	+	+	+	+	+	+	+	0																																
		Brand 2	oven	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+																															
			grill	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+																														
			gas	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+																													
	With seasoning	Brand 1	oven	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+																														
			grill	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+																													
			gas	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+																												
		Brand 2	oven	+	+	+	+	+	+	+	+	+	0	+	+	+	+	+	+	+	+	+	+	+																											
			grill	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+																										
			gas	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+																									

Note: + = significantly different at the significance level of 0.05 and 0 = non- significantly different at the significance level of 0.05
oven = electric oven; grill = electric grill stove; gas = gas stove; Brand 1 = brand 1 (lower aluminium amount) of aluminium foil; Brand 2 = brand 2 (higher aluminium amount) of aluminium foil

Table 4.17 The multiple comparisons of leached aluminium content into cooked meat at different kinds of meat, seasoning, aluminium amount in aluminium foil and types of heat cooking (Continue)

				Seabass fish												Saba fish												Chicken												Beef											
				Without seasoning						With seasoning						Without seasoning						With seasoning						Without seasoning						With seasoning						Without seasoning						With seasoning					
				Brand 1			Brand 2			Brand 1			Brand 2			Brand 1			Brand 2			Brand 1			Brand 2			Brand 1			Brand 2			Brand 1			Brand 2			Brand 1			Brand 2			Brand 1			Brand 2		
				oven	grill	gas	oven	grill	gas	oven	grill	gas	oven	grill	gas	oven	grill	gas	oven	grill	gas	oven	grill	gas	oven	grill	gas	oven	grill	gas	oven	grill	gas	oven	grill	gas	oven	grill	gas	oven	grill	gas	oven	grill	gas	oven	grill	gas	oven	grill	gas
Chicken	Without seasoning	Brand 1	oven	+	+	0	+	+	+	+	+	+	+	+	+	+	0	0	+	+	+	+	+	+	+	+	+																								
			grill	+	+	0	+	+	+	+	+	+	+	+	+	+	0	0	+	+	+	+	+	+	+	+	+	0																							
			gas	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+																						
		Brand 2	oven	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	0	+	+	+	+	+	+	+	+	+	+																					
			grill	+	+	+	+	+	+	0	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+																				
			gas	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+																			
	With seasoning	Brand 1	oven	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+																		
			grill	+	+	+	+	+	+	+	+	0	+	+	+	+	+	+	+	+	+	+	0	+	+	+	+	+	+	+	+	+	+	+																	
			gas	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+																
		Brand 2	oven	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+															
			grill	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+														
			gas	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+													
Beef	Without seasoning	Brand 1	oven	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	0	+	+	+	+	+	+	+	+	+	+												
			grill	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	0	+	+	+	+	+	+	+	+	+	0											
			gas	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	0	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+										
		Brand 2	oven	+	+	+	+	+	0	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+									
			grill	+	+	+	+	+	+	+	0	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+								
			gas	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+							
	With seasoning	Brand 1	oven	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	0	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+						
			grill	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+					
			gas	+	+	+	+	+	+	+	+	+	+	0	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+				
		Brand 2	oven	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+			
			grill	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+		
			gas	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	

Note: + = significantly different at the significance level of 0.05 and 0 = non- significantly different at the significance level of 0.05
oven = electric oven; grill = electric grill stove; gas = gas stove; Brand 1 = brand 1 (lower aluminium amount) of aluminium foil; Brand 2 = brand 2 (higher aluminium amount) of aluminium foil

CHAPTER V
DISCUSSION

This chapter was conducted to discuss in terms of leached aluminium into cooked meat wrapped with aluminium foil at different cooking conditions. The study results in Chapter IV were discussed based on the relevant theories and previous researches. The discussion was shown as follows.

5.1 The comparison of leached aluminium content into cooked meat (mg/kg) wrapped with aluminium foil by using different kinds of meat

In this study, the aluminium contents leached into cooked meat wrapped with aluminium foil was examined by four kinds of meat (including seabass fish, saba fish, chicken and beef). The selected meat species used for this study categorized by types of meat and the levels of fat content in its. The meat was measured in terms of the aluminium contents before and after cooking by wrapping with aluminium foil. The aluminium data are illustrated in Appendix A. However, the leached aluminium contents from aluminium foil into cooked meat was calculated by the difference of aluminium contents in meat between before and after cooking as shown in Table 4.1. The results showed that the different kinds of meat gave different leached aluminium contents into cooked meat.

The results of fresh meats showed that there were the differences of aluminium contents in meats. The aluminium contents in fresh meats contained around 3.085 - 9.624 mg/kg of fresh matter as the data shown in Appendix A. From the study of Muller M et al (109) investigated that most foodstuffs contained aluminium less than 5 μg/g of fresh matter. Several researches (3, 20, 23, 109) reported the different concentrations of aluminium in various foods, which the differences occurred with aluminium content resulted in harvest sites and growing conditions. It was possible that the differences of aluminium in meat may cause animal species, source of animal feed and growing conditions of animal.

After cooking found that the aluminium contents from cooking by wrapping with aluminium foil were increased. This result was corresponded with the study of Onianwa PC et al (108) which found the aluminium contents in processed foods were generally higher than the aluminium contents in raw foods.

According to the statistical analysis of variance, it was found that the result was in agreement with the first hypothesis, which the different kinds of meat significantly affected different leached aluminium contents (p-value < 0.05). The comparison for the difference by each pair, it confirmed that the kinds of meat affected leached aluminium contents. Therefore, this study indicated that the cooking by using different kinds of meat have an influence on differences leached aluminium content, which the order of leached aluminium content into cooked meat was higher in beef than in chicken, saba fish and seabass fish.

Moreover, this study was determined fat content of fresh meats. The fat content of seabass fish (lean fish), saba fish (fatty fish), chicken, and beef was 0.121%. 2.445%, 4.057%, and 6.859% of fresh matter, respectively. The results of fat content are shown in Figure 4.2. According to Lawrie RA et al (75), the order of fat contents in raw meat was generally higher in beef than in chicken and fish.

Besides, the results were found that leached aluminium contents into cooked meat were increased when increasing the fat contents of fresh meat. This result implied that the fat content was positively related to aluminium increase into meats. Corresponding to the study of Sadettin T (27) that determined aluminium contents in baked meat, found raw chicken and turkey breast meat (higher fat contents) contained higher amount of aluminium than the raw chicken and turkey leg meat (lower fat contents), respectively. From the study of Ranau R et al (28) was found the aluminium content of the baked fillets of lean fish were lower than that of fatty fish. Therefore, it is possible that the fat content of meats may influence the increase of aluminium.

In addition, the results of pH value of fresh meats ranged from 5.60 to 6.07, and that of cooked meats ranged from 5.72 to 6.28, as the data of pH shown in Appendix A. The pH values of fresh meats were neutral. After cooking the pH values were slightly increased and they were in the pH range 4.0 to 9.0, which were the accepted values because of the pH range 4.0 to 9.0 do not cause serious damage to the surface layer of aluminium. The theory about corrosion of aluminium mentioned that aluminium may corrode in aggressive environments, especially in strong acid (pH below 4.0) and alkali (pH above 9.0) solution (35, 67). Several researches (17, 20-23, 43-44, 111) reported the migration of aluminium from aluminium cookware and found that the pH value of food is an influencing factor on aluminium migration. Such as, the study of Scancar J et al (20) that cooked sauerkraut and sour turnip in aluminium cookware, it was found that aluminium concentration increased high after cooking in aluminium utensils. Takeda Y et al (112) found that aluminium migration from aluminium foil depends on pH values which cause aluminium contamination into foods. Thus, the aluminium cookware usage is not recommended for acid foods.

5.2 The comparison of leached aluminium content into cooked meat (mg/kg) wrapped with aluminium foil by different use of seasoning

In this study, the aluminium contents leached into cooked meat wrapped with aluminium foil was examined by cooking meat with and without seasoning. The seasoning were added in order to simulate the normal human eating habitat, which the seasoning used (including salt, soy sauce, black pepper and garlic) are popular added for flavoring in Thai cuisine. Seabass fish and saba fish used salt and soy sauce. Chicken and beef used garlic, black pepper and soy sauce. The aluminium contents of meat were measured both before and after cooking by wrapping with aluminium foil as shown in Appendix A. Leached aluminium contents from aluminium foil into cooked meat was calculated by aluminium content in meat between before and after cooking as shown in Table 4.1. As the results found that the cooking meat with seasoning gave higher leached aluminium contents than the cooking meat without seasoning.

