CHAPTER 2

Literature review

2.1 Salt and sodium consumption

Salt, common salt or table salt, also known as sodium chloride, is a mineral substance consisting mainly of two elements; 40% the cation sodium (Na^+) and 60% anion chloride (Cl^-( ) Bureau of Nutrition, Department of Health, 2011(. Salt is the major source of dietary sodium in the diet (approximately 90%). The conversion of sodium and salt as: 1 g sodium = 2.5 g salt and 1 g salt = 0.4 g sodium (He and Macgregor, 2010). Generally, the term of salt means sodium chloride in many countries. The vast majority of sodium in processed and restaurant food comes from salt/sodium chloride. In Thailand, main sodium intake of Thai people comes from salty taste condiments such as fish sauce, soy sauce and other sauces. So the words “salt” and “sodium” are not exactly the same, hence consumer should understand the relationship of salt, sodium and health risk from excess sodium intake (Bureau of Nutrition, Department of Health, 2011).

Salt is one of the few beneficial and abundant minerals on earth. Nowadays, three widely methods are used to produce salt. The oldest salt production is solar evaporation method from sea water and inland brine. Seawater contains salt between 30 and 40 g/L. Other salt are obtained by deep-shaft mining and solution mining methods. Salt is produced by solution mining method is used as table salt (Ertem et al., 2001). Table salt provides a variety of benefits for human life. In food product, functionality of salt can be roughly divided into three categories (Table 2.1). First, salt has been used as food preservative since ancient times due to water activity (a_w) reduction. Second, salt plays an important part in the development of physical properties of foods that are useful for processing or developing final food product qualities. Finally, it is also used to heighten and modify the food flavor and to decrease the sense of bitterness in some foods (Hutton, 2002).

Table 2.1 Role of sodium in food products

Main functionality of sodium in foods	Details
Food preservative	• Reduce water activity • Extend shelf life • Help prevent growth of bacteria and other disease-causing agent
Improvement of physical properties of foods	• Enhance color • Enhance water holding capacity and yield after cooking in processed meat products • Stabilize texture of some products
Food flavor enhancement	• Provide salty taste • Enhance other flavors within products • Increase palatability of foods • Mask off notes including bitterness, and off tastes.

Source: Hutton (2002)

For human body, sodium chloride is an essential nutrient for human life. Half of the salt is found in the blood and body fluids, more than a third is in the bones, and the rest is in the cells. Approximately 98% of dietary sodium is absorbed in the intestine. Sodium ions are important to maintain extracellular fluid and plasma volume within close and regulated limit. They are critical for the proper functioning of muscles and nerves. Sodium also plays an important function to absorption of other nutrients such as glucose (sugar) water and amino acids (Gibson et al., 2000). Sodium interacts with other cations, including potassium and calcium that influence its physiological effects. Excess sodium in human body is controlled by excretion mainly through the kidneys and some is lost with perspiration. Mechanisms of sodium affecting blood pressure and the circulatory system are not completely understood. It has been proposed that, in response to high salt intake, persons with salt-sensitive hypertension do not excrete as much sodium in urine as salt-resistant individuals. Higher serum sodium levels would be followed by an expansion of plasma volume, an increase in cardiac output, and a sustained increase in systemic vascular resistance. This may occur in some people. In addition, blood pressure may be increased as a result of high sodium intake. Untreated high blood pressure is also known to increase incidences of heart disease, stroke, and kidney disease (Doyle and Glass, 2010).

Table 2.2 Salt intake level and recommendation

Country	**Salt intake level (g/day)**	**Salt recommendation**	**Source of dietary sodium**	**References**
United States	9	5.8 g/day	Processed foods (71%)	Drake and Drake (2011)
United Kingdom	8.3–10	6 g/day	Processed foods (95%)	Desmond (2006); Anderson et al. (2010)
Japan	11.6 (4,651 mg/day)	-	Soy sauce, (20%)	Anderson et al. (2010)
Australia	6.5-12	6 g/day	Processed food (80%)	Webster et al. (2009)
Thailand	10.8	6 g/day	Condiments (74%)	Bureau of Nutrition, Department of Health (2011)
China	10.0 (3,990 mg/day)	-	Home cooking (75.8%)	Anderson et al. (2010)

Table 2.2 illustrates data of salt consumption in many countries around the world. The average salt consumption in most countries around the world is approximately 9 - 12 g/day. This rate was more than the limit of salt consumption. The recommended salt intake by The World Health Organization should be less than 5 g/day (World Health Organization, 2007, 2010). A comparison of salt consumption pattern of populations around the world shows different sources of sodium in diets between developed

industrialized countries and developing countries. In developed industrialized countries, the biggest proportion of consumer's salt intake comes from processed foods. In contrast the vast majority of sodium in developing countries diet comes from salt added at home in cooking and at the table. For instance, few studied showed that around 70% of sodium intake comes from processed foods and foods served in restaurants in Western countries such as United Kingdom (95%), United States (95%) and Australia (80%). Salt added at home in cooking and at the table is the main sodium source for consumers in China (75.8%) and Thailand (74%) (Anderson et al., 2010; Bureau of Nutrition, Department of Health, 2010). In Thailand, an average of salt consumption among Thai people (in 2008-2009) is 10.8 g/day/person (Table 2.2). In case of salt consumption from homemade diet contributes 10 g (8 g in condiments where: fish sauce, salt, condiment powder and soy sauce and 2 g in natural food) and 0.8 g salt consumption from ready to eat snack, street food (Bureau of Nutrition, Department of Health, 2010).

The levels of sodium in Thai food products are summarized in Table 2.3. Foods are usually high in sodium including meat, processed meats (such as sausage, ham and meat ball), snack foods, salad dressings, and fast foods. Some foods naturally contain sodium, including, meat, shellfish, dairy products and all vegetables. Especially, table salt, fish sauce and other condiment are quite high in sodium.

Despite the concerted attempt to decrease sodium consumption around the world, salt and sodium intake remains at a high level. There are many barriers in sodium reduction (Gibson et al., 2000; World Health Organization, 2010) such as:

- Reduced and low sodium diets are considered bland and tasteless by consumers. Many consumers have grown accustomed to common salt through processed foods. It is related with a decrease in consumer acceptance.
- Due to functionality of salt, it is difficult to find new ingredients or new approaches of replacing sodium salt as sodium fulfills many important functions of food products.
- Cost of other new ingredients to be used as salt is more expensive than common salt.
- Consumption habit of consumers.

As such find out appropriate sodium reduction strategies are very important to achieve way in dietary sodium intake reduction of the world population.

Table 2.3 Sodium content of food products in Thailand

Food products	Serving size (g)	Sodium content (mg)/serving size
Meats egg and milk		
Cooked freshwater fish	30	17
Cooked chicken	30	32
Cooked Egg	60	107
Cooked meat	30	107
Milk	240 ml	123
Pork ball	30	200
White pork sausage (Mooyor)	30	227
Cooked ham	30	356
Pork sausage	30	388
Condiments		
Oyster sauce	15	690
Soy sauce	15	1,060-1,390
Fish sauce	15	1,170-1,620
Soup cube	10	1,760
Carbohydrate		
Sticky rice	35	4
Rice	55	19
White bread	30	117
Boiled noodle	75	153
Vegetable		
Cucumber	100	5
Cooked Straw mushroom	60	21
Cooked Chinese water convolvulus	50	70
Cooked kale	50	80
Fruit		
Pineapple	125	6
Ripe mango	80	35
Orange	150	50
Rose apple	250	65

Source: Thai Hypertension Society (2013)

2.2 Mechanism of salty taste perception

Human can perceive at least five basic tastes with taste receptor cells: sweet, sour salty, bitter and umami. Taste receptor cells (Figure 2.1) are clustered in taste buds and located throughout the oral cavity. Taste buds are the most widespread on small pegs of epithelium on the tongue called papillae. Each taste bud has a small pore that opens out to the surface of the tongue enabling molecules and ions taken into the mouth to reach the receptor cells inside. In mouth, chemicals of food are dissolved by the saliva, and the free-floating molecules enter the taste bud through a small pore. If the molecule binds to the tip of a receptor cell, it will excite that cell into issuing a series of chemical and electrical signals. The chemical signal is converted to an electrical signal and sent via the seventh, ninth and tenth cranial afferent nerve fibers to the gustatory processing regions of the brain (Chandrashekar et al., 2006; Liem et al., 2011; Matsuo, 2000).

