INFLUENCE OF SEASONING PARTICLE SIZES ON COATING PROPERTIES AND SENSORY PERCEPTIONS OF FRIED FLAT POTATO CHIPS

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A Master's Report Submitted in Partial Fulfillment of the Requirements for the Degree
MASTER OF SCIENCE
Department of Food Technology
Graduate School
SILPAKORN UNIVERSITY
2004
ISBN 974-464-533-4

อิทธิพลของขนาดอนุภาควัตถุแต่งกลิ่นรสแบบผงต่อคุณสมบัติการเคลือบติดและการรับรู้ทางประสาทสัมผัสของมันฝรั่งทอดแผ่นเรียบ

โดย

นางสาวธิดาวรรณ ซาอุรัมย์

สารนิพนธ์นี้เป็นส่วนหนึ่งของการศึกษาตามหลักสูตรปริญญาวิทยาศาสตรมหาบัณฑิต

สาขาวิชาเทคโนโลยีอาหาร

ภาควิชาเทคโนโลยีอาหาร

บัณฑิตวิทยาลัย มหาวิทยาลัยศิลปากร

ปีการศึกษา 2547

ISBN 974-464-533-4

The graduate school, Silpakorn University accepted master's report entitled "INFLUENCE OF SEASONING PARTICLE SIZES ON COATING PROPERTIES AND SENSORY PERCEPTIONS OF FRIED FLAT POTATO CHIPS" by Thidawan Sa-Uram in partial fulfillment of the requirements for the degree of master science, program of food technology

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คำสำคัญ : วัตถุแต่งกลิ่นรส / ขนมขบเคี้ยว / การรับรู้ทางประสาทสัมผัส / ขนาดอนุภาค/ การเคลือบติด

ธิดาวรรณ ซาอุรัมย์ : อิทธิพลของขนาดอนุภาควัตถุแต่งกลิ่นรสแบบผงต่อคุณสมบัติการเคลือบติดและการรับรู้ทางประสาทสัมผัสของมันฝรั่งทอดแผ่นเรียบ (INFLUENCE OF SEASONING PARTICLE SIZES ON COATING PROPERTIES AND SENSORY PERCEPTIONS OF FRIED FLAT POTATO CHIPS) อาจารย์ผู้ควบคุมสารนิพนธ์ : ดร.ประสงค์ ศิริวงศ์วิไลชาติ. 101 หน้า. ISBN 974-464-533-4

การศึกษาผลของขนาดอนุภาควัตถุแต่งกลิ่นรสเกลือโซเดียมคลอไรด์ น้ำตาลซูโครส และกรดซิตริกในมันฝรั่งทอดชนิดแผ่นเรียบที่แตกต่างกัน 3 ขนาด คือ 50, 100 และ 200 mesh ต่อคุณสมบัติการเคลือบติดและการรับรู้ทางประสาทสัมผัสของมันฝรั่งทอดแผ่นเรียบ โดยทดสอบการเคลือบติดของอนุภาคแต่ละชนิดเพียงอย่างเดียว และการเคลือบโดยส่วนผสมของอนุภาคทั้ง 3 ชนิด จากการทดลองพบว่าขนาดของอนุภาคทั้ง 3 มีผลต่อการเคลือบติดและการรับรู้ทางประสาทสัมผัสเมื่อเคลือบมันฝรั่งโดยอนุภาคแต่ละชนิดเพียงอย่างเดียว พบว่าเมื่ออนุภาคใหญ่ขึ้น ปริมาณการเคลือบติดของอนุภาคของเกลือโซเดียมคลอไรด์บนแผ่นมันฝรั่งลดลงอย่างมีนัยสำคัญ ($p<0.05$) ในขณะที่ ขนาดของอนุภาคของน้ำตาลซูโครสและกรดซิตริกไม่มีผลต่อปริมาณการเคลือบติดมันฝรั่งอย่างชัดเจน ($p>0.05$) อย่างไรก็ตาม พบว่าเมื่อขนาดของอนุภาคทั้ง 3 ชนิดใหญ่ขึ้น ความเข้มในการรับรสของอนุภาคแต่ละชนิดดังกล่าวจะลดลง เมื่อทดสอบการเคลือบติดแผ่นมันฝรั่งโดยการผสมอนุภาคทั้ง 3 ที่มีขนาดแตกต่างกันเข้าด้วยกันโดยใช้การทดลองแบบแฟคตอเรียลขนาด 3x3x3 พบว่า ความสัมพันธ์ระหว่างขนาดของอนุภาคแต่ละชนิดกับปริมาณของอนุภาคที่เคลือบติดและการรับรสเค็ม รสหวานและรสเปรี้ยว เปลี่ยนแปลงไปจากการเคลือบโดยอนุภาคเพียงชนิดเดียว เนื่องจากเกิดอิทธิพลร่วมระหว่างชนิดและขนาดของอนุภาคต่อปริมาณการเคลือบติดและการรับรสของมันฝรั่ง

ภาควิชาเทคโนโลยีอาหาร บัณฑิตวิทยาลัย มหาวิทยาลัยศิลปากร ปีการศึกษา 2547

ลายมือชื่อนักศึกษา.....

ลายมือชื่ออาจารย์ผู้ควบคุมสารนิพนธ์.....

K45403305 : MAJOR : FOOD TECHNOLOGY
KEY WORD : SENSORY, SNACK, SENSORY PERCEPTIONS, PARTICLE SIZE, COATING

THIDAWAN SA-URAM : INFLUENCE OF SEASONING PARTICLE SIZES ON COATING PROPERTIES AND SENSORY PERCEPTIONS OF FRIED FLAT POTATO CHIPS. MASTER'S REPORT ADVISOR : PRASONG SIRIWONGWILAICHAT, Ph.D. 101 pp. ISBN 974-646-533-4.

The effects of particle size of seasoning powder on coating properties and sensory perceptions of flat fried potato chips were studied. Sizes of seasoning particles including sodium chloride, sucrose and citric acid were varied at 50, 100 and 200 mesh. The coating included individual coating of each seasoning and mixture of three seasonings coating at various particle sizes. The experimental results revealed that there was relation between the seasoning particle size and coating amount as well as sensory perceptions. When each of 3 seasonings was coated on the potato chip, sodium chloride particles showed decreasing amount coated on the potato chip sample with its increasing particle size. On the other hand, the effect of sugar and citric acid size on coating amount was of non-significance ($p>0.05$). Nevertheless, increases in sizes of these 3 seasonings resulted in decreasing their taste intensity. When mixed seasonings at various sizes were applied on the sample using 3x3x3 factorial design, the relationship between the seasoning particle size and coating amount and that between particle size and sensory perception as saltiness, sweetness and sourness were different from those individual seasoning coating as a result of interactions between the particle type and its size on coating properties and also on taste perceptions of potato chips.

Department of Food Technology Graduate School, Silpakorn University Academic Year 2004
Student's signature……
Master's report Advisor's signature……

ACKNOWLEDGEMENTS

I wish to express my sincere gratitude and respect to my advisor Dr. Prasong Siriwongwilaichat for his kindness, ideas, patience, and knowledgeable advice throughout my seminar. I am thankful for his willingness to take the time to suggest and help me achieve my goals. His support, guidance, and encouragement were most appreciated.

Dr. Bhundit Innawong and Ms. Patchimaporn Udomkun are thanked for their suggestion to statistical analysis. I would like to thank all of the post graduate students who assisted me in this research. I sincerely thank all research staff of Thai Quest Fragrances, Flavours, Food Ingredients Ltd. for a great support to my experiments and information.

Finally, I would especially like to thank my parents for their love, financial support, and encouragement given to me throughout my academic period.

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CHAPTER 1

INTRODUCTION

Snack food are the food eaten during meal time. Their main components are carbohydrate and fat. Thus, snack foods provide energy. They are usually called by nutritional researchers and doctors as junk foods (Bunyasirikun, 1999). Snack foods are the means to prevent tummy rumbles between primary meals. To most kids, the snack is an after-school treat. Meanwhile, for their parents, it is a night time reward after a long, hard day. To the athletically inclined, snacks provide needed energy before and after workouts.

However, the term “snack” can not be confined to traditional style items such as popcorn, expansion-extruded products, potato chips, and similar products, but has a very much wider connotation covering a large proportion of the foods that have been customarily consumed as a component of or with main meals (Booth, 1990).

It is quite difficult to define the real meaning of snack. One problem is the size of portion or the quantity usually offered or eaten. There is no real problem in the case of what might be termed that “mini snack” taken at a traditional time, e.g. mid-morning, late afternoon or at a work break or interruption to whatever activity is going on. Snacks can be eaten at any time one wants.

Snack foods are usually differentiated and classified by seasoning powder coated. For example, potato chips, pretzels, popcorn, and tortilla chips are coated with salt, cheese powder, and assorted seasonings. The amount of seasoning is very important to product acceptability, so the producer has to make certain that the snack are completely and evenly coated on all sides.

Factors influencing coating efficiency include shape, size, oil content, moisture content, flow ability, adhesion and formation of seasoning powder. It also depends on the coating method used. These factors affect snack quality and consumer perception.

Therefore, controlling seasoning powder quality is a key to successful snack product improvement. The main objective of this study was to examine the influences of particle size of main ingredients in seasoning powder: sodium chloride, sucrose, citric acid on coating properties and sensory perceptions.

The results are expected to be beneficial to seasoning improvement by controlling its appropriate size that meets desired taste impact.

CHAPTER 2

LITERATURE REVIEW

2.1 Snack market

The snacks can be divided according to manufacturing process (Lertpattanakom, 2001) as below:

1) Deep fat fried is a long time frying process. The shape of product can be plate, stick, ring or other shape.

2) Quick fried is a short time frying at high temperature of 200 °C and very short time of 10-15 second. The products are thin chips.

3) Extruded snack is produced from the seed of cereals or potato starch mixed with water until dough is formed. The cooking process is made under control pressure and high temperature before the product is dried and passed through the extruder to obtain very thin chip.

4) Roasted snacks are those nut products such as peanut, petachio, green nut etc.

In U.K., snack foods are categorized as candy, cookies/crackers, potato chips, corn/tortilla chips, snack cakes/pies, snack nut meats, frozen pizza and popcorn. These are also some imported items such as dried fruit, extruded snacks, hot snacks, meat snacks, pretzels, fabricated chips, granola snacks, toaster pastries (Booth, 1990).

In Thailand, snack foods are divided into sweet biscuits/cookies, confectionery, dairy products, savoury snacks.

Snack foods in Thailand are fast growing especially savoury category. Market value of snacks in Thailand is showed in Table 2.1.

Table 2.1 Retail sales of savoury snacks: value growth 2001-2002

Categories	Value growth (%)
Extruded snacks	12.5
Chips/crisps	10.4
Nuts	9.0
Corn chips	7.0
Popcorn	5.5
Tortilla chips	5.2
Pretzels	3.2
Other savoury snacks	10.4
Svoury snacks	10.6

Source: Trade press (2002)

2.2 Potato and potato chip manufacturing

2.2.1) Potato was commonly known as potato. Its scientific name is *Solarum turosum*. It grows in cool weather at temperature of 15-20 °C (Putyapiboon, 1983). Chemical components of potato was different by the type of potato, growth area and procedure, age of harvest, and handling after harvest and environment. Its composition is shown in Table 2.2.

Table 2.2. Approximate component of potato

Composition	%
Total carbohydrate	13.30-30.53
Fiber	0.17-3.48
Protein	0.70-4.60
Ash	0.44-1.90
Fat	0.02-0.96

Source: Putyapiboon (1983)

2.2.2) Potato chip manufacturing

Particular varieties of potato with sufficiently high solid content (about 21%) and regular shape and size, have been carefully harvested. They are stored under high-humidity conditions at temperature about 46 F (8 °C) at which moisture loss is minimized and the production of sugar from the potato starch is also maintained at as low level as possible. If sugar content is too high, chips are produced with too strong color (Booth, 1990).

Following washing and destining, potatoes are peeled (steam or lye peeling plus gentle abrasion is usual) and are then hand-trimmed and inspected. Peeling is sometimes omitted in a recent manufacturing development that is claimed to result in a bitter flavoured chip. Then the potatoes are thinly sliced. The slices are then washed to free of adherent starch granules. They are then blanched and dried before passing on a conveyor to the very hot bath of vegetable oil (at about 255 F; 124 °C) in which they are rapidly dehydrated and cooked. Excess oil is drained off, sometimes centrifuged off, before they are cooled. They may then be salted and flavoured in various ways (usually by powder adhesion to residual fat on the chips, but a spray is also possible) before packaging in moisture-proof containers. These products are almost always used in savoury snack context.

2.3 Factors influencing seasoning coating efficiency

2.3.1) Particle size and shape

Since the 3 main seasoning components: i.e. salt, sugar and acid affect overall taste and quality of snack products, their properties need to be considered in coating process. The different particle of ingredients was found effect its solubility, distribution and mixing. The sensory perception of snack is associated with these ingredient properties.

Particle size and shape influence an adhesion of topical seasonings. Smaller particles tend to adhere substrate, such as chips, better than larger particle (Kuntz, 1997). This is due to their light bulk density and the high surface-to-volume ratio that provide more contact surface.

As a result, particle size and shape affect coating efficiency. It is usually assumed that particles are approximately spherical and their shapes are important in electrostatic powder coating. However, Kuntz (1994) reported that particle shape, surface area, and the geometry of the salt particle determine how well the salt adheres to a product. Finer particles have a greater surface area so they are able to obtain a higher charge to mass ratio than their coarser counterparts during electrostatic application. Therefore, smaller particles should be more efficient in coating on the snack surface (Bailey 1998; Sandor 1990; Pannell 1980).

Miller and Barringer (2002) studied the effect of sodium chloride particle size and shape on nonelectrostatic and electrostatic coating of popcorn. It was found that for nonelectrostatic coating, hollow pyramid salts of different sieve sizes were related to coating efficiency. As the salt size decreased, the coating efficiency increased. Due to their decreased weight, smaller particles should be dispersed more evenly across the popcorn by air currents and adhere better, reducing fall off during handling and storage. Large coating particles, 250 μm and larger, are more difficult to handle because of gravity's attraction for their large masses (Sandor, 1990). For crushed flake salts of different sieve size, as the salt size decreased, the coating efficiency also increased. For hollow pyramid salts of different sizes, the smaller the salt, the greater the improvement with electrostatic coating.

Types and grades of salt have different surface properties, therefore, their effects on the savoury profile vary (Burg, 1998). Purified salt is crystallized for food use by several methods. Vacuum pan salt provides cubic crystals grades by size for different applications. They also can be rolled into flakes for better adhesion. Grainer, or Alberger ®, salt is a vacuum-evaporated product having step-sided, hollow pyramidal crystals of greater surface area than that of the regular cubes (Burg, 1998).

According to the study on nonelectrostatic coating of salt by Miller and Barringer, (2002) crushed flake provided the best coating efficiency followed by hollow pyramid, cube, and porous cube. Surface area and the geometry of the particle determine how well the salt adheres to food product (Kuntz, 1994). This is important for salt used in topical applications such as snack seasoning. The crushed flake and hollow pyramid salts provided more surface area than the cube due to more surface area available to adhere to the product.

Particle size of seasoning affects solubility properties. Normally small particles post good solubility when compared with bigger particles because of their more surface area to adhere and combine with water. Water can be adsorbed and infiltrated to smaller particles better than bigger particle. As a result, they are better coated on the product. Because the particle size affects solubility and adhesion of seasoning powder on snack base so perception of consumer on snack products need to be considered. Smaller particles tend to be perceived higher intensity.

Salt solubility also affects the sensory perception. Regardless of form, salt dissolves to a level of approximately 26.4% by weight at room temperature before reaching saturation (Kuntz, 1994). However, the physical form, particularly size and structure, affects the rate at which the salt dissolves. The surface area to weight ratio has the greatest effect on this rate. Porous structure, such as in dendritic salt, solubilizes rapidly. Irregular surface found in Alberger and pulverized salt also make these forms go into solution more quickly than a cube. The larger the cube, the longer it takes to dissolve completely. Therefore, when the application requires rapid solubility, a special salt may give better results.

Particle size also impacts flavour perception. Frank (2000) reported that, in some cases, the more powdery a seasoning is, the more dull the flavour delivery, because it basically gives a straight-line-type flavour delivery. Whereas different particle sizes affect the taste buds at different times causing the perception in the palate more complex (Vil, 2000). A bigger particle size takes a bit longer to dissolve, but once it hits, it gives a burst of flavour. So, there are times when using different sugars, or different acids allows the developer to manipulate the flavour perception of the seasoning.

Seasoning adhesion to a substrate's surface is also associated with its density. Larger particle size and dense particulates will simply roll off a substrate. On the other hand, a smaller sized and less dense particulate is more likely to adhere (Frank, 2000).

Bulk density is also effects solubility. Salt solubility tends to increase with increasing surface area and lower bulk density (Kuntz, 1994). The more irregular shape and the more porous structure of salt provide the lower bulk density. These properties play a role as they become important factors in dried mix applications.

If the bulk density of the salt is equivalent to that of other ingredients it will tend to remain evenly dispersed throughout the mixing, handling and distribution cycles. Bulk density is expressed as weight per volume, usually in grams per 100 cubic centimeters (Kuntz, 1994).

2.3.2) Effect of fat and oil

Fat and oil are among the main ingredients used in snack foods. It is involved in seasoning composition, frying process, and coating.

In particular, it plays an important role in flavour stability and delivery. Klahorst, (1997) reported that they acted as solvents for hydrophobic flavours, and serve as components of the interfaces that are involved in flavour release from food. Fat affects aroma, character , masking, release and reactions of flavours. Most aroma chemicals are partially soluble in fat, which in conjunction with aroma, provides mouthfeel and richness. Aroma compounds are responsible for the buttery, creamy rich flavour of dairy products high in milk fat. Fats are precursors for flavour reactions that occur during heating with protein in baked goods and roasted meats. They participate in aging reactions that give unique flavours to cheeses. The ability of fats to mask off-flavours is attributed to their capacity to solubilize off-flavours, decreasing their volatility.

Deep fried oil, snacks, such as potato chips and corn chips, are processed in a fryer. Several factors influence the selection of the fat used for frying. These factors include stability, melting point, flavour contribution, nutritional profile and fat source (Frank, 2000). The choice ultimately determines finished-product parameters including flavour, nutritional labeling and appearance.

Since snacks are served cold rather than warm like foodservice-type products, the surface of snack needs to be taken into account. The phase of the fat at room temperature defines the snack's surface appearance. For instance, a fat that is solid at room temperature leaves the chip with a dryer appearance than one that is liquid at room temperature (Shockley, 2000).

Spraying snack cracker with 15% to 17% oil by weight of the baked cracker reduces the mouth-drying effect associated with dry cracker (Frank, 2000). Oil also enables seasonings to adhere to the surface of a substrate. In the case of potato or corn

chips, seasonings are merely applied directly out of the fryer while the oil on the chip is still warm. Fat with a high melting point gives better adhesion than one that is liquid at room temperature, which can cause the seasoning to slide off the chip. In addition, an oily chip will coat other snacks in the mix, as well as the interior of the package (Frank, 2000).

Vil (2000) reported that if oil is not applied at the right temperature, and is somewhat plastic, rather than being and adhesive, it will have tendency to grab onto the seasoning and fall off. For example, if the temperature of the substrate is around 120 F when the seasoning is being applied, the surface oil from the fryer being to plasticize will cause inconsistent coverage. With an oil-adhesion system, there are limited to the amount of seasoning that will stick to the surface of the snack item. Too much oil used can affect the flavour of the seasoning.

When oil is sprayed for seasoning adhesion, the ratio of oil to seasoning may be as high as 70:30 and for others as low as 50:50 (Blackwelder, 2000).

Miller and Barringer (2002) found that for all salts of all sizes and shapes, the more oil on the popcorn, the more efficient the coating. This is expected since the oil holds the salt onto the popcorn, hence reducing loss during handling and storage.

2.4 Taste and Ingredients

There are numerous criteria for the classification of ingredients for snacks. However, it is probably most helpful to start with a fundamental one. Snacks can be defined as flavoured products. This criterion amounts to a basic essential attribute in the snack content. The main ingredients of seasoning powder are salt, sugar, acid, monosodium glutamate (MSG), vegetables powder, spices powder and flavours. Flavour sources used are from either synthesis or natural extract such as onion, pepper, chilli, galanga, lemongrass and kaffir lime, meat, chicken, duck, fish sauce and coconut milk flavour. It can also be divided according to the palette of flavours into several principal categories.

