รายงานวิจัยฉบับสมบูรณ์

โครงการ การพัฒนากล้วยทอดแผ่นและเผือกทอดแผ่นปรุงรสโดยใช้วิธีการเคลือบแบบกระแสไฟฟ้าสถิตย์

Development of Seasoned Fried Banana and Fried Taro Chips Coated by Electrostatic Coating.

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พฤศจิกายน 2550

สัญญาเลขที่ MRG 4880189

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สนับสนุนโดยสำนักงานคณะกรรมการการอุดมศึกษา และสำนักงานกองทุนสนับสนุนการวิจัย

Abstract

This research investigated the consumer perception of seasoned banana chips, the optimization of seasoning coating processes and the effects of particle and electrostatic coating on flavor enhancement, consumer acceptances and process efficiency improvements.

Consumer survey and a series of sensory tests were conducted. Barbeque, sour cream and onion and salt were desirable for banana chips with the coating amount of 6, 8 and 2%, respectively. The seasoning particle size was then reduced and coated on samples by using nonelectrostatic (0 kV) and electrostatic coatings (25 kV). For the effect of particle size on sensory evaluation, the coating amount on each chip was controlled at 6±1% for all seasonings except salt (2±1%). In process efficiency test, 10g of seasoning were coated onto aluminum plates. Transfer efficiency, dust, coating evenness and adhesion of were determined (α=0.05).

For all seasonings, electrostatically coated samples with smaller particles were preferred, more even, and received higher liking scores for coating evenness, flavor and taste. In both processes, panelists perceived significantly stronger flavor from smaller particle size of salt and tangy barbeque. The synergistic effects of electrostatic coating and small particles achieved the highest transfer efficiency, adhesion and dust reduction. Large particles showed higher nonelectrostatic transfer efficiency and less dust, but smaller particles had higher adhesion and coating evenness in both processes. Combined with electrostatic coating, small-particle-coated samples received the highest overall acceptance.

Thus, the effects of small particles and electrostatics, most evident in salt, promise flavor and preference improvements in low-sodium snacks. Electrostatic coating also reduces the production cost by achieving higher transfer coating efficiency, less dust and less waste.

Keyword electrostatic coating, preference, process efficiency, flavor enhancement

บทคัดย่อ

งานวิจัยนี้ศึกษาความต้องการของผู้บริโภคต่อกล้วยทอดแผ่นปรุงรส กระบวนการเคลือบผงปรุงแต่งกลิ่นรสที่เหมาะสม และอิทธิพลของขนาดอนุภาคผงปรุงรสร่วมกับการเคลือบผงปรุงรสด้วยกระแสไฟฟ้าสถิตย์ที่มีต่อการเพิ่มกลิ่นรส การยอมรับของผู้บริโภค และการเพิ่มประสิทธิภาพการเคลือบผงปรุงรส โดยสำรวจความต้องการของผู้บริโภคและประเมินคุณภาพทางประสาทสัมผัสเป็นลำดับ พบว่า กลิ่นรสบาร์บีคิว ซาวด์ครีมและหัวหอม และเกลือ ได้รับความนิยมให้ใช้กับกล้วยทอดแผ่นที่การเคลือบปริมาณ 6%, 8% และ 2% ตามลำดับ บดผงปรุงรสเพื่อลดขนาดอนุภาคก่อนเคลือบตัวอย่างโดยไม่ใช้กระแสไฟฟ้าสถิตย์ (0 kV) (วิธีธรรมดา) และวิธีกระแสไฟฟ้าสถิตย์ (25 kV) ในการศึกษาอิทธิพลของขนาดอนุภาคด้วยวิธีทางประสาทสัมผัสนั้นควบคุมปริมาณผงปรุงรสต่อตัวอย่างทุกชิ้นที่ 6±1% สำหรับทุกกลิ่นรสยกเว้นเกลือที่ใช้ 2±1% ส่วนการศึกษาประสิทธิภาพการผลิตจะเคลือบผงปรุงรสทุกชนิดปริมาณ 10 กรัมบนแผ่นอลูมิเนียม แล้วเปรียบเทียบปริมาณผงปรุงรสที่เคลือบบนตัวอย่าง ฝุ่นละออง ความสม่ำเสมอของการเคลือบ และคุณภาพการยึดเกาะตัวอย่าง (α=0.05) พบว่า สำหรับทุกกลิ่นรส ตัวอย่างที่เคลือบขนาดอนุภาคเล็กด้วยกระแสไฟฟ้าสถิตย์ได้รับความชอบมากกว่า มีการเคลือบที่สม่ำเสมอกว่า และได้รับคะแนนการยอมรับด้านคุณภาพการเคลือบ กลิ่นรส และรสชาติมากกว่า โดยวิธีการเคลือบทั้งสองวิธีเมื่อใช้เกลือและบาร์บีคิวรสจัดที่มีอนุภาคขนาดเล็ก ผู้ทดสอบรู้สึกว่าตัวอย่างมีกลิ่นรสมากขึ้นอย่างมีนัยสำคัญ วิธีเคลือบด้วยกระแสไฟฟ้าสถิตย์และอนุภาคขนาดเล็กมีอิทธิพลเสริมกันทำให้ปริมาณการเคลือบสูงสุด คุณภาพการยึดเกาะดีที่สุด และลดฝุ่นละอองมากที่สุด การเคลือบด้วยวิธีธรรมดาควรใช้อนุภาคขนาดใหญ่เพราะมีปริมาณการเคลือบสูงกว่าและฝุ่นละอองน้อยกว่า ส่วนอนุภาคขนาดเล็กจะมีแรงยึดเกาะและคุณภาพการเคลือบดีกว่าสำหรับการเคลือบทั้งสองวิธี และเมื่อใช้กระแสไฟฟ้าสถิตย์ร่วมกับอนุภาคขนาดเล็กทำให้ตัวอย่างทดลองมีคะแนนการยอมรับโดยรวมสูงสุด จากผลการทดลองที่เด่นชัดในเกลือ สรุปได้ว่าอิทธิพลของอนุภาคขนาดเล็กเสริมกับวิธีเคลือบแบบกระแสไฟฟ้าสถิตย์ช่วยเพิ่มกลิ่นรสและความชอบของขนมขบเคี้ยวที่มีเกลือต่ำได้ และวิธีการเคลือบแบบกระแสไฟฟ้าสถิตย์ยังช่วยลดต้นทุนการผลิต ซึ่งเป็นผลจากประสิทธิภาพการผลิตที่มีปริมาณการเคลือบสูงกว่า ทำให้เกิดฝุ่นละอองและผงปรุงรสที่เสียไปน้อยกว่า

คำสำคัญ การเคลือบแบบกระแสไฟฟ้าสถิตย์, ความชอบ, ประสิทธิภาพการผลิต, การเพิ่มกลิ่นรส

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Executive Summary

Title: Development of Seasoned Fried Banana Chips Coated by Electrostatic Coating.

Potato, banana and taro chips are included in the first group of major snacks in the market. Despite the high product volume, there was lack of the banana and taro chip variety and the manufacturers rarely communicate with consumer to determine the needs. No consumer study has been conducted to understand the snacking behaviors and seasonings suitable for banana chips thus the market share of banana chip is limited. Hence, a consumer study on the fried banana chips is greatly needed. The first goal is to understand consumer behavior in terms of snacking fried banana chips, the preferred seasonings and their optimum coating amount and the important sensory attributes for consumer acceptances.

According to the coating process, the amount of seasoning and the adhesion of powder on foods is the key for snack. Electrostatic coating is credited with greater coating efficiency, less waste and less dust. In electrostatic coating, powder particles fall through an electromagnetic field and pick up negative charges. Like charges repel each other so the powder disperses into a uniform cloud rather than a straight line when falling. The charged particles seek out and adhere to the nearest ground target, resulting in more coating amount on product and less on the equipment or dust generation. Thus, it is recommended as the alternative way of seasoning application for fried banana chips based on the theory that it should improve the product quality and process efficiency in many aspects including consumer acceptances, the coating quality and the coating process efficiency.

Despite the use of electrostatic coating in snack industry, the optimization of electrostatic coating process for seasoned fried banana chip has not yet been done. Neither nor the study of consumer perception toward the electrostatically product. Thus, the research objectives were to study consumer perception of seasoned banana chips, to optimize the seasoning coating amounts, and to determine if there is an improvement in flavor enhancement, consumer acceptances and process efficiency by electrostatic coating.

Consumer survey and a series of sensory acceptance test, using a 9-point hedonic scale on color, odor, flavor, taste and overall acceptance, were conducted to select seasonings for fried banana chips and the optimum coating amount of each flavor. Seasonings were applied to fried banana chips using a belt-conveyor electrostatic coater at 0 and 25 kV for

nonelectrostatic and electrostatic coating, respectively. Panelists assessed both nonelectrostatically and electrostatically coated banana chips by using a paired preference test and acceptance test. Preliminary study of electrostatic application was conducted by measuring transfer coating efficiency, dust, and coating evenness of fried banana chips.

The consumer survey indicated that barbeque, sour cream and onion, salt and paprika were desirable seasonings with the corresponding coating amounts of 6, 8, 2 and 8%, respectively. Comparing to nonelectrostatic coating, electrostatically coated banana chips with all seasonings were significantly preferred, were coated more evenly, and had higher flavor intensity, except salt. Electrostatic coating significantly improved the coating efficiency and dust reduction with 61% and 54 %, respectively.

According to the effects of particle and electrostatic coating on flavor enhancement, product acceptances and process efficiency for seasoned fried banana chips. Barbeque, sour cream and onion and salt were used. The coating amount on each chip was controlled at 6±1% for all seasonings except salt (2±1%) for sensory evaluation to avoid unequal amount of coating. Seasoning particle size was reduced and coated by nonelectrostatic (0 kV) and electrostatic coatings (25 kV). In process efficiency test, 10g of seasoning were coated onto aluminum plates. Transfer efficiency, dust, coating evenness and adhesion were determined.

For all seasonings, electrostatically coated samples with smaller particles were preferred, more even, and received higher liking scores for coating evenness, flavor and taste. In both processes, panelists perceived significantly stronger flavor from smaller particle size of salt and tangy barbeque. The synergistic effects of electrostatic coating and small particles achieved the highest transfer efficiency, adhesion and dust reduction. Large particles showed higher nonelectrostatic transfer efficiency and less dust, but smaller particles had higher adhesion and coating evenness in both processes. Combined with electrostatic coating, small-particle-coated samples received the highest overall acceptance, suggesting important roles of flavor and coating appearance for preference.

In conclusion, the effects of small particles and electrostatics, most evident in salt, promise flavor and preference improvements in low-sodium snacks. Not only does electrostatic coating produce seasoned fried banana chip with better quality, more flavor and higher acceptances from consumer, but electrostatic coating also reduces the production cost by achieving higher transfer coating efficiency, less dust and less waste.

The Research Grant for New Scholar
Thailand Research Fund

Title (English) Development of Seasoned Fried Banana Chip and Fried Taro Chip Coated by Electrostatic Coating.

(Thai) การพัฒนากล้วยทอดแผ่นปรุงรสและเผือกทอดแผ่นปรุงรสโดยใช้วิธีการเคลือบแบบกระแสไฟฟ้าสถิตย์

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Research Area

Seasoning application on fried banana and fried taro chips by using electrostatic and nonelectrostatic coatings.

Duration

July 1, 2005 – November 30, 2007

Problem and Significance

The Snack market has experienced significant growth during the past decade as consumers have gradually changed their eating habits away from the regular mails and toward snacking. This change occurred because snacking is fast, easier and more convenient compared to the time and effort involved with regular meals. In this new environment, manufacturers find themselves under pressure to develop new products to keep their market shares and to expand the market by responding to new consumer needs. Seasoning application is one of the main process developments used by manufacturers to rapidly add value to snacks and is also a relatively easy line extension operationally. Potato, banana and taro chips are included in the first group of major snacks in the market. Banana are grown a lot especially in the lower Northern region of Thailand. Despite the high product volume,

there was lack of the banana chip variety and the manufacturers rarely communicate with consumer to determine the needs. No consumer study has been conducted to understand the snacking behaviors and seasonings suitable for banana chips thus the market share of banana chip is limited. Hence, a consumer study on the fried banana chips is greatly needed. The first goal is to understand consumer behavior in terms of snacking fried banana chips, the preferred seasonings and their optimum coating amount and the important sensory attributes for consumer acceptances.