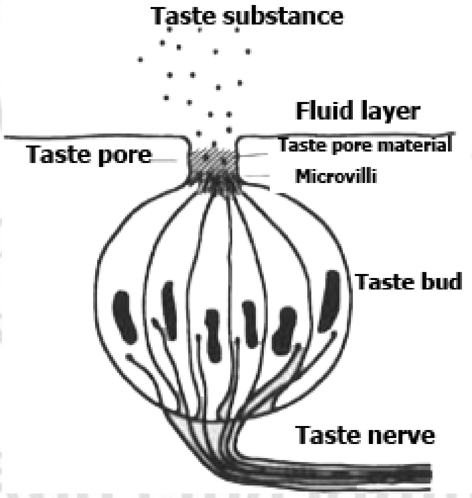

Figure 2.1 Schematic diagram of a cross section through a taste bud with its complement of receptor and basal cells

Source: Matsuo (2000)

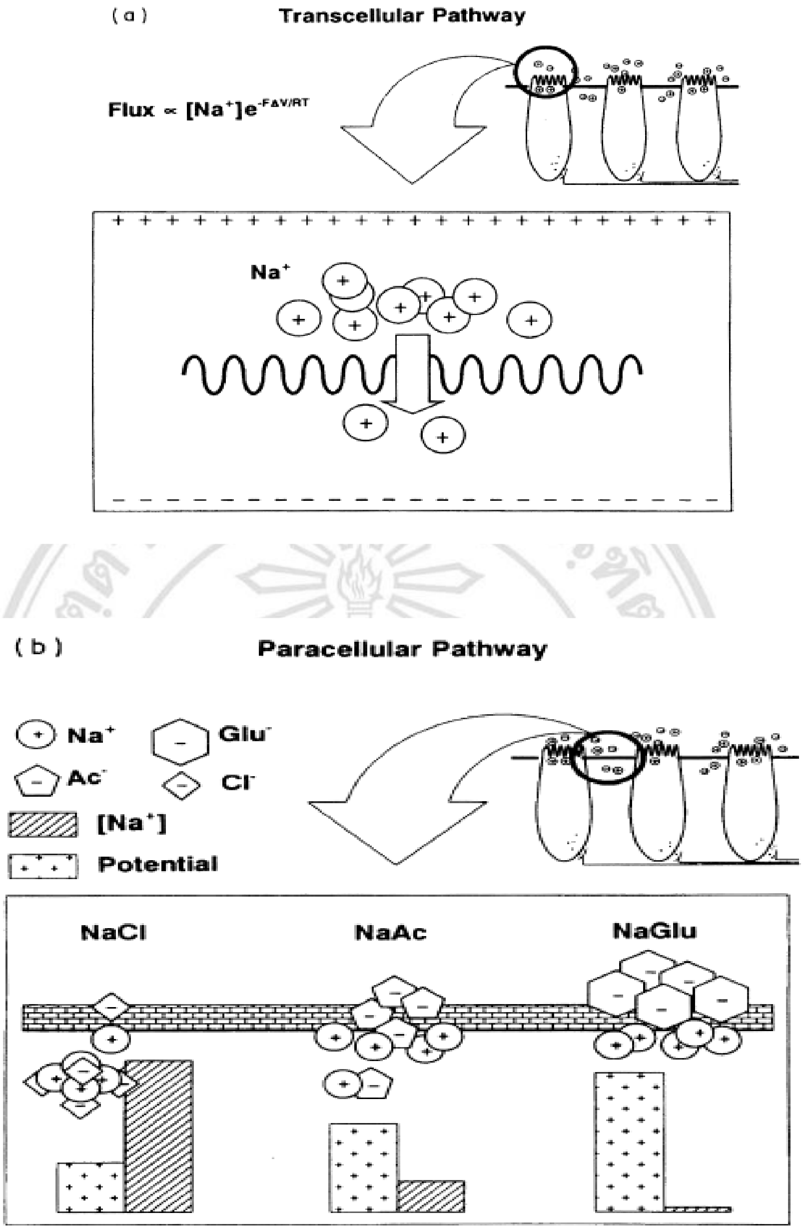

Figure 2.2 Transduction mechanism for sodium salts

(a) Na$^+$ passes through channels on the apical membranes of microvilli to depolarize the receptor cell (transcellular pathway).
(b) An additional source of stimulation is through the tight junctions between taste cells (paracellular pathway). Here, the physical size of the dissociated anion affects the passage of Na+. The small and mobile Cl$^-$ ion permeates the tight junction, permitting Na+ the electrical potential it needs to penetrate deep into the bud. The large Glu$^-$ ion cannot penetrate the tight junction, and so holds Na$^+$ electrostatically close to the surface, preventing its stimulation of deeper receptor sites.
Source: DeSimone et al. (1993)

Mechanism of salty taste sensation specific to sodium was investigated in rats. This mechanism can be described by its unique sodium-specific transduction mechanism (Figure 2.2) involving epithelial sodium channels (ENaCs) on the taste receptor cells. Salty taste perception begins when sodium activates ENaCs on taste receptors and an afferent signal is sent to gustatory processing regions of the brain. Some of ENaCs subtypes specific for sodium, which is activated at low sodium levels, is believed to be responsible for the appetitive nature of salt taste. The other ENaCs are permeable to multiple cations, activated at higher sodium intensities, and is believed to be responsible for the aversive nature of cations (McCaughey, 2007).

For non-specific mechanism, sodium passes through a non-selective cation channel found in taste receptor cells. This channel also allows passage of potassium and calcium ions which is a variant of the VR-1 receptor that blinds the irritant capsicin. It may be activated at low sodium intensities. The seminal research revealing putative salt taste mechanisms was based on a rat model, but there is little reason to believe the mechanisms would differ in humans (McCaughey, 2007).

At the lowest sodium chloride concentrations human can detect taste mildly, sweetness and a noticeable difference from a similar solution without sodium (Figure 2.3). When the intensity of sodium increases the afferent signal strength will increase and reach a level where an individual will be able to discriminate a sodium solution from water, but remain unable to specify the taste quality. This level (0.035 M or 0.20% sodium chloride in water) is known as the detection threshold and is often used as a measure of individual sensitivity to sodium. Actual identification of saltiness perception occurs when the intensity of sodium is high enough not only to activate the taste receptors, but also to produce electrical impulses, which can be carried via sensory neurons to the brain where they are decoded and after which the taste quality can be identified. This level (0.60 M or 2.92% sodium chloride in water) is known as the recognition threshold. The sodium concentrations above the recognition threshold are in the range of perceived saltiness, which is termed suprathreshold (Keast and Breslin, 2003; Keast and Roper, 2007; Liem et al., 2011).

Many factors may affect to perceived saltiness, for instance, food matrices, e.g., it is easier to detect 50 mM NaCl in an aqueous solution than in a bread matrix (Liem et al., 2011). In the same product but different texture, a significantly faster sodium release from the coarse-pored bread compared to the fine-pored bread (at a constant sample weight) was detected in-mouth and in a mastication simulator. The result with a constant sample volume showed that enhanced saltiness, despite of similar amounts of extracted sodium was detected during the first few seconds of chewing. Consequently, salty taste perception was influenced both by the velocity of sodium release and by crumb texture (Pflaum et al., 2013).

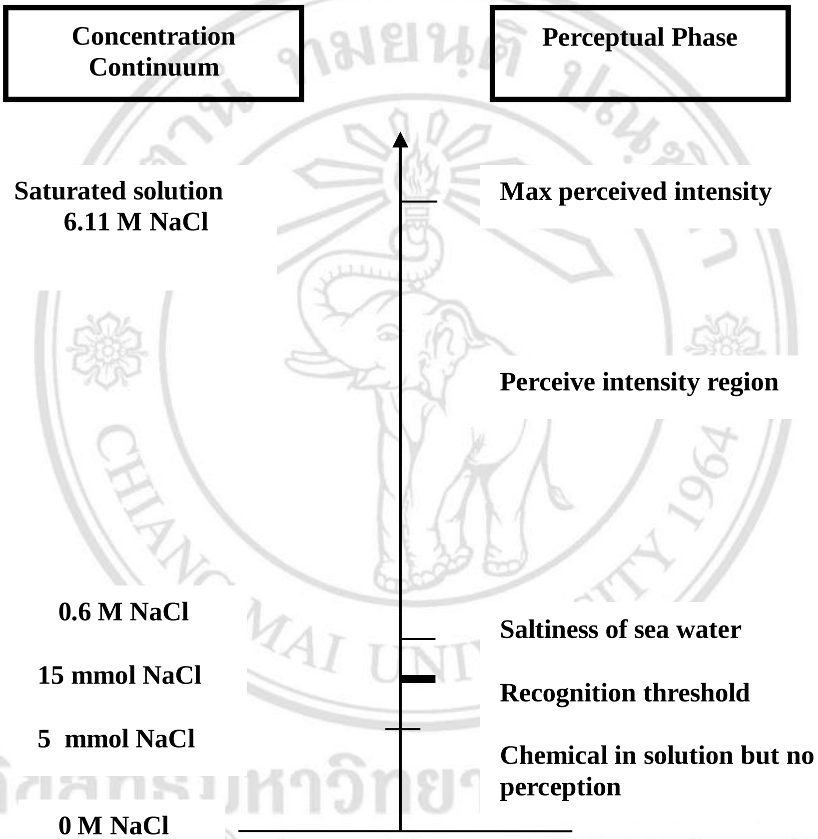

Figure 2.3 Diagram of saltiness perception as concentration increases

Source: Liem et al. (2011)

2.3 Salt and sodium reduction strategies

The current salt consumptions in world population are in excess of recommended daily intake values and many medical studies have also confirmed that excess salt consumption induces health risks and that reducing salt consumption at the population level is extremely cost effective potential instrument to reduce cardiovascular disease risk (Doyle and Glass, 2010; Gibson et al., 2000). A variety of methods used to reduce sodium intake are become a topic of intense international interest.

Public health campaigns in many countries encourage population-wide reduced sodium/salt intake (He and MacGregor, 2009; Legetic and Campbell, 2011; World Health Organization, 2010). Some examples of the national sodium/salt reduction approaches that accomplish in decreasing sodium intake of some countries, for instance, England has had an extensive program based on negotiated voluntary targets and timelines for reducing the salt content of processed foods, education of consumers, close government oversight and a strong nongovernmental advocacy group. Finland utilized many programs to reduce dietary sodium consumption including using salt substitutes by food processors, putting warning labels on foods with high salt content, encouraging use of a partial salt substitute for home use, and educating the public about dietary salt and health risks (He and MacGregor, 2009). Other several countries around the world have lately started a national sodium/salt reduction approaches. In 2011, The Thailand, Bureau of Nutrition, Department of Health launched campaign of sweet, fat, salt, overweight/obesity and diseases reduction. The aim of this campaign was to raise awareness of the consequence of high intake of sugar, fat, salt in diets and to change consumption habit (Bureau of Nutrition, Department of Health, 2011). Generally, the population-wide reduced sodium/salt intake strategies were used in Thailand such as increasing population knowledge about reduced sodium intake, putting warning labels on foods with high salt content and encouraging reduced salt in processed food by manufactures. However, little data showed the consequences from these approaches in Thailand.