2.4.1) Neutral and relatively poorly distinguishable in terms of flavour contribution except when present in large proportion and when in a mainly

unprocessed form. This category includes most cereals such as (1) a number of roots and vegetables (e.g., potatoes, cassava), (2) milk, (3) some meat products, particularly gelatin, tripe, glands, and similar items, (4) a few fishy items e.g. particularly the squid and octopus kinds, (5) a great variety of oils and fats, (6) with the latest addition of some fungal and algal bulk sources of protein. These can be generally regarded as “fillers” or substrates for snacks, but can usually be persuaded to develop significant flavour characteristics.

2.4.2) Salty ingredients

Salt can be present in snack food ingredients either naturally as a part of isotonic fluids in meats for example or by addition usually for preservative or dehydrating purpose (Booth, 1990). Another purpose where its use is almost subliminal is to remove the rawness (almost “off” flavour) that is commonplace in some cereals and other neutral raw materials; for example, bread and porridge.

Sodium chloride (NaCl) is integral to the sensory profile of salty snacks. Grillette (1984) tested the effect of salt in a number of products. It was concluded that the addition of salt affected the overall flavour of the products such as mouthfeel. Salted products were perceived as thicker or less watery. Adding salt enhanced the sweetness, in some cases to a higher degree than the increase in saltiness. Salt often decreased or masked metallic or chemical off-notes flavours. Salt rounded out the flavour balance, blended flavours together and increased the perception of flavour intensity. The increase in the perception of saltiness depends on the salt level used in the product.

NaCl is one of food flavour normally used in potato chips. It not only gave saltiness taste but NaCl can also increase sweetness of sugar and reduces acidic taste of some components. Particle size and solubility were the most important characteristic of NaCl. They normally used NaCl at particle size of 4-40 mesh (Putyapiboon, 1983) as seasoning mix for fried snack products such as potato chips and potato starch.

2.4.3) Sweetening ingredients

The main sweetening ingredient in snack is sugar. Sugar for snack coating can be sucrose which should be in fine powder form or icing sugar. In some formulation, sweeteners such as aspartame or other sweeteners such as Monoammonium glycyrrlizinzte (MaG) might be added. Sucrose and invert sugars are twice as sweet as the inferior of glucoses and saccharin.

It is a major problem to choose horses for courses when it comes to using sweeteners in snack products. The principle constraints are (a) quality of sweetness; (b) cost and availability; (c) stability in the manufacturing and in the final product context; (d) textural considerations; (e) volume, solid content, and cost/weight relationship, all related to sweetness intensity; (f) legislative status, including nontoxic certification, legal, and physiological limitations on use, etc. (Booth, 1990).

2.4.4) Acidic ingredients

Most acidic raw materials contain other flavours, e.g. essential oils and other natural flavouring compounds that characterize them beyond the acidity per se (Booth, 1990).

The organic acid involved in the flavour of these ingredients is also usually characteristic of the raw material and can range for a given pH value from the relatively bland acidity of lactic and butyric through fumaric, tartaric, malic, and citric to the quite sharp acetic. Normally, more than one or two types of acid are used in the food formulation such as citric acid, succinic acid, malic acid and tartaric acid.

2.4.5) Bitter ingredients

In the flavour palette the presence of bitter or astringent flavours is quite important. Many herbs and plants confer a measure of bitterness. Some fruits and vegetables also have pronounced bitterness. Grape skins, for example, contain amount of tannin. Many red wines containing the extract from the grape skins are noticeably astringent (Booth, 1990). The very bitter drug quinine is the basis for tonic water, and practically all citrus fruits contain a quantity of a bitter ingredient. Bitterness is by way of being an appetite enhancement to foods, particularly to those where other “savoury” appetite stimulants, e.g sweet and sour, or just acid are not appropriate or

present, and as such is used in many snack foods. In the area of nuts, bitter almond are well known as flavour enhancers, and various kernels, e.g peach and cherry also contain bitter principles.

2.4.6) Monosodium Glutamate (MSG), Glycine, Ribotide (I + G) or other amino acids are used to increase umaminess.

2.5. Sensory testing

The aim of sensory testing is to measure, analyse and interpret reactions of humans to food characteristics using human senses. There are, at present, no single or group of instruments which can do this with any level of accuracy. Some correlations between instrumental readings and human response are possible, but they tend to focus on single characteristic only such as colour or sweetness.

Sensory testing depends heavily on human perception, and humans are notoriously subject to biases and they are inconsistent in their responses to stimuli. Thus, there is a large capacity for error in collecting, analysing and interpreting sensory data. For this reason correct methodology is crucial. Only foods that have been prepared with due care are worth testing and preparation conditions of any sample must be carefully controlled. The only exception is when tests are conducted on finished products of different brands.

There are also limits on the capabilities of panellists and they should be screened for their ability to detect differences and certain odours, flavours or colours, their likes and dislikes, and the foods they avoid. If the same panellists are used routinely, this information should be documented. All panellists must be willing to participate and the principles of scientific ethics with respect to testing of human subjects should be followed. Any risks to the participants should be outweighed by the benefits to the individual, to society and to the core of knowledge (Quest, 2002).

There are several types of sensory tests from which to choose. The test chosen depends mainly on the objectives of the test. The objectives may involve three classes of test, i.e. discrimination testing that is analytical testing for differences, descriptive

analysis where panelists score or describe a product using a specific language and hedonic or consumer tests where panelists rate the acceptability or give their preferences for products. The first two classes are carried out under controlled conditions and involve only a few panelists. The latter requires panelists who are representative of the consumer and may be carried out in sensory laboratories, but equally can be conducted in the field.

2.5.1) Discrimination Testing

Discrimination tests may be either difference tests or tests of sensitivity. Difference tests are commonly used in quality assurance, cost reduction, raw material evaluation and storage, stability studies and panel selection.

There are two types of difference tests:

1) Simple difference tests which simply try to determine whether a difference is perceptible between samples. This difference can be based on variation in any single or a combined group of attributes.

2) Directional difference tests ask whether the samples differ on the basis of some well defined characteristic such as sweetness or yellowness, etc. Not all testing methods are suitable for both simple or directional differences (Quest, 2002).

Table 2.3 Uses of different sensory tests

Simple Difference	**Directional Difference**	**Preference or Consumer**
Triangle	Paired comparison	Paired comparison
Duo-trio	Ranking	Ranking
	Rating or scaling	Rating or scaling

The only test in table 2.3 which gives any indication on the degree of difference is the rating test.

Threshold tests, which test an individual's sensitivity to certain stimuli such as sweetness or sourness, are also discrimination tests and are used mainly for panel selection and training.

2.5.2) Descriptive Analysis

Descriptive tests which characterise samples with respect to well defined characteristics and semantics become extremely important. It is often necessary to train panelists to recognise the exact meaning of the terms used to describe the product. A much fuller picture of the product is produced than it is possible by difference techniques. However, because extensive training of panelists is essential, this type of test has an extra cost associated with it and requires panelists who have good discrimination ability.

Rating scales may be considered as a difference test but it can also be used to score the attributes in Quantitative Sensory Profiling (QSP) or some other descriptive analysis test. In these tests the sensory attributes are profiled and it is commonly used for flavour and texture assessment.

In QSP testing panelists are often highly trained and small panels of only 5 to 10 judges are used. Training may take up to six months and this is why such panels are so expensive to set up. The trained panelists become 'experts' in evaluating a particular food or group of foods, such as beers.

Once panelists are trained and the standard vocabulary has been generated, there are three main stages in descriptive analysis.

1) Discrimination - panellists determine the characteristics that contribute to the appearance, flavour or texture of the product.

2) Description - the characteristics detected are often described in a common terminology or descriptors although sometimes free form profiling is used where panellists make up their own descriptors.

3) Quantifying the characteristics – the characteristics are scored for strength or intensity.

There may or may not be a panel discussion after the test. Where panel discussions do occur, the panelist should not be overly meek or too forceful.

2.5.3) Hedonic, preference or consumer tests

The aim of these tests are to determine the degree of liking or acceptability of a product and/or whether one product is preferred over another. It is possible for a sample to be preferred over another and yet be unacceptable.

For this type of work panels can be used but they can in no way be considered as representative of consumers in general. This can be partially overcome by using large numbers of "in-house" panelists, but this is still only a compromise because staff members are not necessarily representative of the general population. A special sector of the market with a given product such as working mothers or children might be targeted. Then, members of the sector should be used panelists to get accurate results.

In particular, it must be realized that consumer acceptability often involves other attributes of the product rather than just the sensory attributes. Package design, package size, cost, convenience, nutritional characteristics and social values are amongst the factors which the consumer may consider.

Nevertheless, in-house tests can provide guidance to likely acceptability and preferences. If in-house panelists, who are highly familiar with the product, cannot detect a difference between products, then there is no point in setting up expensive consumer tests to determine preferences.

Quantitative Descriptive Analysis (The QDA Method)®

This procedure was developed to overcome some of the problems of the Flavour Profile method. The scale was extended from three points to an unstructured line scale. There is no post test discussion and therefore the panel leader has less influence on the test outcome. Statistics is used to analyse the results which are usually presented in the form of a spider's web graph. The distance from the centre of the graph provides the mean of the attribute and the angles between the outer lines are derived from correlation coefficients. Overlaying spider's web graphs demonstrates clearly how products differ.

Development of the Texture profile method stimulated interest in research in new descriptive methods and especially methods that would overcome the weaknesses previously identified and reliance on qualitative information, the use of product

characteristics established by the experimenter, and so on. Further interest in descriptive methods developed as a result of the growth of new products and competition in the marketplace for products with unique sensory properties, as well as by advances in measurement and improve data processing systems. The QDA method (Stone et al., 1974) represented an opportunity for sensory evaluation to satisfy these needs; however, it also was a substantive departure from existing methods in the sense that the approach was primarily behavioral in orientation with considerable emphasis on the use of replication as a basis for assessing the quality of the output. It was determined that the method would be more than a simple rephrasing of the test questions or the use of a particular scale. In effect, the method required a different approach to the concept of descriptive analysis, beginning with the subject selection procedure and concluding with communication of results in an understandable and actionable manner.

Stone and Sidel (1985) represented the development of the method evolved from a number of major considerations to ensure that it would be:

1) responsive to all the sensory characteristics
2) a multiproduct test
3) use of number of subjects
4) able to use subjects who are qualified before participation
5) able to employ a language development process free from leader influence
6) quantitative
7) providing a useful data analysis system
8) providing a data processing capability

2.6 Relative humidity, sorption isotherm and hygroscopicity

2.6.1 Relative humidity

Relative humidity is derived from the ratio of absolute moisture content to saturation content. Depending on its temperature, air can absorb different quantities of water vapor until it is saturated (100% relative humidity). Absolute humidity (moisture content) is the quantity of water actually present in the air and is measured in grams per cubic meter (g/m^3). Relative humidity expresses as a percentage the

quantity of water vapor the air has at a specific temperature, relative to its saturation content. If, for instance, air at 20°C has an absolute humidity of 12.1 g/m³, it will have a relative humidity of 70%. If air has reached its saturation content at 20°C, it has absorbed 17.3 g/m³ of water (Scharnow, 2004).

Sorption behavior is absorption or release of water vapor by a hygroscopic cargo until equilibrium is reached. It is the term used to describe the characteristic of hygroscopic goods, as a function of temperature and of a particular water content of the product, to absorb or release water vapor from or into the ambient air until a state of equilibrium is established. Sorption behavior is determined by a partial pressure gradient, in which in accordance with the diffusion law water vapor always flows from the higher to the lower partial pressure until a vapor pressure equilibrium is established (Scharnow, 2004). Intake of water vapor is here known as adsorption, while release of water vapor is known as desorption (Fig. 2.1).

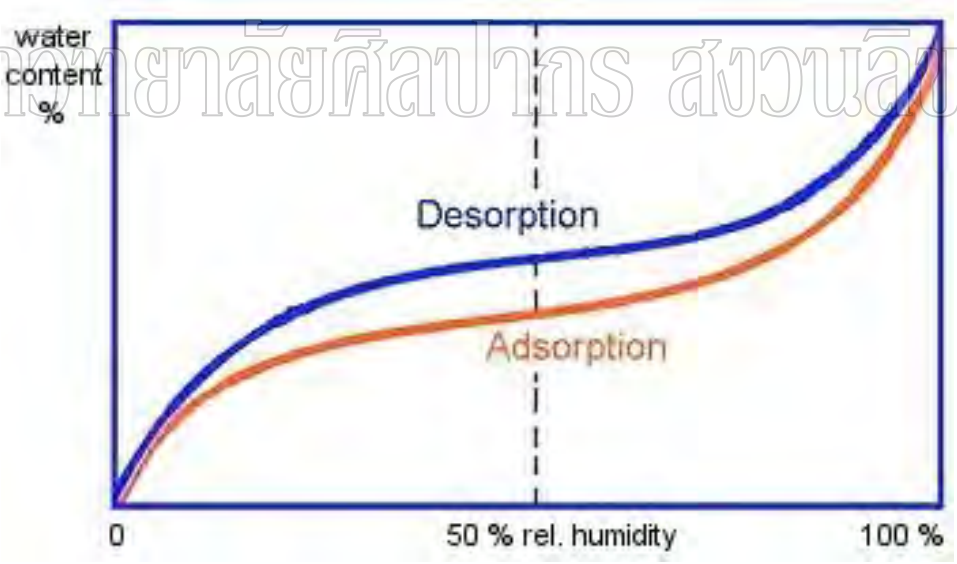


Fig. 2.1 Adsorption and desorption curve: Y-axis: water content, X-axis: relative humidity

2.6.2 Sorption isotherm

A sorption isotherm is the graphic representation of the sorption behavior of a substance at a specified temperature. It describes the relationship between the water content of the substance and the relative humidity of the ambient air at a particular

temperature (Scharnow, 2004).

When determining the equilibrium states between the product and the ambient air, differences are found between the values which are measured during water vapor adsorption (adsorption isotherm) and those which are measured during water vapor release (desorption isotherm). The values for the desorption isotherm are always somewhat higher than those for the adsorption isotherm. The differences between adsorption and desorption isotherms are at their greatest at moderate relative humidities (Fig. 2.1). The adsorption isotherm at 20°C, which describes the state of hygroscopic goods after manufacture, is generally used in practice.

The profile of a sorption isotherm is characteristic of the hygroscopicity of a product. Highly hygroscopic substances exhibit a steep sorption isotherm, while sparingly hygroscopic goods exhibit flat sorption isotherms. Weakly hygroscopic goods exhibit no or only a slight change in their water content as a consequence of variations in relative humidity (Scharnow, 2004).

Sorption isotherm rises steeply, i.e. the product is strongly hygroscopic, as is the case with silica gel (desiccant for corrosion protection) or dried fruits. In contrast, sucrose or tartaric acid exhibit an abrupt change in the sorption isotherm profile. Over a wide range, until the equilibrium moisture content of approx. 85% is reached, water adsorption is low and the product exhibits scarcely any hygroscopicity (anhydrous form); once the flow moisture point has been reached, sucrose rapidly absorbs large amounts of water vapor, causing it to deliquesce, so explaining the steep rise in the second branch of the curve (formation of hydrate). This type of sorption isotherm is typical of many crystalline goods, such as for example salt, sugar, potash and other fertilizers (Scharnow, 2004).

Scharnow (2004) reported that crystalline goods have particular storage climate conditions with regard to temperature, humidity/moisture and ventilation (SC VI) in order to counter the risk of deliquescence or agglomeration (sticking together).

White sugar is regular consumer sugar. It is obtained from raw sugar by washing and centrifuging (affination). Its sucrose content is 99.9%.

Refined sugar is chemically ultrapure sucrose which has been obtained from white sugar by dissolution and recrystallization. It also has a sucrose content of 99.9%.

Powdered sugar is produced by grinding white or refined sugar crystals to a fine

powder and sieving the powder. The max. grain size is 0.05 mm.

Salt (cooking salt), chemically sodium chloride (NaCl): mainly mined as rock salt or obtained from sea salt pans. Depending on how it is produced, salt is classified as rock salt or boiled salt. Rock salt, which is mined and finely ground, is primarily used in the food industry. Boiled salt is obtained from brine and has a higher content of magnesium chloride and calcium chloride than rock salt, as a result of which it is more highly hygroscopic than rock salt, with the finely divided grades being more highly hygroscopic than the coarser grades. Boiled salt also agglomerates more readily than rock salt.

2.6.3 Hygroscopicity

Hygroscopicity is the term used to describe the capability of goods to respond to the moisture content of air by absorbing water vapor from the air or releasing water vapor back into the air (Scharnow, 2004). Of decisive significance for the absorption or release of water vapor are:

- the **relative humidity** of the ambient air
- the **water content** of the goods (product moisture content)
- temperature.

The water content of a product is the percentage of its total mass which is constituted by water. Hygroscopic goods have the characteristic of variable water content. They are capable of absorbing water vapor from the air or releasing it back again. In a first approximation, it may be stated that: In ambient air of low relative humidity, they release water vapor, while in ambient air of high relative humidity, they absorb water vapor. They are thus capable of modifying the proportion of their mass constituted by water, i.e. the water content of the product.

Initially, crystalline goods hardly respond at all to the water vapor content of the ambient air, such that their water content is close to 0% (flat adsorption isotherm). Only once the flow moisture point is reached, which for example for sugar is > 80%, does the sugar absorb water vapor so quickly and in such large quantities that it deliquesces (abrupt rise in adsorption isotherm) and loses its flowability (Fig. 2.2). When moistened sugar dries out, it releases the absorbed water vapor to its

surroundings and hardens and cakes (Scharnow, 2004).

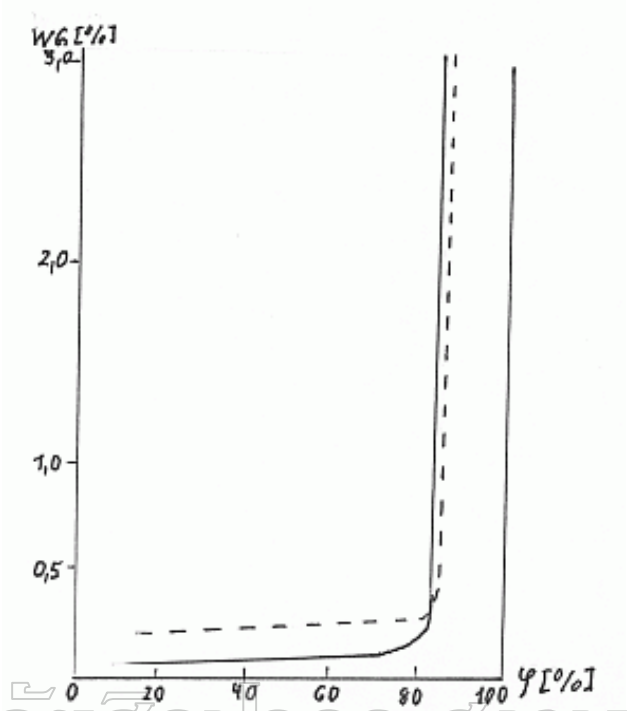


Fig. 2.2 Sorption isotherms for white sugar — 20°C and --- 10°C

Crystalline goods such as sugar, salt, fertilizer are slightly hygroscopic, but very sensitive to moisture at the point at which the flow moisture point is reached and the product deliquesces. Sugar and salt are classed as hygroscopic crystalline goods. Hygroscopic crystalline goods differ from the preceding hygroscopic goods in that they have a substantially lower water content (WC > 0 - < 1.5%), and thus belong to water content class 1 (WCC 1). Moreover, due to their crystalline structure, their adsorption behavior is governed by different rules (Scharnow, 2004).

The sorption isotherm for cooking salt (Fig. 2.3) shows that it absorbs virtually no water vapor from its surroundings at relative humidities of up to 74%. Once the water content has risen from 0.05% to 0.5%, so reaching the flow moisture point, salt begins to absorb water vapor so readily that it passes into solution at a relative humidity of 75% (Scharnow, 2004).