The study seeks to determine what new seasonings are desirable for banana chips, which sensory attributes drive consumer acceptances and preferences, the optimum coating amount for each seasoning, and how the manufacturers could efficiently produce seasoned fried banana and taro chips.

Aside from the lack of consumer study, the snack seasoning application technology also needs to be addressed. The amount of seasoning is greatly important to manufacturers as it is the one of the biggest costing components of snack products. It is also very important to consumer acceptability. The amount of seasoning applied and the adhesion of powder on foods is the key to addressing both these issues. Most manufacturers tend to over apply seasoning in order to ensure that an adequate amount is adhered onto the foods through the shelf life of the product. However, this still produces unequal coating on products and also causes more powder to be suspended in the air as dust. As the seasoning is the most expensive ingredient the producers do not want to use more than absolutely necessary. Any excess seasoning that is added increases the cost, and the excess seasoning falls off on the conveyer belt and filling equipment, requiring more down time for cleaning. Seasonings are also usually dusty, and working in the dusty area is an airborne hazard due to dust inhalation and risk of dust explosion. Continuously breathing high amounts of dust may cause respiratory distress to workers.

Electrostatic coating is considered to be an option to overcome the above problems. It is an innovative new processing technology for application of seasonings to snacks in Thailand. In electrostatic coating, powder particles fall through an electromagnetic field and pick up negative charges. Because the powder is charged and thus attracted to the food product, more of the powder lands on the product and less on the equipment and dispersed in the air as dust. Thus electrostatic coating resulted in greater coating efficiency, less waste and

less dust. Despite the use of electrostatic coating in snack industry, the optimization of electrostatic coating process for seasoned fried banana chip has not yet been done. Neither nor the study of consumer perception toward the electrostatically product.

According to the problem discussed above, once new seasonings, amount of coating, and important sensory attributes of seasoned fried banana chips are determined, the effect of electrostatic coating on improving flavor enhancement, consumer acceptances and process efficiency will be conducted as the second goal of this project. Electrostatic and nonelectrostatic coatings will be compared in many aspects including consumer sensory evaluation, product qualities and process efficiency.

Project Objectives *

1. To study consumer snacking habits in relation to seasoned fried banana chips in order to develop new seasonings for these products, and to specify which sensory attributes drive consumer acceptances and preferences.
2. To optimize seasoning coating level and process parameters for seasoned fried banana chips coated by both nonelectrostatic and electrostatic coatings.
3. To determine the feasibility study of electrostatic coating application for Thai snacks by utilizing the superiority of electrostatic coating in seasoning application for seasoned fried banana chips based on consumer perspectives (preference and acceptance), coating efficiency improvement regarding adhesion, percent amount of coating improvement and dust reduction.
4. To determine the physical properties of seasonings applied on seasoned fried banana chips that affect the coating efficiency of both nonelectrostatic and electrostatic coatings.

* The research objectives had been modified from the original version since the end of the first-year project. This modification was already approved by the TRF committee. The taro chip study was eliminated so the research focused only banana chip because it is more popular. Consumer indicated higher needs for banana chips than taro chips.

Research Plans

Activities	Jul-Dec 2005	Jan-Jun 2006	July-Dec 2006	Jan-Jun 2007	July-Nov 2007
1. Consumer survey study and seasonings identification					
2. Determine the optimum coating level of seasonings and optimize the nonelectrostatic coating operation					
3. Study consumer preference and acceptance of seasoned products					
4. Preliminary study of the electrostatic seasoning application on products					
5. Preliminary study of physical property of seasonings					
6. Write a progress report and prepare the first manuscript					
7. Optimize the coating operations using optimum level determined from step 2 for nonelectrostatic and electrostatic coating of seasoned products					
8. Study consumer preference and acceptance of electrostatically and nonelectrostatically coated products					
9. Study whether seasoning particle size and electrostatic coating enhance flavor intensity of products					
10. Compare nonelectrostatic and electrostatic coatings efficiency by using coating amount improvement, % dust reduction and % seasoning adhesion improvement					
11. Write a final report and prepare the second manuscript					

Material and Methods

Consumer Survey and Seasoning Optimization

122 panelists participated in the consumer survey about their snacking behavior regarding the banana chip and the desired seasonings selected from eight seasoning choices including salt, paprika, barbeque, sour cream and onion, Nori-seaweed, hot chili, wasabi (Japanese herbal paste) and roasted chili paste. These seasonings were popular for snacks in the area. Four of the most preferable seasonings from consumer survey including barbeque-BBQ, sour cream and onion-SCO, paprika-PP (International Flavors and Fragrances (Thailand), Bangkok, Thailand) and sodium chloride-salt (Morton Salt, Chicago, IL, U.S.A) were selected to determine the coating amounts for banana chips. In this research, sodium-chloride-salt would be referred as salt. The particle size of salt was reduced by grinding in the blender for 2 minutes for proper coating. The amount of seasonings for banana chips was chosen based on the average amount used for potato chips (Ratanatriwong and others, 2003). The coating levels used for barbeque, sour cream and onion, paprika were varied in 3 levels of 4, 6 and 8% where those of salt were 1, 2 and 3%. The standard deviation of coating amount on each piece of samples for the sensory evaluation was controlled to be within ± 1% as suggested by Ratanatriwong and others (2003).

The optimum coating amount for each seasoning was determined by a sensory acceptance test using the hedonic rating scale. Product acceptance was based on color, odor, flavor, taste and overall acceptance attributes. There were 40 panelists participated in the sensory evaluations of each seasoning. Then, each seasoning with their respective optimum coating amount was applied on fried banana chips. 100 panelists assessed samples coated with various seasonings in the sensory acceptance test using hedonic rating scale. Then, they ranked samples coated with each seasoning based on their preference in the ranking test.

Comparison of product acceptances by different coating methods

Selected seasonings with their respective coating amounts from a series of sensory evaluation were coated on banana chips at 0 and 25 kV by a belt conveyor electrostatic coater (Terronics Co., IN, U.S.A) for nonelectrostatic (NE) and electrostatic (E) coatings, respectively. Seasoning was fluidized with an air pressure of 345 kPa. The standard deviation

of the seasoning amount on each banana chip was controlled to be within ± 1% (Ratanatriwong and others, 2003) so each panelist received sample with equal amount of coating per piece. Therefore, if there was the effect of coating on any sensory attributes, it was ensured that some experimental error, i.e. unequal amount of seasoning, was avoided. Panelists assessed both of electrostatically and nonelectrostatically coated banana chips for the product acceptances using 9-point hedonic and just-about-right (JAR) scales based on coating evenness, flavor intensity, crispness and overall acceptance.

Comparison of process efficiency by different coating methods

The process efficiency of electrostatic and nonelectrostatic coating methods was compared in various aspects including the amount of seasoning coating, amount of dust generated during coating, and coating evenness. In this case, selected seasonings were coated on banana chips for 15 g. each by nonelectrostatic (0 kV) and electrostatic (25 kV) coatings. Seasoning was fluidized with an air pressure of 345 kPa. The transfer coating efficiency (TE) was determined from the weight difference of samples before and after coating using eq. 1. The transfer efficiency improvement was the difference between transfer efficiency of electrostatic and nonelectrostatic coatings.

$$\%\text{Transfer efficiency} = \frac{\text{total coating wt} \times 100}{\text{g feeding powder}} \qquad (1)$$

The dust generated during seasoning coating was also collected from the air in a cassette/PVC filter (SKC, Inc. Eighty Four, PA) for 3 min. Air was pumped at a rate of 5 L/min by a model HFS 513A Gilian air pump (Wayne, NJ). The amount of dust (g/l) was calculated, and % dust reduction improvement by electrostatic coating was the difference of dust between two coating methods.

The coating evenness was determined by comparing the color reading (L*, a*, b*) of samples taken by a Minolta colorimeter model CR-300 (Minolta Co., LTD, Ramsey, NJ). Hue angle expressed in degree was calculated using eq. 2.

$$\text{Hue angle (degree)} = \tan^{-1}(b/a) \qquad (2)$$

Color was measured in 4 quadrant positions per chip of 3 banana chips. The standard deviation from each chip were used to determine whether electrostatically and nonelectrostatically coated samples were significant different in terms of coating evenness. Samples with smaller standard deviation were considered as more evenly coated (Ratanatriwong and others, 2003).

Effect of particle size and electrostatic coating on improving product preference and process efficiency

Salt (sodium chloride), barbeque, tangy barbeque and sour cream and onion were selected to study the effect of particle size and coating methods on the acceptances. All seasonings were supplied by Kerry Savory (Kent, WA, USA) where salt was from Morton Salt (Chicago, IL, U.S.A). Each seasoning was ground to smaller size before being coated on samples using different coating methods. Selected seasonings with their respective coating amounts were coated on banana chips at 0 and 25 kV by a belt conveyor electrostatic coater (Terronics Co., IN, U.S.A) for nonelectrostatic (NE) and electrostatic (E) coatings, respectively. Seasoning was fluidized with an air pressure of 345 kPa. Seasoning amount on each chip was strictly controlled at 6±1% for all seasonings (barbeque, tangy barbeque and sour cream and onion) except salt (2±1%). The standard deviation of the seasoning amount on each banana chip was controlled to be within ± 1% (Ratanatriwong and others, 2003) so each panelist received sample with relatively equal amount of coating per piece to minimize the effect of coating amount on the sensory attributes of products. Sensory evaluations, participated by 50 panelists, included the intensity tests (coating evenness and flavor intensity with reference anchored in each scale), the hedonic tests (color, coating evenness, flavor, taste and overall acceptance) and overall ranking test.

The process efficiency of electrostatic and nonelectrostatic coating methods was compared. Selected seasonings were coated on banana chips for 10 g. each by nonelectrostatic (0 kV) and electrostatic (25 kV) coatings. The transfer coating efficiency (TE) was determined from the weight difference of samples before and after coating, and the transfer efficiency improvement was compared between TEs of electrostatic and

nonelectrostatic coatings. The dust generated during seasoning coating was collected from the air in a cassette/PVC filter (SKC, Inc. Eighty Four, PA) for 3 min. The amount of dust (g/l) was calculated, and % dust reduction improvement by electrostatic coating was the difference of dust between two coating methods. Data of TE, dust and coating evenness were collected in 5, 5 and 3 replicates, respectively.

Statistical Analysis

The sensory results from the hedonic scale was analyzed using the analysis of variances (ANOVA) and Tukey's test to determine the preferred seasonings and their respective coating amounts. Standard least square regression analysis with effect screening was used to determine which sensory attributes influenced the overall acceptance for each seasoning. Student's T-test and Chi-square was used to analyze whether electrostatic coating could improve the product acceptances from sensory test using a hedonic and JAR scales, respectively. Data of TE, dust and coating evenness were collected in 5, 5 and 3 replicates, respectively. Student's t-test was used to determine whether coating efficiency, dust reduction and coating evenness were significantly improved by electrostatic coating. All statistical analysis was performed at the confidential level of 95% by JMP statistical software version 4.03 (SAS Institute, Cary, NC).

Result and Discussion

There were 122 consumers participating in the survey; 61% were female and 39 % were male. The average ages of the consumers were spread over 4 categories from 15 to older than 45 years. The consumer salaries per month were spread over 7 categories starting from lower-than 4,000 to higher-than 20,000 baht. In regards to consumption frequency, the overwhelming majority of respondents were concentrated in three categories including more than once a day, once a day and once a week. However, the banana chip consumption frequency was localized within two categories; at least once a week and at least once a month. No significant difference was found among the shape (rod-, round- and oval-shape) for fried banana and taro chips based on consumer needs. Consumers were familiar with round banana chips coated only with sugar, salt or butter. However, 68% of consumers indicated their need for different seasoned banana chips and 91% indicated strong purchase intent for banana chips coated with a variety of seasonings that were offered to them.