According to the statistical analysis of variance, it was found that the result was in agreement with the second hypothesis, which the cooking meat with seasoning significantly affected higher leached aluminium contents than the cooking meat without seasoning ($p\text{-value} < 0.05$). The comparison for the difference between cooking with and without seasoning, it confirmed that the cooking meat with seasoning affected higher leached aluminium contents (mg/kg) than the cooking meat without seasoning. Therefore, this study could be concluded that the use of seasoning influenced the aluminium leaching from cooking meat wrapped with aluminium foil into cooked meats.

Moreover, the seasonings used in this study were determined aluminium content, including flavors (salt and soy sauce), spices (black pepper), and herbs (garlic). The aluminium content in seasoning of salt, soy sauce, garlic and black pepper contained 1.965 mg/kg, 34.628 mg/kg, 1.980 mg/kg and 171.403 mg/kg, respectively as shown in Appendix A. According to many investigations (20, 23, 109) found that spices and herbs generally contain high amounts of aluminium. Muller M et al (109) investigated aluminium in foodstuffs found the high aluminium contents in spices, and the different aluminium contents in spices among year 1988 and 1991 because of it depends on harvest sites of spices, which corresponded with Anil DS et al (23) reported the differences of aluminium contents in foods depend on variations in soils, water, and growing conditions. Thus, the differences of aluminium content in the seasoning depend on environment, growing condition and harvest sites of them.

From the results obviously indicated that leached aluminium contents into cooked meat increased when cooking meat with seasoning. It was possible that the high aluminium contents in seasoning may influence on the aluminium increase or may possibly the chloride ions in seasoning promoted the aluminium migration from aluminium foil into meats. From the theory of aluminium corrosion (35, 62) mentioned that aluminium is generally resistant to corrosion in the neutral, because of aluminium has a natural protection from its oxide layer. The oxide layer may corrode if exposed to aggressive environments. The presences of aggressive ions (e.g., chloride, fluoride, etc.) affect the stability of the aluminium oxide layer. Salt as the seasoning contains chloride ions (102). In addition to soy sauce, dressing, and dripping comprise of salt about 15%, they also contain chloride ions cause pitting and crevice corrosion (66). Besides, it was found chloride ions accelerate the corrosion process but whether this is due to oxide film breakdown and directly affect the corrosion potential of aluminium in fresh water. The higher concentration of chloride ions are the corrosion potential and will fast corrode (65). Therefore, the cooking with seasoning which have the high aluminium contents or the chloride ions may cause the aluminium leaching from aluminium foil into cooked meat.

Considering meats in this study was divided into two groups by type of seasoning used for cooking as shown in Table 3.1. The seasonings were selected to correspond with the kinds of meat for specific dish. The same seasoning were used the same seasoning for seabass fish and saba fish, including salt and soy sauce. While the seasoning for chicken and beef were the same ingredients, including garlic, black pepper and soy sauce. According to aluminium contents in seasoning as shown in Appendix A, black pepper contained high amounts of aluminium (171.403 mg/kg) and higher than other seasoning which added especially in chicken and beef. Therefore, the black peppers can influence the increase of aluminium contents in cooked meat. Moreover, the results clearly showed the cooking with garlic, black pepper and soy sauce gave higher leached aluminium contents than the cooking with salt and soy sauce. Besides, considering the highest and the lowest mean of leached aluminium content into cooked meats and statistical difference in each group of seasoning used, it could be concluded the most suitable cooking condition which selected from the lowest mean of leached aluminium content into cooked meat in order to safety of consumer was as follows.

The highest mean of leached aluminium content into cooked meat when cooking with salt and soy sauce as seasoning (5.739 mg/kg) was the cooking by using saba fish - wrapped with brand 2 (higher aluminium amount) of aluminium foil - by gas stove and significantly different from others at α level of 0.05. Whereas the lowest mean of leached aluminium content into cooked meat when cooking with salt and soy sauce as seasoning (1.412 mg/kg) was the cooking by using seabass fish - wrapped with brand 1 (lower aluminium amount) of aluminium foil - by electric oven and non-significantly different from the mean of leached aluminium content into cooked meat (mg/kg) when cooking by using chicken - without garlic, black pepper and soy sauce as seasoning - wrapped with brand 2 (higher aluminium amount) of aluminium foil - by electric grill stove (1.438 mg/kg) at α level of 0.05. Thus, the most suitable cooking condition by using salt and soy sauce as seasoning was the cooking by wrapping with brand 1 (lower aluminium amount) of aluminium foil and heated by electric oven for seabass fish and saba fish.

The highest mean of leached aluminium content into cooked meat when cooking with garlic, black pepper and soy sauce as seasoning (8.573 mg/kg) was the cooking by using beef - wrapped with brand 2 (higher aluminium amount) of aluminium foil - by gas stove and significantly different from others at α level of 0.05. While the lowest mean of leached aluminium content into cooked meat when cooking with garlic, black pepper and soy sauce as seasoning (1.886 mg/kg) was the cooking by using chicken - wrapped with brand 1 (lower aluminium amount) of aluminium foil - by electric oven and significantly different from others at α level of 0.05. Thus, the most suitable cooking condition by using garlic, black pepper and soy sauce as seasoning was the cooking by wrapping with brand 1 (lower aluminium amount) of aluminium foil and heated by electric oven for chicken and beef.

5.3 The comparison of leached aluminium content into cooked meat (mg/kg) wrapped with aluminium foil by using different aluminium amounts in aluminium foil

In this study, the aluminium contents leached into cooked meat was examined by cooking meat wrapped with two brands of aluminium foils (including brand 1 - lower aluminium amount and brand 2 - higher aluminium amount). The aluminium contents of meat were measured both before and after cooking by wrapping with aluminium foil as shown in Appendix A. Leached aluminium contents from aluminium foil into cooked meat was calculated by aluminium content in meat between before and after cooking as shown in Table 4.1. Aluminium foils in this study are thin foils for food wrapping. Size of aluminium foil and the method for wrapping were controlled. Moreover, the amounts of aluminium in aluminium foil were measured. The amounts of aluminium were 69.483% and 83.419% for brand 1 and brand 2 of aluminium foil, respectively. From the results found that the higher amount of aluminium in aluminium foil (brand 2) gave higher leached aluminium contents than the lower amount of aluminium in aluminium foil (brand 1).

According to the statistical analysis of variance, it was found that the result was in agreement with the third hypothesis, which the cooking meat by wrapping with brand 2 (higher aluminium amount) of aluminium foil significantly affected higher leached aluminium contents than the cooking by wrapping with brand 1 (lower aluminium amount) of aluminium foil (p-value < 0.05). The comparison for the difference between cooking by wrapping with brand 1 (lower aluminium amount) and brand 2 (higher aluminium amount) of aluminium foil, it confirmed that the cooking meat by wrapping with brand 2 (higher aluminium amount) of aluminium foil affected higher leached aluminium contents (mg/kg) than the cooking meat by wrapping with brand 1 (lower aluminium amount) of aluminium foil. Therefore, this study could be concluded that the amount of aluminium in aluminium foil influenced the aluminium leaching from cooking meat wrapped with aluminium foil into cooked meats.

Moreover, aluminium corrosion theory (35, 62) mentioned that pure aluminium is highly resistant to corrosion. While the results found that the cooking meat by wrapping with brand 2 (higher aluminium amount) of aluminium foil is higher leached aluminium contents than brand 1 (lower aluminium amount) of aluminium foil. The study of KS Jagannatha Rao et al (68) reported that the utensils and packaging materials made of Al-Pb alloy which is low quality that causes to enhance the aluminium leaching. Al-Pb alloy is a weak alloy with a loose crystal structure, and is susceptible to acid attack. When compared with the high quality utensils made of Al-Mn alloy, it is a strong alloy with compact crystal structure and is not easily susceptible to acid and fluoride attack. As the results of the chemical composition in aluminium foil, found alloy elements in aluminium foil contain primarily aluminium element and also contain Na, Fe and Se (1.50, 0.19, 0.01 ppm, respectively) in brand 1 of aluminium foil. Brand 2 of aluminium foil contains Na, Fe, Se, Ti and Pb (2.48, 0.26, 0.06, 0.002 and 0.003 ppm, respectively). From the corrosion behavior of aluminium (35) mentioned that iron element is probably the most common cause of pitting in aluminium alloys and reduces corrosion resistance; the high iron content increases the bursting strength but reduces the corrosion resistance. Titanium element has a little influence on corrosion resistance of aluminium alloys. According to the aluminium corrosion theory mentioned that certain elements include gallium (Ga), titanium (Ti), indium (In), tin (Sn) and lead (Pb) as the anodic material for potential power sources, may become incorporated in the oxide and destabilize it (62). From the results observed that brand 2 (higher aluminium amount) of aluminium foil was higher level of above elements than brand 1 (lower aluminium amount) of aluminium foil. Therefore, the cooking meat by wrapping with brand 2 (higher aluminium amount) of aluminium foil gave higher leached aluminium contents than the cooking by wrapping with brand 1 (lower aluminium amount) of aluminium foil, it may possible that the presence of other chemical composition in aluminium foil may cause aluminium migration.