In addition to the population-wide reduced sodium/salt intake strategies, reformulation of food products for sodium reduction were also interested by research and development. For example, finding the suitable processing method is also one way to maintain food quality of reduced sodium products. The effect of high pressure processing (HPP) on beef sausages with low-salt content was evaluated. HPP was found to produce a dramatic improvement in the moisture retention of the cooked products. Enhanced meat binding through extraction of salt-soluble proteins is an essential step in the formulation of sausages. The ability to reduce salt and achieve high binding and water retention through use of HPP is important in being able to produce healthier foods. However, there was a slight increase in “whiteness” with pressure treatment; both appearance and texture of pressure treated sausages with lower salt content compared with non-pressure-treated samples were also acceptability from consumers (Sikes et al., 2009). Some major reduced sodium approaches apply in food products are discussed below.

2.3.1 Salt replacement by substitutes

Using a salt replacer is the most common approach used in low or reduced salt/sodium foods which based on the reduction of sodium-ions (Na^+) by other salt-tasting compounds such as potassium chloride, calcium chloride and sodium lactate (Desmond, 2006). Most studies pointed out that less than 50% of common salt replacement appears to be the range at which the flavor impact is not as noticeable (Guàrdia et al., 2006). Disadvantage of other mineral compounds used as partial substitution of common salt is that they impert bitterness and other sensations such as off flavor and astringent. Only sodium and lithium chloride have uniquely salty taste (McCaughey, 2007). Studies of other mineral showed that the divalent cation of calcium chloride, magnesium chloride and magnesium sulfate were characterized primarily by bitter taste, with additional sensations described as salty, metallic, astringent, sour and sweet, generally in decreasing order of intensity. Calcium gluconate, calcium glycerophosphate and calcium lactate had lower salty and bitter responses than calcium chloride (Lim and Lawless, 2006). The mixture of various mineral salt also was use as salt replacer in many food (Table 2.4). Ruusunen et al. (2005) supported that the use of mineral salt mixtures is a good way to decrease the sodium content in meat products.

Potassium chloride is the most common salt substitute used in low or reduced salt/sodium foods. It is approved as Generally Regarded As Safe (GRAS) and has antimicrobial and rheological properties of dough effect similar to sodium chloride (Cauvain, 2007). The US Dietary Guidelines (2005) also announced that the recommended potassium intake is 4.7 g potassium/day. Similar to other mineral salts, one problem with the use of potassium chloride as a salt substitute is a bitter aftertaste. Thus, it is used in reduced or low sodium food products with other ingredient, for instance, other mineral, flavor enhancer and bitterness inhibitors. Data from numerous studies indicated feasible use of potassium chloride and other salt replacers in food products (Table 2.4).

Table 2.4 Salt substitutes in reduced or low food products

Food products	Salt replacers	Salt/Sodium reduction (%)	References
Fermented sausages	KCl (50%) KCl (40%) and K-lactate (10%)	50	Guàrdia et al. (2006)
Mortadella	KCl (25 or 50%), $MgCl_2$ (25%) and $CaCl_2$ (25%)	50,75	Horita et al. (2011)
Dry fermented Pamplona–style chorizos	KCl (20%) and $CaCl_2$ (38%)	58	Beriain et al. (2011)
Bread	KCl (0.55, 0.60, 0.87 %) and yeast extract	31,52 and 67	Bolhuis et al. (2011)
Home-cooked foods and a standard salty soup	KCl (25%) and $MgSO_4$ (10%)	35	Li et al. (2009)
Wheat flour	KCl, $MgCl_2$, $CaCl_2$, $MgSO_4$,Na2SO_4	25,50 and 100	Kaur et al. (2011)
Chicken nugget	KCl (0.2 g/100 g),citric acid (0.03 g/100 g), tartaric acid (0.03 g/100 g) and sucrose (1.0 g/100 g), sodium hexa meta phosphate, sodium nitrite, spice mix and other ingredients	40	Verma et al. (2010)
Frozen lasagne ready Meal	Potassium Chloride (KCl) AlsoSalt® KCl and L-lysine AlsoSalt®, Autolysed yeast extract AllinAll Ingredients, Dublin	0.50%	Mitchell et al. (2009)

2.3.2 Sea salt

A vast category of “sea salt” preparations are an increasingly common ingredient that is applied in many foods. Sea salts have unique configurations of chemical composition, grain size, crystal shape and color depending on the salt origin, water source and manufacturing specifications. Sea salt includes typically 98% sodium chloride and 2% minerals such as magnesium, potassium, iron, calcium, zinc and sometimes other compounds that contribute to flavor (Drake and Drake, 2011). Some studied confirmed that sea salts can be used to replace common salt and their use may significantly decrease sodium consumption (Pietrasik and Gaudette, 2013). Drake and Drake (2011) indicated that sea salts are lower in sodium content and have distinct mineral profiles that may also influence salty taste intensity and/or time intensity profiles. They showed salty taste perception in sea salts is related to sodium content based on weight per volume. Moreover, Vella et al. (2012) found that crystal shape and mineral content of sea salts also can affect salty taste intensity.

Following researches of sea salts application in food products supported that sea salt can be used as a salt replacer, for instance, sodium reduction with two sea salt replacers (Ocean’s Flavor – OF45, OF60) and one savory flavor enhancer [Fonterra™ 'Savory Powder' (SP)] in restructured hams had no effect on the shelf life of the cooked ham for up to 60 days of refrigerated storage. Unfortunately, mean hedonic scores for flavor and aftertaste of ham containing OF45 and OF60 were lower than control ham (Pietrasik and Gaudette, 2013). The 32.3% reduced-sodium brown bread with SOLO® Low Sodium sea salt (a salt replacement produced from Icelandic water, which provides 60% less sodium than ordinary table salt) was developed and was acceptable in terms of baking qualities, appearance, texture and taste (Charlton et al., 2007).

2.3.4 Flavor enhancer

Flavor enhancers do not have a salty taste but it can increase saltiness perception by activating receptors in the mouth and throat, which helps improving the qualities for reduced or low salt products (Desmond, 2006). Flavor enhancers include nucleotides, lactate, monosodium glutamate (MSG), products derived from mycoprotein and yeast extract. MSG is widely present in many foods such as soup, snacks and meat products (Roininen et al., 1996; Wakita et al., 2013) and it imparts umami taste. MSG plays important roles in the taste, palatability and acceptability of foods. Yeast extract also is rich in MSG, peptides, nucleotides, glutathione, group B vitamins, minerals or other flavor compounds and has been used in food products, i.e. bread, meat product (Bolhuis et al., 2011; Campagnol et al., 2011). Use of herbs and spices, rather than salt, has been done to provide other flavoring characteristics to foods and to help alleviate blandness following salt removal (Carraro et al., 2012). Table 2.5 demonstrates some flavor enhancer applications in reduced or low salt products.

Using new flavors may be another way to decrease sodium in food products. Manebe (2008) investigated a traditionally Japanese stock (dried bonito) in a solution model and real food product models such as Japanese clear soup and egg steam custard. Saltiness enhancement could be found when using 6% dried bonito in a solution model. Dried bonito stock could enhance saltiness and improve palatability of egg steam custard. Replacing salt with naturally brewed soy sauce have been studied in salad dressing, soup, and stir-fried pork. Kremer et al. (2009) demonstrated the possibility to substitute NaCl by natural brew soy sauce in salad dressing, soup, and stir-fried pork of, respectively, at 50%, 17%, and 29% without leading to significant losses in either overall taste intensity or product pleasantness. In addition, Batenburg and van de Velden (2011) expressed that the combination between commercial beef flavor and sodium replacer (KCl/NH_4Cl) completely compensated for the flavor changes caused by the salt reduction in a beef soup product.

The utilization of flavor enhancers in reduced or low sodium food products still have some drawbacks about negative organoleptic sensory and health problems. Some flavor enhancing ingredients can impart a strong flavor. To illustrate, HVP and yeasts extract can impart the flavor of a food with a strong meaty or beefy flavor, which some consumers may dislike these flavors. In case of MSG, it is indicated to be linked with possible health implications including hyperactivity, sickness and migraines “Chinese Restaurant Syndrome” (Fernstrom, 2007).

Table 2.5 Type and concentration of flavor enhancer in food products.

Food products	flavor enhancer compounds	% Content	% Reduced sodium	References
Fermented sausages	yeast extract	1, 2	25,50	Campagnol et al. (2011)
Soup	MSG 5-Ribonucleotides	0.2 0.05	40	Roininen et al. (1996)
Surimi seafood	L-lysine mono hydrochloride (AlsoSalt®sodium-free salt substitute, AlsoSalt, Maple Valley, WA)	-	0.33,0.67	Tahergorabi et al. (2012)
Salad dressing, soup, stir-fried pork	Soy sauce powder	1.18, 2.36, 3.54 and 4.72	17, 29 and 50	Kremer et al. (2009)

2.3.5 Bitterness inhibitors

The utilization of salt substitutes in reduced sodium food product often impart bitterness, metallic taste and off flavor. These off notes are a major problem in the food industry due to its negative hedonic impact on food consumption. Some ingredients were investigated to decrease this problem in both food and pharmaceutical industries. Some substances can interfere with taste receptor cells. Sodium chloride also interacts with bitter compounds so that bitterness is suppressed to some variable degree and saltiness is unaffected. Sweeteners, like sucrose, lactose and thaumatin, have been used to interfere with the perception of bitter compounds to be effective in reducing bitterness. Dihydroxybenzoic acid and its salts also have been reported to effectively counteract metallic aftertastes without affecting sweetness (McGregor, 2007).