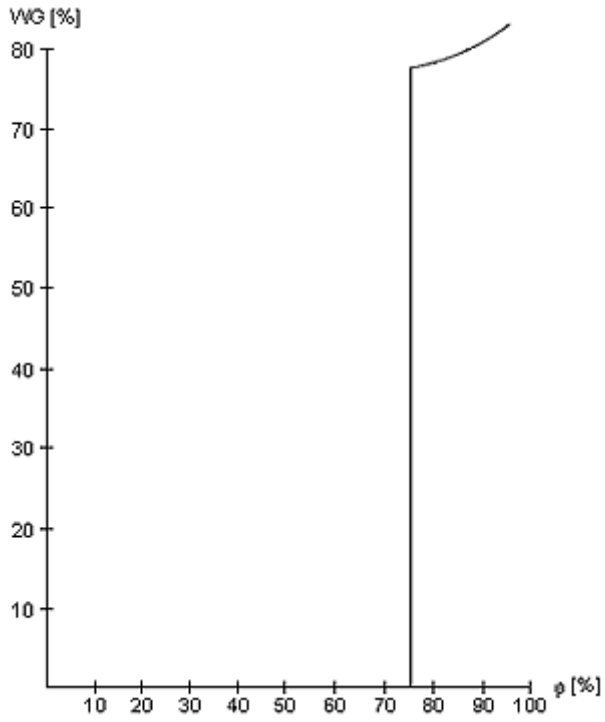


Fig.2.3 Sorption isotherm for cooking salt (sodium chloride, 20°C)

CHAPTER 3

PARTICLE CHARACTERISTICS AND SIZE DISTRIBUTION OF SODIUM CHLORIDE SUCROSE AND CITRIC ACID

Particle size is normally separated by sieving but it is reported only as the number of the sieve. For example, the particle size of 50 mesh is that retaining in USS sieve number 50 with perforation size of 300 μm. Average particle size could be represented by mode value.

In this study, particle size of sodium chloride, sucrose and citric acid were determined. Their distribution on fried flat potato chips by Scanning Electron Microscope (SEM) was also included.

MATERIALS AND METHODS

3.1 Materials and equipments

3.1.1) Deep fried flat potato chips from factory

3.1.2) Sugar whole

3.1.3) Salt whole

3.1.4) Citric acid

3.1.5) Hexane

3.1.6) Acetone

3.1.7) Miller

3.1.8) Sieve shaker U.S. standard sieve series

3.1.9) High density polyethylene OPP20u/PE (White)
18u/PET (VM) 12u/DL/CPP20u (thick-73u+/-5u), size 7”x11” and 8”x12”

3.1.10) Mater Impulse Sealer

3.1.11) Particle size analyzer**,** model Coulter LS 100 Q Series, USA

3.1.12) Scanning Electron Microscope (SEM), model Cam Scan MX-2000, UK

3.1.13) Force air Oven, Memmert

3.1.14) Snack coating machine

3.1.15) Refrigerator and freezer, Electrolux

3.1.16) Balance

3.2 Particle size preparation

To determine particle size of sodium chloride, sucrose and citric acid, sodium chloride, sucrose and citric acid were ground by a hammer mill. The particle size was determined by placing 500 grams of ground sample in sieve shaker (U.S. standard sieve series). Each particle sample was run on the sieve shaker for 10 minutes at 0.5 rpm. Then individual sieve was weighed. The percentage of sodium chloride, sucrose and citric acid retained in each sieve was determined. Three different sieve sizes were used: 50, 100 and 200 mesh size. The sieve size of sodium chloride, sucrose and citric acid are indicated below. As the number increases, the size decreases.

Sieve size (mesh)	Perforation size of USS sieve (μm)
35	500
50	300
100	150
200	75

Samples were packed size in high density polyethylene OPP20u/PE (White) 18u/PET (VM) 12u/DL/CPP20u (thick-73u+/-5u) and sealing (Mater Impulse Sealer).

3.3 Determination of particle size and size distribution

Sodium chloride, sucrose and citric acid are distributed in hexane (commercial grade). Their particle sizes were measured by Particle Size Analyzer model Coulter LS 100 Q Series. The characteristics and distribution of particles and their appearance on potato chip when coated were determined by Scanning Electron

Microscope (SEM). Weight each ingredient for individual coating: sodium chloride at 1.13%, sucrose at 1.28% and citric acid at 0.16 % of total weight of product formulation. Bake fried flat potato chip in force air oven at 120 ° C for 10 minutes. Coat sodium chloride, sucrose and citric acid on potato chip in coating machine (Appendix 8) for 11.30-12.00 minutes. Coated sample were packed in high density polyethylene and kept in freezer at -21 °C. Leave samples until reach ambient temperature, sizes distribution of sodium chloride, sucrose and citric acid on fried flat potato chips were determined by Scanning Electron Microscope (SEM).

RESULTS AND DISCUSSIONS

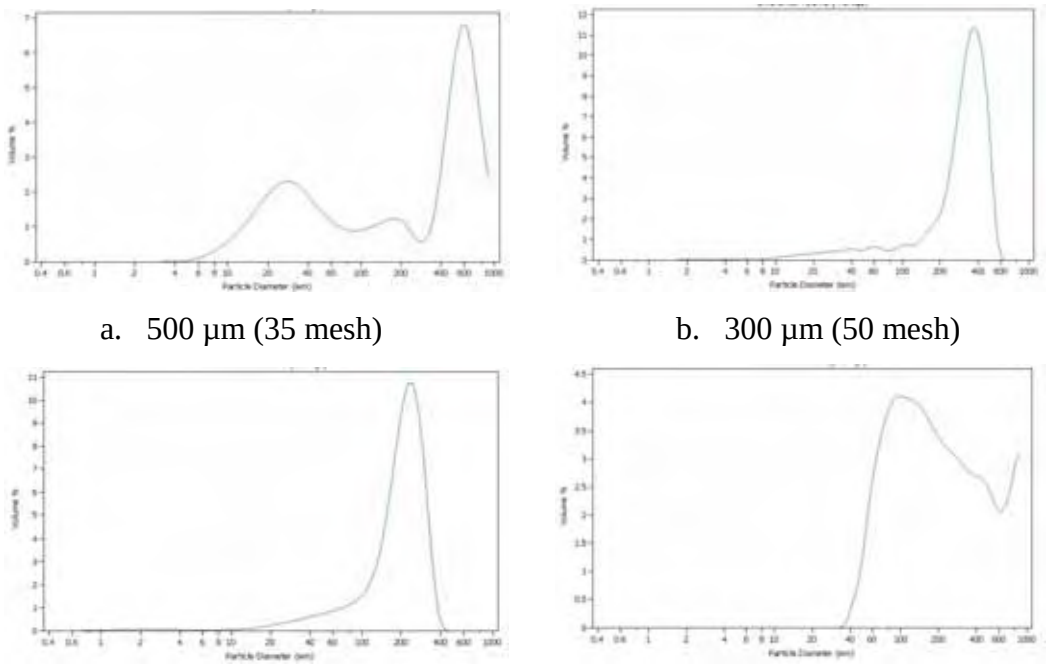
3.4 Particle size and size distribution of ingredient

3.4.1) Sodium chloride

There were more than one peak of sizes distribution care of sodium chloride retaining on sieve perforation size of 500 µm (35 mesh). Two peaks were found in sizes distribution plot of sodium chloride of 20-40 and 200 µm due to some fine particle size which might be attached to the big particles retained on the sieve. However, the average particle size was represented by mode value of 623.30 µm.

Particle size distribution of sodium chloride retaining on sieve perforation sizes of 300 µm (50 mesh), 150 µm (100 mesh), 75 m (200 mesh) were shown in Fig. 3.1. The average particle sizes were found as mode value of 356.00, 223.40, and 96.49 µm, respectively.

Characteristics of sodium chloride retaining at various sieve sizes were exhibited by SEM (Fig. 3.2). Smaller particle size gave finer appearance. However, fine particles were also found with larger particles. It is possible that the smaller particles can be adhered on surface of bigger particle size and can not passed through the sieve. Some of smaller particles can also adhere itself to bigger particles due to their higher moisture adsorption leading to lumping. These could affect the sizes distribution curve in Fig. 3.1.



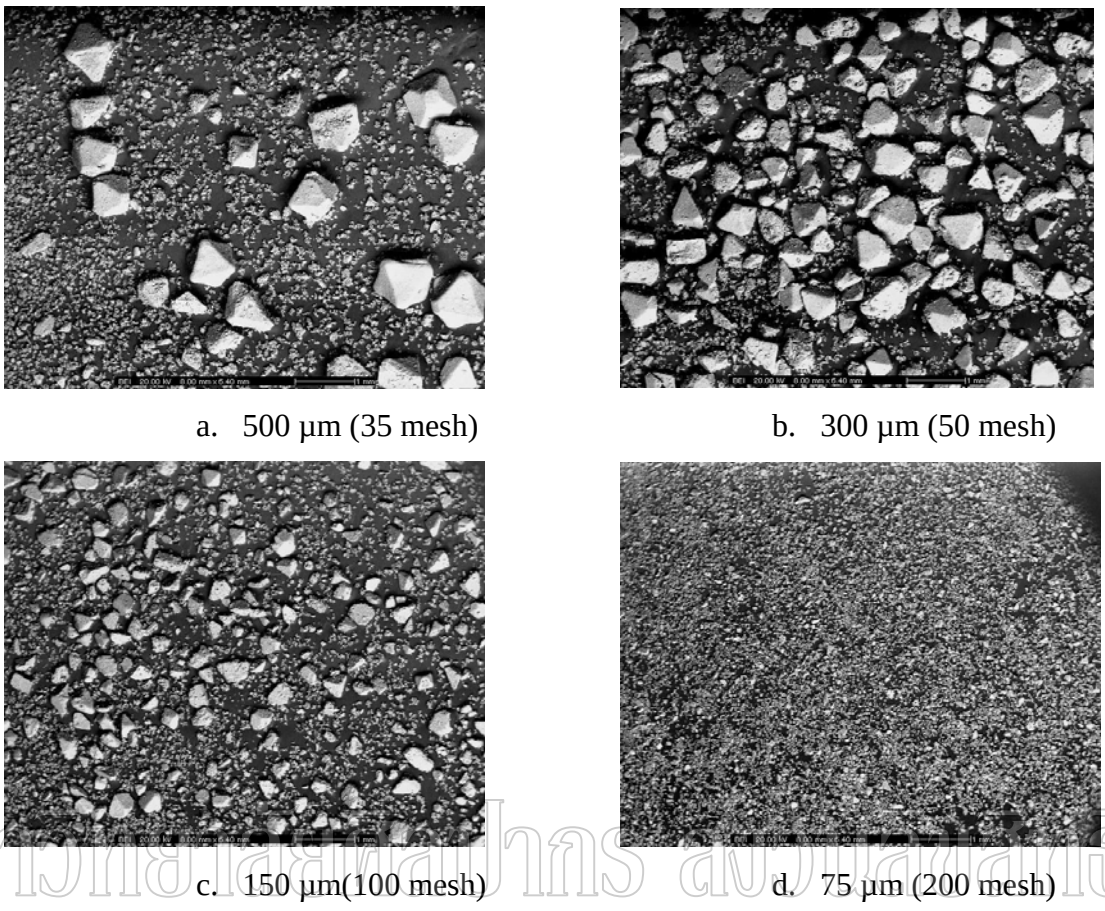
a. 500 µm (35 mesh)

b. 300 µm (50 mesh)

c. 150 µm (100 mesh)

d. 75 µm (200 mesh)

Fig. 3.1 The particle diameter sizes distribution of sodium chloride retaining on various sieve perforation sizes



a. 500 µm (35 mesh) b. 300 µm (50 mesh)

c. 150 µm(100 mesh) d. 75 µm (200 mesh)

Fig. 3.2 Characteristics of sodium chloride retaining on various sieve perforation sizes from SEM (7.75X)

3.4.1) Sucrose

Only sucrose retaining on sieve perforation size of 150 µm (100 mesh) could be detected by particle size analyzer. The average particle diameter of sucrose given by mode value was 185.30 µm (Fig. 3.3). Peak showed two size variations, there was some smaller particle size approximately 40 µm adhering on surface of sucrose retaining on sieve perforation size of 150 µm. The particle size of sucrose which retained on sieve perforation size of 300 µm (50 mesh) could not suspend in solvent, thus the sample sizes distribution could not be analysed.

For sucrose that retained on sieve perforation size of 75 µm (200 mesh), the particle size was very small and dissolved in solvent so no sample was available for analysis system.

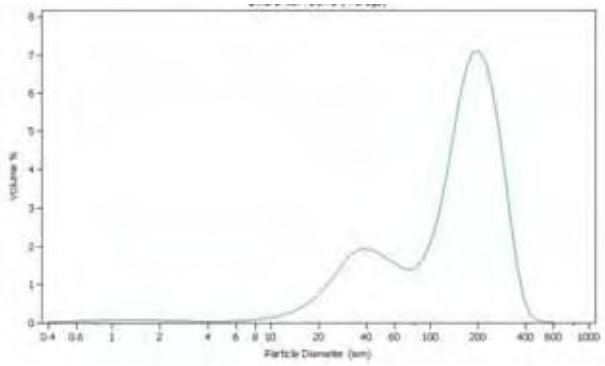


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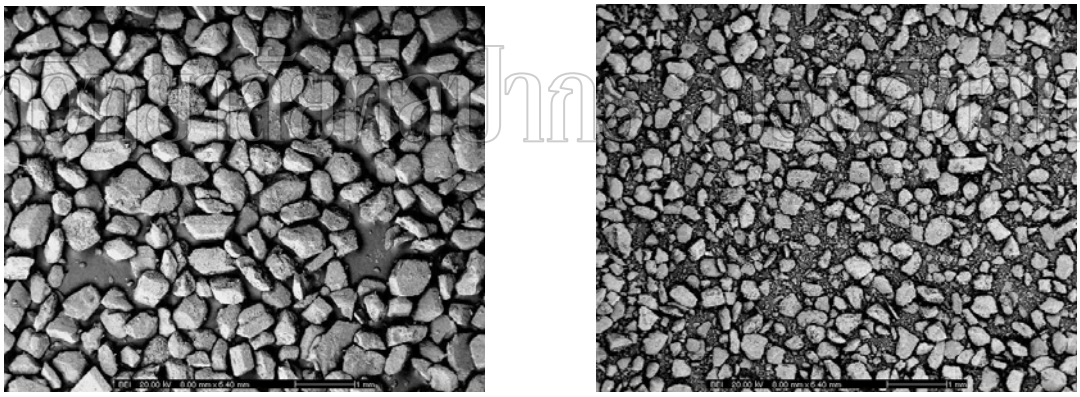
Fig. 3.3 The particle diameter sizes distribution of sucrose retaining on various sieve perforation size of 150 µm (100 mesh)

Characteristics of sucrose retaining on various sieve perforation sizes were shown in Fig. 3.4. There were less smaller particles sizes mixed with bigger particles compared to that of sodium chloride.



a. 300 µm (50 mesh)

b. 150 µm (100 mesh)

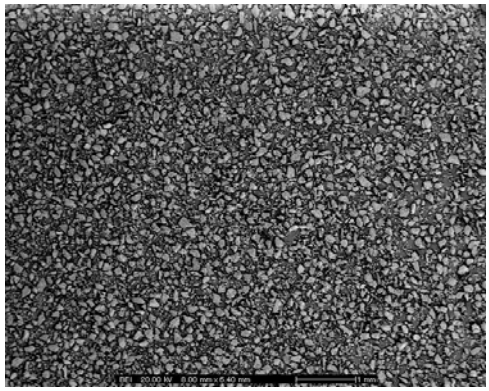
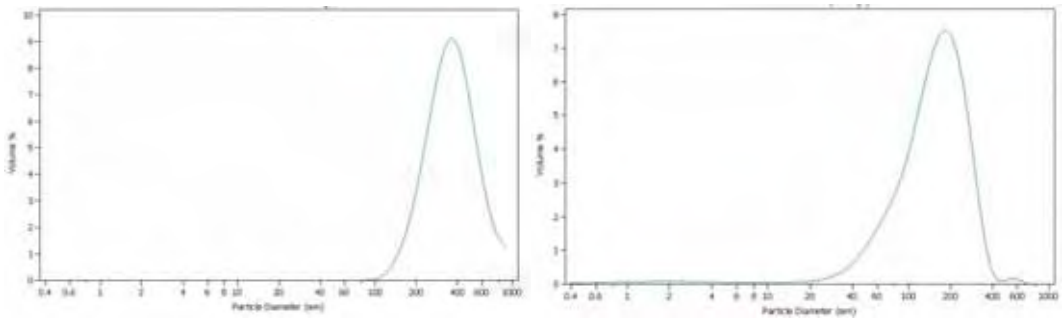


Fig. 3.4 Characteristics of sucrose retaining on various sieve perforation sizes from SEM (7.75X)

3.4.2) Citric acid

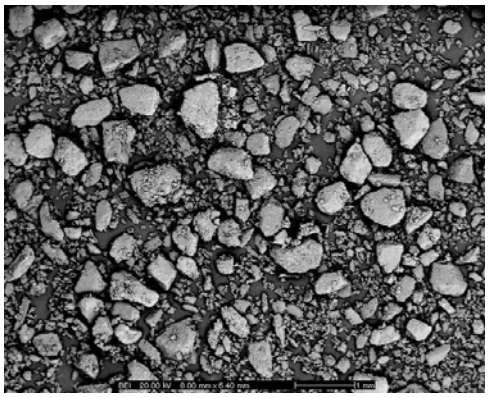
Only citric acid retaining on sieve perforation size of 300 µm (50 mesh) and 150 µm (100 mesh) was detected by particle size analyzer. The average sizes as mode values were 324.30 and 185.30 µm respectively. The size distribution curves were shown in Fig. 3.5.



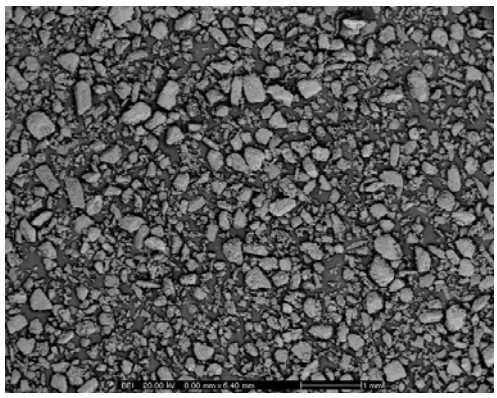
a. 300 µm (50 mesh) b. 150 µm (100 mesh)

Fig. 3.5 The particle diameter sizes distribution of citric acid retaining on various sieve perforation sizes

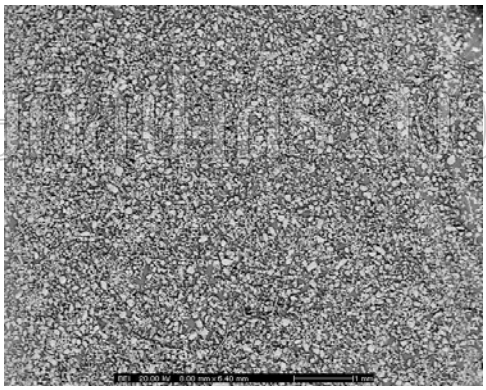
Characteristics of citric acid retaining on various sieve perforation sizes were shown in Fig. 3.6. Finer particles were also found with bigger particles. Therefore smaller particle adhered on bigger surface and some of fine powder could be adhered together and could not pass to the smaller sieve sizes.



a. sieve size 300 µm (50 mesh)



b. sieve size 150 µm (100 mesh)



c. sieve size 75 µm (200 mesh)

Fig. 3.6 Characteristics of citric acid retaining on various sieve perforation sizes from SEM (7.75X)

Average particle diameters of samples were shown in Table 3.1. Since all ranges of particle sizes could not be determined, the perforation size of sieve in which particles retained was used to represent particle size of each ingredient.

Table 3.1 Average particle size of ingredients retaining on various sieve sizes

Ingredients	Sieve size.		Mode average particle Diameter at peak (μm)
	Mesh	Perforation (μm)	
Sodium chloride	35	500	623.30
Sodium chloride	50	300	356.00
Sodium chloride	100	150	223.40
Sodium chloride	200	75	96.49
Sucrose	50	300	-
Sucrose	100	150	185.30
Sucrose	200	75	-
Citric acid	50	300	324.30
Citric acid	100	150	185.30
Citric acid	200	75	-

- unmeasurable

Some samples could be dissolved in hexane, the mode average particle diameter would less than actual. Ethyl acetate or ethanol 99% would suggested to use as solvent to protect solubility during analysis by Particle size analyzer.