5.4 The comparison of leached aluminium content into cooked meat (mg/kg) wrapped with aluminium foil by using different types of heat cooking

In this study, the aluminium contents leached into cooked meat wrapped with aluminium foil was examined by cooking with three types of heat cooking (including electric oven, electric grill stove and gas stove). Each type of heat cooking was selected the cooking temperature and cooking time that make meat just enough cooking and appetizing. The aluminium contents of meat were measured both before and after cooking by wrapping with aluminium foil as shown in Appendix A. Leached aluminium contents from aluminium foil into cooked meat was calculated by aluminium content in meat between before and after cooking as shown in Table 4.1. From the results found that the different types of heat cooking gave different leached aluminium contents into cooked meat.

According to the statistical analysis of variance, it was found that the result was in agreement with the fourth hypothesis, which the different types of heat cooking significantly affected different leached aluminium contents ($p\text{-value} < 0.05$). The comparison for the difference by each pair, it confirmed that the types of heat cooking affected leached aluminium contents. Therefore, this study indicated that the cooking by using different types of heat cooking have an influence on differences leached aluminium content, which the order of leached aluminium content into cooked meat was higher in gas stove than in electric grill stove and electric oven.

Considering cooking temperature of electric oven and electric grill stove were 200ºC, whereas cooking temperature of gas stove was 300ºC. When comparing between cooking temperature and leached aluminium contents into cooked meat, found that the cooking meat by gas stove (higher temperature) was higher leached aluminium contents than the cooking meat by electric oven and electric grill stove (lower temperature). This result corresponded with the study of Piyasatidtham W (22) and Boonyanan S (26) which found cooking temperatures affected the increase of aluminium in foods. According to the theory of aluminium corrosion (35) mentioned that the temperature is a factor affecting the rate of corrosion, which the increase of temperature generally affect the corrosion rate, as more reactant ions are activated and can cross over the energy barrier.

Considering cooking time of electric oven, electric grill stove and gas stove were 60 min, 60 min and 20 min respectively. The cooking meat by gas stove (lower time) was higher leached aluminium contents than the cooking meat by electric oven and electric grill stove (higher time) which contrasted with Boonyanan S (26) that found baking time affected on aluminium increase into baked meat. It may possible that the cooking temperature may influence aluminium leaching more than cooking time, because of the oxide layer becomes thicker and changes from an amorphous to a crystalline structure at the elevated temperatures (33, 62).

Moreover, the different types of heat cooking use different heat sources. Electric oven and electric grill stove used electricity as heat source that heat builds up within the heating element from the flow of electricity. While heat source of gas stove comes from direct flame which using liquefied petroleum gas (LPG) as a fuel source. The study results were observed that the cooking by using a direct flame as heat source (gas stove) were higher leached aluminium contents than the cooking by using electricity as heat source (electric oven and electric grill stove). Corresponds with the study of Ranau R et al (28) that the aluminium contents of grilled fillets over charcoal were higher than the aluminium contents of baked fillets in an oven. Possibly the different heat sources may influence the aluminium migration from aluminium foil into cooked meats.

According to the theory of heat transfer during the cooking process (74), found the form of heat transfer in electric oven is primarily convection from the hot air in the oven and radiation from the heat being emitted from the hot walls of the oven. While, electric grill stove is convection from the surrounding air and radiation from a heat source. While, most of heat transfer in gas stove is convection and small contributes from the burning gas producing electromagnetic radiation in both the visible and infrared spectrums, and conduction from the hot metal prongs that support the rack. Furthermore, this study used aluminium foil for wrapping meats before placed them on the baking/grilling rack. Aluminium foil is heated during the cooking process. The temperature of aluminium foil is near the temperature of the cooking equipment. The meats being cooked contact with aluminium foil sheet, and then aluminium foil will transfer heat to the meats by conduction. Conduction is a more effective way to transfer heat than convection (74). It was possible that the form of heat transfer in each type of heat cooking may influence aluminium leaching.

In this study, electric oven and electric grill stove are similar cooking temperature (200°C) and cooking time (60 min) as shown in Table 3.1, but the statistical result found that leached aluminium content into cooked meat from cooking by electric oven and electric grill stove was significantly different (p-value < 0.05). It was possible that the operation of each type of heat cooking (Appendix D) may cause aluminium leaching. It was observed that electric oven has a thermostat for control the cooking temperature when compared with electric grill stove. Whereas, electric grill stove has not a thermostat. Moreover, the electric power of electric oven and electric grill stove were 1350 W and 1500 W, respectively. It indicated that electric grill stove is higher heat transfer rate than electric oven. It was possible that cooking for a long time by electric grill stove may cause exceed the cooking temperature of 200°C because electric grill stove has not thermostat for control cooking temperature and it is also higher electric power than electric oven. Besides, the distance between heat source and the rack for placed the wrapped meat of each type of heat cooking was differed. The distance between heat source and the rack of electric oven and electric grill stove were 10 cm and 3 cm, respectively. The distance between heat source and the rack of electric grill stove was shorter than that of electric oven. It may promote the aluminium migration from aluminium foil into meats when cooking by electric grill stove more than cooking by electric oven. Therefore, it may possibly be that the different operation and function of electric oven and electric grill stove result in cooking meat by electric grill stove giving higher leached aluminium content than cooking meat by electric oven, which these causes may influence the aluminium migration from aluminium foil into cooked meats.

5.5 The comparison of leached aluminium contents into cooked meat (mg/kg) wrapped with aluminium foil by using different kinds of meat, use of seasoning, aluminium amounts in aluminium foil and types of heat cooking

This study was compared in terms of leached aluminium contents into cooked meat (mg/kg) by using different kinds of meat, use of seasoning, aluminium amounts in aluminium foil and types of heat cooking. The study results concern the comparisons of leached aluminium contents into cooked meat that cooking by four kinds of meat (seabass fish, saba fish, chicken and beef) without and with seasoning wrapping with two brands of aluminium foil (brand 1 – lower aluminium amount and brand 2 – higher aluminium amount) and cooked by three types of heat cooking (electric oven, electric grill stove and gas stove).

The analysis of variance showed the results for determining the interaction effect among the kind of meat, the use of seasoning, the aluminium amount in aluminium foil and the type of heat cooking on leached aluminium contents into cooked meats (mg/kg) wrapped with aluminium foil, that were significantly different (p-value < 0.05). It was concluded that among kinds of meat, use of seasoning, aluminium amounts in aluminium foil and types of heat cooking were interaction affect leached aluminium content into cooked meat (mg/kg). This result was agreement with the fifth hypothesis. The reasons of these different leached aluminium contents into cooked meat from four independent variables include the different kinds of meat have different fat contents of fresh meat that influencing on aluminium migration (27, 28); leached aluminium contents into cooked meat increased with the high amounts of aluminium in seasoning (spices and herbs) used for meat cooking (20, 23) and the presence of aggressive ions (chloride ions) in the seasoning (table salt and soy sauce) (65-66, 111); the chemical composition of aluminium foil influence on aluminium migration from aluminium foil into cooked meat that the presence of some element (e.g. Ti, Pb, Sn) causes to increase of leached aluminium contents into cooked meat (62); the different types of heat cooking have different cooking temperatures, cooking time, heat source, heat transfer, electric power and operation which they influence on aluminium increase in cooked meat (70, 73-74).