2.3.6 Inhomogeneous distribution of salt

Food texture affects taste perception at the cognitive level. Several studies have reported that saltiness perception is related to the texture of food, for example, increasing the viscosity of salt solution, that were thickened to various degrees with sodium carboxymethylcellulose (CMC) tended to decrease taste intensity perception. Recently, the concept of using salt inhomogeneous distribution approach was studied to achieve salt reduction in food products. However, the relationship between the distribution of salt in product and the effect on saltiness sensation has not been vastly investigated and not systematically.

Noort et al. (2012) showed that inhomogeneous distribution of salt can be utilized to enable a 25% reduction of salt in bread products. The study of inhomogeneous distribution of salt technique in this bread has achieved by using encapsulate salt to create salty spots distribution throughout the bread. The inhomogeneous distribution of salt approach may also be used to decrease sodium content with the same saltiness intensity (Stieger et al., 2009). In addition, the effects of inhomogeneous tastant distribution may be through the notion that consumers expect a constant product, whereby the salt content in part of the product lowered (e.g. through layers) but the sensory differences remain unnoticed (Wood et al., 2010).

In liquid food products such as soups, the addition of particulates salt can be immobilized to some extent. This soup with salt particulates was perceived by consumers as saltier than soup that had the same sodium content (Busch et al., 2008; Busch et al., 2010). Another way of inhomogeneous distribution of salt in food products may also be using fillers. The function of the filler is to fill with the volume so that less water is required and hence less salt is also required to obtain the same salt concentration in the aqueous phase. This concept of fillers has been studied in an oil-in-water emulsion, where the oil droplets form a filler phase in the continuous water phase. Malone et al. (2003) has shown that using oils as fillers can increase salty taste perception as a result of the increase in salt concentration in the aqueous phase given the same salt content in the food. However, one drawback of adding fillers to foods is that other sensorial qualities may be changed. Oils have also been shown to give a mouth coating effect such that the saltiness of solutions with the same salt concentration decreases in the presence of oil. The suppression of saltiness due to the oil is dependent on the amount of oil, with a higher amount of oil leading to a lower taste perception.

2.4 Optimizing physical form of salt

One of the hypotheses about increasing the efficiency of saltiness perception stated that suggested when the ions comprising sodium salt could reach the receptor more quickly. Surface area of salt crystal has an effect on dissolution rate of sodium chloride in the mouth. Generally, structure of common salt occurs in the form of transparent cubic crystals (Figure 2.4) that are typically produced through the evaporation of brine and saltiness perception of sodium chloride interacts with taste receptor only when in solution (Ertem et al., 2001). The general objective of the modification of salt structure as a strategy for sodium reduction is to optimize the delivery of sodium ions to taste buds in order to cause maximum stimulation of the taste receptor without increasing the sodium content in food products. The perception of saltiness taste in the solid salt form is affected by crystal size and shape. So changing crystal size and form of salt may increase the solubility rate of salt crystals that will increase the saltiness perception for a given amount of salt.

The smaller magnitudes and lower bulk density of crystals, inturn the large surface area, hence the faster rate of dissolution. The finest salt crystal sizes produced a more rapid release of saltiness perception than the larger crystal sizes (de Ridder and Kilcast, 2005). Rama et al. (2013) showed that salt crystal size influences the delivery rate and perceived saltiness. They studied the impact of different salt crystal size fractions on the delivery rate of sodium to the tongue and resultant saltiness in fried, sliced potato crisps. The different delivery rates can be explained by differential dissolution kinetics and enhanced mass transfer of sodium across the saliva. They supported that a reduced particle size, that have a fixed mass of sodium chloride, will result in an increase in surface area. This increase in surface area could explain a higher surface area will facilitate a more rapid dissolution of sodium into the saliva, which would explain the more rapid increase in oral sodium concentration observed in the samples with the smallest crystal size. A smaller crystal size of salt can accomplish a greater saltiness per unit of sodium consumed.

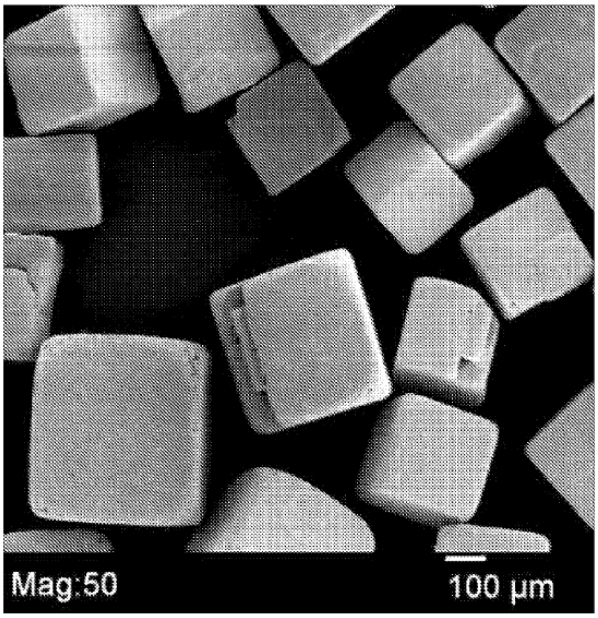

Figure 2.4 Scanning electron microscopy of table salt

Source: Chigurupati (2011)

Research has been implemented using several forms of salt as a mode of reducing salt content in food products. Many different salt crystal structures from available manufactures can be produced depending on different processes according to The Leatherhead Food International (Angus et al., 2005). Salt with different crystal forms elicit different salt dissolution rate. McGough et al. (2012) utilized Fine Flake Improved salt with natural flavor enhancer and salt substitute (KCl) to decrease sodium levels in frankfurters. In case of sea salts, many show the perceived higher quality in comparison to common table salt owing to the different form of sea salts and metal ions component. For example, the unusual hollow pyramid shape of Maldon salt from the east coast of England exhibits a high dissolution rate (de kidcast and Ridder, 2007).

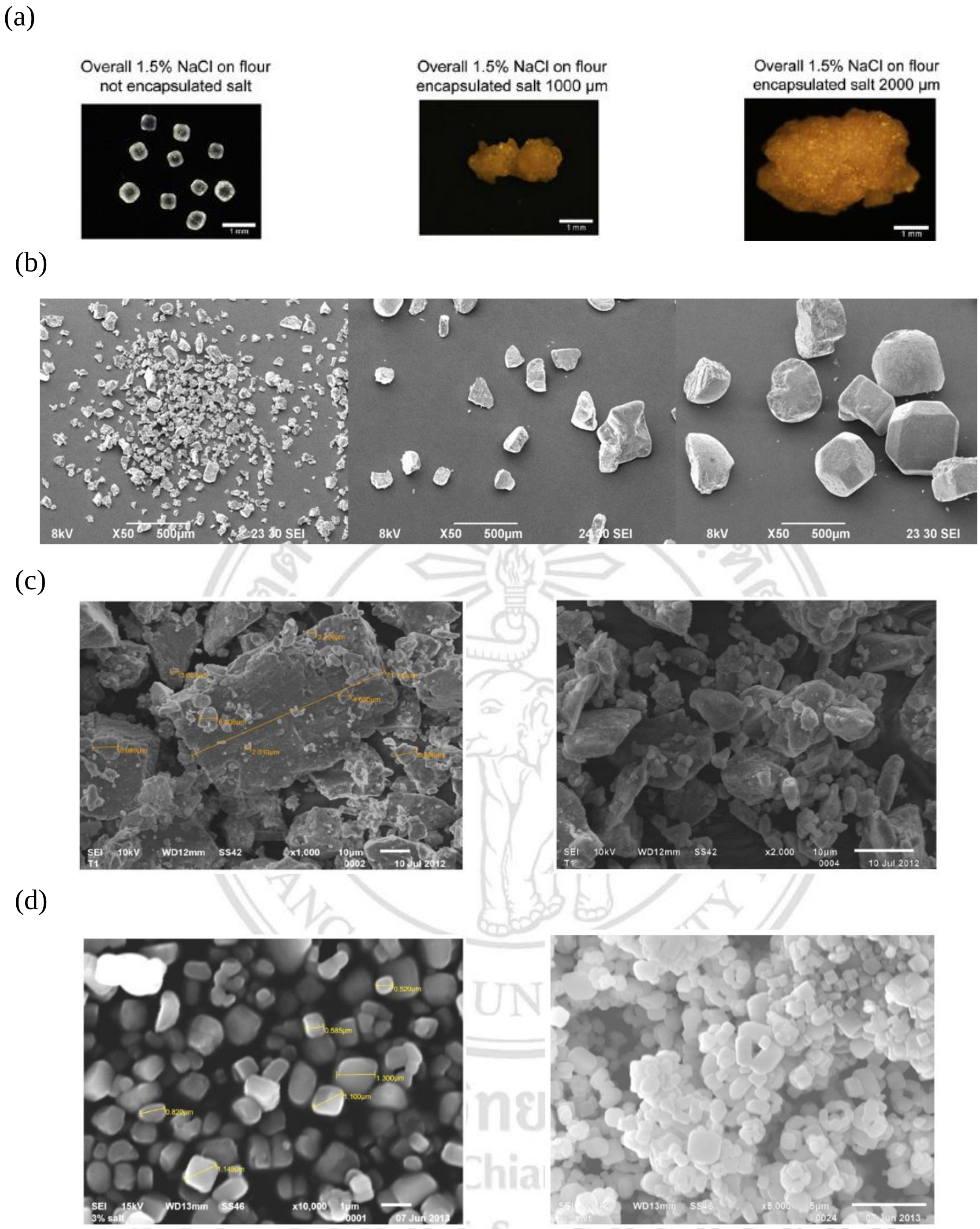

Figure 2.5 Different size and shape of salt particles were used in previous study to study their effect on saltiness perception in food products