Four seasonings including salt, paprika, barbeque and sour cream and onion were preferred from eight seasonings that were offered for banana chips ($p<0.05$). Nori-seaweed, hot chili, wasabi and roasted chili paste were less preferred by consumer. According to the coating levels, the preferred coating amount of each seasoning was selected from the acceptances of panelists based on color, odor, taste, flavor and overall acceptance. The optimum coating amount of salt, paprika, barbeque and sour cream and onion were 2, 8, 6 and 8%, respectively ($p<0.05$).

The results from the acceptance and ranking test of seasoned banana chips were shown in table 1. Amongst the four seasonings with their respective coating amount, barbeque was the most significantly preferred based on all attributes followed by sour cream and onion, salt and paprika, respectively.

Table 1 The acceptances of banana chips coated with various seasonings.

Seasoning	Color	Odor	Taste	Flavor	Overall acceptance	ranking
Barbeque	7.07[a]	7.1 [a]	7.33 [a]	7.26 [a]	7.42 [a]	1
Sour cream and onion	6.67 [b]	7.06 [a]	6.89 [b]	6.97 [a]	7.12 [a]	2
Salt (NaCl)	5.68 [c]	6.02 [b]	6.28 [c]	6.33 [b]	6.34 [b]	3
Paprika	5.77 [c]	5.33 [c]	5.07 [d]	5.28 [c]	5.56 [c]	4

Values with a different letter are significantly different ($p<0.05$).

The result also showed that some attributes may be the important factors driving the overall acceptance of consumer toward banana chip for each seasoning (Table 2). For barbeque, color, odor, taste and flavor showed their effects on overall acceptances with the correlation of 78%. However, color did not drive the overall acceptance of salt and sour cream and onion banana chips whereas taste was not a major effect for paprika and sour cream and onion banana chips. Only odor, taste and flavor indicated their effects on overall acceptance of salted banana chips with the correlation of 81%. For paprika, color, odor and flavor showed the effect on banana chip acceptances with the correlation of 80%. However, only flavor seemed to play a role in driving the consumer acceptances on sour cream and onion banana chips with the correlation of 46%. Since paprika banana chip only got an average score of five in every attributes, barbeque, salt and sour cream and onion were selected for further study. These seasonings were coated on banana chips by NE and E coating methods. Panelists assessed seasoned banana chips coated by two different methods in the acceptance test using hedonic test for overall acceptance and the JAR scale for coating evenness, flavor intensity and crispness.

Table 2 Sensory attributes that may influence the overall acceptances of seasoned banana chips based on the Standard least square regression analysis with effect screening.

Seasoning	Color	Odor	Taste	Flavor	R^2
Barbeque	*	*	*	*	0.79
Sour cream and onion	*	-	-	*	0.46
Salt (NaCl)	-	*	*	*	0.81
Paprika	*	*	-	*	0.80

* Significantly different ($p<0.05$).

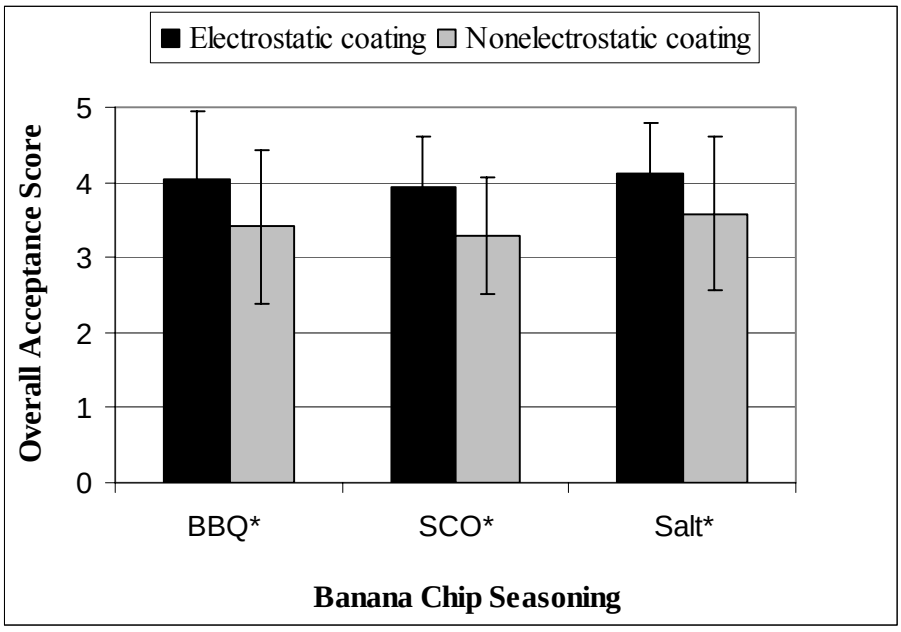

Fig. 1 E coated banana chips were significantly preferred over NE banana chips in all seasonings. * Significantly different ($p<0.05$).

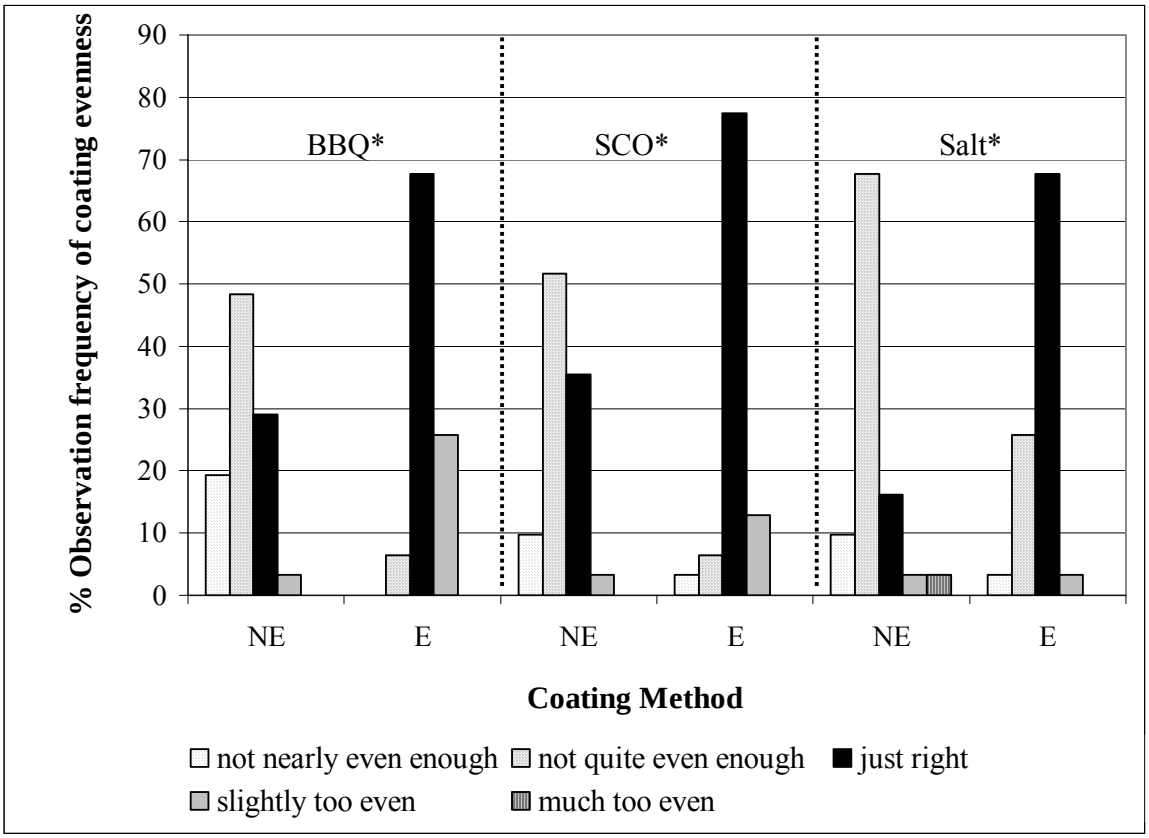

Fig. 2 Electrostatically coated banana chips were rated as more even than nonelectrostatically coated samples for all seasonings based on JAR scale.

* Significantly different ($p<0.05$).

For all seasonings, E coated banana chips were significantly preferred (Fig. 1), and were more evenly coated than NE coated samples ($p<0.05$) (Fig. 2). All electrostatically coated samples were located in the coating evenness preference map closer to ideal (just-right) than those of nonelectrostatic ones (Fig. 3).

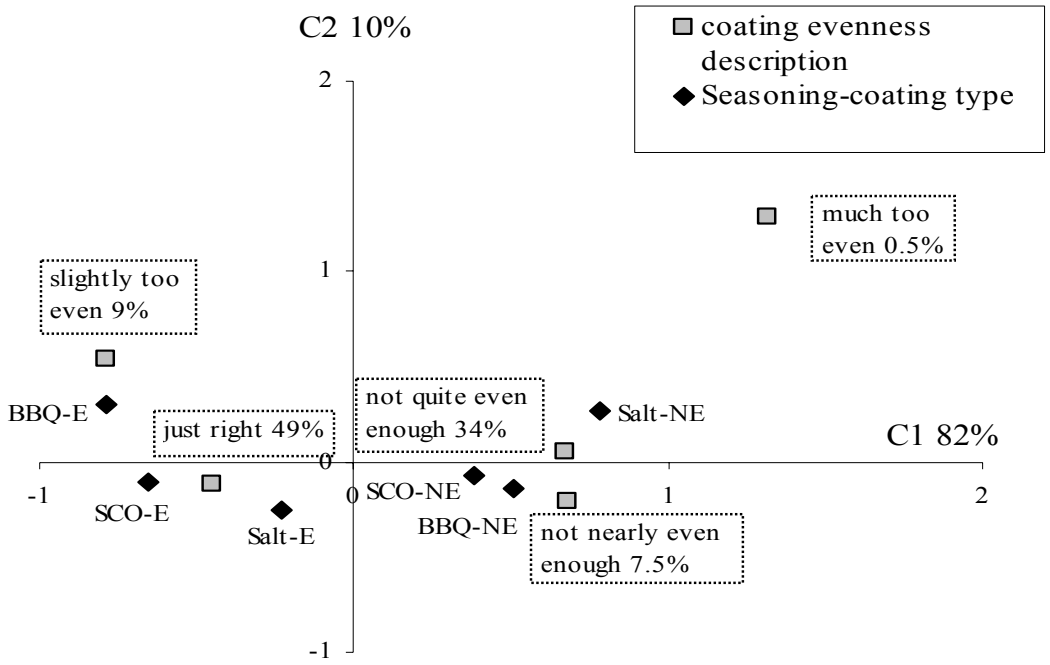

Fig. 3 The coating evenness of electrostatically coated banana chips for all seasonings were close to ideal (just-right) while nonelectrostatically coated samples were not uniform enough.

The instrumental result of coating evenness also correlated well with sensory. The standard deviation value of b and hue angle values in one piece of banana chip for E coated samples were significantly lower than those of NE samples, indicating more evenly coated (Fig. 4). Strietelmeier and Reynolds (1969) found that an electrostatic salter produced salted crackers that had a lower average standard deviation of salt than those coated with the conventional method. Ratanatriwong and others (2003) reported the advantage of more-even coating on potato chips by electrostatic coating as well.