From the multiple comparisons results indicated that the lowest mean of leached aluminium content into cooked meat (0.148 mg/kg) was cooking by using seabass fish - without seasoning - wrapped with brand 1 (lower aluminium amount) of aluminium foil - by electric oven and non-significantly different from the mean of leached aluminium content into cooked meat (mg/kg) when cooking by using seabass fish - without seasoning - wrapped with brand 1 (lower aluminium amount) of aluminium foil - by electric grill stove and cooking by using saba fish - without seasoning - wrapped with brand 1 (lower aluminium amount) of aluminium foil - by electric oven at α level of 0.05. The result observed that leached aluminium contents from the cooking by using seabass fish without seasoning wrapped with brand 1 (lower aluminium amount) of aluminium foil was not significantly difference from the cooking by using saba fish without seasoning wrapped with brand 1 (lower aluminium amount) of aluminium foil, it may cause the fat levels of both fish were nearby more than the fat levels in chicken and beef. Therefore, cooking by using seabass fish and saba fish gave the lowest of leached aluminium content at same cooking condition. It could be suggested that the most suitable cooking condition for all cooking conditions is the cooking by using seabass fish or saba fish - without seasoning - wrapped with brand 1 (lower aluminium amount) of aluminium foil – heated by electric oven.

However, the cooking by using beef - with seasoning - wrapped with brand 2 (higher aluminium amount) of aluminium foil cooked - by gas stove was the highest mean of leached aluminium contents into cooked meat (8.573 mg/kg) and this condition significantly different from others at α level of 0.05. Therefore, the cooking by using beef - with seasoning - wrapped with brand 2 (higher aluminium amount) of aluminium foil cooked - by gas stove was not suitable for cooking because it gave the highest leached aluminium content. According to the JECFA that set the provisional tolerable weekly intake (PTWI) is 1 mg/kg body weight for aluminium from all sources including food additives (40). Although, the results indicated that aluminium contents from cooking meats by wrapping with aluminium foil does not exceed the intake limit and does not cause immediate impairment to human health, it can be accumulated in the body - which in a long time it may cause illness or impairment. This study could be concluded about the most suitable cooking condition in each kind of meat for use of aluminium foil as follows.

For cooking by using seabass fish, the most suitable cooking condition was the cooking without seasoning - wrapped with brand 1 (lower aluminium amount) of aluminium foil - by electric oven or electric grill stove.

For cooking by using saba fish, the most suitable cooking condition was the cooking without seasoning - wrapped with brand 1 (lower aluminium amount) of aluminium foil - by electric oven.

For cooking by using chicken, the most suitable cooking condition was the cooking without seasoning - wrapped with brand 1 (lower aluminium amount) of aluminium foil - by electric oven or electric grill stove.

For cooking by using beef, the most suitable cooking condition was the cooking without seasoning - wrapped with brand 1 (lower aluminium amount) of aluminium foil - by electric oven or electric grill stove.

CHAPTER VI
CONCLUSION AND RECOMMENDATION

This study aimed to determine the effect of four influencing factors in leached aluminium content into cooked meat wrapped with aluminium foil for guide to suitable condition for safety of consumer. Those factors were kinds of meat, seasoning, aluminium amounts in aluminium foil and types of heat cooking. The study results could be concluded and recommended in this chapter as follows.

6.1 Conclusion

6.1.1 Leached aluminium contents into cooked meats (mg/kg) wrapped with aluminium foil by using different kinds of meat

This finding showed that the cooking by using different kinds of meat influenced the difference of leached aluminium content into cooked meat. The mean leached aluminium contents ranged from 0.149 to 4.093 mg/kg in seabass fish, 0.188 to 5.739 mg/kg in saba fish, 0.315 to 6.018 mg/kg in chicken and 0.407 to 8.573 mg/kg in beef. In all samples, the highest value (8.573 mg/kg) of leached aluminium content into cooked meat were observed in the cooking by using beef, the lowest value (0.149 mg/kg) in the cooking by using seabass fish. Finally, the result can be concluded that the different kinds of meat affected to different leached aluminium content. Moreover, it was found that leached aluminium content into cooked meat also depended on fat content of fresh meat as the cooking by using the higher fatty meat had higher leached aluminium content than the lower fatty meat.

6.1.2 Leached aluminium contents into cooked meats (mg/kg) wrapped with aluminium foil by using different use of seasoning

This finding showed that the cooking meat with seasoning influenced the increasing of leached aluminium content into cooked meat. The mean leached aluminium contents ranged from 0.149 to 2.325 mg/kg when cooking without seasoning and 1.412 to 8.573 mg/kg when cooking with seasoning. Finally, the result can be concluded that the cooking meat with seasoning affected to higher leached aluminium content than the cooking meat without seasoning.

6.1.3 Leached aluminium contents into cooked meats (mg/kg) wrapped with aluminium foil by using different aluminium amounts in aluminium foil

This finding showed that the high amount of aluminium in aluminium foil influenced the increasing of leached aluminium content into cooked meat. The mean leached aluminium contents ranged from 0.149 to 3.683 mg/kg when wrapping with brand 1 (lower aluminium amount) of aluminium foil and 0.635 to 8.573 mg/kg when wrapping with brand 2 (higher aluminium amount) of aluminium foil. Finally, the result can be concluded that the higher aluminium amount in aluminium foil affected to higher leached aluminium content than the lower aluminium amount in aluminium foil.

6.1.4 Leached aluminium contents into cooked meats (mg/kg) wrapped with aluminium foil by using different types of heat cooking

This finding showed that the cooking meat by using different types of heat cooking influenced the difference of leached aluminium content into cooked meat. The mean leached aluminium contents ranged from 0.149 to 4.436 mg/kg when cooking by electric oven, 0.193 to 6.951 mg/kg when cooking by electric grill stove and 0.301 to 8.573 mg/kg when cooking by gas stove. In all samples, the highest value (8.573 mg/kg) of leached aluminium content into cooked meat were observed in the cooking by gas stove, the lowest value (0.149 mg/kg) in the cooking by electric oven. Finally, the result can be concluded that the different types of heat cooking affected to different leached aluminium content.

6.1.5 Leached aluminium contents into cooked meats (mg/kg) wrapped with aluminium foil by using different kinds of meat, use of seasoning, aluminium amounts in aluminium foil and types of heat cooking

This finding found that the kind of meat, use of seasoning, aluminium amount in aluminium foil and type of heat cooking co-operatively influenced the leached aluminium content into cooked meat. This study result showed that leached aluminium content when cooking meat with seasoning increased clearly in every kinds of meat when compared to without seasoning. Furthermore, the cooking by using aluminium foil with the high amount of aluminium was too increased when compared with aluminium foil with the low amount of aluminium. Besides, leached aluminium content also depended on the type of heat cooking. It was found that the cooking by gas stove have higher leached aluminium content than other types of heat cooking. Thus, the cooking meat with seasoning wrapped with brand 2 (higher initial aluminium amount) of aluminium foil by gas stove gave the highest leached aluminium content when using the same kind of meat. However, the cooking meat with seasoning is commonly used for cooking methods particularly in Thai cooking methods. Therefore, this study could be recommended the cooking meat should be use aluminium foil with the low amount of aluminium foil (brand 1) by electric oven because this condition was the lowest value of leached aluminium content into cooked meat (mg/kg) for all kinds of meat, both with and without seasoning.

6.2 Recommendation

6.2.1 Recommendation of research methodology

This study was analyzed in terms of aluminium content by using the flame atomic absorption spectrophotometer method which is lower accuracy and had restricted such as when compare with the graphite furnace atomic absorption spectrophotometer method. This study was the validity control. The error controls were done in the part of samples collection, cooking material preparation and sampling method.

6.2.2 Recommendation for further study

The following aspects are recommended for further study.

1. The other chemical compositions of the meats (except fat content in fresh meat) need to further study to evaluate aluminium exposure of human.

2. The presence of other elements in aluminium foil such as iron (Fe), chromium (Cr), lead (Pb), sodium (Na) is still questionable. So it needs to study them on leaching of aluminium into food.

3. The meat wrapped with aluminium foil and grilling on the charcoal or charcoal stoves is very popular cooking method by the street venders should be studied on aluminium leaching.