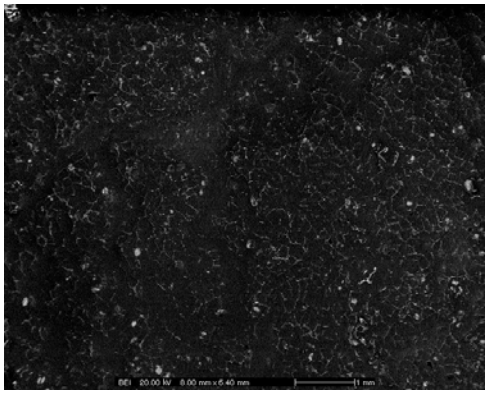
3.5 Distribution of ingredients on fried flat potato chips

3.5.1) Sodium chloride

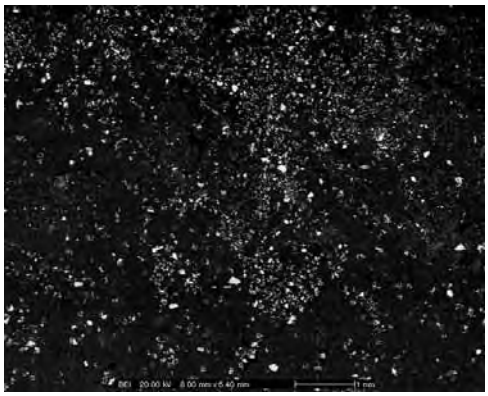
The distribution of sodium chloride, sucrose and citric acid on fried flat potato chips are shown in Figure 3.7, 3.8 and 3.9 respectively. Only sodium chloride showed very clear size distribution.

The particles of smaller size were more evenly distributed. This result could be caused by their more surface area so its could be adhered well and also their re-

crystallization in potato chips after coating. The heat from the potato chips baked at 120 °C before coating could melt the particle of sodium chloride, sucrose and citric acid. These particles could then be re-crystallized to new crystals and distributed under surface of potato chips.



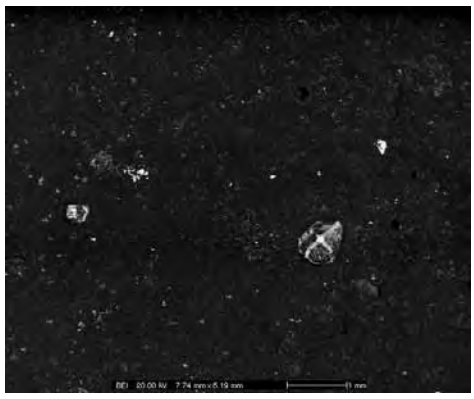
a. potato chip



b. potato chip coated by 200 mesh NaCl

c. potato chip coated by 100 mesh NaCl

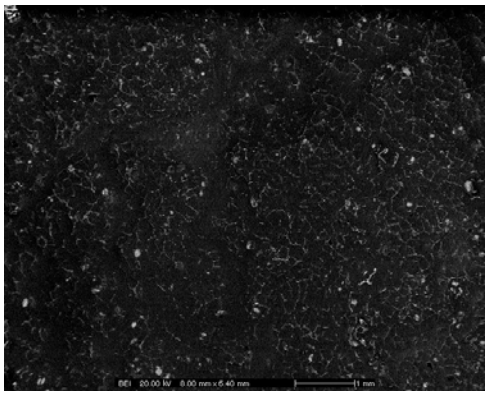
d. potato chip coated by 50 mesh NaCl



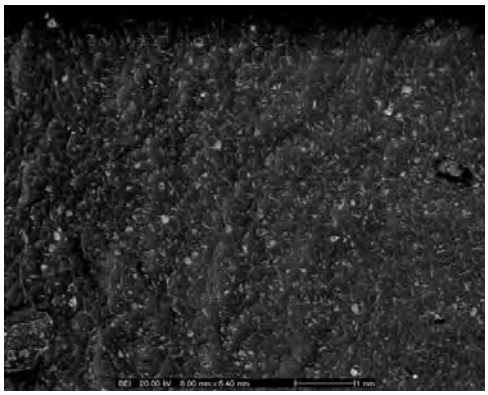
e. potato chip coated by 35 mesh NaCl (8.01X)

Fig. 3.7 Characteristics of sodium chloride of various perforation sizes coated on potato chips from SEM (7.75X)

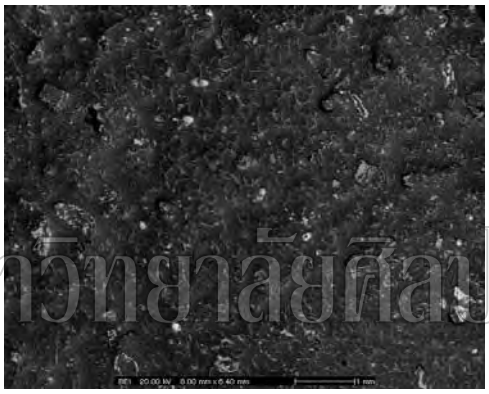
3.5.2) Sucrose



a. potato chip



b. potato chip coated by 200 mesh sucrose

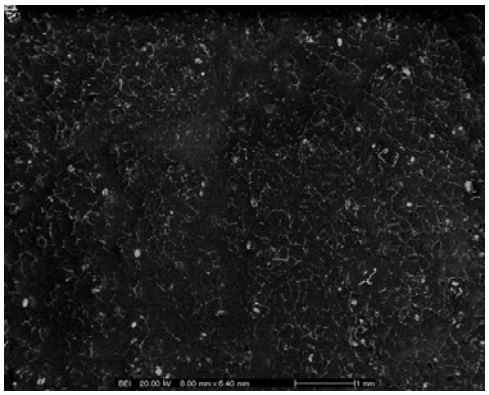


c. potato chip coated by 100 mesh sucrose

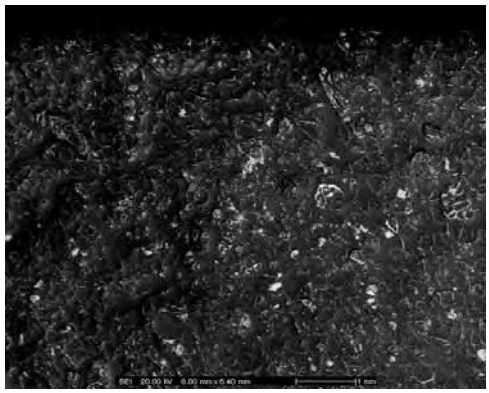
d. potato chip coated by 50 mesh sucrose

Fig. 3.8 Characteristics of sucrose of various perforation sizes coated on potato chips from SEM (7.75X)

3.5.3) Citric acid



a. potato chip



b. potato chip coated by 200 mesh citric acid

c. potato chip coated by 100 mesh

d. potato chip coated by 50 mesh citric acid

Fig. 3.9 Characteristics of citric acid of various perforation sizes coated on potato chips from SEM (7.75X)

CONCLUSIONS

The particle sizes of sodium chloride, sucrose and citric acid, were measured as mode value by using particle size analyzer. Particle sizes of sodium chloride were 96.49, 223.40, 356.00 and 623.30 µm for samples size retaining on sieve perforation sizes of 75, 150, 300, and 500 µm respectively. Average particle size of sucrose retaining on sieve perforation size 150 µm was 185.30 µm. The average particle sizes of citric acid were 185.30 µm and 324.30 µm for sample retaining on sieve perforation size of 150 µm and 300 µm respectively. Not all particle sizes could be determined due to some property limitation and nature of the samples.

CHAPTER 4

EFFECT OF SIZE OF SODIUM CHLORIDE, SUCROSE AND CITRIC ACID ON COATING PROPERTIES AND SENSORY PERCEPTIONS OF FRIED FLAT POTATO CHIPS

This experiment aimed at determining how each granular ingredient at various sizes was coated on potato chips base and how they affected sensory perceptions. Their moisture adsorptions after coating were also compared.

MATERIALS AND METHODS

4.1 Materials

4.1.1) Fried flat potato chips

4.1.2) Automatic salt and acidity titrator, The 799 GPT Titrino, Switzerland

4.1.3) Chemical substance for total sugar assay (%)

4.2 Methods

4.2.1) Various particle sizes of sodium chloride, sucrose and citric acid were prepared as described in 3.2.

4.2 .2) Determination of sodium chloride, sucrose and citric acid coating properties.

Weight each ingredient for individual coating: sodium chloride at 1.13%, sucrose at 1.28% and citric acid at 0.16% of total weight of product formulation. Bake fried flat potato chip in force air oven at 120 ° C for 10 minutes. Coat sodium chloride, sucrose and citric acid on potato chip in coating machine (Appendix 7) for 11.30-12.00 minutes. Coated sample were packed in high density polyethylene and kept in freezer at -21 °C. Determine % NaCl and % acidity on sample by automatic

salt titrator, % sucrose as total sugar by Phenol-sulphuric acid assay (AOAC, 1995). Coating efficiency of each ingredient on sample was calculated as following.

$$\text{Coating efficiency (\%)} = \frac{\text{\% Ingredient in coated sample}}{\text{\% Ingredient in sample formulation}} \times 100$$

4.2.3 Sensory evaluation

Sensory characteristics of fried flat potato chips after coating were evaluated by QDA (quantitative descriptive analysis) method with 4 trained panels. Samples from freezer were allowed to reach room temperature before using for the sensory test.

4.2.4 Moisture adsorption rate

The moisture adsorption rate of each ingredient was determined by placing chips on aluminum foil and leave for 0, 30, 60, 90 and 120 minutes. Relative humidity and temperature were also recorded during the experiment.

RESULTS AND DISCUSSIONS

4.3 Sodium chloride content in coated sample

Amount of sodium chloride of various sizes coated on potato chips were shown in Table 4.1. To enable simple interpretation, perforation sieve size on which the particles retained was used to represent particle size of sodium chloride. It was found that sodium chloride size of 150 μm gave the highest amount in coated sample but not much different from those sizes of 300 μm. On the other hand, it was significantly different from that at size of 75 and 500 μm ($p<0.05$).

Table 4.1 Amount of sodium chloride coated on potato chip

Particle size as size of sieve perforation (µm)	Amount of NaCl in potato chip % (w/w)	Coating efficiency (%)
75	0.60 ± 0.03^{b}	53.70 ± 2.23^{ab}
150	0.72 ± 0.05^{a}	63.35 ± 4.32^{a}
300	0.64 ± 0.06^{ab}	56.88 ± 4.86^{ab}
500*	0.54 ± 0.02^{b}	47.86 ± 1.59^{b}

* The size used in existing company's product formulation

Particle size is reported as perforation size of sieve on which the sample retains.

The letter a, b in column indicate significant different means at 95% confidence level.

Coating efficiency of sodium chloride at sizes of 150 µm was highest and not significantly different from that at size of 75 µm and 300 µm. It was noticed that the coating efficiency tended to decrease with increasing size of sodium chloride.

4.4 Sucrose content in coated sample

Amount of sugar of various sizes coated on potato chips were shown in Table 4.2. The smaller particle size of sucrose resulted in its higher amount coated on the sample. However, there were no significant differences ($p>0.05$) for amount of sugar and coating efficiency at different particle sizes.

Table 4.2 Amount of total sugar coated on potato chips

Particle size as size of sieve perforation (µm)	Amount of total sugar in potato chip % (w/w) x 10^{-3}
75	2.70 ± 0.66^{ns}
150	2.01 ± 0.10^{ns}
300	1.46 ± 0.44^{ns}

Note: Coating efficiency of sucrose was not reported due to its value exceeding 100% as a result of hydrolysis during total sugar analysis**.**

ns = not significantly different ($p>0.05$)

4.5 Citric acid content in coated sample

Amount of acid of various sizes coated on potato chips were shown in Table 4.3. It was found that amount of citric acid coated on sample tended to increase with increasing its particle size. Citric acid at particles size of 150 μm gave the highest amount in coated sample and higher percentage of citric acid on coated sample than that at size of 75 and 300 μm. However, there was no significant difference ($p>0.05$) of amount of acid and coating efficiency at all particle sizes.

Table 4.3 Amount of citric acid coated on potato chip

Particle size as size of sieve perforation (μm)	Amount of acid in potato chip % (w/w) x 10^{-3}	Coating efficiency (%) x 10^{-3}
75	1.00 ± 0.85^{ns}	0.68 ± 0.58^{ns}
150	3.10 ± 0.42^{ns}	2.11 ± 0.29^{ns}
300	2.00 ± 0.14^{ns}	1.35 ± 0.10^{ns}

ns = not significantly different ($p>0.05$)

Thus, only particle size of sodium chloride showed its significant association with potato chip coating efficiency. Nevertheless coating efficiency of sodium chloride and sugar tended to decrease with increasing particle size of each ingredient due to higher surface area of finer particles that provided more contact area (Bailey 1998; Sandor 1990; Pannell 1980). On the other hand, an opposite result seemed to be found for citric acid, although its effect was not significant.

4.6 Moisture adsorption of potato chips

4.6.1 Moisture adsorption of potato chips coated by sodium chloride

The moisture adsorptions of potato chips coated by sodium chloride at different particle sizes were examined. It was found that moisture adsorption of potato chips increased with decreasing particle size of sodium chloride (Fig. 4.1). It appeared that at size of 150 μm, sodium chloride absorb moisture as much as that at size of 75 μm. It was more likely that moisture adsorption was also related to coating efficiency as discussed earlier.

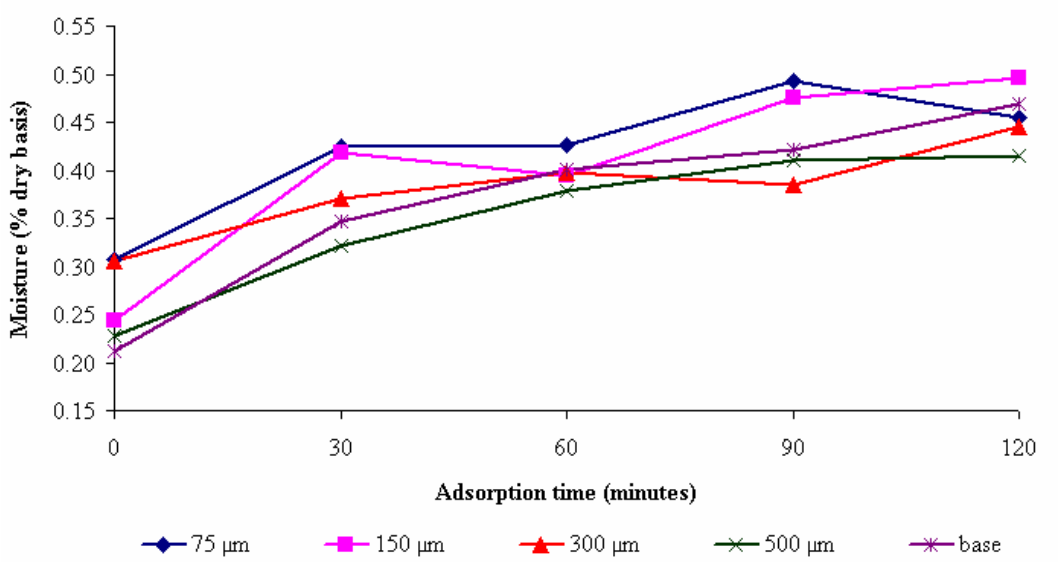


Fig. 4.1 Moisture adsorption potato chips coated by sodium chloride at different particle sizes under ambient air (30 ± 2 °C, 27 ± 1 % RH)

It was found that at 0 minutes there were significant differences ($p<0.05$) of moisture content of sample at size of 75 µm and 300 µm from 150, 500 µm and chips base. The statistical comparisons of moisture content of samples coated by sodium chloride were shown in Appendix 1.1.

4.6.2 Moisture adsorption of potato chips coated by sucrose

The moisture adsorptions of potato chips coated by sucrose at different particle sizes were examined. It was found that moisture adsorption of potato chips increased with decreasing particle size of sucrose (Fig. 4.2). It appeared that at size of 150 µm, sodium chloride absorb moisture as much as that at size of 75 µm at 60, 90 and 120 minutes. It was also more likely that moisture adsorption was also related to coating efficiency as discussed earlier. The higher sucrose content in potato chips the higher was its moisture adsorption.

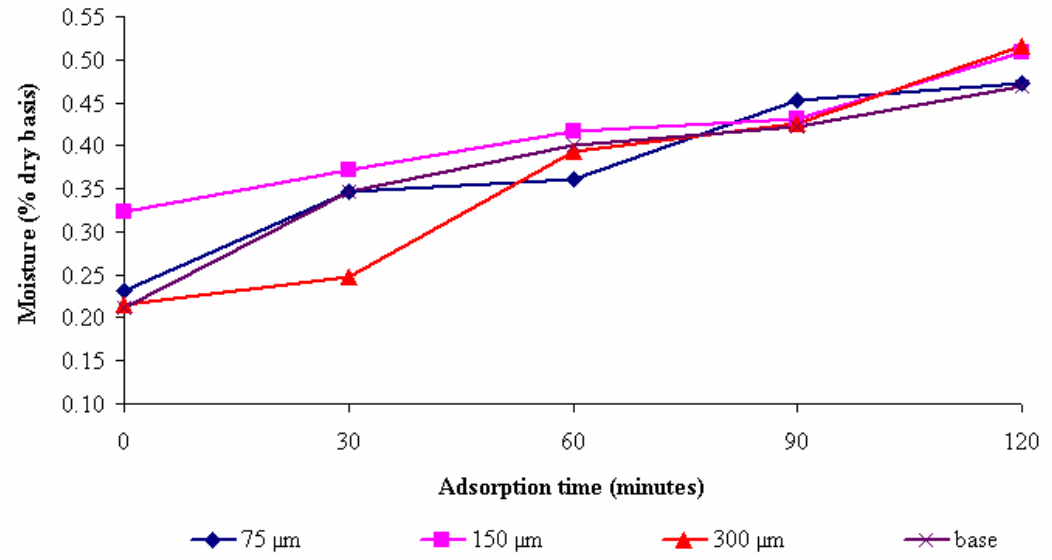


Fig. 4.2 Moisture adsorption potato chips coated by sucrose at different particle sizes under ambient air (30 ± 2 °C, 27 ± 1 % RH)

It was noticed that moisture adsorption of sucrose was slowest at particle size of 300 µm during 30 minutes, After 60 minutes, moisture adsorption rate of sample was not related to sucrose particle size. Statistical comparisons of moisture content of samples coated by sugar were shown in Appendix 1.2.

4.6.3 Moisture adsorption of potato chips coated by citric acid

The moisture adsorption of potato chips coated by citric acid of different particle sizes were examined. It was found that moisture adsorption of potato chips increased with decreasing particle size of sucrose (Fig. 4.3). It appeared that sodium chloride at size of 150 µm gave the highest moisture adsorption. At particle size of 300 µm, sodium chloride absorbed moisture as much as that at size of 75 µm. It was more likely that moisture adsorption was also related to coating efficiency as highest efficiency was also found at citric particle size of 150 µm. The statistical comparisons of moisture content of potato chip samples were shown in Appendix 1.3.

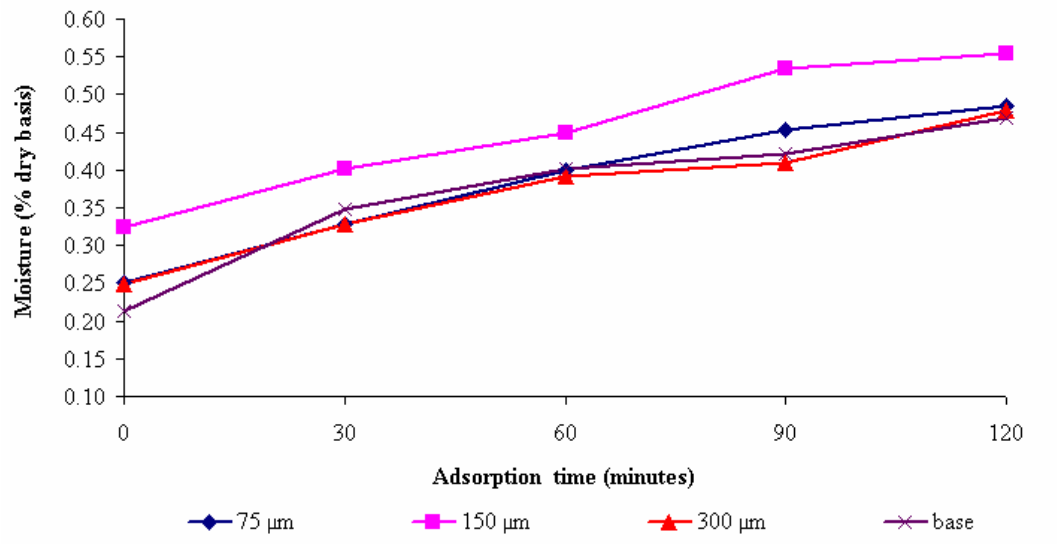


Fig. 4.3 Moisture adsorption potato chips coated by citric acid at different particle Sizes under ambient air (30 ± 2 °C, 27 ± 1 % RH)

It might be concluded that moisture adsorption was related to amount of ingredient coated on the sample which was varied with particle size. The more amount of ingredient coated on the sample, the higher was the moisture adsorption.