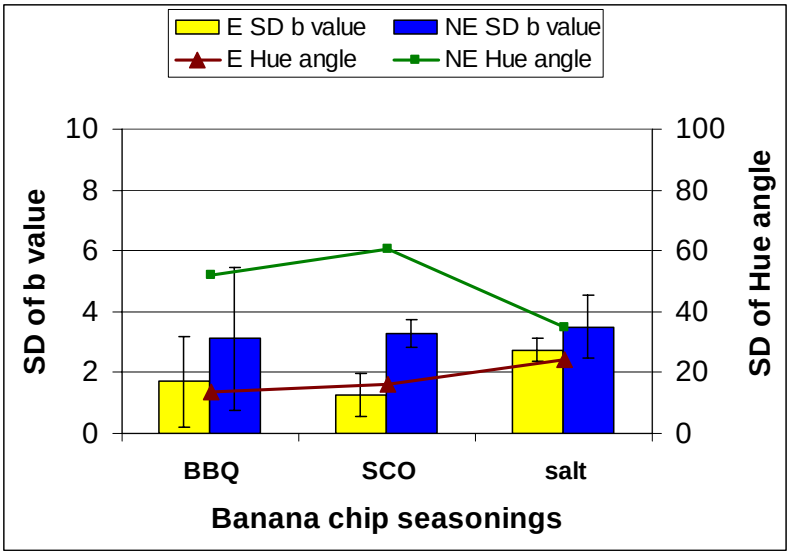

Fig. 4 E coated banana chips were coated more evenly than NE coated samples because of lower standard deviation of color parameter values ($p<0.05$).

The observation frequency of panelists rating their flavor intensity liking of electrostatically coated banana chips as just-right was significantly higher than nonelectrostatic samples for all seasonings except salt ($p<0.05$) (Fig. 5). This result indicated that the flavor intensity of electrostatically coated samples were more preferred as shown in the flavor preference map (Fig. 6). E coated banana chips were rated as higher flavor intensity than NE samples in all seasonings except salt ($p<0.05$). The flavor intensity locations of electrostatic samples for all seasonings were closer to ideal (just-right) than those of nonelectrostatic samples that were localized in the less-flavor area. Only nonelectrostatic-coated-salt sample was close to just-right thus no significant difference in flavor liking between two coating methods was found.

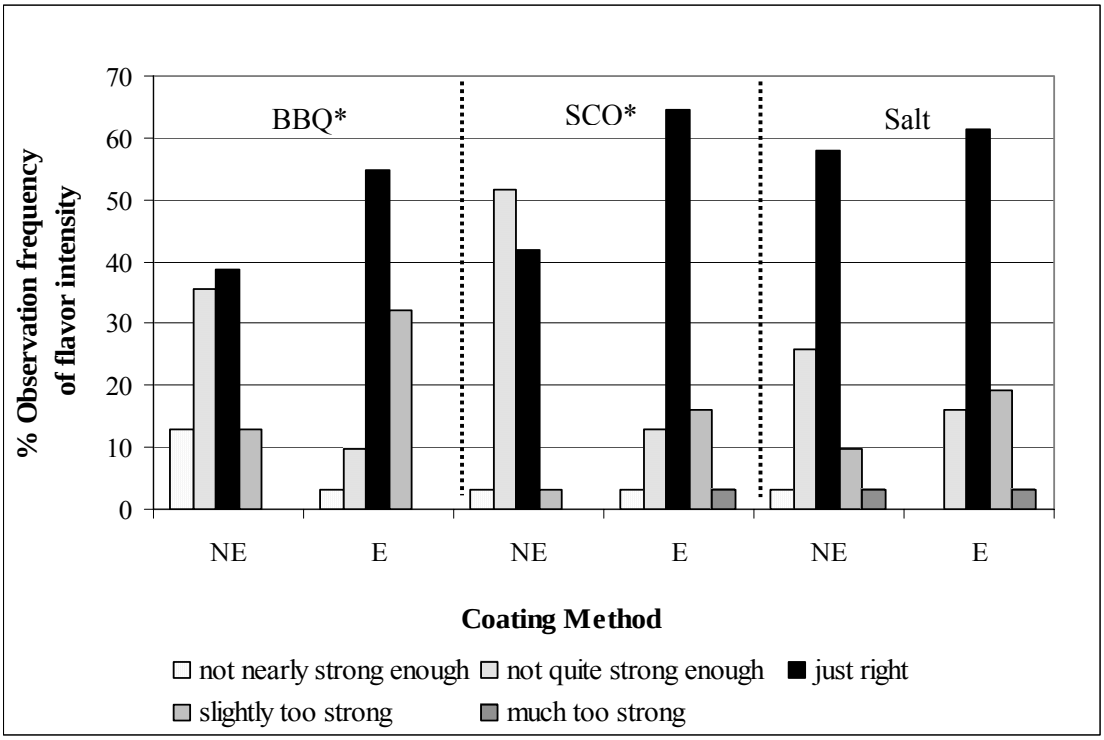

Fig. 5 E coated banana chips were rated as higher flavor intensity than NE coated samples in all seasonings except salt based on JAR scale. * Significantly different ($p<0.05$).

The effect of electrostatic coating on flavor intensity found in this study agreed with the assumption previously reported that electrostatic may enhance flavor intensity. Due to the fact that evenly coating covers larger surface area, it may result in more flavor distribution (Clark, 1995; Seighman, 2001). In contrast, this phenomenon was not found in electrostatically coated potato chips (Ratanatriwong and others, 2003). Only coating uniformity seems to be the most important effect that drives consumer preference since no significant difference in flavor intensity was found between electrostatically and nonelectrostatically coated samples in that study. However, since electrostatically coated banana chips were more evenly coated than nonelectrostatic samples as discussed earlier, the surface area of seasoning should be larger that it would result in greater flavor distribution when panelist assessed samples.

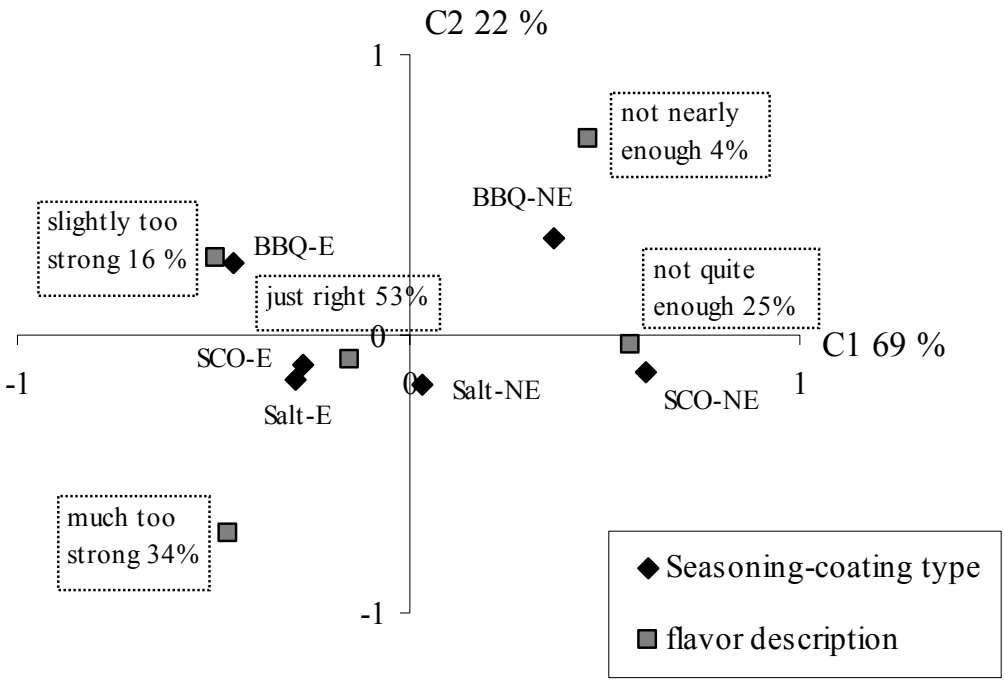

Fig. 6 The flavor intensity of electrostatically coated banana chips were close to ideal (just-right) or slightly too strong while that of nonelectrostatically coated samples were not strong enough except salt.

There was however no significant difference between coating methods based on crispness. This attribute was suggested just to check the panelist accuracy (Ratanatriwong and others, 2003). Difference coating procedure in this study does not affect sample crispness.

Table 3 Comparison of the coating efficiency between nonelectrostatic (NE) and electrostatic (E) coating by the transfer efficiency, dustiness and the electrostatic coating improvement and dust reduction.

Seasoning	Transfer efficiency (%)		E Coating improvement*	Dustiness (mg/L)		E Dust reduction*
	Nonelectrostatic	Electrostatic	at 25 kV (%)	Nonelectrostatic	Electrostatic	at 25 kV (%)
Barbeque	56	78*	41	0.00079	0.00033*	50
Sour cream and onion	37	58*	58	0.00085	0.00029*	46
Salt (NaCl)	40	74*	84	0.0022	0.00031*	37

* Significantly different ($p<0.05$).

According to the preliminary study of electrostatic coating application on fried banana chips, the comparison of the coating efficiency between nonelectrostatic (NE) and electrostatic (E) coating by the transfer efficiency, dustiness and the electrostatic coating improvement and dust reduction were determined (Table 3). For all seasonings, E coating achieved significantly greater coating amount than NE coating with the average of 70% and less dust of 0.0003 g/l. E coating also significantly improved transfer efficiency and dust reduction over NE coating with the average from all seasonings of 61 and 54%, respectively (Fig. 7-8).

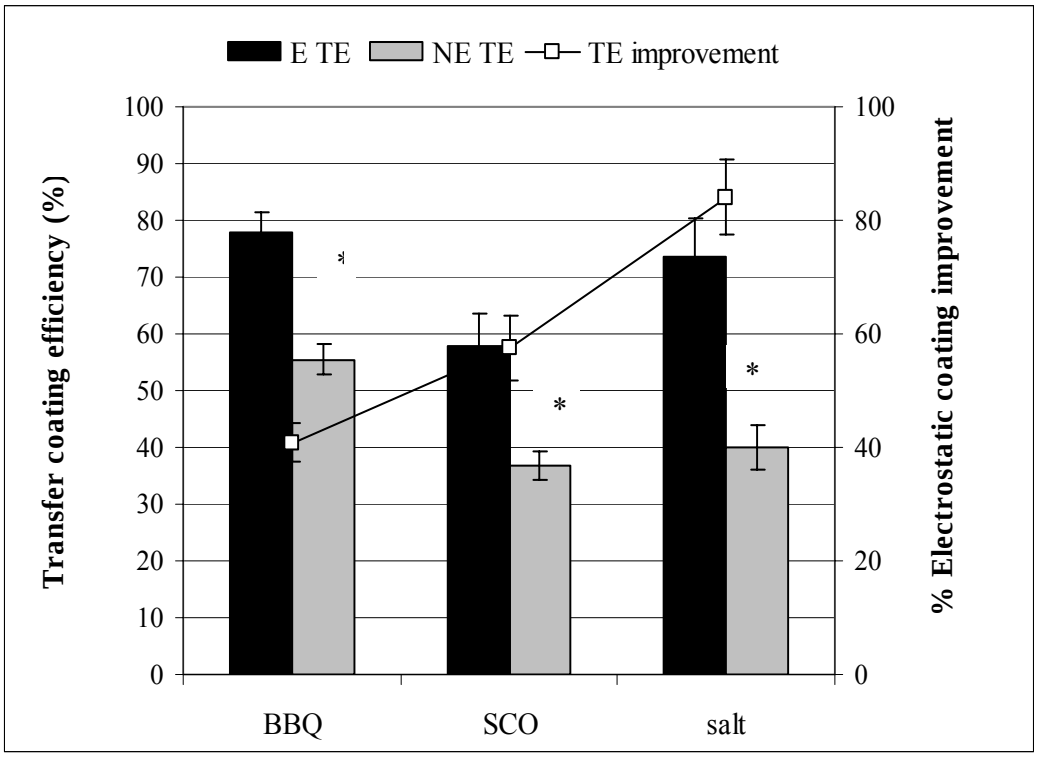

Fig. 7 Electrostatic static achieved significantly greater transfer coating efficiency on banana chips where salt had the highest Electrostatic transfer efficiency improvement.
* Significantly different ($p<0.05$).