6.2.3 Recommendation as research application

This study can be applied for the suggestion in appropriate use of aluminium foil which the result showed that the mostly case of cooking meat without seasoning - by using aluminium foil with the low amount of aluminium for wrapping foods - in electric oven gave the lowest leached aluminium content into cooked meat for all kinds of meat. The most suitable cooking condition for seabass fish, chicken and beef is the cooking meat without seasoning wrapped with brand 1 - lower initial aluminium amount in aluminium foil - heated by electric oven or electric grill stove. The most suitable cooking condition for saba fish is the cooking meat without seasoning wrapped with brand 1 - lower initial aluminium amount in aluminium foil - heated by electric oven. Whereas the cooking meat with seasoning, wrapped with brand 2 - higher aluminium amount in aluminium foil - and heated by gas stove was the highest mean of leached aluminium contents into cooked meat for all kinds of meat. In addition, one should beware of ingredients of the black pepper that contained high amounts of aluminium, which added especially in specific dish. Although, the results indicated that aluminium contents from cooking meats by wrapping with aluminium foil was not exceed the provisional tolerable weekly intake (PTWI) limit as 1 mg/kg body weight, for a long time aluminium can be accumulated in the human body and this reason may cause impairment of consumer.

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APPENDICES

APPENDIX A
THE DATA OF EXPERIMENT

Table A-1 Aluminium contents (mg/kg) of seabass fish both before and after cooking between with and without seasonings, aluminium amounts in aluminium foil and types of heat cooking

Use of seasonings				Without seasonings		With seasonings	
Aluminium amounts in aluminium foil				Brand 1 (lower amount)	Brand 2 (higher amount)	Brand 1 (lower amount)	Brand 2 (higher amount)
Types of heat cooking	Electric oven	Sample 1	1	9.860 (9.614)	10.148 (9.614)	11.040 (9.622)	12.534 (9.625)
			2	9.652 (9.638)	10.108 (9.638)	11.056 (9.620)	12.710 (9.611)
			3	9.785 (9.609)	10.184 (9.609)	11.020 (9.613)	12.656 (9.615)
		Sample 2	1	9.647 (9.624)	10.399 (9.624)	11.059 (9.616)	12.501 (9.619)
			2	9.651 (9.620)	10.413 (9.620)	11.018 (9.636)	12.421 (9.619)
			3	9.665 (9.626)	10.411 (9.626)	11.052 (9.610)	12.531 (9.626)
		Sample 3	1	9.973 (9.636)	10.236 (9.636)	11.013 (9.623)	12.416 (9.619)
			2	9.775 (9.613)	10.215 (9.613)	11.025 (9.633)	12.407 (9.636)
			3	9.940 (9.630)	10.212 (9.630)	11.004 (9.610)	12.499 (9.604)
		Total		**9.772 (9.623)**	**10.258 (9.623)**	**11.032 (9.620)**	**12.519 (9.619)**
	Electric grill stove	Sample 1	1	9.883 (9.614)	10.182 (9.622)	11.586 (9.622)	12.993 (9.625)
			2	9.792 (9.638)	10.311 (9.620)	11.683 (9.620)	13.013 (9.611)
			3	10.031 (9.609)	10.246 (9.613)	11.709 (9.613)	13.010 (9.615)
		Sample 2	1	9.757 (9.624)	10.360 (9.616)	11.585 (9.616)	13.340 (9.619)
			2	9.877 (9.620)	10.380 (9.636)	11.673 (9.636)	13.441 (9.619)
			3	10.038 (9.626)	10.609 (9.610)	11.477 (9.610)	13.430 (9.626)
		Sample 3	1	9.686 (9.636)	10.399 (9.623)	11.879 (9.623)	13.611 (9.619)
			2	9.643 (9.613)	10.315 (9.633)	11.790 (9.633)	13.423 (9.636)
			3	9.636 (9.630)	10.246 (9.610)	11.476 (9.610)	13.659 (9.604)
		Total		**9.816 (9.623)**	**10.339 (9.620)**	**11.651 (9.620)**	**13.324 (9.619)**

Values are aluminium contents in seabass fish.
Different values in the parenthesis indicate aluminium contents of seabass fish before cooking (fresh meat).
Different values out the parenthesis indicate aluminium contents of seabass fish after cooking (cooked meat).

Table A-1 Aluminium contents (mg/kg) of seabass fish both before and after cooking between with and without seasonings, aluminium amounts in aluminium foil and types of heat cooking (Cont.)

Use of seasonings				Without seasonings		With seasonings	
Aluminium amounts in aluminium foil				Brand 1 (lower amount)	Brand 2 (higher amount)	Brand 1 (lower amount)	Brand 2 (higher amount)
Types of heat cooking	Gas stove	Sample 1	1	9.956 (9.630)	10.890 (9.630)	11.871 (9.630)	13.886 (9.625)
			2	9.934 (9.628)	10.738 (9.628)	11.740 (9.628)	14.079 (9.611)
			3	9.968 (9.633)	10.936 (9.633)	11.696 (9.633)	13.640 (9.615)
		Sample 2	1	9.924 (9.614)	10.841 (9.614)	11.998 (9.614)	13.756 (9.619)
			2	9.944 (9.594)	10.606 (9.594)	11.980 (9.594)	13.707 (9.619)
			3	9.869 (9.616)	10.777 (9.616)	11.993 (9.616)	13.705 (9.626)
		Sample 3	1	9.906 (9.624)	10.896 (9.624)	11.770 (9.624)	13.563 (9.619)
			2	9.926 (9.638)	11.044 (9.638)	11.814 (9.638)	13.479 (9.636)
			3	9.896 (9.635)	11.125 (9.635)	11.693 (9.635)	13.595 (9.604)
		Total		**9.925 (9.624)**	**10.873 (9.624)**	**11.839 (9.624)**	**13.712 (9.619)**

Values are aluminium contents in seabass fish.
Different values in the parenthesis indicate aluminium contents of seabass fish before cooking (fresh meat).
Different values out the parenthesis indicate aluminium contents of seabass fish after cooking (cooked meat).

Table A-2 Aluminium contents (mg/kg) of saba fish both before and after cooking between with and without seasonings, aluminium amounts in aluminium foil and types of heat cooking

Use of seasonings				Without seasonings		With seasonings	
Aluminium amounts in aluminium foil				Brand 1 (lower amount)	Brand 2 (higher amount)	Brand 1 (lower amount)	Brand 2 (higher amount)
Types of heat cooking	Electric oven	Sample 1	1	3.317 (3.089)	3.906 (3.096)	4.720 (3.087)	5.997 (3.092)
			2	3.291 (3.092)	3.895 (3.076)	4.733 (3.072)	6.035 (3.090)
			3	3.315 (3.083)	3.882 (3.084)	4.740 (3.101)	6.025 (3.085)
		Sample 2	1	3.097 (3.093)	3.882 (3.098)	4.754 (3.080)	6.010 (3.083)
			2	3.109 (3.092)	3.892 (3.086)	4.750 (3.086)	6.009 (3.093)
			3	3.101 (3.095)	3.892 (3.087)	4.746 (3.090)	6.008 (3.095)
		Sample 3	1	3.398 (3.073)	3.888 (3.079)	4.746 (3.095)	5.993 (3.086)
			2	3.420 (3.074)	3.910 (3.096)	4.749 (3.081)	5.984 (3.085)
			3	3.431 (3.088)	3.913 (3.091)	4.740 (3.074)	5.984 (3.082)
		Total		**3.275 (3.087)**	**3.896 (3.088)**	**4.742 (3.085)**	**6.005 (3.088)**
	Electric grill stove	Sample 1	1	3.399 (3.089)	4.056 (3.096)	5.192 (3.087)	8.174 (3.092)
			2	3.347 (3.092)	4.075 (3.076)	5.188 (3.072)	8.186 (3.090)
			3	3.382 (3.083)	4.072 (3.084)	5.202 (3.101)	8.204 (3.085)
		Sample 2	1	3.385 (3.093)	4.018 (3.098)	5.229 (3.080)	8.177 (3.083)
			2	3.356 (3.092)	4.012 (3.086)	5.248 (3.086)	8.170 (3.093)
			3	3.385 (3.095)	4.014 (3.087)	5.258 (3.090)	8.172 (3.095)
		Sample 3	1	3.374 (3.073)	4.032 (3.079)	5.226 (3.095)	8.172 (3.086)
			2	3.353 (3.074)	4.025 (3.096)	5.233 (3.081)	8.175 (3.085)
			3	3.355 (3.088)	4.022 (3.091)	5.231 (3.074)	8.172 (3.082)
		Total		**3.371 (3.087)**	**4.036 (3.088)**	**5.223 (3.085)**	**8.178 (3.088)**
	Gas stove	Sample 1	1	3.434 (3.089)	4.099 (3.096)	5.558 (3.087)	8.828 (3.092)
			2	3.434 (3.092)	4.092 (3.076)	5.564 (3.072)	8.827 (3.090)
			3	3.400 (3.083)	4.093 (3.084)	5.561 (3.101)	8.817 (3.085)
		Sample 2	1	3.411 (3.093)	4.343 (3.098)	5.560 (3.080)	8.827 (3.083)
			2	3.416 (3.092)	4.330 (3.086)	5.551 (3.086)	8.828 (3.093)
			3	3.411 (3.095)	4.323 (3.087)	5.554 (3.090)	8.832 (3.095)
		Sample 3	1	3.361 (3.073)	4.217 (3.079)	5.532 (3.095)	8.830 (3.086)
			2	3.361 (3.074)	4.225 (3.096)	5.536 (3.081)	8.825 (3.085)
			3	3.368 (3.088)	4.203 (3.091)	5.543 (3.074)	8.829 (3.082)
		Total		**3.400 (3.087)**	**4.214 (3.088)**	**5.551 (3.085)**	**8.827 (3.088)**