(a) Different size and shape for encapsulated salt particles in bread (Noort et al., 2012)
(b) Different sizes of salt particles in fried, sliced potato crisps (Rama et al., 2013)
(c) Microsalt in salted cheese cracker (Reyes, 2014)
(d) Submicrosalt in salted cheese cracker (Reyes, 2014)

The application of encapsulated salt crystals was investigated to reduce the sodium content in bread product (Noort et al., 2012). The method for preparing encapsulated salt included the two salt fractions obtained by pan sieving (1000 mm and 2000 mm) were encapsulated with fat by using a rotating drum. Batches of 35 g salt crystals were kept moving in the rotating drum while spraying the melted encapsulation fat (70 °C) with a manual spraying pump. The component of 1,000 mm encapsulates consisted of 62.5% salt and 37.5% fat, whereas the 2,000 mm encapsulates consisted of 62.7% salt and 37.3% fat. The appearances of two encapsulated salt show are in Figure 2.5. This experiment demonstrated enhancement of saltiness scores by increasing particle sizes within each NaCl level of bread. The bread samples prepared with large salt encapsulates (2,000 µm) received a higher saltiness intensity but large encapsulated salt in bread led to large concentration that reduced consumer liking. Nevertheless, this approach based on the different size and salt crystal particles can only utilize in food product formulated with the solid form of salt such as surface coated snack.

2.5 Odor and taste interactions

Flavor of food is the sensation that combines olfactory, gustatory and trigeminal sensations. It is role in food quality and acceptance. Interaction sensations between olfactory and gustatory have been widely investigated in solution and food products models. The majority of studies concentrated on odor and sweetness interactions (Frank and Byram, 1988; Stevenson et al., 1995; Stevenson and Boakes, 1998; Valentin et al., 2006). Odor induced sweetness modulation was widely studied in water and sucrose solution model (Table 2.6). Other solution model was used such as saccharin solution (Dalton et al., 2000). Types of odorant that interact with sweetness perception include strawberry, benzaldehyde, lemon, vanilla, maltol, prune, waterchestnut and lychee (Dalton et al., 2000). A few earlier studies have shown that odor and other tastes interactions with sourness (Stevenson and Prescott, 1995), bitterness (Mukai et al., 2009) or saltiness (Djordjevic et al., 2004; Lawrence et al., 2009). Stevenson and Prescott (1995) studied interactions between sourness of citric acid and walter chestnut flavor in a solution model. Gabriella et al. (2004) studied the effect of green aroma (cut grass odor) on affected bitterness in a model virgin olive oil. Principles of odor and bitter taste interactions were widely utilized in food and pharmaceutical products. For instance, Labbe et al. (2006) investigated an enhancement of bitterness in a cocoa drink by the cocoa aroma and an increase in sweetness by vanilla aroma. In pharmaceutical studies, specific odors were used to suppress bitterness taste and improve palatability of some pharmaceutical products. More bitterness taste and poor palatability may seriously limit medication compliance and cause severe problems during treatment. The means for the improvement in palatability included the "sweetness" of flavored powders, pleasant odors and other flavors. Improvement of the palatability of the nutrient product for liver failure patients which contained BCAA using flavored powders were established by Mukai et al. (2009). BCAAs are components of nutritional products used for liver failure, are strongly hydrophobic, with a bitter taste and a peculiar strong odor, and elemental diets which contain high concentrations of BCAAs have particularly poor palatability. The odor and flavor were used in this study, namely, three powder flavors (fruit, coffee, or green tea) and three odorants (apple, coffee, and fruit-mix aromas). This study concluded the sweetness evoked by the odor of the aroma inhibited the bitterness of BCAA.

Main investigation about odor and taste interactions in most previous studies have focused on verification of the possibility of suppressed or enhanced trend between odor and taste interactions, investigation of factor that affected odor and taste interactions and the suitable strategies to apply principle of odor and taste interaction in real food and others products. In verification the possibility and suppressed or enhanced trend between odor and taste interaction, most studies expressed the effect of odor and taste interaction (Frank et al., 1989). Nevertheless some studies show no evidence for taste intensity changing by odor (Godinot et al., 2009; Johnson et al., 1982; Fujimaru and Lim, 2013).

There are some factors influencing the differences found among various studies on taste/odor interactions. These factors were expressed in odor and taste interactions researches as follow (Table 2.6):

Table 2.6 Other odor and taste interaction researches

Tastant	Odorant	Scale rating	Reference
sucrose solution (150 g/L)	aroma solution (isoamyl acetate; 1 g/L)	sweetness taste	Burseg et al. (2010)
sucrose 0.18 M, 0.32 M, and 0.56 M	citral 0.000005, 0.00005, and 0.0005 % (v/v)	sweetness citrus flavor	Fujimaru and Lim (2013)
sucrose 0.35 M and 0.30 M NaCl	1% citral and anethole aroma	sweetness saltiness licorice lemon	Gillan (1983)
sucrose 0.56 M, 0.32 M NaCl, 10 mM citric acid, 0.56 mM caffeine	0.012 % (v/v) citral and 0.4 % (v/v) coffee odor	congruency rating sweetness sourness bitterness	Lim et al. (2013)
sucrose 0-10%, 0-0.3% citric malic lactic phosphoric acid	0.06-0.3% a commercial strawberry aroma	strawberry flavor	Pfeiffer et al. (2006)
sucrose 0.06-1.0 M	kiwi, aniseed, citral, eugenol, limonene, carvone, plum, amyl acetate, sweetness enhancer, cherry, strawberry, vanilla, ethyl butyrate, caramel odorant at $7.5\text{x}10^{-8}$-$2.5\text{x}10^{-2}$%	sweetness	Stevenson and Mahmut (2010)

- The subjective similarity between the odorant and the tastant, for instance, types of odorants and tastants were used in odor and taste interaction model, difference of odorants and tastants concentration. Stevenson and Prescott (1995) showed ham odor did not affect sweetness so specific and suitable odors could affect taste quality. Murphy and Cain (1980) expressed that the intensity of tastes was greater with the combination odors in mixtures compared to bring present alone. Frank et al. (1989) illustrated a deficiency of an odorant influences at the high sucrose concentration and many assume that a low concentration of odorant and tastant seems to be more effective than a high concentration.

- The number of appropriate response scales and methodologies, such as, intensity rating scale, palatability scale, threshold test, a functional magnetic resonance imaging (fMRI) scanner.

- The different of participants who participated in experiments, for instance, consumers, untrained and trained panel. Moreover, that taste and odor interactions may be dependent on the subject’s previous experience (Pfeiffer et al., 2005). Boakes and Hemberger (2012) stated that, in general the participants in the above studies were university students without any explicit training related to taste or odor perception. Training and experience can enhance perceptual abilities in various domains. So their study has investigated effect of the sensory abilities of culinary professionals on odor-modulation of taste rating.

The appropriate utilization of odor and taste interactions were widely investigated in real food and others products. These applications may depend on several factors that affect taste/odor interactions. For example, the application sweetness flavors to inhibit the bitterness and unacceptable odor/flavor of pharmaceutical products (Mukai et al., 2009), using suitable and specific commercial tasteless aromas (comté cheese and sardine) in saltiness enhancement of low saltiness concentration solid food (cheese model) (Lawrence et al., 2011), using a combination of KCl-based salt replacer and extra aroma to compensate sodium reduction in beef bouillon (Batenburg et al., 2010).

2.5.1 Odor-induced saltiness enhancement

One of approaches has recently been proposed with the use of tasteless odorants to compensate for salt reduction through multisensory-integration mechanisms (Salles, 2006). This approach can be used interactions between the olfactory and gustatory to reduced sodium/salt in real food products. Generally, odor-induced saltiness enhancement (OISE) was used to salt and tasteless solution model (Table 2.7). The OISE was first found by Djordjevic et al. (2004) to using soy sauce odor in water and salt solution model. Soy sauce odor enhanced perceived saltiness of weak sodium chloride solutions)0.056 M). They suggested that this may be associated with the ceiling effect with strongest salty tastant, which are either easily detected or rated as strong, so simultaneous presentation of odorants has no further effects on salty perception. Nasri et al. (2011) also showed that the saltiness of a low concentration of sodium chloride in water)0.01 M and 0.02 M(increased significantly when panels perceived simultaneously the congruent sardine aroma.