4.7 Sensory perception on saltiness, sweetness and sourness

The results indicated the particle size of sodium chloride, sucrose and citric acid coated on potato chips was inversely related to taste intensity (Figure 4.4). Particle of all ingredients at size of 75 µm gave the highest taste intensity (saltiness, sweetness and sourness for sodium chloride, sucrose and citric acid respectively). As the particle size of each of three ingredients increased, the taste intensity decreased. This was related to the solubility of particle. As particle size was small, its solubility was better compared to that of bigger particle because its more surface area to adhere and combine with water. While taste intensity of sodium chloride and sugar seemed to be positively related to their amount coated on the samples, it was opposite for citric acid. However, amounts of citric acid coated on the samples at different sizes were not significantly different. Thus, its influence on taste intensity was of minor importance compared to its size.

At the same particle size, sodium chloride gave the highest taste intensity possibly due to its largest amount coated on the sample. While the amount of sucrose in the chip was higher as compared to that of citric acid, its intensity was similar to that of citric acid.

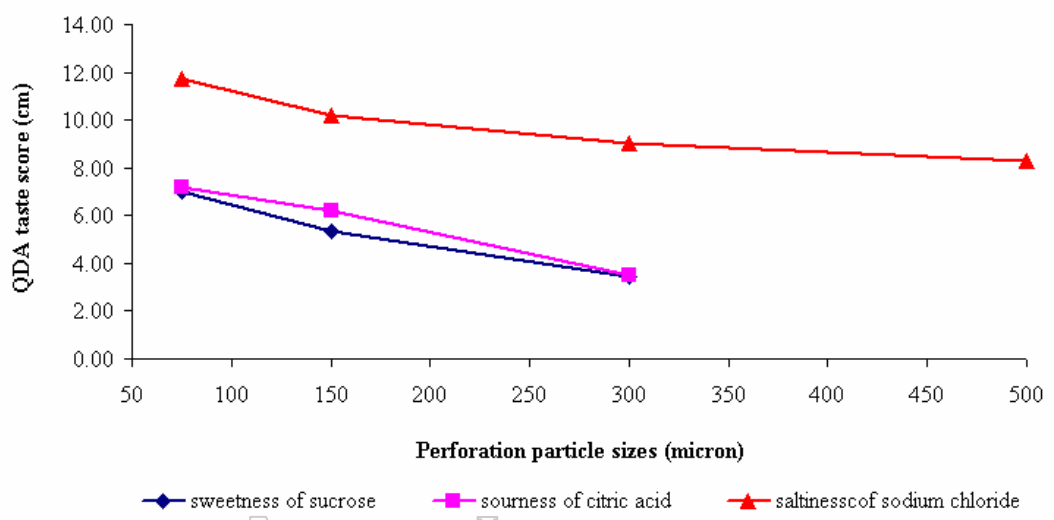


Fig. 4.4 Taste perceptions of potato chip coated by sodium chloride, sucrose and citric acid at different particle sizes.

CONCLUSIONS

Coating properties and their impacts on sensory perception of each of three ingredients at three various particle sizes were studied. Sodium chloride, sucrose and citric acid were individually coated on potato chips. The experimental results revealed that the size of these three ingredients was associated with coating efficiency and taste intensity. Particle size of sodium chloride was positively related to coating efficiency and saltiness intensity. While the similar result was found for citric acid, its relationship between particle size and coating efficiency was not strong. On the other hand, sucrose gave an opposite result. At decreasing particle size, sucrose provided higher coating efficiency whereas increasing sweetness intensity. The results indicated that particle size was a major factor influencing taste perceptions, provided that amounts of ingredient particles at various sizes coated on the sample were not much different.

CHAPTER 5

EFFECT OF MIXED SEASONING ON COATING PROPERTIES AND SENSORY PERCEPTIONS

This experiment aims at determining how the mixed seasoning of varied sizes of sodium chloride, sucrose and citric acid coated on potato chips and how they affected sensory perceptions.

MATERIALS AND METHODS

5.1 Materials

Materials were prepared as described in 4.1.

5.2 Three particle sizes (75, 150 and 300 µm) of sodium chloride, sucrose and citric acid were prepared as described in 3.2

5.3 Coating properties of mixed seasoning powder

Factorial design (3x3x3) was employed in the experiment resulting in 9 treatments combinations with 3 replications. Coated sample were prepared by weight and mixing sodium chloride, sucrose and citric acid at ratio 15:17:2. The formulation is shown in Table 5.1. Fried flat potato chips were baked in force air oven at 120 ° C for 10 minutes before coating in a coating machine (Appendix 8) for 11.30-12.00 minutes. Coated samples were packed in high density polyethylene and kept in freezer at -21 °C. Determine % NaCl and % acidity in samples by automatic salt titrator, % sucrose as total sugar by Phenol-sulphuric acid assay (AOAC, 1995).

Table 5.1 Formulation of coated potato chips

Materials	Weight (g)
Potato chips	97.43
NaCl	1.13
Sucrose	1.28
Citric acid	0.16
Total	100.00

5.4 Sensory characteristics were evaluated as described in 4.2.3

5.5 Moisture adsorption were determined following the method as described in 4.2.4

RESULTS AND DISCUSSIONS

5.6 Sodium chloride content in mixed seasoning coated potato chips

Table 5.2 shows sodium chloride content at various sizes in mixed seasoning coated potato chips. The data were ranked in descending order according to amount of sodium chloride and its coating efficiency on the potato chip samples. It was found that the highest amount of sodium chloride was obtained when the smallest sizes of 3 seasonings were used. However, it was not significantly different from the other two subsequent seasoning size combinations ($p>0.05$), i.e. 150-150-75 µm and 75-150-150 µm. The combinations in which 75 µm of NaCl was used were more likely to give the high NaCl amount. On the other hand, sugar sizes were varied between 75 and 300 µm while those of citric acid were varied between 75 and 150 µm to give high NaCl content in the samples, especially at a given sodium chloride size of 75 µm. The statistical analysis indicated that there was significant difference of NaCl content in the sample ($p<0.05$). In addition there were significant interactions between the size and the ingredient on sodium chloride content and coating efficiency.

Table 5.2 Sodium chloride content in mixed seasoning coated potato chips

Treatment	Particle size of mixed seasoning NaCl, Sugar, Citric (µm)	Amount of sodium chloride % w/w sample	Coating efficiency (%)
T27	75, 75, 75	1.02 ± 0.09^{a}	91.61 ± 7.99^{a}
T15	150, 150, 75	0.97 ± 0.05^{ab}	86.18 ± 4.38^{ab}
T23	75, 150, 150	0.90 ± 0.00^{abc}	80.31 ± 0.38^{bc}
T21	75, 300, 75	0.85 ± 0.06^{bcd}	75.18 ± 5.27^{bcd}
T12	150, 300, 75	0.83 ± 0.00^{cd}	74.03 ± 0.25^{cd}
T26	75, 75, 150	0.83 ± 0.11^{cd}	73.61 ± 9.54^{cd}
T20	75, 300, 150	0.79 ± 0.04^{cde}	70.96 ± 3.18^{cde}
T14	150, 150, 150	0.79 ± 0.00^{cde}	70.85 ± 0.15^{cde}
T13	150, 150, 300	0.77 ± 0.00^{def}	68.60 ± 0.08^{def}
T17	150, 75, 150	0.77 ± 0.19^{def}	67.91 ± 16.85^{def}
T16	150, 75, 300	0.75 ± 0.02^{defg}	66.79 ± 2.03^{def}
T7	300, 75, 300	0.74 ± 0.05^{defgh}	65.71 ± 4.73^{defg}
T22	75, 150, 300	0.74 ± 0.00^{defgh}	65.36 ± 0.04^{defgh}
T3	300, 300, 75	0.67 ± 0.03^{efghi}	60.18 ± 2.58^{efghi}
T18	150, 75, 75	0.66 ± 0.06^{fghi}	59.24 ± 5.57^{fghi}
T4	300, 150, 300	0.66 ± 0.02^{fghi}	58.62 ± 1.96^{fghi}
T24	75, 150, 75	0.65 ± 0.09^{fghij}	57.89 ± 8.35^{fghij}
T5	300, 150, 150	0.62 ± 0.04^{ghij}	55.34 ± 3.14^{ghij}
T19	75, 300, 300	0.61 ± 0.04^{hijk}	54.45 ± 3.71^{hijk}
T25	75, 75, 300	0.60 ± 0.01^{ijkl}	53.36 ± 0.63^{ijkl}
T9	300, 75, 75	$0.59\ 0.02^{ijklm}$	51.97 ± 1.95^{ijklm}
T1	300, 300, 300	0.53 ± 0.11^{jklm}	47.01 ± 9.56^{jklm}
T6	300, 150, 75	0.49 ± 0.05^{klm}	43.67 ± 4.52^{klm}
T2	300, 300, 150	0.47 ± 0.01^{lm}	42.56 ± 0.86^{lm}
STD	500, 75, 75	0.47 ± 0.02^{lm}	42.23 ± 1.87^{lm}
T8	300, 75, 150	0.46 ± 0.06^{mn}	41.03 ± 5.65^{mn}
T10	150, 300, 300	0.34 ± 0.06^{n}	30.31 ± 5.70^{n}
T11	150, 300, 150	0.34 ± 0.00^{n}	30.26 ± 0.06^{n}

5.7 Sucrose content in mixed seasoning coated potato chips

Table 5.3 illustrates that sucrose content at various sizes in mixed seasoning coated potato chips. The data were ranked in descending order according to amount of sugar and its coating efficiency on the potato chip samples. It was found that the highest amount of sucrose was obtained when the bigger sizes of 3 seasonings were used. The highest coating efficiency of sugar was found at the combination of sodium chloride-sucrose-citric acid of 300-150-300. However, it was not significantly different from the other six subsequent seasoning size combinations ($p>0.05$). It was noticed that the bigger sizes of three seasonings tended to provide higher amount of sucrose coated on the potato chip samples.

Table 5.3 Total sugar content in mixed seasoning and coated on potato chips

Treatment	Particle size of mixed seasoning NaCl, Sugar, Citric (µm)	Amount of total sugar % w/w sample
T4	300, 150, 300	2.19 ± 0.80[a]
T19	75, 300, 300	2.13 ± 0.00[a]
T1	300, 300, 300	1.88 ± 0.32[ab]
T5	300, 150, 150	1.78 ± 0.45[abc]
T3	300, 300, 75	1.69 ± 0.37[abcd]
T8	300, 75, 150	1.65 ± 0.16[abcde]
T2	300, 300, 150	1.60 ± 0.20[abcde]
T22	75, 150, 300	1.44 ± 1.32[abcde]
T24	75, 150, 75	1.25 ± 0.04[bcdef]
STD	500, 75, 75	1.22 ± 0.29[bcdef]
T6	300, 150, 75	1.21 ± 0.12[bcdef]
T23	75, 150, 150	1.20± 0.95[bcdef]
T12	150, 300, 75	0.97± 0.66[cdefg]
T7	300, 75, 300	0.89 ± 0.47[defgh]
T10	150, 300, 300	0.84 ± 0.21[efghi]
T26	75, 75, 150	0.53 ± 0.09[fghi]
T20	75, 300, 150	0.53 ± 0.17[fghi]
T25	75, 75, 300	0.44 ± 0.08[fghi]
T14	150, 150, 150	0.43 ± 0.30[fghi]
T13	150, 150, 300	0.35 ± 0.15[ghi]
T27	75, 75, 75	0.35 ± 0.00[ghi]
T21	75, 300, 75	0.34 ± 0.03[ghi]
T16	150, 75, 300	0.20 ± 0.08[ghi]
T15	150, 150, 75	0.16 ± 0.12[ghi]
T9	300, 75, 75	0.12± 0.10[hi]
T11	150, 300, 150	0.06± 0.00[hi]
T17	150, 75, 150	0.0± 0 0.00[i]
T18	150, 75, 75	0.0± 0 0.00[i]

Note: Coating efficiency was not accurate since there was analyzed as total sugar, not sucrose in samples

5.8 Citric acid content in mixed seasoning coated potato chips

Data in Table 5.4 was found that the seasoning mixture of existing formulation (STD) gave the highest amount and coating efficiency of citric acid on coated potato chip samples. However, they were not significantly different from the other subsequent five size combinations ($p>0.05$). It was noticed that at particle size of citric acid of 150 µm, the heterogeneous seasoning sizes of combination provide higher coating efficiency, especially at the fixed sodium chloride size of 150 µm with varied sized of sucrose of 75 and 300 µm. On the other hand, at 75 and 300 µm of citric acid, the homogeneous seasoning sizes combination, i.e. 75-75-75 µm and 300-300-300 µm tended to give high coating efficiency.

Table 5.4 Citric acid content in mixed seasoning coated potato chips

Treatment	Particle size of mixed seasoning NaCl, Sugar, Citric (µm)	Amount of citric acid % w/w sample x 10^{-3}	Coating efficiency (%)
STD	500, 75, 75	2.65 ± 0.21^{a}	1.78 ± 0.14^{a}
T18	150, 75, 75	2.25 ± 0.35^{ab}	1.51 ± 0.24^{ab}
T11	150, 300, 150	2.10 ± 0.28^{abc}	1.40 ± 0.19^{abc}
T27	75, 75, 75	2.05 ± 0.78^{abcd}	1.38 ± 0.52^{abcd}
T1	300, 300, 300	2.05 ± 0.07^{abcd}	1.37 ± 0.05^{abcde}
T17	150, 75, 150	2.00 ± 0.42^{abcde}	1.33 ± 0.28^{abcde}
T22	75, 150, 300	1.90 ± 0.14^{bcdef}	1.26 ± 0.09^{bcdef}
T19	75, 300, 300	1.85 ± 0.49^{bcdefg}	1.23 ± 0.33^{bcdef}
T20	75, 300, 150	1.80 ± 0.00^{bcdefgh}	1.21 ± 0.00^{bcdefg}
T26	75, 75, 150	1.80 ± 0.57^{bcdefgh}	1.20 ± 0.33^{bcdefg}
T10	150, 300, 300	1.70 ± 0.42^{bcdefgh}	1.14 ± 0.28^{bcdefg}
T8	300, 75, 150	1.60 ± 0.00^{bcdefgh}	1.07 ± 0.00^{bcdefg}
T7	300, 75, 300	1.60 ± 0.28^{bcdefgh}	1.07 ± 0.19^{bcdefg}
T2	300, 300, 150	1.55 ± 0.35^{cdefgh}	1.05 ± 0.24^{bcdefg}
T4	300, 150, 300	1.55 ± 0.49^{cdefgh}	1.04 ± 0.33^{cdefg}
T9	300, 75, 75	1.55 ± 0.49^{cdefgh}	1.03 ± 0.33^{cdefg}
T24	75, 150, 75	1.50 ± 0.00^{cdefgh}	1.00 ± 0.00^{cdefg}
T23	75, 150, 150	1.45 ± 0.35^{cdefgh}	0.97 ± 0.24^{cdefg}
T6	300, 150, 75	1.40 ± 0.14^{defgh}	0.93 ± 0.09^{defg}
T13	150, 150, 300	1.35 ± 0.21^{efgh}	0.91 ± 0.14^{efg}
T21	75, 300, 75	1.30 ± 0.42^{fghi}	0.87 ± 0.28^{fgh}
T25	75, 75, 300	1.25 ± 0.07^{fghi}	0.84 ± 0.05^{fgh}
T5	300, 150, 150	1.25 ± 0.07^{fghi}	0.84 ± 0.05^{fgh}
T14	150, 150, 150	1.20 ± 0.42^{ghij}	0.80 ± 0.28^{fghi}
T3	300, 300, 75	1.15 ± 0.07^{hij}	0.77 ± 0.05^{ghi}
T16	150, 75, 300	0.65 ± 0.07^{ij}	0.44 ± 0.05^{hi}
T12	150, 300, 75	0.55 ± 0.35^{j}	0.37 ± 0.24^{i}
T15	150, 150, 75	0.55 ± 0.07^{j}	0.37 ± 0.05^{i}

Note : STD is the sizes of mixed seasoning used in existing product formulation

5.9 Effect of mixed seasoning on sensory perceptions of coated potato chips

5.9.1) Effect of mixed seasoning on saltiness

Figure 5.1 illustrates the relationship between particle size of sodium chloride and saltiness intensity measured as QDA saltiness score at various size combinations with sucrose and citric acid. It was observed that the smaller particle size of sodium chloride still gave higher saltiness intensity at almost all size combinations. However, the exception was found at sodium chloride-sucrose-citric acid size combinations of 75-75-150 μm and 75-75-75 μm of which sodium chloride and citric acid coated in the samples was high. On the other hand, these combinations gave low sucrose content in the coated sample (Table 5.2-5.4). Of these combinations, the saltiness perception of sodium chloride would be masked by strong intensity of sweetness and sourness of smaller particles of sucrose and citric acid respectively. The 75-150-75 μm combination gave the highest saltiness intensity while sodium chloride content in the sample was low. Thus, the combination of particle size of the three seasonings rather than their amount coated on the sample seemed to affect the saltiness intensity. This experimental result implies that the interactions amongst the three ingredients on saltiness perceptions exists.

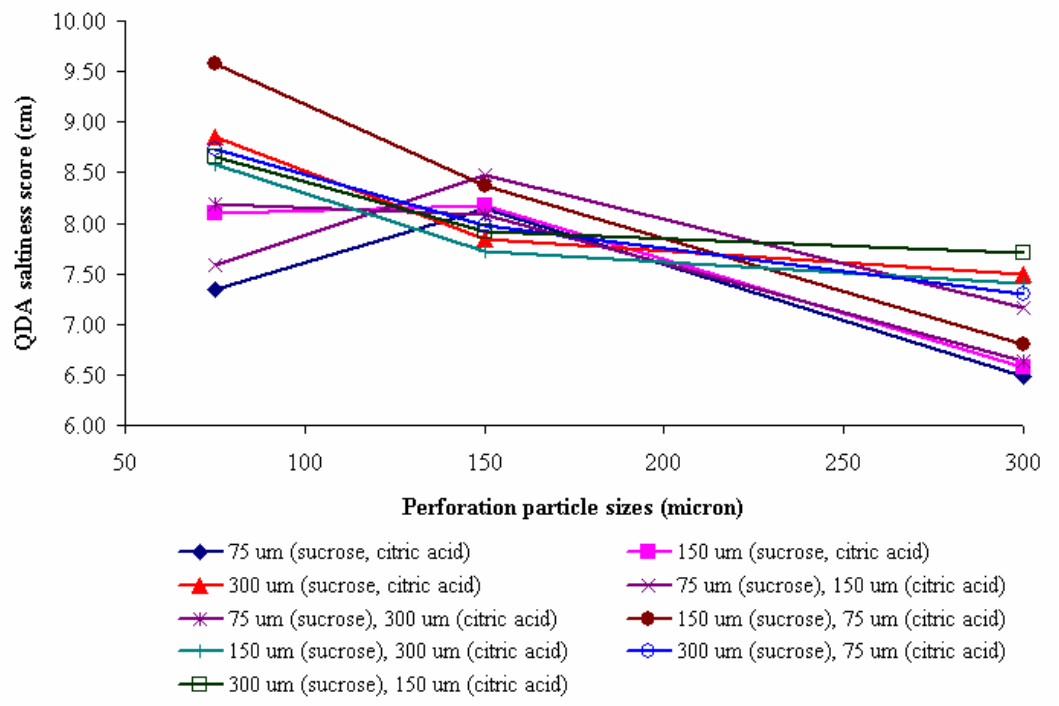


Fig. 5.1 The relationship between particle size of NaCl and saltiness intensity of potato chips at various particle sizes of sucrose and citric acid

5.9.2) Effect of mixed seasoning on sweetness

Figure 5.2 shows the relationship between particle size of sucrose and sweetness intensity measured as QDA sweetness score at various size combinations with sodium chloride and citric acid. At particular sizes of sodium chloride and citric acid, the sweetness of coated sample remained decrease with increasing sucrose sizes. The highest sweetness intensity was found at sucrose-citric acid-sodium chloride combination of 75-150-300 µm which sugar and citric acid coated in samples was high while sodium chloride in the sample was low (Table 5.2-5.4). The sweetness perception of sucrose could not be masked by strong intensity of sourness and the sweetness intensity was higher impact with smaller particle size of sucrose. At the small size of sucrose (75 µm), the sweetness of sample was found lowest at the combination of 75-300-75 µm. The lowest sweetness intensity was also found at combinations of 150-75-75 µm and 300-150-75 µm. The sweetness perception of sucrose would be masked by strong intensity of sourness of smaller particles

of citric acid. With regardless of citric acid particle size, the change in size of sodium chloride seemed to affect the reduction of sweetness. At smaller size of sodium chloride (75 µm), the sweetness intensity was more reduced when compared to that at bigger size of sodium chloride (300 µm).