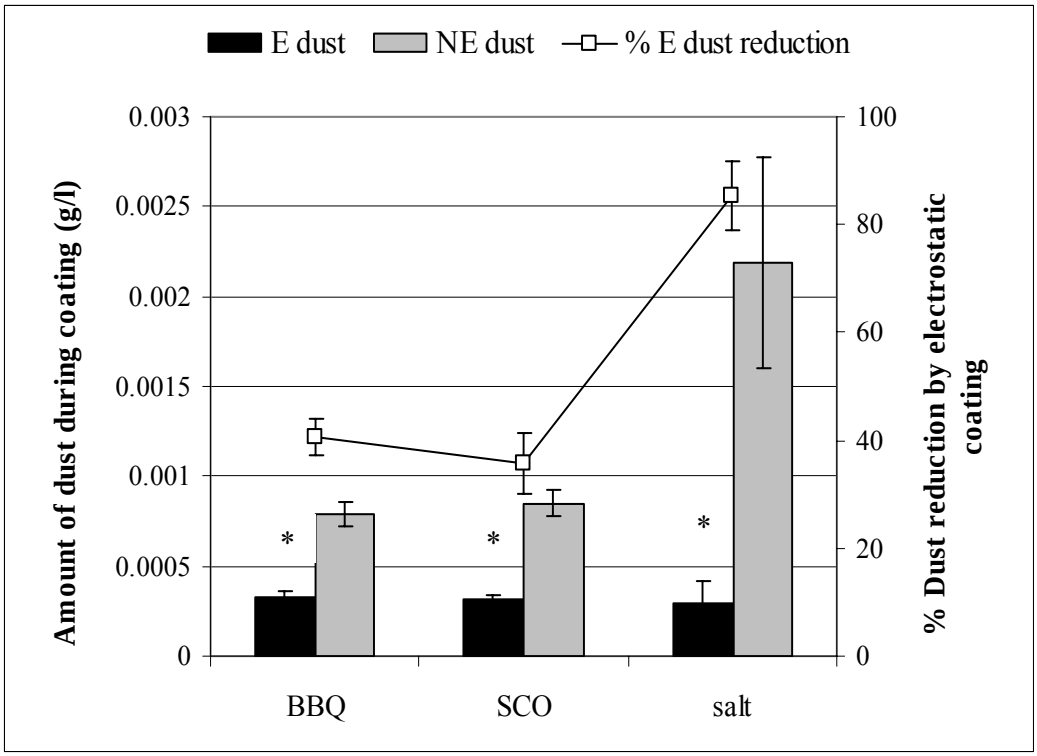

Fig. 8 Electrostatic static resulted in significantly lower amount of dust during coating where salt showed the highest improvement by electrostatic coating on dust reduction.
* Significantly different ($p<0.05$).

The seasonings including barbeque, tangy barbeque, sour cream and onion and salt were used to further study the effects of particle size and coating process on sensory perception. The optimum coating amount on each chip was controlled to avoid experiment errors of panelists having unequal amount of seasonings on each banana chip. For all seasonings, electrostatically coated samples with smaller particles were preferred, more even, and received higher liking scores for coating evenness, flavor and taste ($p<0.05$). Electrostatic coating resulted in the improvement of coating evenness and coating quality of products (Amefia and others, 2006; Ratanatriwong and others, 2003). In both processes, small-particle-coated samples were more even so they were more preferred (Fig. 9). Smaller size and E coating enhanced flavor intensity

and liking (Fig. 10). The higher the flavor intensity, the higher the flavor liking. In both processes, panelists perceived significantly stronger flavor from smaller particle size of salt and tangy barbeque. This indicated that electrostatic coating coupled with smaller particle size could enchance flavor intensity and flavor liking for coated banana chips.

The synergistic effects of electrostatic coating and small particles achieved the highest transfer efficiency, adhesion and dust reduction (Fig. 11). Electrostatic coating is known for its benefit in improving the product quality such as coating evenness (Ratanatriwong and others, 2003; Reyes and Barringer, 2005) and process efficiency including transfer efficiency and dust reduction (Biehl and Barringer, 2004; Ratanatriwong and Barringer, 2007). Large particles showed higher nonelectrostatic transfer efficiency (Fig. 12) and less dust (Fig. 13). This agreed with the fact previously reported (Ratanatriwong and others, 2003; Ricks and others, 2002). Smaller particles had higher adhesion (Fig. 14) and coating evenness in both processes.

Conclusion

The consumer desirable banana-chip seasonings and their optimum coating amounts were determined. E-coated banana chips were preferred based on coating evenness, flavor intensity and overall acceptance. E coating achieved greater coating process efficiency and product quality. Combined with electrostatic coating, small-particle-coated samples received the highest overall acceptance, suggesting important roles of flavor and coating appearance for preference. The effects of small particles and electrostatics, most evident in salt, promised flavor and preference improvements in low-sodium snacks. Thus, electrostatic coating is a promising process for seasoned banana chip with better product quality, less cost and less waste.

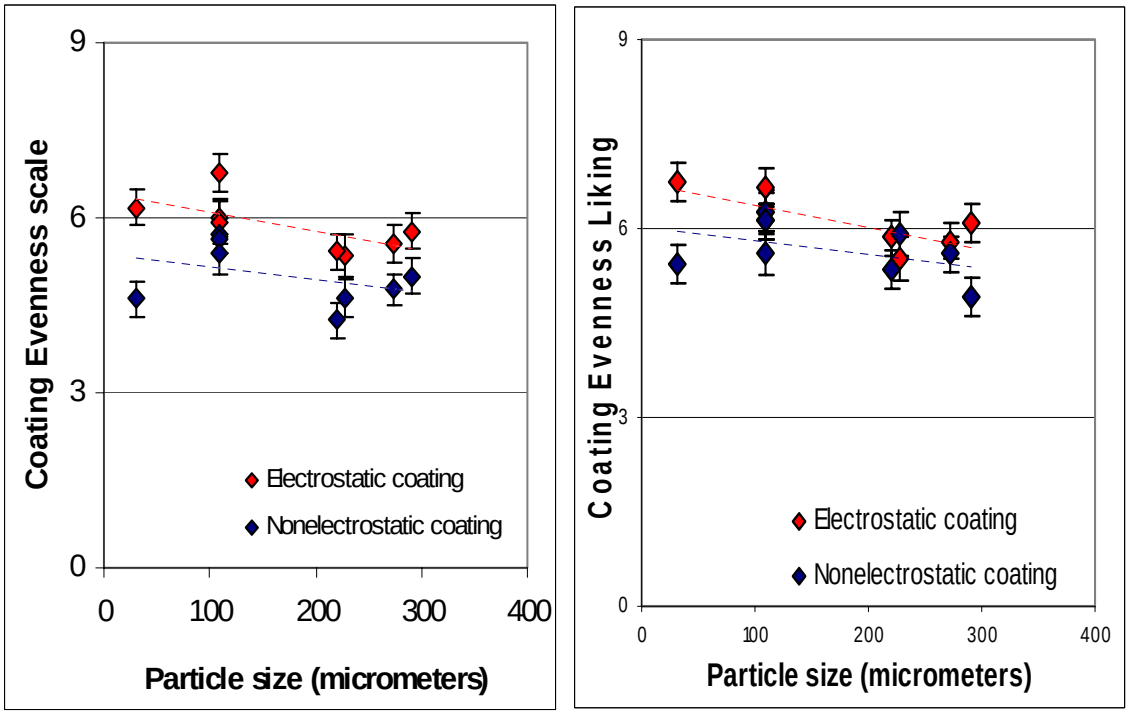

Fig. 9 The coating evenness of seasoned banana chips coated with different methods and their liking score.

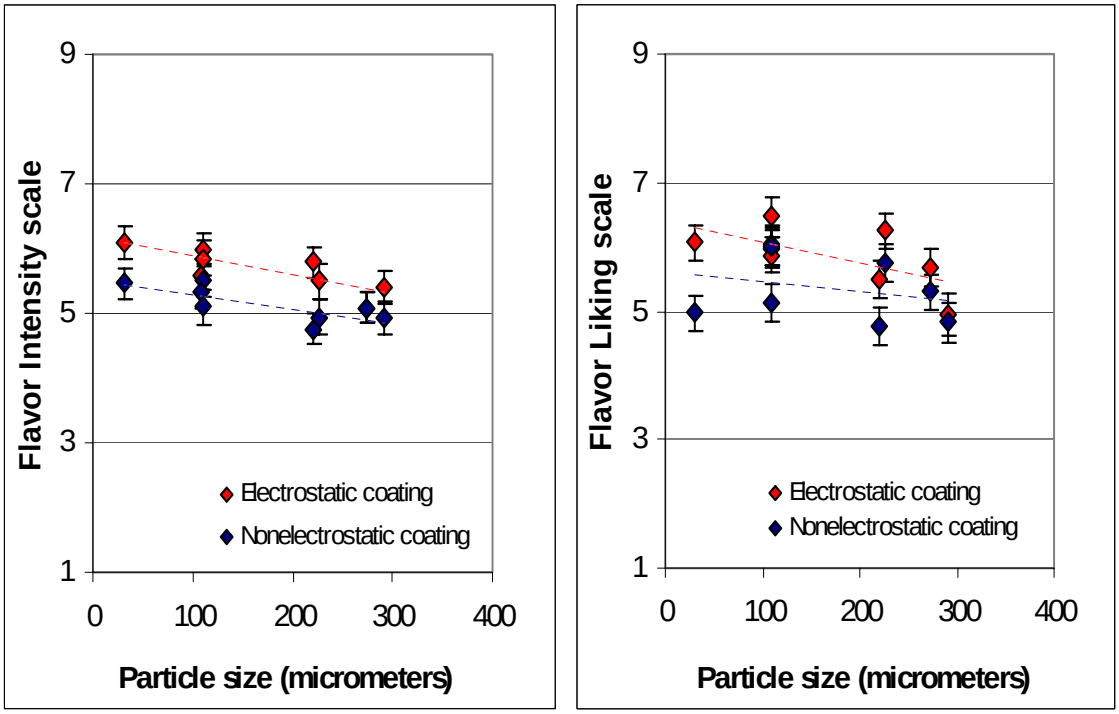

Fig. 10 The flavor intensity of seasoned banana chips coated with different methods and their liking score.

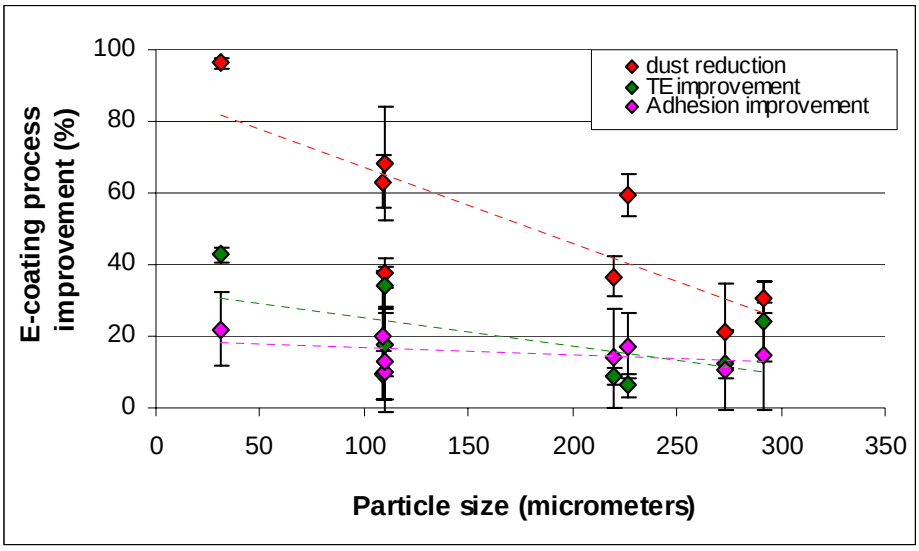

Fig. 11 Process efficiency improvement for seasoned banana chips by electrostatic coating.