Table 2.7 Saltiness enhancement by odor in solution model

Experiment methods and results	References
Solution Type: Aqueous solutions of NaCl in three concentrations: zero (0 M), weak (0.056M), and strong (0.32 M) **Type of odor**: Strawberry odor (10% diluted in distilled water), soy sauce, no odor) **Method**: Rating saltiness taste intensity on linear scales (0: none; 10: extremely strong) **Result**: Specific taste-smell interactions: salty taste enhancement by soy sauce odor	Djordjevic et al. (2004)
Solution Type: Evian mineral water and Evian mineral water containing NaCl at 0.02 M **Type of odor**: Commercial odors such as anchovy, bacon 0.25 g/L sardine, tuna 0.5 g/L **Method**: Rating saltiness taste intensity on linear scale (0-10) **Result**: Saltiness associated odors can enhance saltiness in simple water solutions and NaCl solution 0.02 M	Lawrence et al. (2009)
Solution Type: Evian mineral water containing NaCl at 0.01, 0.02, or 0.04 M concentration. **Type of odor**: No aroma, sardine aroma was used at 0.10 g/L and carrot aroma at 0.50 g/L. **Method**: Rating saltiness taste intensity on linear scale (0-10) **Result**: The saltiness of a low- or medium-salt-content solution increased significantly when subjects perceived congruent sardine aroma	Nasri et al. (2011)

2.5.2 Mechanism of odor and saltiness taste interactions

Generally, the mechanism of odor and taste perception in human involves food mastication. When food is chewed, this leads to the breakdown of its matrix which, in turn, releases odorants, tastants and chemesthetic substances. Tastants and chemesthetic substances will become available to the mucosal papillae depending on their partitioning, diffusion and transport in the saliva. Volatiles may be released from the saliva and reach the olfactory mucosa retronasally via the nasopharynx. The release of flavor compounds from food, and their delivery to the receptors located in the mouth and nose.

The evidence of odor and taste interactions may be a result from physicochemical, physiological and psychological effects (Salles, 2006). Several researches also investigated to find information to explain about mechanism of odor and taste interactions. In physicochemical interaction research, odor and taste interactions may have associated with “Salting out” effects that it influences volatiles perception. The mechanisms of volatile compound release rely on its nature and on the nature and salt concentration in the media (Dubois et al., 1995). Aroma-matrices interactions (proteins, lipids, polysaccharides) and several parameters in mouth condition also influence the release and perception of odor and taste interaction. For physiological effect, many researchers showed taste-aroma interactions have to be related to other phenomenon. Dalton et al. (2000) suggested that cross-modal response summation requires the existence of a central point of intermodal convergence containing neurons responsive to the combined inputs: insular cortex, orbitofrontal cortex and the amygdala. Additionally, de Araujo et al. (2003) investigated the place of odor and taste interactions may occur in the human brain by using functional magnetic resonance imaging (fMRI). They used sucrose as a taste stimulus and strawberry aroma as an olfactive stimulus, that common brain areas activated by both taste and smell are parts of the caudal orbitofrontal cortex, amygdala, insular cortex and adjoining areas, and adjoining insular cortex. A small part of the anterior insula responded to unimodal taste and to unimodal olfactory stimuli, and a part of the anterior frontal operculum was a unimodal taste area not activated by olfactory stimuli. An area of the left anterior orbitofrontal cortex that was activated more by the combined odor and taste stimuli. Furthermore, multisensory odor and taste integration seems not to be restricted to olfactory-taste stimuli. It was dependent upon the mode of olfaction delivery (Small et al., 1997). Finally, psychological effects of odor and taste interaction include odor-taste integration, for instance, relationship of odor and taste (such as odors defined by taste descriptors), the level concentration of flavor compounds, specific of cultures and cognitive aspects in flavor perception. The degree of integration of the two modalities still is dependent on various and controlling of analytical method.

Within relationship of odor and saltiness taste perception seem to be unclear in this mechanism and have supported by few researches. It may conclude that odor induced saltiness enhancement technique using tasteless odorants to compensate for saltiness reduction through multisensory-integration mechanisms in the brain and not in the mouth (Lawrence et al., 2009; Salles, 2006).

2.5.3 Factors on saltiness taste intensity and quality by odorant

Changes in taste quality of odor induced saltiness enhancement depend on the components of the mixture and several factors follow as:

1) Salt concentration

The numerous studies demonstrated that OISE depends on salt concentration, i.e., saltiness level. Indeed, the saltiness of a low concentration of sodium chloride in water increased significantly in the presence of aromas (Djordjevic et al. 2004; Nasri et al., 2011). Murphy et al. (1977) indicated that the effect of tastant concentration on odor-induced taste enhancement could be linked to the psychophysical function of stimuli that usually display compression of output over input such as negatively accelerated psychophysical functions. When saltiness is already high, i.e., in the upper part of the salt stimulus response function, it is difficult to increase salty perception because the asymptotical plateau is reached. In other hand, at lower salt concentrations, within the still increasing part of the stimulus response function, an increase in saltiness could be much more salient so OISE should be much more efficient (Djordjevic et al., 2004).

Recently, findings that OISE has increasing when saltiness level is too high could have important implications in salt reduction sensory compensation approaches. Nevertheless, OISE is the way to maintain saltiness in low salt food, it is important to consider that the approach could be utilized if the salt content is too high in food products. In that case, one possibility could be to combine different reduced sodium approaches (Nasri et al., 2011). Nasri et al. (2013) studied the effect of using salt substitute (potassium chloride), citric acid and odor induce saltiness enhancement (sardine aroma) in solution model. The sardine aroma was used at a concentration of 0.5 g/L. The taste factor included water (no tastant), sodium chloride (20 mM in water), citric acid (2.5 mM), potassium chloride (40 mM) and the following two mixtures: citric acid / sodium chloride and potassium chloride / sodium chloride. The panelists were asked to rate the aroma intensity and the taste intensity (sourness, bitterness, saltiness, and sweetness). This study confirmed that a mixture of KCl and NaCl shows a higher perception of saltiness and lower bitterness compared with KCl alone. The different of saltiness enhancement by sardine aroma was observed in the potassium solution but no evidence in the KCl–NaCl mixture solution. These results may be due to a bitterness-suppressing effect of the salt-related sardine aroma. Some odors enhance taste as other odors can suppress taste. Additionally, the highest enhancement was observed in the ternary odor–sour-salty solution. This research indicated the sodium decreasing in complex food systems should use a combination between odor and taste interaction strategy and salt substitutes to achieve in sodium reduction.

2) Odor type

Djordjevic et al. (2004) expressed that odorant-specific enhancement of perceived saltiness induced by a salty-congruent odor. Similarly, Lawrence et al. (2009) evaluated the OISE in water and salt solution model and stated that odor selection evoked saltiness on the basis of their name so well selected odors could effective on enhances saltiness perception. Each food name evidences significant differences in saltiness. They suggested that anchovy and bacon items were especially considered as the most saltiness-associated food names. Other odor induce saltiness enhancement in this study include comté cheese, chicken, ham, sardine, soy sauce, stolon and tuna odors. On the contrary, non-salt related odorant couldn’t enhance salty taste perception in solution model such as strawberry, tomato and carrot (Djordjevic et al., 2004; Lawrence et al., 2009). Lawrence et al., 2009 indicated that carrot and tomato odors evoked sweetness and, despite their medium odor intensity, were found not to enhance saltiness. This point is limitation to using odor induce saltiness enhancement in food application. All congruent odors are not suitable for each food so salted specific and familiar aroma have suitable in saltiness taste and each food product.

3) Odor concentration

Lawrence et al., 2009 assumed that odor intensity is a key driver of odor induced saltiness enhancement (OISE) amplitude, the higher odor intensity the higher OISE. As a consequence, one reasonable hypothesis is the interactions between salty intensity and odor intensity that may be an optimum high OISE for a combination of these factors. However, Nasri et al. (2013) investigated the effectiveness of saltiness enhancement by an odor to maintain the perception of saltiness in reduced salt content solutions. The sardine aroma was used at a concentration of 0, 0.25, 0.50 or 1 g/L and diluted either in water (without salt condition) or in water containing sodium chloride at 0.02 M concentration (with salt condition) and a reference solution including 25% more sodium chloride (0.025 M in water) was used. All samples were chosen according to their perceived intensity and acceptability. The result showed the addition of the sardine aroma to the salt-containing solution compensated for a decrease of 25% of the salt content. However, no significant difference in saltiness was perceived when the concentration of the sardine aroma increased from 0.25 to 1 g/L for the solutions both with and without salt. Nasri et al. (2013) concluded no clear influence of odor intensity either in tasteless solutions or in low-salt content solutions.

4) Cultural differences

Cultural differences might be affect different OISE results (Lawrence et al., 2009) such as knowledge and experience in the participant. Several studies about odor-saltiness interaction used untrained panelists to determine those effects (Djordjevic et al., 2004; Lawrence et al., 2009; Lawrence et al., 2011; Nasri et al., 2011). Batenburg and van der Velden (2011) have made use of three categories of subjects: untrained panelists, trained panelists and naïve consumers to study the effect of these cross-modal interactions of taste enhancement in a commercial chicken bouillon. Using the naïve panelists, they found that several "congruent" single compounds significantly enhanced salt perception such as "seasoning", "brothy" and "sotolon" (4,5-dimethyl-3-hydroxy-2(5*H*)-furanone) aroma compounds had the largest impact. Significant salt enhancement was also found for several sulphur-containing "meaty" and "roasted" aroma components. The trained panel did not demonstrate a statistically significant effect on saltiness so the analytical way of tasting and due to its training, which leads to unlearning of the associations on which multi-sensory interactions.