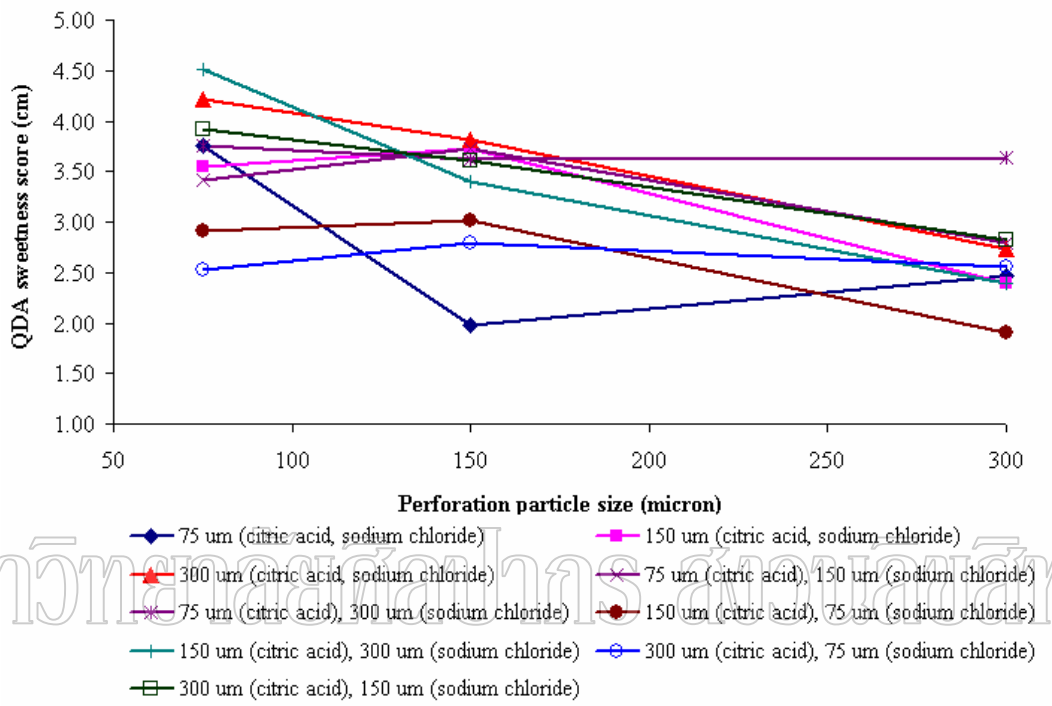


Fig. 5.2 The relationship between particle size of sucrose and sweetness intensity of potato chips at various particle sizes of citric acid and sodium chloride

5.9.3) Effect of mixed seasoning on sourness

Figure 5.3 shows the relationship between particle size of citric acid and sourness intensity measured as QDA sourness score at various size combinations with sucrose and sodium chloride. The highest sourness intensity was found at the citric acid-sucrose-sodium chloride combination of 75-150-75 µm which sugar and citric acid content in the sample were high while low sodium chloride content. Most combinations tended to follow the same relationship pattern, i.e. the sourness intensity decreased with increasing citric acid particle size. However, this relationship pattern

was strong only at the combination of which sucrose and sodium chloride sizes were fixed at 150 and 75 µm respectively. At the combination of which sucrose and sodium chloride sizes were fixed at 300 and 75 µm and of that at 75 and 300 µm respectively, the relationship of citric acid size and sourness intensity did not obey the linearity.

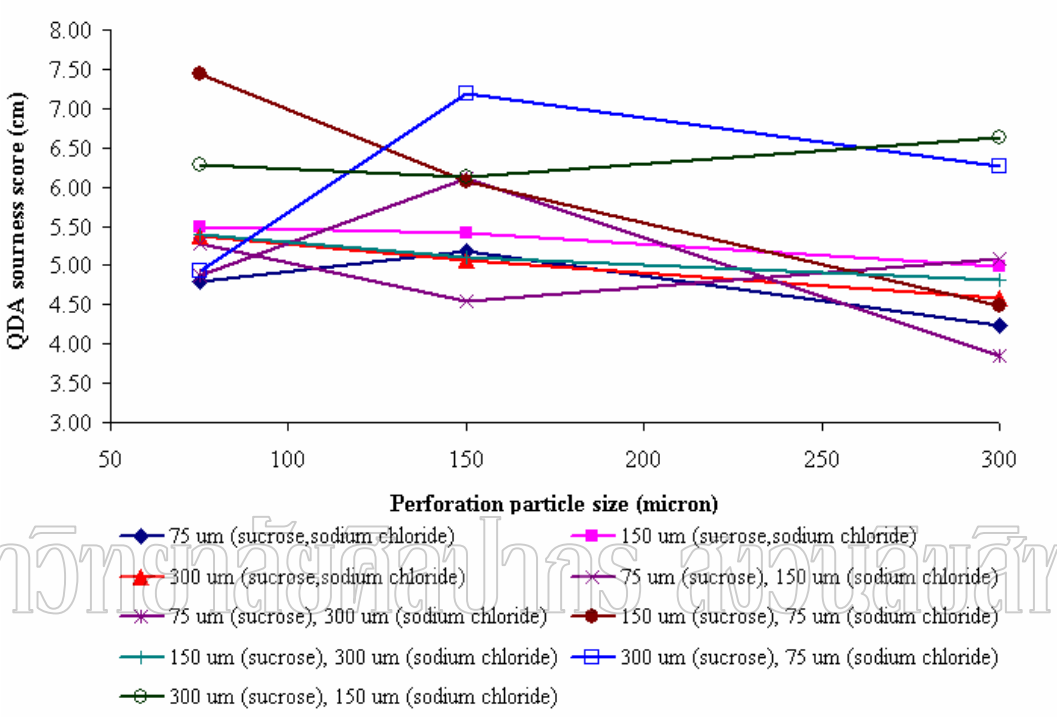


Fig. 5.3 The relationship between perforation particle size and sourness intensity of potato chips of citric acid at various particle sizes of sucrose and sodium chloride

CONCLUSION

Seasoning coating properties and their impacts on sensory perception of mixed seasoning at three various particle sizes were studied. Sodium chloride, sucrose and citric acid were mixed at various sizes and applied on the sample using 3x3x3 factorial design. The experimental results indicated interactions between the particle type and its size on coating efficiency and taste perceptions of potato chips. The smaller size of each seasoning particle still gave higher amount coated on potato chips, provided that the suitable sizes of the other 2 ingredients were mixed.

According to taste intensity measured by QDA, it was observed that the smaller particle size of sodium chloride gave higher saltiness intensity at almost all size combination. At sodium chloride-sucrose-citric acid size combination of 75-150-75 µm gave the highest saltiness intensity while the 75-75-75 µm combination gave the lowest saltiness intensity. At particular sizes of citric acid and sodium chloride, the sweetness intensity remained decrease with increasing sucrose particle sizes. At sucrose-citric acid-sodium chloride combination of 75-150-300 µm gave the highest sweetness intensity. The lowest sweetness intensity was found at combinations of 75-300-75 µm, 150-75-75 µm and 300-150-75 µm. The sourness intensity decreased with increasing citric acid particle sizes. The highest sourness intensity was found at citric acid-sucrose-sodium chloride combinations of 75-150-75 µm. The high sourness intensity was also found at combinations of 150-300-75 µm and 300-300-150 µm. Combinations of 300-75-300 gave lowest sourness intensity.

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RECOMMENDATIONS

1. The effect of seasoning size on shelf-life stability needs further investigation.
2. The effect of seasoning size on its bulk density which might be related to coating properties should be determined.
3. Consumer preference on coated product obtained from various seasoning sizes should also be studied.

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APPENDIX 1

Appendix 1.1 Moisture adsorption of potato chips coated by sodium chloride at different perforation particle size, relative humidity wet 27 ± 1 %, dry 30 ± 1 %, temperature 30 ± 2 °C

Time (minutes)	Sieve perforation size (μm)	Moisture adsorption, dry basis/surface area (g/in^2)
0	Potato chips	0.21 ± 0.04^{b}
0	75	0.31 ± 0.03^{a}
0	150	0.24 ± 0.04^{b}
0	300	0.31 ± 0.02^{a}
0	500	0.23 ± 0.02^{b}
30	Potato chips	0.35 ± 0.02^{bc}
30	75	0.43 ± 0.02^{a}
30	150	0.42 ± 0.02^{a}
30	300	0.37 ± 0.02^{b}
30	500	0.32 ± 0.03^{c}
60	Potato chips	0.35 ± 0.02^{b}
60	75	0.43 ± 0.06^{a}
60	150	0.39 ± 0.01^{ab}
60	300	0.40 ± 0.05^{ab}
60	500	0.38 ± 0.01^{ab}
90	Potato chips	0.42 ± 0.04^{abc}
90	75	0.49 ± 0.07^{a}
90	150	0.48 ± 0.02^{ab}
90	300	0.39 ± 0.05^{c}
90	500	0.41 ± 0.01^{bc}
120	Potato chips	0.47 ± 0.00^{a}
120	75	0.46 ± 0.01^{ab}
120	150	0.50 ± 0.03^{a}
120	300	0.45 ± 0.05^{ab}
120	500	0.42 ± 0.03^{b}

Appendix 1.2 Moisture adsorption of potato chips coated by sucrose at different perforation particle size, relative humidity wet 27 ± 1 %, dry 30 ± 1 %, temperature 30 ± 2 °C

Time (minutes)	Sieve perforation size (μm)	Moisture adsorption, dry basis/surface area (g/in^2)
0	Potato chips	0.21 ± 0.04^{b}
0	75	0.23 ± 0.05^{b}
0	150	0.32 ± 0.05^{a}
0	300	0.22 ± 0.03^{b}
30	Potato chips	0.35 ± 0.02^{a}
30	75	0.35 ± 0.04^{a}
30	150	0.37 ± 0.02^{a}
30	300	0.25 ± 0.03^{b}
60	Potato chips	0.40 ± 0.02^{ab}
60	75	0.36 ± 0.03^{b}
60	150	0.42 ± 0.04^{a}
60	300	0.39 ± 0.02^{ab}
90	Potato chips	0.42 ± 0.04^{ns}
90	75	0.45 ± 0.03^{ns}
90	150	0.43 ± 0.04^{ns}
90	300	0.43 ± 0.06^{ns}
120	Potato chips	0.47 ± 0.00^{ns}
120	75	0.47 ± 0.05^{ns}
120	150	0.51 ± 0.02^{ns}
120	300	0.52 ± 0.02^{ns}

Appendix 1.3 Moisture adsorption of potato chips coated by citric acid at different perforation particle sizes, relative humidity wet 27 ± 1 %, dry 30 ± 1 %, temperature 30 ± 2 °C

Time (minutes)	Sieve perforation size (µm)	Moisture adsorption, dry basis/surface area (g/in^2)
0	Potato chips	0.21 ± 0.04^{b}
0	75	0.25 ± 0.00^{b}
0	150	0.32 ± 0.01^{a}
0	300	0.25 ± 0.00^{b}
30	Potato chips	0.35 ± 0.02^{b}
30	75	0.34 ± 0.01^{b}
30	150	0.40 ± 0.02^{a}
30	300	0.33 ± 0.01^{b}
60	Potato chips	0.04 ± 0.02^{b}
60	75	0.40 ± 0.01^{b}
60	150	0.05 ± 0.03^{a}
60	300	0.40 ± 0.01^{b}
90	Potato chips	0.42 ± 0.04^{b}
90	75	0.45 ± 0.03^{b}
90	150	0.53 ± 0.01^{a}
90	300	0.41 ± 0.03^{b}
120	Potato chips	0.47 ± 0.00^{b}
120	75	4.85 ± 0.33^{ab}
120	150	5.55 ± 0.57^{a}
120	300	4.79 ± 0.45^{b}

Appendix 1.4 Effect of different particle size of sodium chloride, sucrose and citric acid on sensory perception of fried flat potato chips after coated by individual ingredients

Ingredients	Taste impact	Particle size sodium chloride, sucrose and citric acid, retained on sieve size (micron)	QDA taste score (cm)
Sodium chloride	saltiness	75	11.70 ± 0.19
Sodium chloride	saltiness	150	10.16 ± 0.08
Sodium chloride	saltiness	300	9.00 ± 0.24
Sodium chloride	saltiness	500	8.28 ± 0.06
Sucrose	sweetness	75	7.03 ± 0.16
Sucrose	sweetness	150	5.31 ± 0.25
Sucrose	sweetness	300	3.43 ± 0.05
Citric acid	sourness	75	7.21 ± 0.80
Citric acid	sourness	150	6.19 ± 0.55
Citric acid	sourness	300	3.53 ± 0.13

Appendix 1.5 Effect of different particle size sodium chloride, sucrose and citric acid on sensory perceptions of fried flat potato chips after coated by seasoning mix

Treatment	Taste impact	Particle size sodium chloride, sucrose and citric acid, retained on sieve size (micron)	QDA taste score (cm)
STD	saltiness	500	7.09 ± 0.56
	sweetness	75	3.23 ± 0.03
	sourness	75	5.61 ± 0.59
T1	saltiness	300	7.49 ± 0.05
	sweetness	300	2.74 ± 0.23
	sourness	300	4.58 ± 0.26
T2	saltiness	300	7.71 ± 0.10
	sweetness	300	2.39 ± 0.34
	sourness	150	5.08 ± 0.15
T3	saltiness	300	7.30 ± 0.07
	sweetness	300	3.64 ± 0.05
	sourness	75	5.38 ± 0.10
T4	saltiness	300	7.40 ± 0.07
	sweetness	150	3.81 ± 0.07
	sourness	300	4.81 ± 0.23
T5	saltiness	300	6.58 ± 0.06
	sweetness	150	3.40 ± 0.08
	sourness	150	5.11 ± 0.19
T6	saltiness	300	6.80 ± 0.07
	sweetness	150	3.63 ± 0.10
	sourness	75	5.39 ± 0.07
T7	saltiness	300	6.64 ± 0.26
	sweetness	75	4.21 ± 0.02
	sourness	300	3.85 ± 0.17

Treatment	Taste impact	Particle size sodium chloride, sucrose and citric acid, retained on sieve size (micron)	QDA taste score (cm)
T8	saltiness	300	7.16 ± 0.22
	sweetness	75	4.51 ± 0.10
	sourness	150	6.10 ± 0.14
T9	saltiness	300	6.49 ± 0.27
	sweetness	75	3.76 ± 0.05
	sourness	75	4.88 ± 0.13
T10	saltiness	150	7.84 ± 0.45
	sweetness	300	2.83 ± 0.24
	sourness	300	6.63 ± 0.13
T11	saltiness	150	7.91 ± 0.25
	sweetness	300	2.40 ± 0.19
	sourness	150	6.13 ± 0.17
T12	saltiness	75	7.98 ± 0.10
	sweetness	150	2.79 ± 0.10
	sourness	300	6.28 ± 0.21
T13	saltiness	150	7.73 ± 0.05
	sweetness	150	3.61 ± 0.09
	sourness	300	4.99 ± 0.18
T14	saltiness	150	8.18 ± 0.06
	sweetness	150	3.73 ± 0.19
	sourness	150	5.41 ± 0.09
T15	saltiness	150	8.36 ± 0.05
	sweetness	150	3.73 ± 0.10
	sourness	75	5.50 ± 0.08
T16	saltiness	150	8.09 ± 0.02
	sweetness	75	3.91 ± 0.02
	sourness	300	5.09 ± 0.06

Treatment	Taste impact	Particle size sodium chloride, sucrose and citric acid, retained on sieve size (micron)	QDA taste score (cm)
T17	saltiness	150	8.48 ± 0.22
	sweetness	75	3.55 ± 0.00
	sourness	150	4.55 ± 0.33
T18	saltiness	150	8.14 ± 0.19
	sweetness	75	3.41 ± 0.05
	sourness	75	5.29 ± 0.13
T19	saltiness	75	8.85 ± 0.12
	sweetness	300	2.56 ± 0.32
	sourness	300	6.26 ± 0.09
T20	saltiness	75	8.66 ± 0.07
	sweetness	300	1.90 ± 0.27
	sourness	150	7.19 ± 0.40
T21	saltiness	75	8.74 ± 0.02
	sweetness	300	2.46 ± 0.14
	sourness	75	4.93 ± 0.24
T22	saltiness	75	8.59 ± 0.06
	sweetness	150	2.80 ± 0.00
	sourness	300	4.49 ± 0.09
T23	saltiness	75	8.10 ± 0.04
	sweetness	150	3.01 ± 0.02
	sourness	150	6.06 ± 0.20
T24	saltiness	75	9.58 ± 0.34
	sweetness	150	1.98 ± 0.26
	sourness	75	7.44 ± 0.30
T25	saltiness	75	8.19 ± 0.06
	sweetness	75	2.53 ± 0.22
	sourness	300	4.24 ± 0.58

Treatment	Taste impact	Particle size sodium chloride, sucrose and citric acid, retained on sieve size (micron)	QDA taste score (cm)
T26	saltiness	75	7.59 ± 0.18
	sweetness	75	2.91 ± 0.12
	sweetness	75	2.91 ± 0.12
	sourness	150	5.19 ± 0.20
T27	saltiness	75	7.35 ± 0.11
	sweetness	75	3.75 ± 0.07
	sourness	75	4.79 ± 0.46

APPENDIX 2

ANALYSIS OF VARIANCE TABLE

Appendix 2.1 Analysis of variance (ANOVA) for coating efficiency of NaCl on potato chip

Source	DF	Sum of squares	Mean square	F Value	Pr > F
Model	3	250.33	83.44	6.71	0.0486 significant
Error	4	49.77	12.44		
Corrected Total	7	300.10			

Appendix 2.2 Analysis of variance (ANOVA) for NaCl content weight by weight on potato chips

Source	DF	Sum of squares	Mean square	F Value	Pr > F
Model	3	3.46×10^{-2}	11.54×10^{-3}	7.30	0.0424 significant
Error	4	6.32×10^{-3}	1.58×10^{-3}		
Corrected Total	7	4.09×10^{-2}			

Appendix 2.3 Analysis of variance (ANOVA) for coating efficiency of sucrose potato chips

Source	DF	Sum of squares	Mean square	F Value	Pr > F
Model	2	9804.77	4902.39	3.66	0.1568 ns
Error	3	4019.87	1339.96		
Corrected Total	5	13824.66			

ns = not significantly different

Appendix 2.4 Analysis of variance (ANOVA) for sugar content weight by weight on potato chips

Source	DF	Sum of squares	Mean square	F Value	Pr > F
Model	2	1.53	76.71×10^{-2}	3.58	0.1605 ns
Error	3	64.31×10^{-2}	21.44×10^{-2}		
Corrected Total	5	2.18			

ns = not significantly different

Appendix 2.5 Analysis of variance (ANOVA) for acid content weight by weight on potato chips

Source	DF	Sum of squares	Mean square	F Value	Pr > F
Model	2	2.04	1.02	7.20	0.0716 ns
Error	3	42.56×10^{-2}	2.14		
Corrected Total	5	2.47			

ns = not significantly different

Appendix 2.6 Analysis of variance (ANOVA) for acid content weight by weight on potato chips