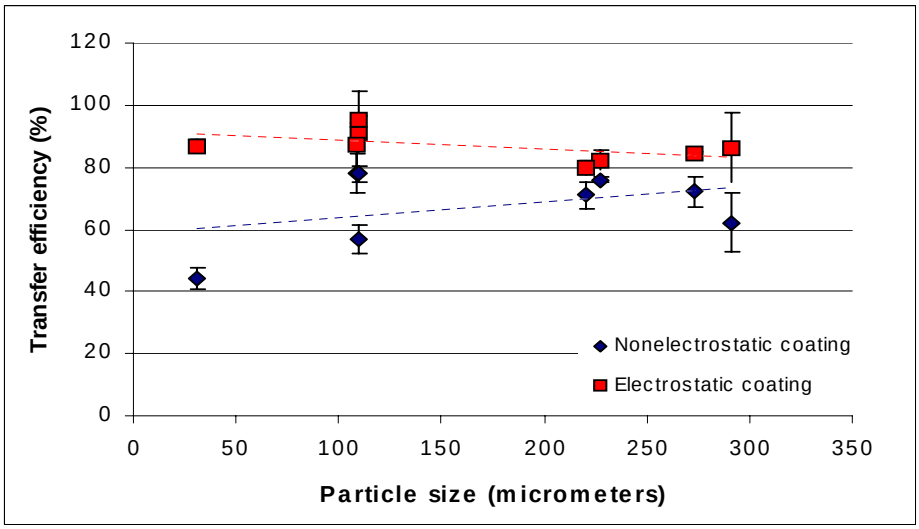

Fig. 12 Transfer efficiency of seasoned banana chips coated by different methods.

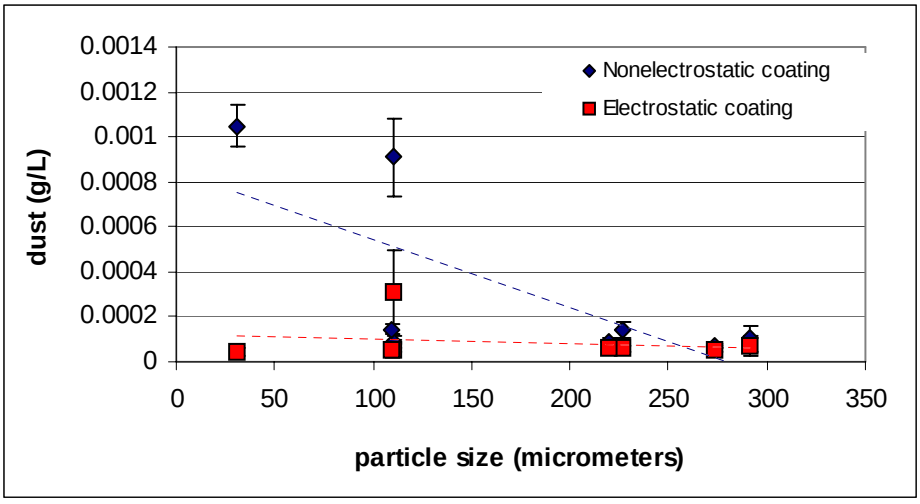

Fig. 13 Seasoning dust generated from coating seasoned banana chips by different methods.

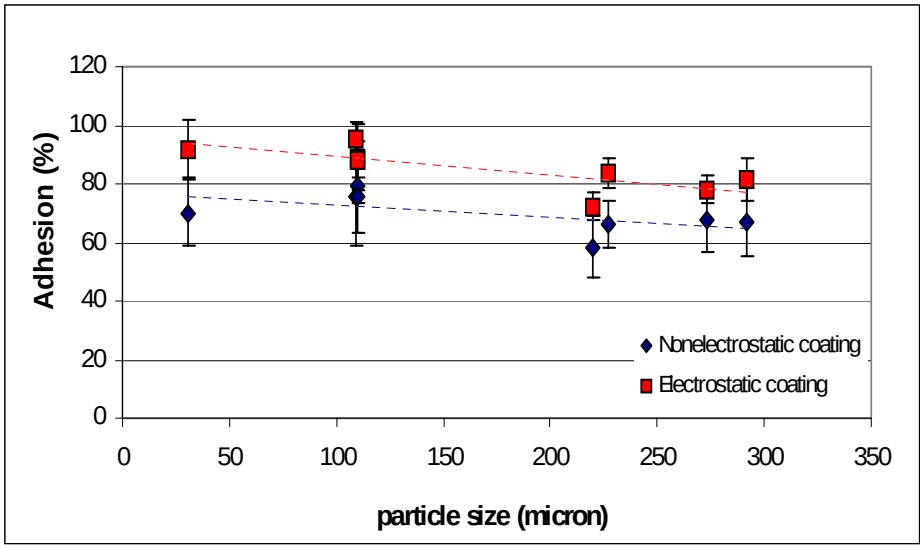

Fig. 14 Seasoning adhesion (%) of banana chips coated by different methods.

Acknowledgement

The authors would like to thank the Thailand Research Fund (TRF) and Faculty of Agriculture Natural Resources and Environment, Naresuan University for the project fund, Department of Food Science and Technology, The Ohio State University for the electrostatic coating machine usage, International Flavors and Fragrances (Thailand) Co., Ltd. and Kerry Savory for the seasoning samples.

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Appendix I

Project Outputs

1. Five presentation in both national and international conferences as following:

1.1 National conference

1.1.1 **Ratanatriwong, P.**, Tanasukarn, P. 2006. Consumer Acceptance and Process Efficiency of Banana Chips Coated by Electrostatic Coating. Proceeding of the Kaset-Naresuan Conference. Pitsanulok. Thailand.

1.1.2 **Ratanatriwong, P.**, Suwansri, S., Barringer, S.A. 2007. Flavor enhancement, product quality and process improvement of seasoned banana chips by electrostatic coating. Naresuan Agriculture Conference "Agro-Industry 3rd". Faculty of Agriculture, Natural Resources and Environment. Naresuan University. Pitsanulok. Thailand. paper# OAI-12. (Invited paper)

1.2 International conference

1.2.1 **Ratanatriwong, P.** Barringer, S.A., Tanasukarn, P. and Suwansri, S. 2006. Development of seasoned fried banana chip coated by electrostatic powder coating. IFT Annual Meeting Paper # 020I-14. Orlando. FL. USA.

1.2.2 **Ratanatriwong, P**., Suwansri, S., Barringer, S.A. 2007. The effects of particle size and electrostatic coating on flavor enhancement, preference and coating efficiency of seasoning coated snacks. Institute of Food Technologists Annual meeting paper# 0185-05. Chicago. IL. USA.

1.2.3 **Ratanatriwong, P**, Suwansri, S. and Barringer S.A. The effect of particle size and electrostatic coating on flavor enhancement, preference and coating efficiency of seasoning coated snacks. Proceeding of Food Innovation Asia Conference 2008, "Healthy Food For All". Bangkok. Thailand. June 12-13th, 2008. paper O2-7: 1-6.

2. Three manuscripts were prepared/submitted for publication in international journals.

2.1 **Ratanatriwong, P.**, Barringer, S.A., Tanasukarn, P., Suwansri, S. The effect of electrostatic oating on consumer acceptance and process efficiency improvement of seasoned coated snacks. Asean Food Journal. *(Submitted).*

2.2 **Ratanatriwong, P.**, Barringer, S.A.,Suwansri, S. The effect of particle size and electrostatic coating on flavor enhancement, preference and coating efficiency of seasoning coated snacks. Journal of Electrostatics. *(Submitted).*

2.3 **Ratanatriwong, P.**, Abu-Ali, J.M., Barringer, S.A. Enhancement of food additive functionality and product preference by electrostatic coating. Journal of Food Process and Preservation. *(Submitted).*

3. The article titled "การเพิ่มกลิ่นรส คุณภาพผลิตภัณฑ์ และเพิ่มประสิทธิภาพการผลิตกล้วยทอดแผ่นปรุงรสด้วยกระแสไฟฟ้าสถิตย์ (Flavor enhancement, product quality and process improvement of seasoned banana chips by electrostatic coating) " was published in the research book "ข้าวของพ่อ" that was distributed in งาน by Faculty of Agriculture, Natural Resources and Environment **(Appendix II)**

Appendix II

การเพิ่มกลิ่นรส คุณภาพผลิตภัณฑ์ และเพิ่มประสิทธิภาพการผลิตกล้วยทอดแผ่นปรุงรสด้วยกระแสไฟฟ้าสถิตย์

Flavor enhancement, product quality and process improvement of seasoned banana chips by electrostatic coating.

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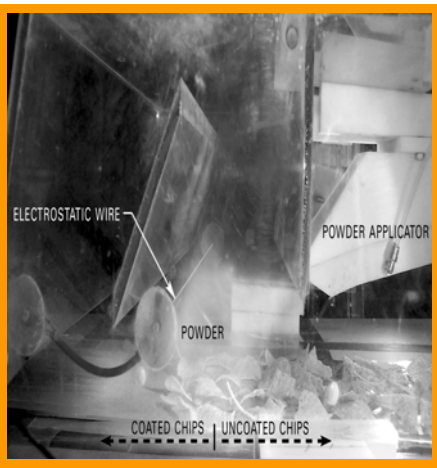
วิธีการเคลือบสารปรุงแต่งกลิ่นรสโดยทั่วไป มักใช้ปริมาณสารปรุงแต่งกลิ่นรสมากเกินความจำเป็นเพื่อให้มั่นใจว่าผลิตภัณฑ์มีสารปรุงแต่งกลิ่นรสเหลืออยู่ในปริมาณที่ผู้บริโภคต้องการ แม้จะเป็นการเพิ่มต้นทุนการผลิตก็ตาม เนื่องจากสารปรุงแต่งกลิ่นรสจะไม่ยึดติดกับผลิตภัณฑ์ดีพอ และหลุดออกจากตัวอาหารระหว่างการผลิตและขนส่งผลิตภัณฑ์ รวมถึงการเพิ่มต้นทุนการผลิตส่วนของการทำความสะอาดเครื่องมือ เนื่องจากพบปริมาณสารปรุงแต่งกลิ่นรสส่วนเกินดังกล่าว และเศษฝุ่นละอองของสารปรุงแต่งกลิ่นรสที่ฟุ้งกระจายอยู่ในอากาศ

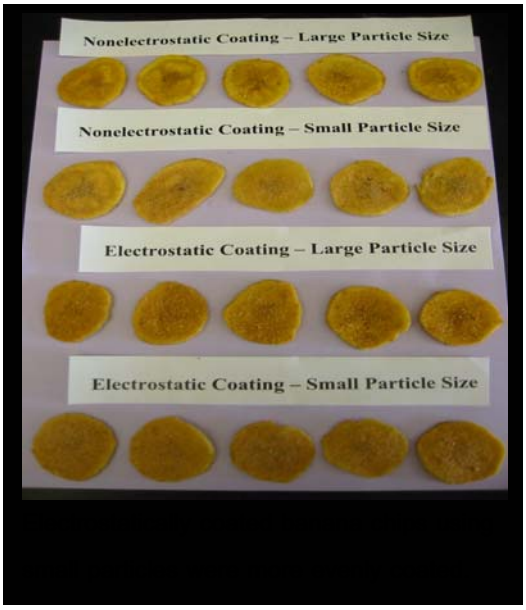


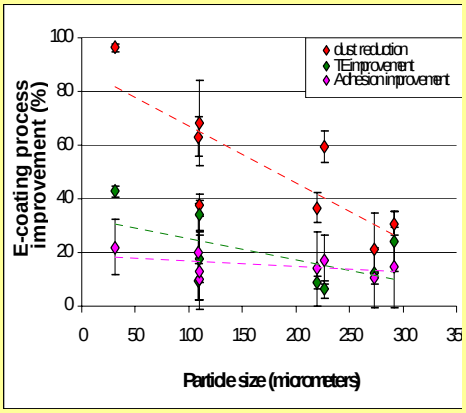
Seasonings were nonelectrostatically and electrostatically coated.