Values are aluminium contents in saba fish.
Different values in the parenthesis indicate aluminium contents of saba fish before cooking (fresh meat).
Different values out the parenthesis indicate aluminium contents of saba fish after cooking (cooked meat).

Table A-3 Aluminium contents (mg/kg) of chicken both before and after cooking between with and without seasonings, aluminium amounts in aluminium foil and types of heat cooking

Use of seasonings				Without seasonings		With seasonings	
Aluminium amounts in aluminium foil				Brand 1 (lower amount)	Brand 2 (higher amount)	Brand 1 (lower amount)	Brand 2 (higher amount)
Types of heat cooking	Electric oven	Sample 1	1	3.451 (3.128)	4.062 (3.127)	5.011 (3.133)	6.301 (3.138)
			2	3.446 (3.132)	4.052 (3.131)	5.010 (3.128)	6.287 (3.131)
			3	3.432 (3.134)	4.048 (3.130)	5.013 (3.131)	6.296 (3.146)
		Sample 2	1	3.415 (3.128)	4.059 (3.140)	5.017 (3.128)	6.305 (3.124)
			2	3.454 (3.140)	4.050 (3.125)	5.016 (3.138)	6.297 (3.142)
			3	3.456 (3.131)	4.051 (3.134)	5.011 (3.129)	6.293 (3.143)
		Sample 3	1	3.454 (3.128)	4.070 (3.145)	5.019 (3.110)	6.284 (3.120)
			2	3.449 (3.133)	4.067 (3.119)	5.020 (3.135)	6.294 (3.130)
			3	3.450 (3.116)	4.059 (3.128)	5.010 (3.126)	6.281 (3.126)
		Total		**3.445 (3.130)**	**4.058 (3.131)**	**5.014 (3.128)**	**6.293 (3.133)**
	Electric grill stove	Sample 1	1	3.483 (3.128)	4.569 (3.127)	5.309 (3.133)	8.408 (3.138)
			2	3.430 (3.132)	4.566 (3.131)	5.316 (3.128)	8.410 (3.131)
			3	3.517 (3.134)	4.559 (3.130)	5.326 (3.131)	8.409 (3.146)
		Sample 2	1	3.486 (3.128)	4.555 (3.140)	5.316 (3.128)	8.424 (3.124)
			2	3.499 (3.140)	4.566 (3.125)	5.333 (3.138)	8.432 (3.142)
			3	3.446 (3.131)	4.581 (3.134)	5.329 (3.129)	8.401 (3.143)
		Sample 3	1	3.496 (3.128)	4.583 (3.145)	5.325 (3.110)	8.425 (3.120)
			2	3.459 (3.133)	4.578 (3.119)	5.331 (3.135)	8.408 (3.130)
			3	3.491 (3.116)	4.567 (3.128)	5.324 (3.126)	8.411 (3.126)
		Total		**3.479 (3.130)**	**4.569 (3.131)**	**5.323 (3.128)**	**8.414 (3.133)**
	Gas stove	Sample 1	1	3.600 (3.128)	4.876 (3.127)	5.686 (3.133)	9.156 (3.138)
			2	3.610 (3.132)	4.865 (3.131)	5.699 (3.128)	9.151 (3.131)
			3	3.616 (3.134)	4.873 (3.130)	5.685 (3.131)	9.154 (3.146)
		Sample 2	1	3.628 (3.128)	4.863 (3.140)	5.703 (3.128)	9.153 (3.124)
			2	3.615 (3.140)	4.868 (3.125)	5.690 (3.138)	9.149 (3.142)
			3	3.616 (3.131)	4.869 (3.134)	5.708 (3.129)	9.140 (3.143)
		Sample 3	1	3.604 (3.128)	4.872 (3.145)	5.702 (3.110)	9.150 (3.120)
			2	3.621 (3.133)	4.876 (3.119)	5.688 (3.135)	9.148 (3.130)
			3	3.616 (3.116)	4.857 (3.128)	5.696 (3.126)	9.155 (3.126)
		Total		**3.614 (3.130)**	**4.869 (3.131)**	**5.695 (3.128)**	**9.151 (3.133)**

Values are aluminium contents in chicken.
Different values in the parenthesis indicate aluminium contents of chicken before cooking (fresh meat).
Different values out the parenthesis indicate aluminium contents of chicken after cooking (cooked meat).

Table A-4 Aluminium contents (mg/kg) of beef both before and after cooking between with and without seasonings, aluminium amounts in aluminium foil and types of heat cooking

Use of seasonings				Without seasonings		With seasonings	
Aluminium amounts in aluminium foil				Brand 1 (lower amount)	Brand 2 (higher amount)	Brand 1 (lower amount)	Brand 2 (higher amount)
Types of heat cooking	Electric oven	Sample 1	1	4.349 (3.956)	5.245 (3.937)	6.336 (3.929)	8.386 (3.951)
			2	4.376 (3.942)	5.261 (3.953)	6.347 (3.932)	8.388 (3.938)
			3	4.342 (3.956)	5.262 (3.937)	6.338 (3.967)	8.364 (3.940)
		Sample 2	1	4.362 (3.962)	5.260 (3.954)	6.342 (3.957)	8.374 (3.935)
			2	4.354 (3.958)	5.246 (3.945)	6.337 (3.938)	8.379 (3.939)
			3	4.369 (3.924)	5.259 (3.941)	6.333 (3.945)	8.382 (3.937)
		Sample 3	1	4.349 (3.955)	5.243 (3.946)	6.453 (3.949)	8.365 (3.943)
			2	4.353 (3.941)	5.259 (3.952)	6.335 (3.943)	8.377 (3.938)
			3	4.347 (3.950)	5.235 (3.941)	6.337 (3.939)	8.366 (3.942)
		Total		**4.356 (3.949)**	**5.252 (3.945)**	**6.351 (3.944)**	**8.376 (3.940)**
	Electric grill stove	Sample 1	1	4.418 (3.956)	5.952 (3.937)	6.945 (3.929)	10.900 (3.951)
			2	4.408 (3.942)	5.977 (3.953)	6.936 (3.932)	10.897 (3.938)
			3	4.394 (3.956)	5.954 (3.937)	6.941 (3.967)	10.888 (3.940)
		Sample 2	1	4.415 (3.962)	5.968 (3.954)	6.936 (3.957)	10.895 (3.935)
			2	4.400 (3.958)	5.961 (3.945)	6.947 (3.938)	10.879 (3.939)
			3	4.396 (3.924)	5.956 (3.941)	6.942 (3.945)	10.896 (3.937)
		Sample 3	1	4.414 (3.955)	5.954 (3.946)	6.950 (3.949)	10.879 (3.943)
			2	4.415 (3.941)	5.947 (3.952)	6.951 (3.943)	10.880 (3.938)
			3	4.411 (3.950)	5.957 (3.941)	6.944 (3.939)	10.902 (3.942)
		Total		**4.408 (3.949)**	**5.958 (3.945)**	**6.944 (3.944)**	**10.891 (3.940)**
	Gas stove	Sample 1	1	5.021 (3.956)	6.260 (3.937)	7.615 (3.929)	12.509 (3.951)
			2	5.022 (3.942)	6.277 (3.953)	7.624 (3.932)	12.512 (3.938)
			3	5.006 (3.956)	6.275 (3.937)	7.631 (3.967)	12.517 (3.940)
		Sample 2	1	5.025 (3.962)	6.267 (3.954)	7.628 (3.957)	12.506 (3.935)
			2	5.012 (3.958)	6.279 (3.945)	7.635 (3.938)	12.512 (3.939)
			3	5.014 (3.924)	6.275 (3.941)	7.635 (3.945)	12.514 (3.937)
		Sample 3	1	5.003 (3.955)	6.269 (3.946)	7.618 (3.949)	12.519 (3.943)
			2	5.009 (3.941)	6.262 (3.952)	7.628 (3.943)	12.509 (3.938)
			3	5.017 (3.950)	6.267 (3.941)	7.632 (3.939)	12.521 (3.942)
		Total		**5.014 (3.949)**	**6.270 (3.945)**	**7.627 (3.944)**	**12.513 (3.940)**