Table 2.8 Saltiness taste enhancement by odor in food model

Food product	Type of odor	Concentration of odor	References
Chesses	Commercial tasteless aromas (comté cheese and carrot Sardine)	0.08% 0.94%	Lawrence et al. (2011)
Chicken bouillon	Sotolon (brothy) Abhexon (brothy) Furfuryl thiol (FFT; roasted) 2-Methyl-3-tetrahydro furanthiol (meaty)	10-30 ppb, 40 ppb 5-20 ppb 5-25 ppb 40-60 ppb	Batenburg and van der Velden (2011)

2.5.4 Application of odor-induced saltiness enhancement in food products

Currently, OISE is more interested in food products model (Table 2.8). Lawrence et al. (2011) found that salt-associated odors (e.g., comté cheese and sardine) could enhance saltiness in complex solid-food matrices (chesses) containing a low amount of sodium chloride. Comté cheese and sardine were more appreciated than products flavored with carrot odor. Other application of OISE with other salt reduction strategy in liquid food, salt reduction that could be compensated in savory products like soups remain limited to approximately 15-20%. As using sotolon (4,5-dimethyl-3-hydroxy-2(5*H*)-furanone) aroma in beef bouillon that combine KCl-based salt replacer and sotolon (4,5-dimethyl-3-hydroxy-2(5*H*)-furanone) aroma was found to compensate approximately 30% sodium reduction without significant change of the flavor profile (Batenburg et al., 2011).

2.5.5 Measurement of odor and taste interactions

Many methodologies were used to approve or determine odor induce taste enhancement. These methods reflect respondents perceive intensity of odor or taste in odor induce taste enhancement model.

1) Intensity rating

Intensity rating scale was widely used to investigate odor and taste interactions. Most intensity rating scales have all taste sensation scales such as sweetness, sourness, saltiness bitterness and overall odor intensity scales. Using multiple and appropriate scales prevent bias (dumping effect). In case, subjects are unable to rate sensory favor qualities of odor in a sample, they 'dump' these qualities onto ratings of other qualities that are rated (such as sweetness, saltiness), thereby producing apparent enhancement. The length of intensity scales on odor and taste interactions model was different, for example, Schifferstein and Verlegh (1996) shown that subjects rated the sweetness intensity of the experimental stimuli on a 150 mm line scale labelled "not sweet at all" at the left end and 'extremely sweet' at the right end., Frank et al. (1993) demonstrated that odor-induced changes in sweetness. Subjects were to judge the sweetness, sourness, and fruitiness of solution and rated the total intensity of the stimuli on a 21-point category scale labeled 0-no taste, 5-weak, Io-medium, 15-strong, and 20-very strong. Some studies applied the Labeled Magnitude Scale (LMS) to determine the relationship of odor and taste (Fujimaru and Lim, 2013; Stevenson and Mahmut, 2010). Cerf-Ducastel and Murphy (2004) expressed that participants were asked to rate the overall intensity using the Labeled Magnitude Scale (LMS) from 0 (no sensation at all) to 100 (strongest sensation imaginable) for odor-saltiness interaction study.

Different intensity scale rating was also used to measure the level of saltiness perception for solution model and food products by consumers and trained panelist. Intensity rating method for odor and taste interactions determination is a subjective measure of perception exhibited to be liable to influences of knowledge and expectations (Schifferstein 1997). In previous studies demonstrated interactions in OISE model as measured by consumers who rated odor and taste (bitterness, sourness, saltiness, and sweetness) intensity orthonasally and retronasally of water/low salt solution on linear scales from 0 to 10 (0: none and 10: extremely strong) or to indicate ‘‘not known” if the food name was unknown (Lawrence et al., 2009; Nasri et al., 2011). Djordjevic et al. (2004) measured odor-induced effects on perceived saltiness of water/low salt solution on a 21-point scale.

For food model, the scales are used to odor and taste interactions determination. Lawrence et al. (2011) used linear scales 0-10 to investigate odor and taste intensity of cheese model using untrained panelist. Bouillon products were also used to determine odor- saltiness interaction. The attributes were scored on a 12-points scale using bouillons of two different salt levels as references. To reduce the dumping effect (a salt enhancement effect only due to the response bias), it was decided to score on two attributes: the “salt intensity” and the “overall flavor intensity”. Data are only shown salt intensity (Batenburg et al., 2010).

2) Palatability testing

For odor and taste interactions widely used these methodologies to investigate effect between all sensations. Different scales have been investigated the interactions, for example, Schifferstein and Verlegh (1996) shown that subjects judged the pleasantness of the 40 stimuli on a 150 mm line scale, labelled “not pleasant at all” at the left end and “extremely pleasant” at the right end. Stevenson et al. (1995) used the rating sheet contained four 153-mm visual analog scales (VAS) in the following order, Liking/ Disliking (anchors: Dislike extremely, Like extremely; plus a central marker; Indifference) due to determine sweetness and sourness interaction with odors. Robert and Hamberger (2012) examined that adding a tasteless odorant can change a taste’s attributes. They observed the overall pleasantness of water solution adding caramel and citral odors by filling out 21-point linear rating scales (-10 to 10, anchor: extremely dislike, indifferent, extremely like) of the 15 Sydney-based chefs.

Salty compound elicit not only salty taste quality and intensity, but also palatability and acceptability of food products. Most consumers prefer salted food over pure solution. However, some odor-saltiness interaction researches used water and salt solution to evaluate pleasantness of judges. Cerf-Ducastel and Murphy (2004) observed pleasantness of odor–taste interactions in salt solution by rating the overall pleasantness on a scale from 0 (most unpleasant imaginable) to 100 (most pleasant imaginable), with 50 being neutral (scale derived from the LMS). For odor induce saltiness in cheese sample, consumers rated liking of each attribute (odor intensity and taste intensity (sourness, bitterness, saltiness and sweetness); second, texture (firmness, moistness and granularity) and congruence between odor and taste) on dedicated linear scales from 0 to 10 (0: none and 10: extremely strong, or for the liking, 0: I do not like it and 10: I like it).

3) Threshold analysis

The main utilization of threshold analysis is investigating the potential of substances at low concentrations to impart sensory attributes such as odor and taste form of matter. Nevertheless, few studies have investigated threshold analysis for odor and taste interactions model (Pfeiffer et al., 2005). The perceptual interaction of taste and odor was determined based on a subthreshold methodology. Detection thresholds for taste and smell stimuli were quantified using a two-alternative forced choice. This study used saccharin, which elicits a sweet sensation, as the taste stimulus, and benzaldehyde, commonly referred to as having an almond-like odor. The experiment was repeated using retronasal and orthonasal delivery of the odor and with tastant present or absent in the mouth. The result showed that integration of taste and odor only occurred when both stimuli were present at the same time.

4) Instrument analysis

Few functional magnetic resonance imaging (fMRI) studies have assessed the cross modal interactions between odor and taste. Eldeghaidy et al. (2011) use an immediate swallow protocol to assess taste and aroma integration in fMRI studies. This research used these methods to access the cortical representation of taste and retro-nasal aroma (flavor) associations to a congruent flavor (sucrose and banana/pear aroma) stimulus and compare this to the delivery of a unimodal taste (sucrose) and a unimodal aroma (banana/pear aroma) stimulus. Investigations of odor–taste interactions in a functional magnetic resonance imaging (fMRI) scanner had investigate by Cerf-Ducastel and Murphy, 2004. This study establish the validity of a stimulation protocol designed for the presentation of odor–taste mixtures in a fMRI scanner by collecting psychophysical measures in response to odors, tastes and odor–taste mixtures delivered under the protocol and thereby to provide a foundation for future interpretation of neuroimaging data. In this study, stimuli were three concentrations of two tastants (i.e., sucrose and NaCl) and two odorants [i.e., ethyl butyrate (fruity) and citral (citrus)] and all possible odor–taste mixtures. Stimuli were presented to the mouth of the participant (twelve young healthy participants) through plastic syringes and plastic tubes as 50 Al every 3 s for 18 s. Participants were lying on the back to simulate the conditions in a fMRI scanner and gave pleasantness and intensity ratings in response to each stimulus using a Labeled Magnitude Scale (LMS). Results showed that additively of intensity in odor–taste mixtures was linear and did not rely on the pleasantness of the mixture. This study expressed the feasibility of acquiring reliable psychophysical data with a stimulation device compatible with the fMRI environment and provided the foundation for the interpretation of future fMRI investigations of odor–taste interactions in flavor.

2.6 Application reduced sodium approaches in peanut products

Peanuts are widely used to apply for the preparation of new and improved food products. Normally, peanut kernels contain approximately 50-55% oil with 30–35% and 45–50% of the oil being linoleic and oleic acids, respectively, 25-28% protein, 19-21% carbohydrates and 2.3-2.5% ashes (Grosso and Guzman, 1995). Sodium content in raw peanut kernel has average in range 10-22 mg/100 g raw peanut kernels (USDA, 2011). Salted peanuts are one of the most popular confections. The processes of roasted peanuts making are two primary methods for roasting peanuts: dry roasting and oil roasting. Most roasted peanuts are usually roasted in oil and packed in retail-size plastic bags or hermetically sealed cans.

In addition to obviously salty foods, such as certain snacks, sodium content is quite high. The large variety types of snack foods include potato chips, popcorn, crackers, nuts and extruded snacks. Table 2.9 shows sodium content in various snack foods and peanut snack products.

The role of salt in snack foods can be complicated, serving many functions depending on the product and level of addition. Because of salt has a variety of functions. It involved in the rheological and physical properties of snack products and it interact with the other components (Ainsworth and Plunkett, 2007). Salt can act as a process aid generating structure and color in processed snacks. It is one of the slightest costly ingredient however is usually one of the major components applied as part of seasoning so it can as a topical tastant either on its own or in combination with other flavors (Miller and Barringer, 2002).