เนื่องจากสารปรุงแต่งกลิ่นรสและขนมขบเคี้ยวมีมูลค่าทางการตลาดสูงขึ้นเรื่อย ๆ ดังนั้น การเคลือบสารปรุงแต่งกลิ่นรสโดยใช้เทคโนโลยีการเคลือบไฟฟ้าสถิตย์จากกระแสไฟฟ้าแรงสูงจึงถูกนำมาประยุกต์เพื่อเพิ่มประสิทธิภาพการเคลือบสารปรุงแต่งกลิ่นรส ทำให้ประหยัดและสามารถลดต้นทุนการผลิตได้ ปัจจุบันมีอุตสาหกรรมอาหาร เช่น มันฝรั่งทอด ที่เริ่มใช้เทคโนโลยีนี้ในการผลิต

โครงการวิจัยนี้ศึกษาอิทธิพลของขนาดอนุภาคการกระจายตัวในอากาศ และอิทธิพลของการเคลือบด้วยกระแสไฟฟ้าสถิตย์ที่มีต่อการเพิ่มกลิ่นรสของกล้วยทอดแผ่นปรุงรส ปรับปรุงคุณลักษณะทางกายภาพของผลิตภัณฑ์เพื่อตอบสนองความต้องการของผู้บริโภค และเพิ่มประสิทธิภาพในการเคลือบกล้วยทอดแผ่นปรุงรส นอกเหนือจากการสำรวจความนิยมของผู้บริโภคต่อชนิดของผงปรุงรสสำหรับกล้วยทอดแผ่น ซึ่งพบว่าการเคลือบด้วยกระแสไฟฟ้าสถิตย์จะทำให้ผลิตภัณฑ์มีความสม่ำเสมอมากกว่า มีกลิ่นรสมากกว่าผลิตภัณฑ์ที่เคลือบแบบปกติ (ปริมาณผงปรุงรสต่อชิ้นเท่ากัน)ประสิทธิภาพการเคลือบสูงกว่า เนื่องจากมี

ปริมาณของผงเคลือบต่อชิ้นมากกว่า (ปริมาณผงปรุงรสที่ใช้ในการเคลือบต่อครั้งเท่ากัน) และสูญเสียผงปรุงรสในระหว่างการผลิตน้อยกว่าการเคลือบโดยทั่วไป ส่งผลให้สามารถลดค่าใช้จ่ายในการผลิต การเคลือบแบบกระแสไฟฟ้าสถิตย์นี้มีประสิทธิภาพสูงขึ้นเมื่อขนาดอนุภาคมีขนาดเล็ก กระจายตัวดี และไม่เกาะตัวกัน ในขณะที่การเคลือบแบบธรรมดานั้นควรใช้ขนาดอนุภาคใหญ่และมีการกระจายตัวดี





The synergistic effects of E coating and small particles achieved the highest transfer efficiency, adhesion and dust reduction.

โครงการวิจัยนี้ได้รับทุนสนับสนุนจากคณะเกษตรศาสตร์ ทรัพยากรธรรมชาติและสิ่งแวดล้อม มหาวิทยาลัยนเรศวร ปีงบประมาณ 2548 และทุนสนับสนุนการวิจัยจากสำนักงานกองทุนสนับสนุนการวิจัย (สกว) ปีงบประมาณ 2548 นอกจากนี้ผลงานบางส่วนของโครงการที่นำเสนอในการประชุมระดับนานาชาติ (IFT) Annual Meeting ณ ประเทศสหรัฐอเมริกา ได้รับรางวัล 2005 Award for Excellence in Scientific Research จาก Institute of Food Technologists

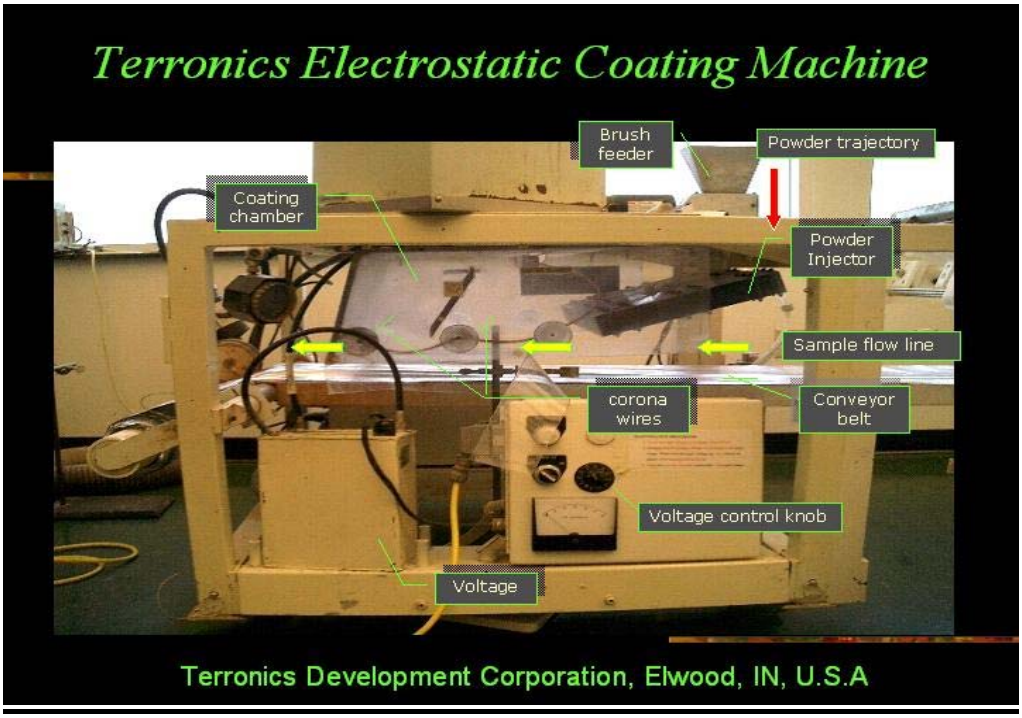
ผลงานวิจัย: 1. Ratanatriwong P and Barringer SA. 2005. Particle size, cohesiveness and powder composition effects on electrostatic and nonelectrostatic powder coating.IFT Annual meeting paper# 52-2. New Orleans. LA. USA.

2. Ratanatriwong P, Barringer SA, Tanasukarn P and Suwansri S. 2006. Development of seasoned fried banana chip coated by electrostatic powder coating. IFT Annual meeting paper# 020I-14. Orlando. FL. USA.

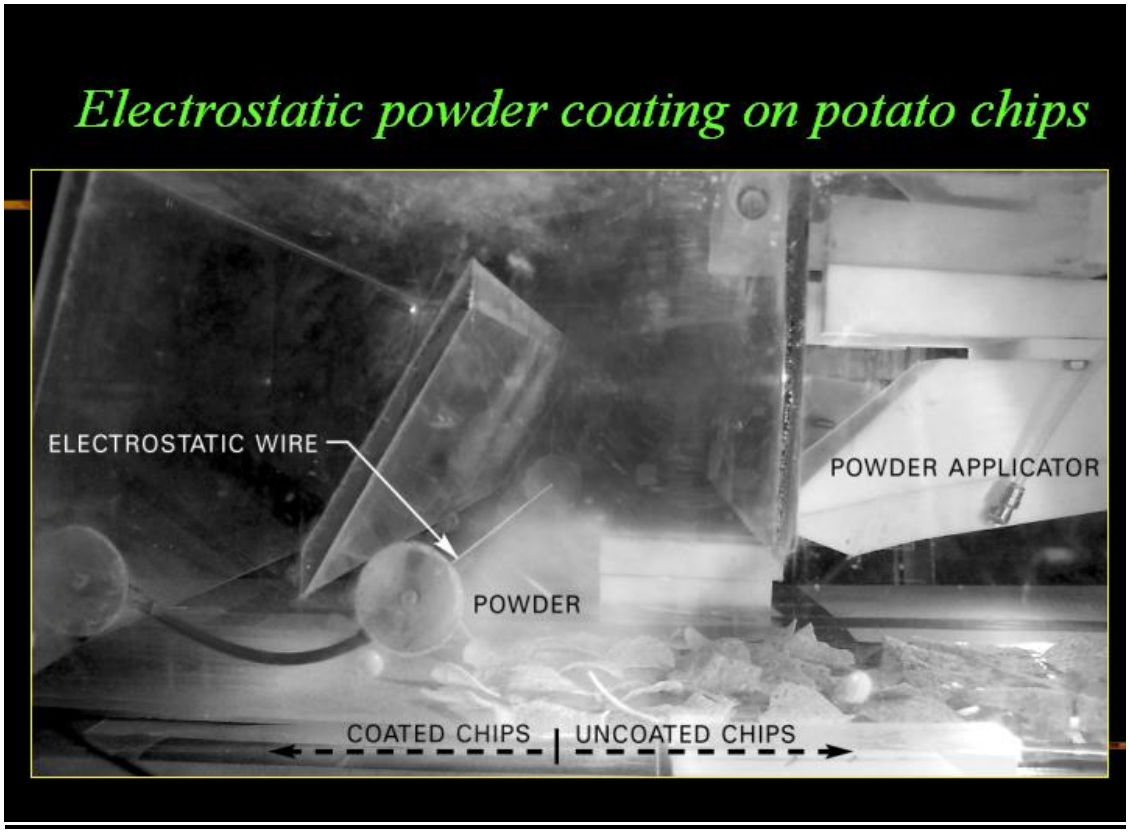
3. Ratanatriwong, P., Suwansri, S., Barringer, S.A. 2007. The effects of particle size and electrostatic coating on flavor enhancement, preference and coating efficiency of seasoning coated snacks. IFT Annual meeting paper# 0185-05. Chicago. IL. USA.

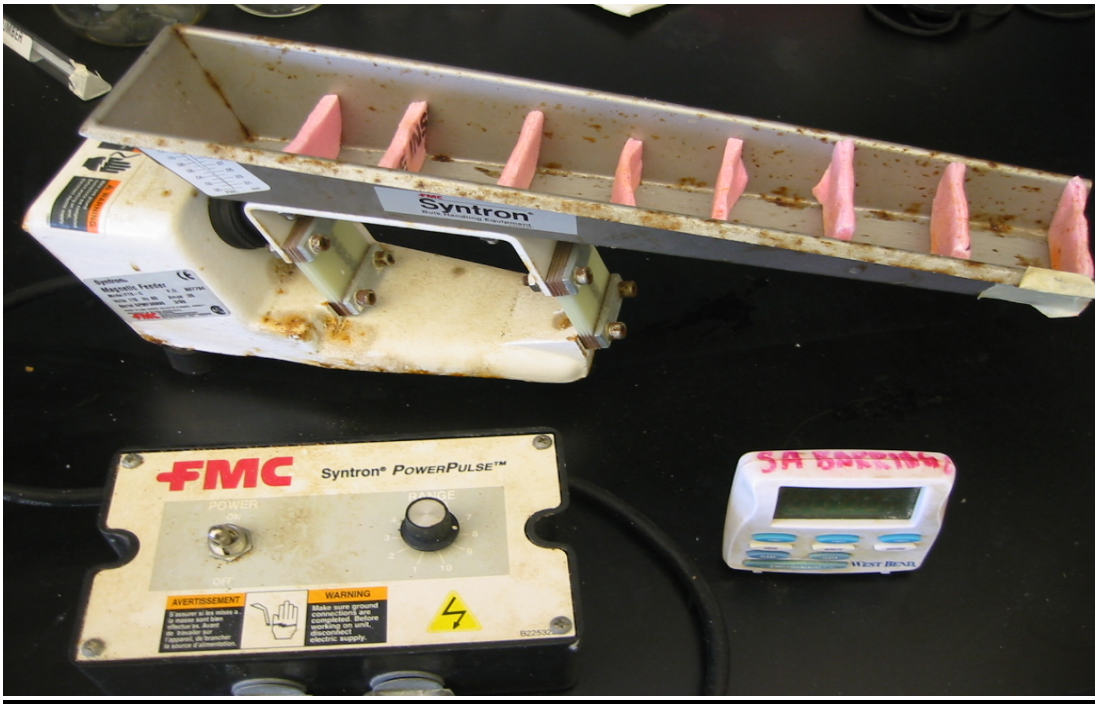
4. 2005 Award for Excellence in Scientific Research. IFT Phi Tau Sigma Graduate Research Competition. IFT Annual Meeting, New Orleans, LA, U.S.A.