Values are aluminium contents in beef.
Different values in the parenthesis indicate aluminium contents of beef before cooking (fresh meat).
Different values out the parenthesis indicate aluminium contents of beef after cooking (cooked meat).

Table A-5 Lipid contents in fresh meat (%)

Kinds of meat	Rep.	Weights of meat sample (g)	Weights of Extraction Flask (g)		Lipid contents in fresh meat (%)	Mean ± SD
			Before	After		
Seabass fish	1	2.017	111.639	111.642	0.119	0.121 ± 0.003
	2	2.017	108.335	108.337	0.119	
	3	2.017	107.880	107.882	0.124	
Saba fish	1	2.055	110.512	110.562	2.443	2.445 ± 0.008
	2	2.055	109.931	109.981	2.438	
	3	2.055	108.673	108.723	2.453	
Chicken	1	2.054	105.512	105.595	4.055	4.057 ± 0.003
	2	2.056	106.632	106.716	4.056	
	3	2.057	107.564	107.647	4.060	
Beef	1	2.287	106.645	106.802	6.856	6.859 ± 0.005
	2	2.287	105.835	105.992	6.864	
	3	2.287	108.318	108.475	6.856	

Table A- 6 Aluminium amounts in aluminium foil (%)

Aluminium foil	Rep.	Aluminium amount in Al foil (mg/kg)	Aluminium amount in Al foil (% w/w)	Mean ± SD
Brand 1 (lower Al amount)	1	701499.014	71.132	69.483 ± 1.050
	2	686688.055	69.562	
	3	691672.139	69.513	
	4	683231.647	68.870	
	5	678635.551	68.339	
Brand 2 (higher Al amount)	1	869984.293	83.084	83.419 ± 1.101
	2	867598.429	82.769	
	3	884981.656	84.516	
	4	890623.684	84.609	
	5	859877.933	82.118	

Table A- 7 Aluminium contents of seasonings (mg/kg)

Seasonings	Replication	Aluminium contents (mg/kg)	Mean ± SD
Garlic, crushed	1	1.906	1.980 ± 0.081
	2	2.066	
	3	1.967	
Table salt	1	1.964	1.965 ± 0.080
	2	1.885	
	3	2.045	
Soy sauce	1	34.235	34.628 ± 0.428
	2	34.565	
	3	35.084	
Black pepper	1	162.444	171.403 ± 8.186
	2	173.272	
	3	178.492	

Table A- 8 The pH values of fresh meat and cooked meat at different cooking conditions

Use of seasonings	Aluminium amounts in aluminium foil	Types of heat cooking	Kinds of meat [a, b]			
			Seabass fish	Saba fish	Chicken	Beef
Without seasonings	Brand 1 (lower Al amount)	Electric oven	5.96 (5.87)	6.07 (5.90)	6.20 (6.05)	5.72 (5.60)
		Electric grill stove	5.93 (5.87)	6.07 (5.90)	6.24 (6.05)	5.92 (5.60)
		Gas stove	5.89 (5.87)	6.05 (5.90)	6.28 (6.05)	5.79 (5.60)
	Brand 2 (higher Al amount)	Electric oven	6.01 (5.89)	6.00 (5.92)	6.20 (6.05)	5.86 (5.62)
		Electric grill stove	6.01 (5.89)	6.01 (5.92)	6.26 (6.05)	5.94 (5.62)
		Gas stove	5.94 (5.89)	6.08 (5.92)	6.22 (6.05)	5.92 (5.62)
With seasonings	Brand 1 (lower Al amount)	Electric oven	6.01 (5.92)	6.04 (5.95)	6.27 (6.07)	5.94 (5.82)
		Electric grill stove	6.01 (5.92)	6.08 (5.95)	6.22 (6.07)	5.92 (5.82)
		Gas stove	6.03 (5.92)	6.06 (5.95)	6.28 (6.07)	5.86 (5.82)
	Brand 2 (higher Al amount)	Electric oven	5.97 (5.92)	6.07 (5.96)	6.27 (6.07)	5.86 (5.82)
		Electric grill stove	5.98 (5.92)	6.04 (5.96)	6.20 (6.07)	5.94 (5.82)
		Gas stove	5.97 (5.92)	6.07 (5.96)	6.25 (6.07)	5.92 (5.82)

Values are Means of three replications.
[a] Different values in the parenthesis indicate pH value of meat before cooking (fresh meat).
[b] Different values out the parenthesis indicate pH value of meat after cooking (cooked meat).

APPENDIX B
STATISTICAL ANALYSIS

The results of factorial ANOVA test at a significance level of 0.05

Tests of between-subjects effects

Dependent variable: Leached aluminium contents into cooked meat

Source of Variation	SS	df	MS	F	Sig.
CORRECTED MODEL	1611.779 [a]	47	34.293	5945.808	.000
INTERCEPT	2117.098	1	2117.098	367066.058	.000
MEAT	118.577	3	39.526	6853.017	.000
SEASONING	836.230	1	836.230	144987.055	.000
AMOUNT	329.694	1	329.694	57162.889	.000
COOKING	97.267	2	48.633	8432.153	.000
MEAT * SEASONING	27.369	3	9.123	1581.744	.000
MEAT * AMOUNT	22.380	3	7.460	1293.440	.000
MEAT * COOKING	11.567	6	1.928	334.265	.000
SEASONING * AMOUNT	78.638	1	78.638	13634.406	.000
SEASONING * COOKING	34.815	2	17.408	3018.175	.000
AMOUNT * COOKING	25.226	2	12.613	2186.878	.000
MEAT * SEASONING * AMOUNT	6.330	3	2.110	365.857	.000
MEAT * SEASONING * COOKING	4.019	6	.670	116.133	.000
MEAT * AMOUNT * COOKING	4.902	6	.817	141.648	.000
SEASONING * AMOUNT * COOKING	10.252	2	5.126	888.797	.000
MEAT * SEASONING * AMOUNT * COOKING	4.511	6	.752	130.358	.000
ERROR	2.215	384	.006		
TOTAL	3731.091	432			
CORRECTED TOTAL	1613.993	431			

[a] R Squared = .999 (Adjusted R Squared = .998); SS: Sum of squares; MS: Mean of squares

T-test

Independent Samples Test of use of seasonings at a significance level of 0.05

		T-test for Equality of Means		Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
		t	df				Lower	Upper
Leached aluminium content	Equal variances assumed	-21.502	430	3.632E-70	-2.783	0.129	-3.037	-2.528

Independent Samples Test of aluminium amounts in aluminium foil at a significance level of 0.05

		T-test for Equality of Means		Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
		t	df				Lower	Upper
Leached aluminium content	Equal variances assumed	-10.506	430	3.894E-23	-1.747	0.166	-2.074	-1.420