Source	DF	Sum of squares	Mean square	F Value	Pr > F
Model	2	4.41×10^{-6}	2.21×10^{-6}	7.20	0.0716 ns
Error	3	9.20×10^{-7}	3.07×10^{-7}		
Corrected Total	5	5.33×10^{-6}			

ns = not significantly different

Appendix 2.7 Analysis of variance (ANOVA) for moisture adsorption of chips coated by NaCl

a. at 0 min

Source	DF	Sum of squares	Mean square	F Value	Pr > F
Model	4	23.69×10^{-3}	59.22×10^{-4}	6.25	0.0087 significant
Error	10	9.48×10^{-3}	9.48×10^{-4}		
Corrected Total	14	33.17×10^{-3}			

b. at 30 min

Source	DF	Sum of squares	Mean square	F Value	Pr > F
Model	4	24.10×10^{-3}	60.25×10^{-4}	14.02	0.0004 significant
Error	10	4.30×10^{-3}	4.30×10^{-4}		
Corrected Total	14	28.40×10^{-3}			

c. at 60 min

Source	DF	Sum of squares	Mean square	F Value	Pr > F
Model	4	98.70×10^{-4}	24.68×10^{-4}	1.77	0.2111 ns
Error	10	139.31×10^{-4}	139.31×10^{-5}		
Corrected Total	14	238.01×10^{-4}			

ns = not significantly different

d. at 90 min

Source	DF	Sum of squares	Mean square	F Value	Pr > F
Model	4	24.74×10^{-3}	61.86×10^{-4}	3.63	0.0447 significant
Error	10	17.04×10^{-3}	17.04×10^{-4}		
Corrected Total	14	41.79×10^{-3}			

e. at 120 min

Source	DF	Sum of squares	Mean square	F Value	Pr > F
Model	4	10.74×10^{-3}	26.86×10^{-4}	3.10	0.0668 ns
Error	10	8.66×10^{-3}	8.66×10^{-4}		
Corrected Total	14	419.40×10^{-3}			

ns = not significantly different

Appendix 2.8 Analysis of variance (ANOVA) for moisture adsorption of chips coated by sucrose

a. at 0 min

Source	DF	Sum of squares	Mean square	F Value	Pr > F
Model	3	24.37×10^{-3}	81.25×10^{-4}	4.62	0.0372 significant
Error	8	14.08×10^{-3}	17.60×10^{-4}		
Corrected Total	11	38.46×10^{-3}			

b. at 30 min

Source	DF	Sum of squares	Mean square	F Value	Pr > F
Model	3	27.62×10^{-3}	92.06×10^{-4}	13.17	0.0018 significant
Error	8	5.59×10^{-3}	6.99×10^{-4}		
Corrected Total	11	33.21×10^{-3}			

c. at 60 min

Source	DF	Sum of squares	Mean square	F Value	Pr > F
Model	3	5.05×10^{-3}	16.82×10^{-4}	2.44	0.1397 ns
Error	8	5.52×10^{-3}	6.91×10^{-4}		
Corrected Total	11	10.57×10^{-3}			

ns = not significantly different

d. at 90 min

Source	DF	Sum of squares	Mean square	F Value	Pr > F
Model	3	1.78×10^{-3}	5.95×10^{-4}	0.34	0.7960 ns
Error	8	13.92×10^{-3}	17.40×10^{-4}		
Corrected Total	11	15.70×10^{-3}			

ns = not significantly different

e. at 120 min

Source	DF	Sum of squares	Mean square	F Value	Pr > F
Model	3	5.17×10^{-3}	17.25×10^{-4}	2.16	0.1710 ns
Error	8	6.39×10^{-3}	7.99×10^{-4}		
Corrected Total	11	11.57×10^{-3}			

ns = not significantly different

Appendix 2.9 Analysis of variance (ANOVA) for moisture adsorption of chips coated by citric acid

a. at 0 min

Source	DF	Sum of squares	Mean square	F Value	Pr > F
Model	3	19.86×10^{-3}	66.19×10^{-4}	11.26	0.0030 significant
Error	8	4.70×10^{-3}	5.88×10^{-4}		
Corrected Total	11	24.56×10^{-3}			

b. at 30 min

Source	DF	Sum of squares	Mean square	F Value	Pr > F
Model	3	10.92×10^{-3}	36.39×10^{-4}	14.19	0.00314 significant
Error	8	2.05×10^{-3}	2.56×10^{-4}		
Corrected Total	11	12.97×10^{-3}			

c. at 60 min

Source	DF	Sum of squares	Mean square	F Value	Pr > F
Model	3	63.21×10^{-4}	21.07×10^{-4}	5.54	0.0236 significant
Error	8	30.43×10^{-4}	3.80×10^{-4}		
Corrected Total	11	93.64×10^{-4}			

d. at 90 min

Source	DF	Sum of squares	Mean square	F Value	Pr > F
Model	3	28.14×10^{-3}	93.79×10^{-4}	11.40	0.0029 significant
Error	8	6.58×10^{-3}	8.22×10^{-4}		
Corrected Total	11	34.71×10^{-3}			

e. at 120 min

Source	DF	Sum of squares	Mean square	F Value	Pr > F
Model	3	13.66×10^{-3}	45.54×10^{-4}	2.85	0.1047 ns
Error	8	12.76×10^{-3}	15.96×10^{-4}		
Corrected Total	11	26.43×10^{-3}			

ns = not significantly different

Appendix 2.10 Analysis of variance (ANOVA) for on sensory perception of potato chips coated by mixed seasoning

Source	DF	Type III SS	Mean square	F Value	Pr > F	
Panelist	3	34.55×10^{-2}	11.51×10^{-2}	0.28	0.8420	
Ingredient	2	12.02×10^{2}	600.92	1445.52	< 0.0001	significant
Size	3	58.32	19.44	46.77	< 0.0001	significant
Ingredient* Size	4	6.22	1.55	3.74	0.0054	significant

APPENDIX 3

Particle size analyzer: Coulter LS 100 Q Series (PCL Holding Ltd., 1998)

The LS Series instruments are light scattering particle size analyzer. All LS Series instrument use the diffraction of laser light by particles as the main source of information about particle size. A Coulter LS Series instrument with a small volume module measures size distributions of particles suspended in liquid. The LS100 measure particles from 0.4 µm to 900 µm.

Components

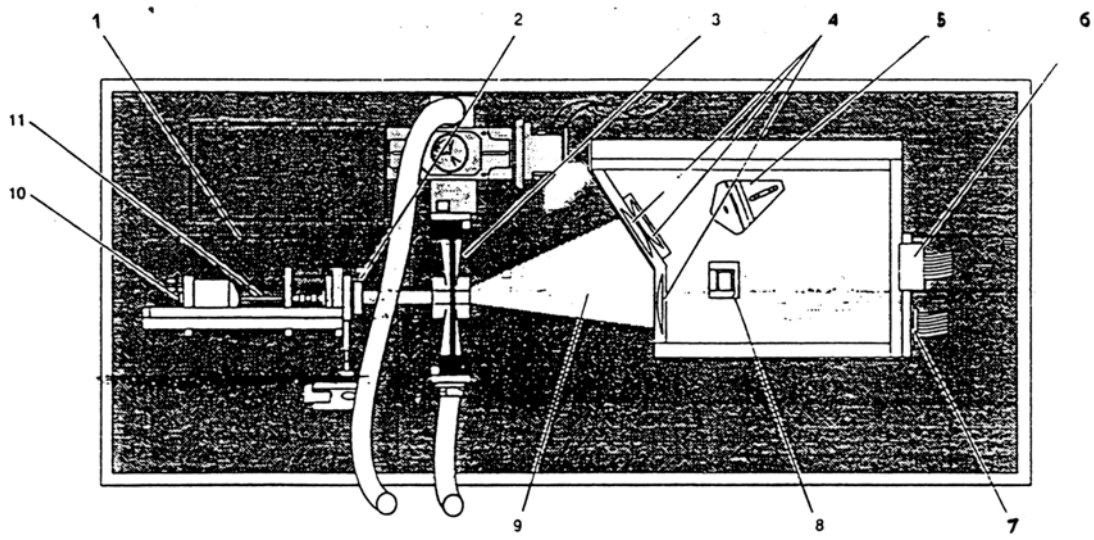
Diffraction sizing uses these components in the optical module.

- Laser light source, spatial filter and projection lens
- Diffraction sample cell, or Micro Volume Cell
- 126 photodiode detectors
- Fourier lenses

Description

The LS series use laser light a wavelength of 750 nm to size particles with diameters from 0.4 µm to 2000 µm by light diffraction. The laser's radiation passes through a spatial filter and projection lens to form a beam of light. The beam passes through the sample cell where particles suspended in liquid or air scatter the incident light in characteristic patterns which depend on their sizes.

Fourier optics collect the diffracted light and focus it onto three sets of detectors, one for the low-angle scattering, the second for mid-angle scattering, and the third for high angle scattering (Fig. A3-1).



1. Spatial filter (cover off)
2. Projection lens assembly
3. Diffraction sample cell
4. Fourier lenses
5. High-angle detectors
6. Low-angle detectors
7. Mid-angle detectors
8. Beam dump
9. Laser beam
10. Laser diode
11. Fiber optic cable

Fig. A3-1 Laser Optical Path

Measuring moving particles

The LS series measures particle size distributions by measuring the pattern of light scattered by the constituent particles in the sample. This pattern of scattered light is called a diffraction pattern. More specifically, a diffraction pattern is the scattered light intensity as a function of scattering angle. Each particle's diffraction pattern is characteristic of its size. The pattern measured by the LS is the sum of the patterns scattered by each constituent particle in the sample. An important component of making this measurement is an LS series instrument is the Fourier lens (Fig. A3-2).

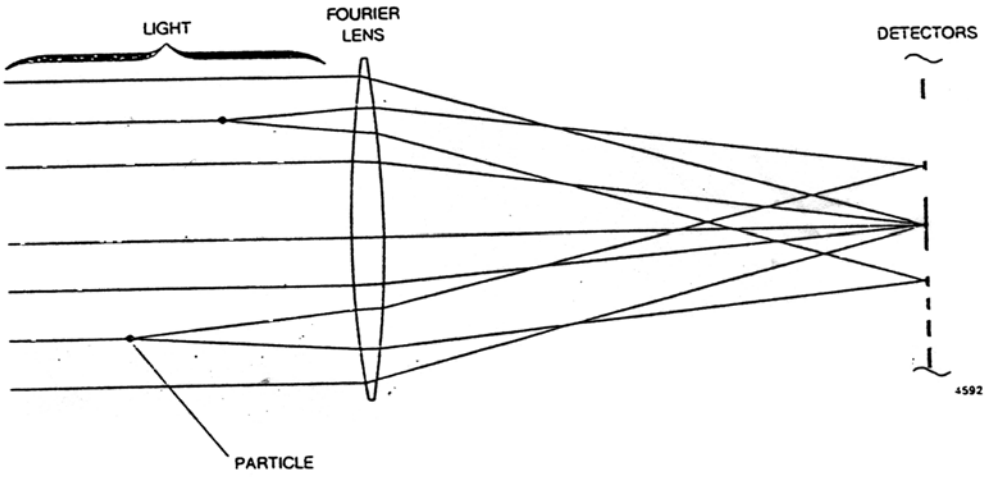


Fig. A3-2 Fourier Lens Focusing

A Fourier lens is an ordinary lens that is used in a special way which gives it special properties. One such property is that the Fourier lens focuses any light striking any part of the lens at a given angle onto a single annular area on its plane of focus, the Fourier plane. The Fourier lens is sensitive only to the angle of the light rays incident on it and not to the position or velocity of the source of light.

The result is that the Fourier lens forms an image of the entire diffraction pattern of each particle, the image being centered at a fixed spot on the Fourier plane. This image is centered at the same fixed spot regardless of the position or velocity of the particle in the diffraction sample cell. The individual diffraction patterns from the many moving particles in the sample cell are therefore superimposed, creating a single composite diffraction pattern that reflects the contributions from all the particles in the sample cell. This composite diffraction pattern can be accurately sensed by detectors judiciously placed on the Fourier plane. Over the course of a measurement, a running average is computed of the flux patterns at every instant. When the duration of the measurement is long enough that the flux pattern accurately represents the contributions from all sample size distribution of the sample.

Summary

The Fourier lens forms the moving diffraction patterns of the particle traversing the diffraction sample cell to change by a stationary composite diffraction pattern that can be measured by a stationary set of detector arrays. The composite, time-averaged diffraction pattern is used to measure the particle size distribution.

APPENDIX 4

Scanning Electron Microscope, SEM (Hollywood Ltd., 1998)

Since its invention in the early 1960's, the Scanning Electron Microscope has moved out of the specialist laboratory, and become an everyday tool, used by many. It opens up a world of amazing three-dimensional structures, which are easily interpreted, even by those with little experience.

As technology produces smaller and smaller structures, many too small to see with any conventional light microscope, the SEM has become increasingly essential and widespread. With more instruments being used, relative costs have fallen, and there is intense competition between manufacturers to develop more powderful and sophisticated instruments.

Developments from the space and computer industries have been borrowed, and many modern instruments are digitally controlled and often have image enhancing systems built-in to 'clean up' poor images.

Operating principles

Although at first a scanning electron microscope many appear quite complex , layout of Scanning Electron Microscope (Figure A4-1).

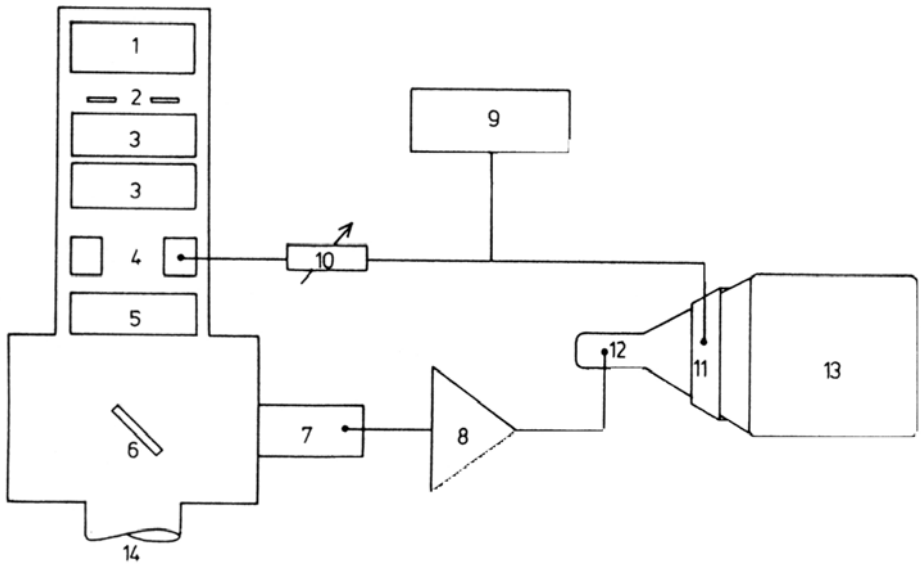


Fig. A4-1 Layout of Scanning Electron Microscope

Electron optical column	Display/ electronics
1. Electron gun	8. Signal amplifier
2. Anode disc	9. Waveform generator
3. Condenser lens	10. Magnification control
4. Scan coils	11. Scan coils
5. Objective lens	12. CRT brightness control
6. Specimen	13. CRT display screen
7. Detector	14. Vacuum connection

The instrument can be simplified by separating it into three major sections:

1. electron-optical ‘column’, this part is number 1 to 4 in the figure 12a, it is lens section and produce electron
2. vacuum system, it is the connection from number 14
3. electronics and display system, it is number 8 to 13

Let’s begin with the optical part of the instrument, the electron optical ‘column’. There is no light microscope equivalent to the SEM, the detail of each component in the column as below.

The first thing is a source of illumination. No visible photons of light, but an invisible beam of electrons. The beam is produced from an electron ‘gun’. A cross-section through a simplified gun is shown in Figure A4-2.

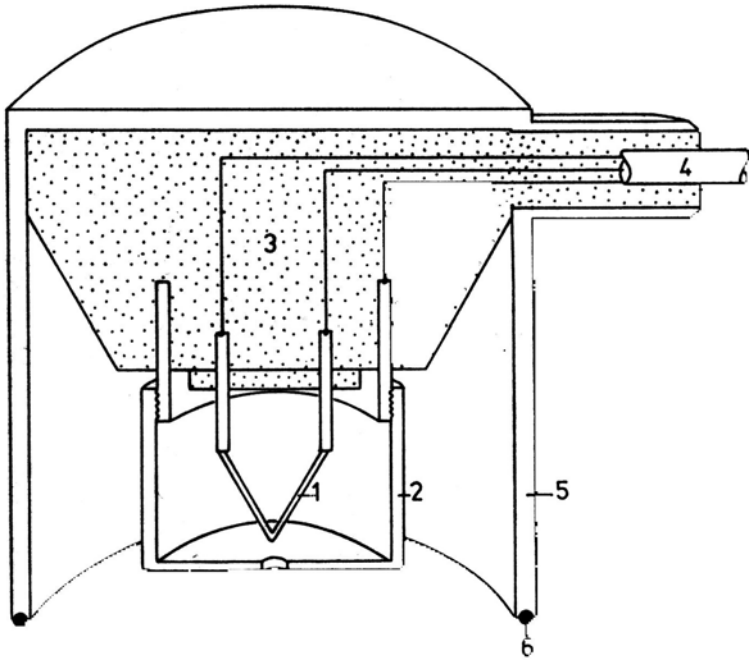


Fig. A4-2 Cross-section through an electron ‘gun’

1. Tungsten filament
2. Wehnelt cylinder
3. Insulation
4. Electrical supply
5. Column casing
6. Vacuum seal

A V-shaped tungsten filament (1) is heated electrically to about 2700 K. This high temperature causes many of the electrons in the tungsten to become sufficiently excited for them to escape. The process is called thermionic emission.

Once freed the electrons would be quickly recaptured by the filament, because in losing them, it will have become positively charged. Applying a high negative voltage (typically 2-25 kV) between the filament and a nearby earthed anode disc, accelerates the electrons away from the filament. Their velocity depends on the accelerating voltage and is only a fraction of the speed of the light. Because of the high voltages applied to the gun, good electrical insulation (3) is essential.

Enclosing the filament in a metal cylinder (2), usually called the Wehnelt cylinder or cathode, shapes the beam electrostatically, so that it emerges 10-50 μm in diameter. Unfortunately in air, or any other atmosphere, the electrons would be scattered by collision with gas molecules. They could travel only a few millimeters.

A vacuum system is connected (Fig. A4-1) to the column, so as to remove most of the gas molecules from the beam's path.

In Fig A4-1 the upper two lenses, the condensers (3), control the beam's diameter. They demagnify it, reducing it from about 50 μm to around 5 nm. It seems odd but the only lenses used in an SEM are not used to magnify at all, in fact they do the exact opposite.

Electron lenses are very different from their optical counterparts. Fig. A4-3 shows their main features.

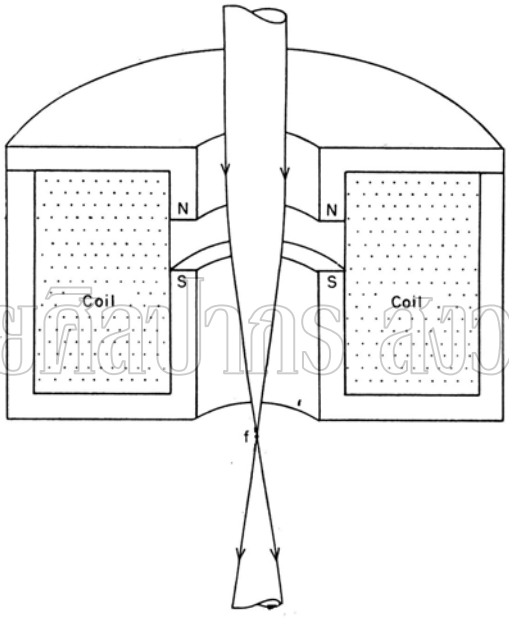


Fig. A4-3 Simplified electron lens (Cross-section)

A coil of wire, with its axis aligned along the beam's path, is partially enclosed in a cylindrical iron case. There is a small gap in the inner bore of the case. When a direct current is passed through the coil an electromagnet is produced, with magnetic poles (N and S), created at the gap in the iron case. This is the 'polepiece gap', and it is really the magnetic lines of force, bridging this space, that form the lens.

Because of their charge, electrons are deflected as they intersect the lines of force. All electrons, entering the bore at the top of the lens, converge at a focal point (f), below the lens. A single point of focus is only produced if all the electrons have

the same energy. This means the gun's accelerating voltage must be kept very stable, any variation will result in electrons of different wavelength or 'chromatic aberration'.

Changing the current through the coil changes the magnetic field strength. This in turn changes the angle through which the electrons are deflected, resulting in a change in the focal length of the lens.

In the overall diagram(Fig. A4-1) shows a typical lens arrangement. Two condenser lenses (3) control the beam diameter, and a third lens, the objective (5), ensures hat the beam has its smallest diameter when it strikes the specimen surface (6). This will focus the image. When bombarded, many different interactions occur between the specimen and the electrons. Electrons are emitted from the specimen. These are collected by a detector (7) which converts them into a small electrical signal, this signal contains a variety of information about a single point on the specimen's surface. For example, a point on a smooth surface would reflect incident electrons well, producing a strong signal in a suitable detector. On the other hand, an adjacent point might be part of small depression or hole which might produce a very small signal.