Appendix III

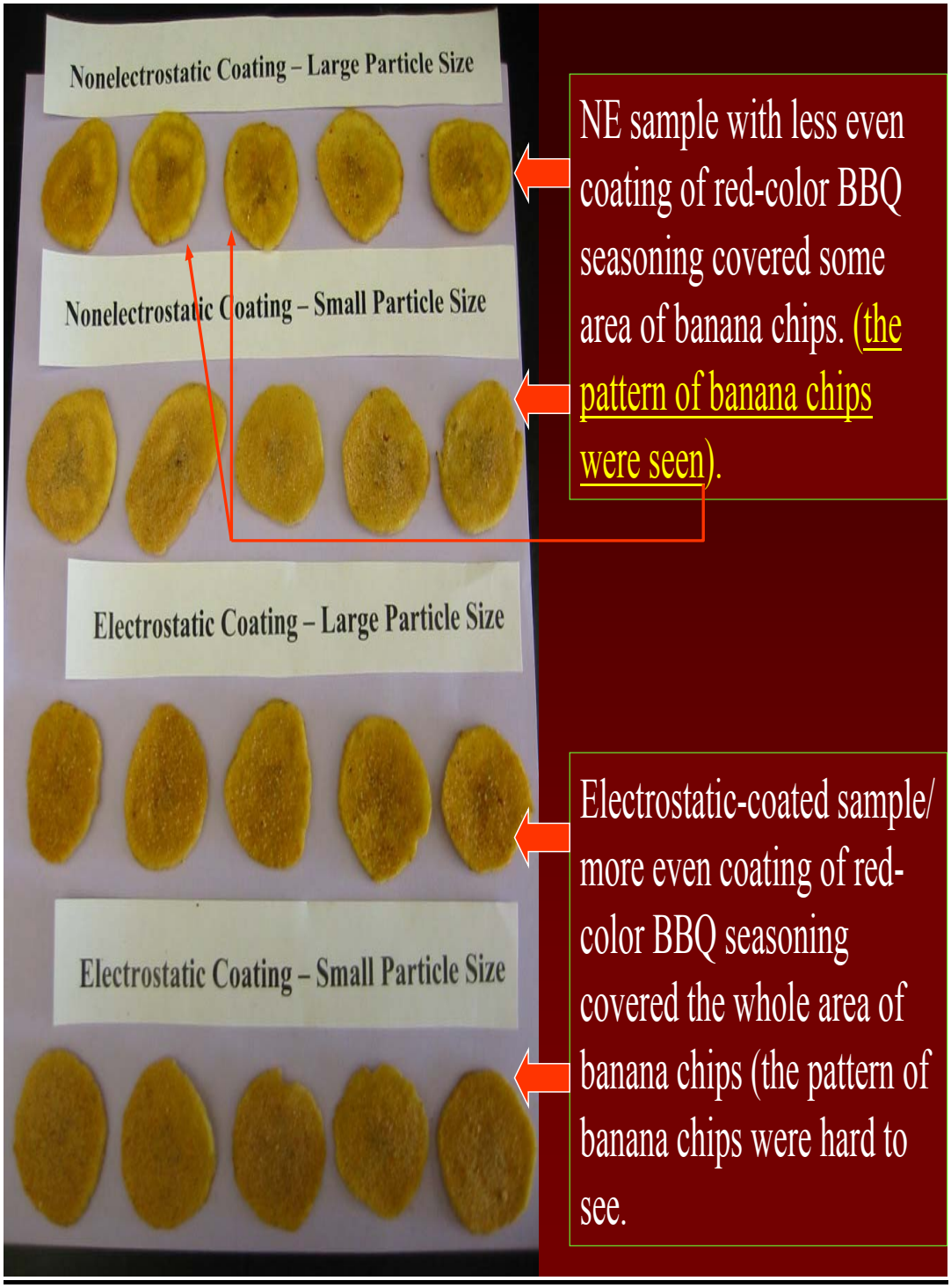

Terronics Electrostatic Coating Machine
Brush feeder
Powder trajectory
Coating chamber
Powder Injector
Sample flow line
corona wires
Conveyor belt
Voltage control knob
Voltage
Terronics Development Corporation, Elwood, IN, U.S.A


Terronics Electrostatic Coating Machine
Terronics Development Corporation, Elwood, IN, U.S.A

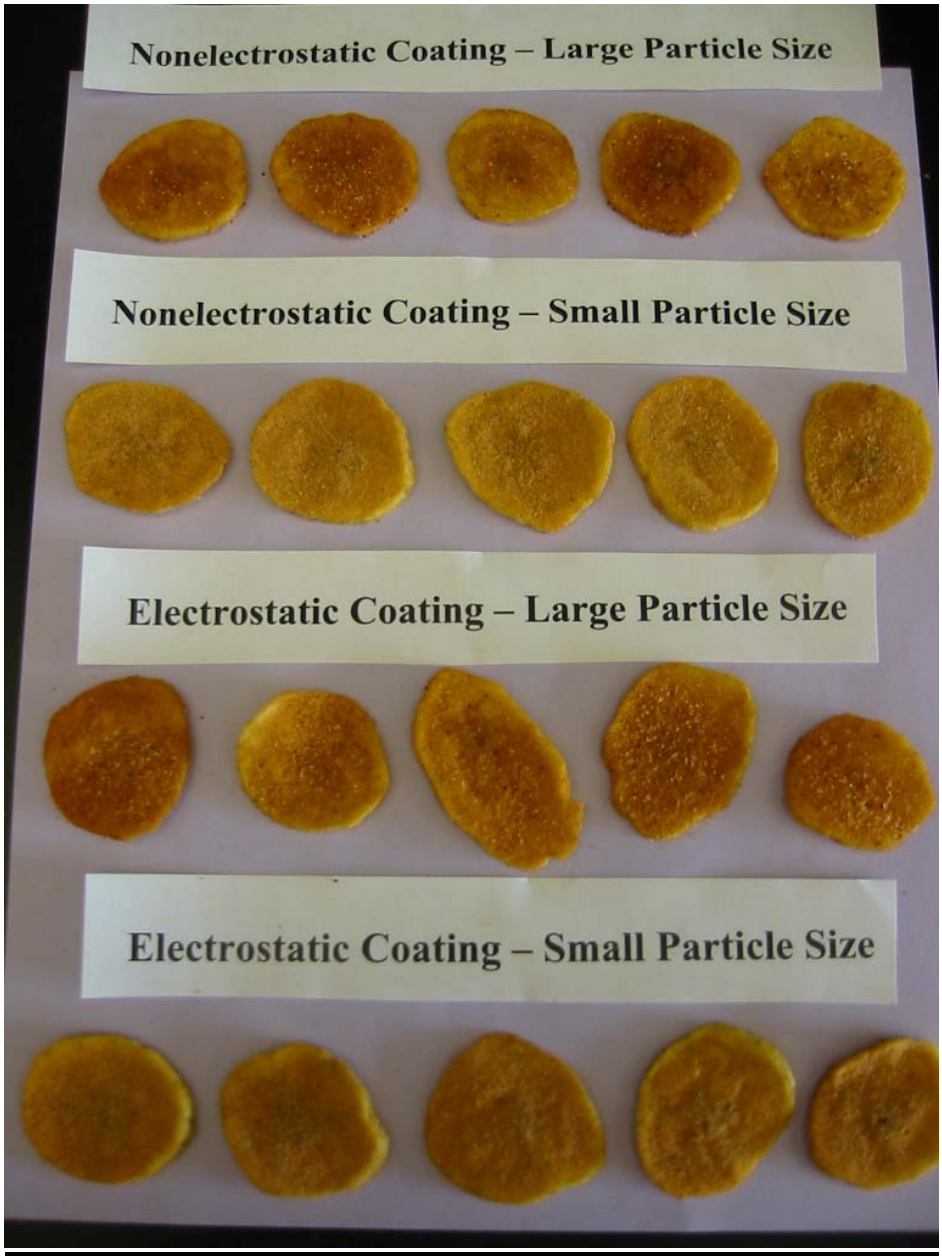




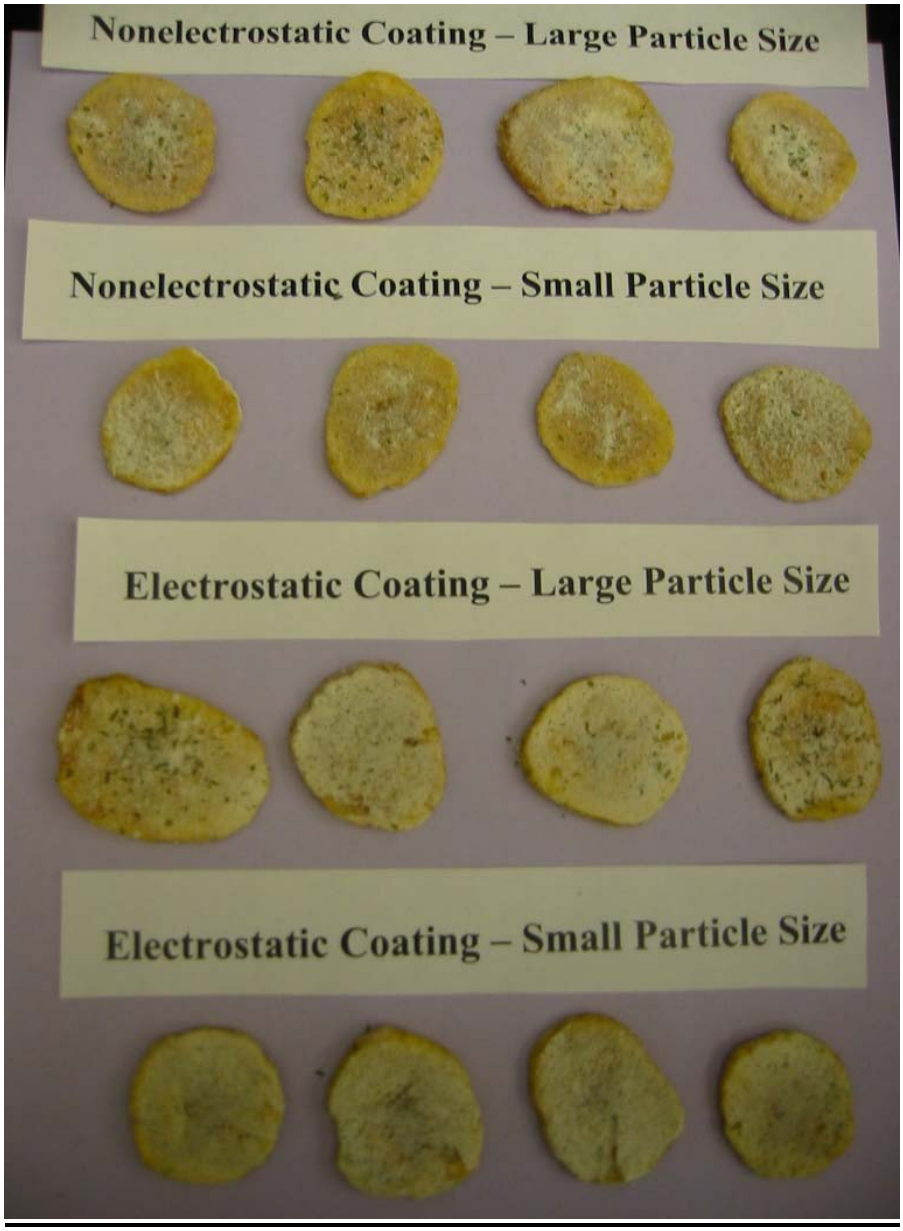
The shaking equipment for adhesion test.



Barbeque banana chips



Tangy Barbeque banana chips



Sour-cream-and-onion banana chips