APPENDIX C
PHOTOGRAPHS OF EXPERIMENT

Figure C-1 Flame Atomic Absorption Spectrophotometer

Figure C-2 Microwave Digestion System

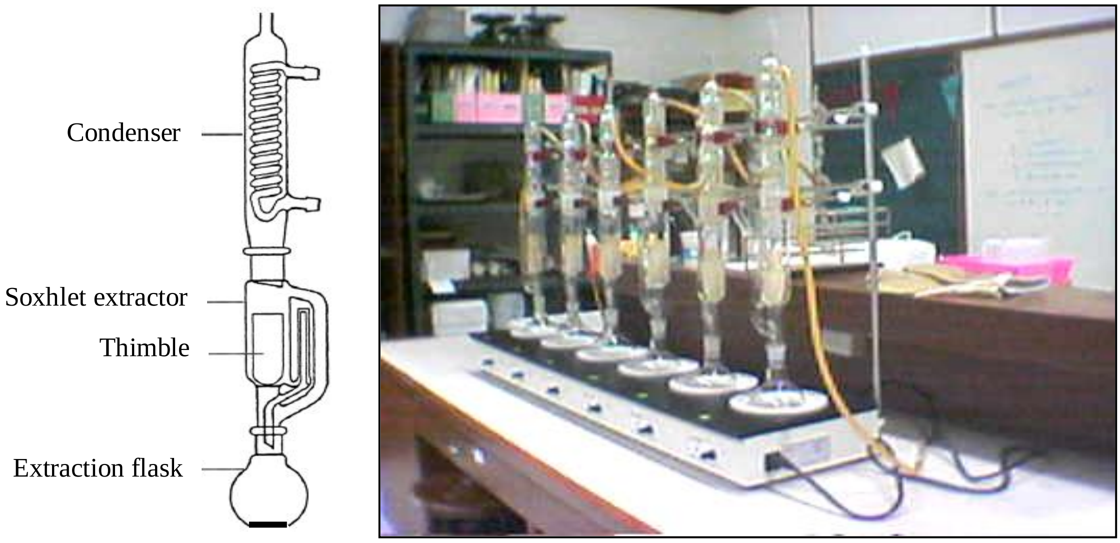

Figure C-3 Soxhlet Extraction System

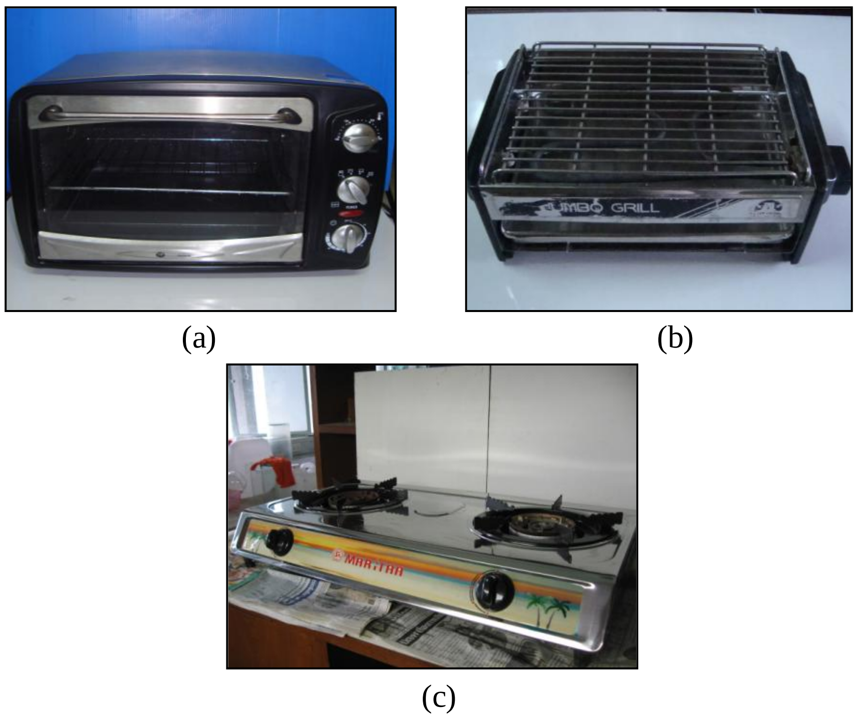

Figure C-4 Types of heat cooking used in the experiment including (a) electric oven, (b) electric grill stove and (c) gas stove

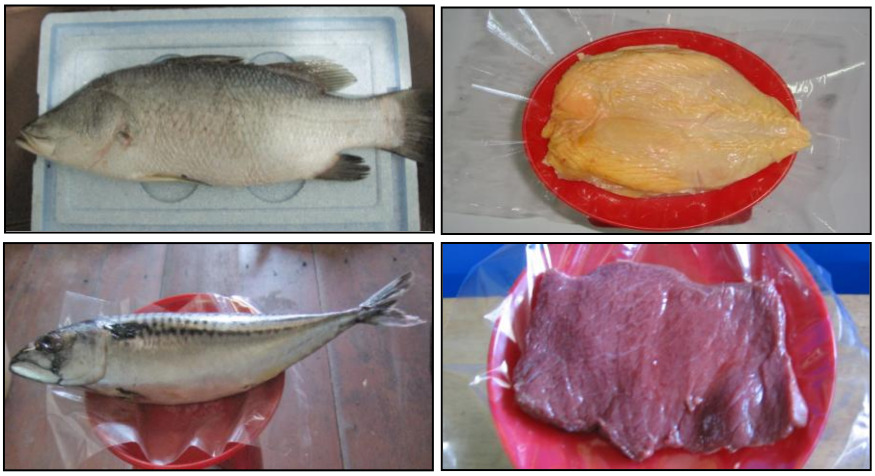

Figure C-5 Meats and seasonings used in the experiment

Figure C-6 Aluminium foil used in the experiment

APPENDIX D
THE PRINCIPLE OPERATION OF EACH TYPE OF HEAT COOKING

1) Electric oven

Electric oven used in this study as an oven of the Alfa Kitch brand, model EOV-19RC/S (1350W), made in China. Electric oven has several dials on the exterior which is used to operate the oven. A thermostat to regulate the temperature of the oven is located in the temperature control dial. There is also a time/clock control dial. Upon opening an electric oven, there will be baking rack, a top heating element and a bottom heating element. Moreover, it was also measured the distance between the heat element and the baking rack approximately 10 cm.

Thermostat is the part of the oven as electric model that is attached to a long probe extending into the oven. The thermostat is wired to a small circuit board inside the oven that controls the heat source. This component monitors the interior temperature of the oven, turning on and shutting off the heat source according the temperature setting. When the probe senses that the oven has reached the correct temperature, it sends a signal to the thermostat's circuit board. That signal tells the oven to turn off the electric burners heating it.

The temperature control dial is used to set the cooking temperature required for a specific dish. This study set cooking temperature of 200°C. The temperature control is connected to the oven by a copper wire. When this control is turned on to a specific temperature, the heating element of the oven begins to heat until it reaches the designated temperature, at which point it will turn off. When the temperature has decreased, the oven will heat again to the desired temperature. The oven can turn the desired heating element dial. In this study, the selected heating element dial for baking is function controlled by heat from both top and bottom heating element sides. When the oven knob is turned on position and the thermostat set to a temperature, electricity flows to the heating element. After the element is heated to the desired temperature, electricity flows in an on-off pattern to maintain a constant temperature.

The time control dial can be set like a normal clock. The timer dial is used to set the amount of cooking time required for a particular dish. This study set cooking time of 60 min. At the end of the time, a buzzer will sound and the heating element will shut off.

2) Electric grill stove

Electric grill stove used in this study as a grill stove of Kuma Denki brand, model 150-OAP (1500W), made in Thailand. It has spiral coil shaped burner on top and heat producing element for grilling inside. There are grilling rack and a tray. This grill stove has not the turn on-off knob, it starts when plug the grill stove. It does not have a thermostat control, so when it is turned on, it heats up swiftly. There is not a time control dial. Moreover, the distance between the heat source element and the rack in this electric grill stove is approximately 3 cm.

This study controls the initial cooking temperature of the electric grill stove by a thermocouple. The initial cooking temperature of the electric grill stove is approximately 200°C. The cooking time (60 min) was controlled by a stop watch.

3) Gas stove

Gas stove used in this study as a gas stove of Marritaa brand, made in Thailand. It used liquefied petroleum gas (LPG) as a fuel source. A gas stove with a standing pilot continuously burning gas flame under the cooktop called a pilot flame. When the gas stove is turned on, this flame lights the gas flowing out of the burners. This study uses the grilling rack for place the wrapped meat. When place the rack on the cooktop, it found the distance between the heat source and the grilling rack is about 4 cm. Moreover, the study controlled the initial cooking temperature of gas stove about 300°C by a thermocouple and take cooking time of 20 min by a stop watch.

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