To from an image of the specimen they need to sample a large number of points over an area. The beam is systematically moved, point-by-point along a line, and the reflected electron signal is collected. After completing a line of 1000 points, the beam is then shifted down one line width before repeating its 'scan'. A thousand lines are scanned, and the beam is rapidly restored to its initial starting point.

One complete scan, consisting of one thousand lines, each of one thousand points, is called a 'frame' (Fig. A4-4).

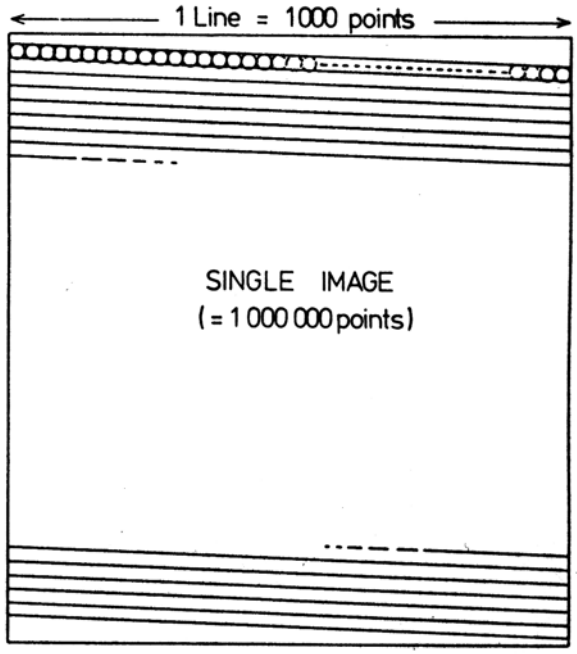


Fig. A4-4 Raster scan

It work the same way as television, although in the UK, it only uses 625 lines per ‘frame’. Technically this is known as a ‘raster scan’. It is this scanning action that gives this type of election microscope its name. It’s our familiar electromagnets again, but this time they are not arranged along the axis of the beam but at right angles to it.

Two pairs of ‘scan coils’ are arranged at right angles to each other, and at right angle to the beam (Fig. A4-1). The coils (4), are arranged in pairs (X and Y), on opposite sides of the column, between the objective and condenser lenses. Each pair is supplied with specially shaped current waveforms, produced in the waveform generator (9).

Controls allow us to scan the pencil of electrons over a chosen area of the specimen. We can use the signal collected from each point visited to construct an image. A cathode-ray tube (CRT) is used to present the signal in an instantly recognizable form-a picture. Inside the CRT a second, independent beam of electrons is produced. When focused as a small spot on the tube’s viewing screen (13), it appears as a small bright spot of light. In addition to the two pairs of scan coils located in the electron-optical column (Fig. A4-1), another two pairs of coils (11) are fitted to the CRT. The same current waveform which produced the raster scan in the

column, is also fed to these CRT scan coils. As a result the CRT beam and the column beam follow the same synchronized scanning pattern.

The signal from the detector (7) is fed to an amplifier (8) and on to the CRT'[s brightness control (12). A small signal reduces the spot's brightness and a large one increases it. Now that we have a complete imaging system let's just summarise the set-up.

The beam in the column looks at each point on the specimen in the turn, if it is a reflective point a large signal is collected. The corresponding point on the CRT screen is made bright, and both the column beam and CRT spot, move along the line to the point. Again the signal is collected, the CRT screen brightness adjusted, according to the signal strength, and so on. After completing a line (1000 points) both beams 'fly back' to the start of the next line and continue. When the final point on the final (thousandth) line is reached, both beams return to their starting point. The scanning sequence is repeated all over again.

When the repetition is very rapid, say 25 times every second, the image on the CRT appears as a flicker-free TV picture. There are problems associated with very fast scan speeds.

So far we have managed to produce some sort of image of the specimen. If we are to use the imaging system as a microscope we must now provide magnification. Scanning electron microscopes enlarge the image in a unique and very simple way. Assume that the beam in the column scans an area 20 cm square, and that the CRT screen is also 20 cm square. Image is

'life-size', in other words there is a magnification of one (1X). Features on the specimen 1 cm apart will appear 1 cm apart on the viewing screen.

Now, for example, if limit the area scanned in the column to 1 cm, but still display the image on the 20 cm screen, the image is magnified twenty times (20X).

APPENDIX 5

1. Panel selection & training

The ideal panelist is someone who is motivated, in good health, provides reliable and consistent results and has the time to attend sessions. It is also desirable that they have few allergies or sensitivities to food, normal taste acuity and are not colour blind if colour work is carried out. Most laboratory panels in food laboratories can be considered experienced, in some cases they are specially trained. Trained panels are not ideal for hedonic testing. Those persons involved in setting up the test should not be used as panelists since their responses will be biased. There are also limits on the capabilities of panelists and they should be screened for their ability to detect differences and certain odours, flavours or colours, their likes and dislikes, and the foods they avoid. If the same panelists are used routinely, this information should be documented. All panelists must be willing to participate and the principles of scientific ethics with respect to testing of human subjects should be followed. Any risks to the participants should be outweighed by the benefits to the individual, to society and to the core of knowledge.

1) Steps in Selection of New Panelists

1.1) Screening

Initial selection should provide about twice as many panellists as you think you will need. All company employees can be considered as potential panelists and it may be necessary to recruit members from outside the organisation. It is important that management recognises the importance of the time staff spends on panels and encourages employees to attend.

The panelist's chosen depend on the type of test you wish to run. You may need to present these panelists with a series of tests to pick up any impairments such as taste blindness, determine their acuity or ability to perceive (also called sensitivity) and discriminate between perceptions and/or evaluate their ability to communicate and describe their responses.

Simple tests involving basic tastes, common odours, textures, matching, ranking and if necessary colour vision are chosen depending on the purpose of the panel. A small group session to familiarise panelists with sensory evaluation, the scales to be used, food characteristics is useful. Group sessions also allow the supervisor to assess how panelists will interact and identify any individuals who may antagonise the others, thereby affecting the results.

However, Piggott and Hunter (1999) warn about placing too much reliance on such screening tests. They caution that good sensitivity is not a good guide to ability and because a panellist is good with a particular food does not mean that they perform as well with other foods.

1.2) Personal Interview

A personal interview to determine availability, likes and dislikes, interest, motivation, cultural, ethnic background, general health, allergies and sensitivities or other reasons for not eating certain foods is essential. In descriptive analysis where panel interaction may occur the panelist should not be overly meek or too forceful. Panelists should also be willing and able to follow instructions.

1.3) Training

Formal training may or may not take place. The screening tests may provide sufficient training. It may however be necessary to provide experience with procedures and good laboratory behavior, develop the panelist's ability to detect, recognise and describe sensory stimuli or develop a common language describing the attributes of a product.

2) Performance Monitoring

With regular panelists the supervisor should be able to discriminate between the abilities of the panelists available. If possible, panelists who have appropriate skills should be selected for specific tests. The performance of panelists should be monitored; a panelist who is not performing does not contribute to the outcome. Monitoring is performed by statistical methods such as Analysis of Variance (ANOVA), Principal Component Analysis (PCA) and Generalised Procrustes Analysis.

Presenting panelists with difference tests in which they must get a high percentage of correct responses can do this. Panelists should also score consistently on replicate judgments when the same samples are presented twice. Sequential analysis can also be used for an ongoing performance check if triangle or duo-trio tests are used.

Performance should be maintained by tangible rewards to the panelists. There are many ways of doing this such as acknowledging good performance to the panelist's supervisors, providing refreshments after each session, a special lunch or dinner or some other treat.

3) Factors influencing panelist performance

Panelists need to be motivated, available and in good health. For laboratory panels and statistical validity you should use up to 30 panelists – the actual number depends on the type of test chosen. For consumer work you want at least 100, preferably naive, panelists.

3.1) Psychological Factors

3.1.1) Motivation

This is most important, non-motivated people do not make good panelists. Motivation can be maximized by providing variety in the samples that panelists assess and not using panelists who do not like the food being assessed or are too busy to spend time evaluating the product. Feedback of experiment results will make it more interesting for panelists. Management should encourage panelist participation through company policy and some sort of provision for a reward is a good idea. Rewards are important – raffles, 'Frequent Panel Points', cake and coffee treats are all good motivators and keep panelists interested.

3.1.2) Coding

Samples must be coded to hide their identity. Letters of the alphabet and numbers are

both suitable. Whatever is used, it should be randomly chosen and assigned. More than one set of codes should be used per session to preclude panelists comparing responses and influencing others.

3.1.3) Order of Presentation

In a session the position of the sample should be randomised. The first sample is often

rated higher and the middle in a triangle set is more often selected as the different sample. Other factors, which can cause bias, are the Contrast Effect and Convergence Effect.

3.1.4) Experimenter Effect

Most panelists would like to give the answer which will please the experimenter. The supervisor should give the panelist sufficient information to carry out the test and no more.

3.1.5) Halo Effect

It is difficult to evaluate single attributes. Usually our evaluation of, say taste, is influenced by colour etc. Where possible this should be avoided by using coloured lights, mincing to remove textural differences etc.

3.2) Physiological Factors

3.2.1) Timing of Tests

Most sources agree that a condition of slight hunger is beneficial, therefore late morning and about 1 hour after lunch are suitable times. Monday mornings and Friday afternoons are not usually used. However availability of panelists is the deciding factor.

3.2.2) Smoking and strong foods

Smoking just before a test should be discouraged it can affect bitterness. Also panelists should be discouraged from consuming strong tasting foods, such as mint flavoured sweets, just before a session.

3.3.3) Health

Panelists should be in good health and definitely not suffering from nasal congestion.

3.3.4) Palate Cleansers

To reduce fatigue and carryover palate cleansers are often used. Bread, peeled and sliced apple, salt-free crackers and tap water at room temperature are usually used. For fatty foods warm water or soda water can be used.

In most cases the use of palate cleansers can be left to the discretion of the panelist. However it is important that if panelists use them they do so between each sample.

3.3.5) Adaptation and Fatigue

Sessions can be broken down to fewer samples to reduce adaptation and fatigue. In strongly flavoured samples it may be wise to present only one sample per session. A time lapse between sample presentation can also be used.

2. Setting up Sensory Tests

2.1) General Requirements

2.1.1) Testing facility

An ideal testing facility should have four distinct areas:

a. preparation area,

b. testing area with privacy booths,

c. area for focus groups, discussion and training,

d. reception and office.

The preparation and testing areas should be separate but adjacent. In the testing area there should be some form of partitioning between panelists, usually booths.

Apart from this it is only essential that the environment is neutral, comfortable for the panelist. Panelists need to be able to concentrate at a maximum level without distractions. If hot food is likely to be prepared it will be necessary to have positive pressure in the testing area to avoid smells from the preparation area influencing the panelists. More detailed requirements are set out in ISO standards, but it is not essential to have this level of facilities to carry out sensory testing.

2.1.2) Sample selection and preparation

Samples presented to the panelists must be representative of the product to obtain accurate results. Panelists should not be exposed to bias by letting them see how the samples are prepared. Preparation methods should be documented and carefully followed and to ensure that all samples have been prepared in exactly the same manner.

2.1.3) Sample containers

For convenience disposable containers are often used. Care should be taken to ensure that any containers used are neutral in colour, odour and taste. Some plastic and paper containers have a smell of their own which may influence the results. If non-disposable containers are used, ensure that there is no residual odour from the dishwashing detergents.

When colour is being assessed, it is important that all samples are presented on the same coloured container. Background colour can influence colour perception.

2.1.4) Serving Temperature

Samples are usually served at normal eating temperature. This is particularly important if aroma or taste are being evaluated. However, if maintaining samples at normal eating temperature leads to changes in the product such as drying out or sogginess, or this is very difficult, service at room temperature is acceptable. All samples must be served at the same temperature, as differences in temperature will affect flavour and aroma.

Remember that foods must be stored in such a way that it does not become hazardous through the growth of food poisoning bacteria. Time of storage in the Temperature Danger Zone (that is between 5 and 60 degrees) should be controlled. You should have a policy that hazardous foods should only be kept within these temperatures for a maximum level of time, say 2 hours, before the sample must be discarded.

2.1.5) Dilution and Carriers

Intensely flavoured foods, such as chilli paste and spices, should be diluted in a neutral sauce or water. Bland breads, noodles or pastry may be used as carriers. This gives a more realistic indication of how the product will perform and is useful

for other product characteristics such as spreadability, sauce adhesion, or texture of the final product.

2.1.6) Amount of Sample

For most tests about 30mL or 30g of sample is sufficient. For consumer tests this amount can be doubled.

2.1.7) Number of Samples per Session

The number of samples that you present to a panelist at a single session depends on the product, the characteristics being assessed and the experience of the panelist. Fatigue, which causes a reduction in the ability of a panelist to discriminate, is a real problem when there are too many samples. As a general rule of thumb, no more than six samples should be evaluated in a single session, but more can be tested if the food is bland, colour or appearance only are being evaluated or the panelists are very experienced. Coffee, tea and cheese tasters can evaluate many samples at once.

In some cases carryover must be considered. Pungent spices like chilli for example, have a long after effect in the mouth. It may be necessary to give panelists' mouths some time to recover after doing an assessment. The presentation of subsequent samples should be delayed for a standard amount of time.

2.1.8) Staff

Ideally a single staff member should be dedicated to sensory testing. They should liaise with other staffs who want tests carried out. Ideally the person should have some food science or technology qualification and have a good knowledge of food behavior and food hygiene.

The personality of this person is very important – they must be well liked and friendly but firm and discreet. They will need to ensure that panelists do as they are bid and keep them motivated. They need to be thorough and not cut corners in methodology and very organised.

2.2) Steps in Sensory Testing

2.2.1) Define objectives

Bench-topping can be extremely useful at this stage. You must also have realistic objectives and match your objectives to your resources. It may be necessary to use outside consultants if you do not have the resources.

2.2.2) Select test

The appropriate type of test, that is paired comparison or rating etc., to use in a particular situation is based on the chosen objectives. Not all tests are suitable for all situations. There are a large variety of possible tests to choose from, some of which are infrequently used and not covered in this workshop.

2.2.3) Plan how results will be interpreted

Although it is tempting to leave the decisions on how the results will be interpreted and the acceptable significance level until after the test has been conducted, it is important to make this decision early. It is extremely easy to discover that not all the required information has been collected or the experimental design is not suitable for the statistics required. Once the test has been conducted it is difficult to remedy this without redoing the whole test again.

2.2.4) Plan and select the panel

Follow the procedures set out to choose the panel. Always make sure that you have sufficient panelists to obtain a statistically valid result. If more panelists are required than you have access to, it may be necessary to reuse panelists.

2.2.5) Plan and print the questionnaire

The questionnaire is a very important part of the test. It must be easy to understand, neat and gather as much information as you require. Do not add questions which contain information you do not intend to use, unless you have a reason for adding them – such as deflecting the panelist's focus away from what you are really trying to discern.

Following are a few simple rules in questionnaire design which you may find useful:

1. Keep it simple and uncluttered.

2. Make sure you use language carefully and that your panelists will understand what you want of them.

3. Avoid confusing quality and quantity.

4. Don't dictate the response by asking leading questions – such as asking whether there is a difference in a paired comparison.

5. Check the order of attribute evaluation. Appearance, colour and odour are usually evaluated before flavour and texture. There is some debate as to whether ‘overall preference’ or ‘overall quality’ should be assessed first or last in a test.

6. In rating scales be aware of the phenomenon of central tendency. Most panelists will avoid scoring 1 or 10 therefore the scale is actually shorter than it appears. By lengthening it this can be overcome and the longer the scale, the finer the discrimination becomes.

7. Make sure that there is a 1-1 correspondence on the form. There should be as many places for response as there are samples to be evaluated.

2.2.6) Plan the test requirements

Book the area if necessary; ensure you work out how much sample you will need, how the samples will be presented and the serving temperature and how to overcome biases.

Remember that your accuracy and precision depend upon your experimental design.

2.2.7) Select apparatus

Collect all the sample containers ensuring that they will not bias the results.

APPENDIX 6

Example: Quantitative Descriptive Analysis, scales 15 cm. (The QDA Method)®

Judge_____

Date_____

Code_____

Please evaluate the basic tastes, the Sweet, Salt, Sour tastes of the sample in sequence. Please a vertical line across the horizontal line at the point that best describes each property in the sample.

Thank you very much.

a. Sweet

---

weak moderate strong

b. Sour

---

weak moderate strong

c. Salty

---

weak moderate strong

APPENDIX 7

The 799 GPT Titrino: compact titrator with extensive capabilities for NaCl and acidity titration (Metrohm, 2004)

APPENDIX 8

Snack coating machine and oven (Quest, 2004)

APPENDIX 9

Preparation of samples for analysis

1. Samples analysis by SEM (Cam Scan MX-2000)

Put sample on aluminium stup and coated by 99.99% gold 0.1 mm. for 130 second then leave into SEM machine for analysis process.

2. Carbonydrate analysis as total sugar: Phenol-sulphuric acid assay

Total sugar assay

A number of assays have been developed which rely on the action of concentrated (or near concentrated) sulphuric acid causing hydrolysis of all glycosidic linkages and the subsequent dehydration of the monosaccharides released to give derivatives of furfural (e.g. hexoses produce 5-hydroxymethyl furfuraldehyde). The dehydration products react with a number of compounds such as L-cysteine (3), phenol (4), orcinol (5) and anthrone (6) to give coloured products. Whilst total sugar concentrations are readily obtained for homoglycans, care must be taken in interpreting the results obtained with heteroglycans due to the different colour intensities produced by different monosaccharides (Chaplin M. and Kennedy J., 1986).

Reagents:

1. Phenol dissolved in water (5% w/v). This solution is stable indefinitely.

2. Concentrated sulphuric acid.

3. Standard glucose solution 0-100 µg/ml, weight glucose 0.01 gram (after oven at 80 ºC for 12 hours and cool down in desiccators), dissolve in distilled water up to 100 µg/ml in volumetric flash, 100 g/ml of glucose solution was given. Use the solution 100 µg/ml as start solution and dilute as follow:

Glucose solution (ml)	Distill water (ml)	Concentration (µg/ml)
1.0	0.0	100
0.8	0.2	80
0.6	0.4	60
0.4	0.6	40
0.2	0.8	20
0.0	1.0	0

Methods

1. Weight random 6 fried flat potato chips from the treatments, record exactly weight in gram, grind chips and weight 1 g. samples with 2 replicate.

2. Dissolve in distilled water and adjust volume to 100 ml by volumetric flash, separate chip particle with filter paper no. 4 and keep filtrate for analysis.

3. Pipette dilute solution, standard glucose, sample and blank 1 ml into glass tubes

4. Add 5% phenol solution 1 ml and shake well by vortex mixer then add 5 ml of concentrated sulphuric acid rapidly and directly to the solution surface, will have steam of acid 9must keep in hood, shake well

5. Leave the solutions undisturbed for 10 minutes to complete the reaction then keep in cool water 25 ºC for 20 minutes.

6. Determine the absorbance at 488 nm by spectrophotometer

7. Calculate total sugar compare with standard grape of glucose from reaction with phenol

3. Sodium chloride assay by automatic titrations

Reagents:

1. Silver Nitrate ($AgNO_3$) 0.1 mol/L

2. Nitric acid (HNO_3) 2 %

3. NaCl anhydrous for standardized $AgNO_3$

Methods:

1. Weight random 6 fried flat potato chips from the treatments, record exactly weight in gram.

2. Grind and weight 2 gram (record exactly weight) and add distilled water 60-80 ml.

3. Mix well and add 2 ml of 2% nitric acid solution

4. Automatic titrations with Silver Nitrate 0.1 mol/L

5. Result as gram of NaCl and % chloride in samples

4. Acidity assay by automatic titrations

Reagents:

1. Sodium hydroxide (NaOH) 0.1 mol/L

2. Potassium acid phthalate (KHP) anhydrous for standardized NaOH

Methods:

1. Weight random 6 fried flat potato chips from the treatments, record exactly weight in gram.

2. Grind and weight 2 gram (record exactly weight) and add distilled water 60-80 ml.

3. Mix well and automatic titrations with Sodium hydroxide 0.1 mol/L

4. Result % acidity in samples

CURRICULUM VITAE

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