Table 2.9 Sodium and salt content in snack foods

Confectionery type	Salt content (%)	Sodium content (mg/100g)
Popcorn	1.8-4	720-1600
Pretzel	2.2-2.5	220-1000
Tortilla chips	2-2.5	800-1000
Extruded snack	1-2	400-800
Crips	1-2	400-800
Peanut oil roasted (with salt)	0.8-1.08	320-433
Peanut dry roasted (with salt)	1.69	667

Source: Ainsworth and Plunkett (2007); USDA (2011)

Salt is maintained in solid crystal state for food products that are intake dry form such as crisps and other snacks. It will first have to be dissolved in the mouth before the sodium ions can be detected by the receptors. Different in size and shape of salt are used in snack food to affect consumer acceptance.

The trend of snack food market demonstrated that people are still choosing salty snack (Packaged Facts, 2013). The removal, or reduction, of sodium from snack foods is technically challenging and requires all aspects of the functionality of sodium containing ingredients to be addressed. The following techniques were used to decrease sodium in snack products.

- Product formulation was changed by using many cereals to give more intense flavors and consumer acceptability due to reduce sodium in snack products. Moreover, reduction salt content in a product formulation by stealth approach. This reduction is small and is carried out stepwise that the reduced sodium product can be undetected by consumers. The result from researches reported that this method can applied to reduce 33% and 25% of salt content in cereal and bread. The utilization of sodium reduction by stealth approach has also been made in some major branded products (Ainsworth and Plunkett, 2007) and cooperation of snack manufacturer also is important way to decrease sodium consumption.

- Flavor enhancers are used to increase salt perception of snack products. Glutamate is widely used as flavor enhancer in most snack products. Generally, glutamate will work very well with salty or sour food. The optimum amount of added glutamate to enhance the taste of food is at 0.1–0.8% by weight (Jinap and Hajeb, 2010). The use of excess amount of glutamate does not make the food taste better, but it actually worsens the taste. Sodium and monosodium glutamate content survey of snack foods (six types of snack foods comprise potatoes, seasoning-flour, corn, squid, fish snacks and crispy peas and beans) in Thailand showed sodium and monosodium glutamate contents of those snacks were range from 195.9-1,126.8 mg/100 g and 0-0.34 %, respectively (Tangkanakul et al., 1999).

- Salt substitutes
- Natural or new flavors
- Using new physical salt form
- Inhomogeneous distribution of salt approach, the study of heterogeneous salt distribution approach in hot snacks enhances saltiness without loss of acceptability. This study determined that table salt distribution could affect salt perception in a salty baked food composed of two different layers (cereal-based and cream-based layers) and a four-layer cream-based model food. Consumer panels rated the saltiness intensity for each product and their liking for the four-layer products only. The saltiness enhancement was observed in samples with a heterogeneous salt distribution for both types of snacks. The role of salt in the cereal-based layer may be less available for taste receptors because this layer had a lower water content compared with that of the cream-based layer, which likely reduced the salt diffusion in the saliva. The consequence could be a faster release of salt in mouth at the beginning of the chewing process which was responsible for higher saltiness intensity. In the bi-layer products, salt perception was more dependent on the salt concentration in the cream-based layer than in the cereal-based layer (Emorine et al., 2013).

2.7 Threshold analysis

For the sensory thresholds determination, the sensory thresholds are used to determine the potential of substances at low concentrations to impart odor, taste, etc. to some form of matter (ASTM International, 2011). Sensory threshold is defined according to a criterion level of performance in a particular psychophysical task. Thus, thresholds are a function of both subject sensitivity and method (Wise *et al*. 2008). There are many different methods for determining thresholds, including: triangle tests, ascending forced choice, semi ascending paired difference, adaptive transformed response, random double staircase, and CHARM analysis and researchers have interested to develop more efficient methods due to find accurate threshold estimates that can require a large number of experimental trials, a drawback particularly troublesome in the adaptation-prone olfactory system (Cometto-Muñiz and Cain, 1995).

The three alternate forced choice tests (ASTM 679-04) for taste and smell are one of most widely applied for threshold determination and a rapid test for determining sensory thresholds of any substance in any medium. The panelists indicate the sample that is different from the two others and the threshold value is in concentration or dilution units appropriate for the substance tested (ASTM International, 2011). The sensory thresholds determination in many food applications is highly desirable. It gives the product developer a powerful tool in knowing the amount of a compound that can be incorporated to achieve the desired sensory reaction.

2.7.1 Application Threshold analysis in food product

- Estimation of detection threshold will be helpful in finding the lowest level of ingredient to be used to provide the background note in the food. For example, determining the detection threshold of cardamom in water, sugar solution (2.5%) and milk (Senthil and Bhat, 2011).

- Determination of important compounds threshold in food products will be find key aroma that effect upon flavor quality of food products. Previous studies showed that using detection threshold method to obtain an accurate estimate of both the ortho and retronasal detection thresholds of DMMP (2,5-Dimethyl-3-methoxypyrazine) in red wine and to understand how DMMP contributes to the aroma profile of red wine (Botezatu and Pickering, 2012).

- Developing quality assurance sensory methodology to evaluate potential food flavor spoilage, for instance, determining rancidity threshold of food products, determining the taste detection threshold of guaiacol, which is a metabolic by-product of the bacterium (*Alicyclobacillus acidoterrestris*), in water and commercial pasteurized apple juice from concentrate using the forced-choice ascending concentration method (Eisele and Semon, 2005).

2.8 Focus group

The first mention of focus group is one of market research technique in the 1920s by Basch (1987) and Bogardus (1926). Focus group also was originally utilized to determine the influence of films and television programs on wartime propaganda by Merton in the 1950s (Kitzinger, 1994). Various definitions of focus group were described in many literatures.

Powell and Single (1996) stated that ‘A focus group is a group of individuals selected and assembled by researchers to discuss and comment on, from personal experience.’ For Kitzinger (1995) mentioned that ‘Focus groups are a form of group interview that capitalizes on communication between research participants in order to generate data.’ Berg (2001) also defined that ‘the focus group may be defined as an interview style designed for small groups. Using this approach, researchers strive to learn through discussion about conscious, semiconscious, and unconscious psychological and sociocultural characteristics and processes among various groups.’

The focus group interviewing was commonly used in many fields such as health services research, market research, and social research. The role of focus group for evaluation include to obtained in-depth information about perceptions, insights, attitudes, experiences, or beliefs. The focus group can be used as a method to complement with other methods such as developing questions or concepts for questionnaires and interview guides (Cameron, 2005; Kitzinger, 1995; Powell and Single, 1996; Rabiee, 2004). Moreover, this method can also collect quantitative information as qualitative data collection methodologies. The focus group interviewing also was applied to assess the information about salt consumption.

In research about the knowledge, perceptions, and behavior related to the consumption of salt and sodium in food and its relationship to health and the nutritional labeling of food in three countries of the Region, the six focus groups were cooperated with the in-depth semi structured interviews with individuals (Sánchez et al., 2012). In part of the knowledge about salt and sodium, they summarized that food could not consumed without salt because the assessors were unable to defined the true meaning of table salt. Many assessors believed that only people who intake high amount of salt would have health risks. Moreover, this research revealed that the most of the assessors did not review nutritional information and they did not understand it.

Powell and Single (1996) indicated that ‘The focus group has advantages over the qualitative methods, such as, the in-depth interview and nominal group technique.’
The focus group also has disadvantages for utilization. The potentials and limitations of this method were shown in Table 2.10 (Powell and Single, 1996; Kitzinger, 1995).

The organization of focus group include developing the focus group guide, selecting the number and type of participants for each focus group, conducting the Focus Group Session, recording information and analyzing information (Powell and Single, 1996; Kitzinger, 1995).

Table 2.10 The advantages and disadvantage of focus group interviewing

The advantages of focus group	The disadvantage of focus group
• The information can be obtained more quickly and this method relatively easy to set up.	• Focus group is unable to provide inferential statistics as a survey by individuals.
• This group of this method can provide beneficial information that individual data collection does not provide.	• The data is not representative of other groups.
• The moderator of a focus group will have access to ‘‘the nonverbal nuances and emotional content that are reflected in voice patterns.	• Information analysis is time consuming and needs to be well planned in advance.

2.9 The labeled affective magnitude (LAM) scale

In spite of the fact that the category scales like 9-point hedonic scale (Peryam and Pilgrim, 1957) are the most widely used for determining consumer preference and acceptability of food products.   There are alternative methods for scaling affect. One of alternative scaling methods is the labeled affective magnitude (LAM) scale (See Lim, 2011). The LAM scale was first used to evaluate food liking/disliking by Schutz and

Cardello, 2000. They indicated The LAM scale was also evaluated by consumers to be as easy to use as the 9-point hedonic scale and significantly less difficult than magnitude estimation. The characteristic of the LAM scale (Figure 2.6) is a line scale that includes the 9-point hedonic scale as intermediated anchor, with two additional anchors: ‘greatest imaginable like’ and ‘greatest imaginable dislike’ (Lim, 2011).

Figure 2.6 The labeled affective magnitude (LAM) scale

Source: Schutz and Cardello (2000)

Because of the good point of the LAM scale, several researches have focused on using this scale to achieve their objectives. For example, the study a comparison of the LAM scale and other scales (Lawless et al., 2010), the consumer acceptability evaluation of food products (Jaeger et al., 2011).