

Research Article

Effect of electrostatic coating on consumer acceptance and process efficiency of seasoned coated snacks

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Abstract: Electrostatic coating is used in seasoning application due to its higher process efficiency, yet the optimization of electrostatic coating process for seasoned fried banana chips has not been undertaken and consumer perception toward the final product is unclear. The objectives of this research were to study consumer perception of seasoned banana chips, to optimize the coating conditions and to determine if there is an improvement in coating efficiency and product quality by using electrostatic coating. Consumer surveys and a series of sensory acceptance tests were conducted to select seasonings for fried banana chips and the optimum coating amount of each flavour. Seasonings were applied to samples using a belt-conveyor electrostatic coater at 0 and 25 kV for non-electrostatic and electrostatic coating, respectively. Panelists assessed samples with selected seasonings in the acceptance test. The coating efficiency, dust and coating evenness of fried banana chips coated by both methods were compared. Four seasonings including barbeque, sour cream and onion, salt and paprika were preferred with the optimum coating amounts of 6, 8, 2 and 8%, respectively. For all seasonings except salt, electrostatically coated banana chip seasonings were significantly preferred, were more evenly coated and had higher flavour intensity than non-electrostatically coated samples. Electrostatic coating significantly improved the coating efficiency and reduced dust by 61% and 54%, respectively. Salt had the highest improvement followed by sour cream and onion and barbeque. Thus, electrostatic coating produced seasoned fried banana chips with better quality and reduced production cost.

Keywords: food additives, seasoning, banana chip, consumer preference, Thailand

Introduction

Despite a high production volume of bananas in Thailand, for fried chips there is a surprising lack of variety. Traditionally, manufacturers rarely communicate with consumers to determine their needs and to understand the snacking behaviours and seasonings suitable for banana chips. Thus the market share for banana chips is limited. There is a need to better understand consumer behaviour on consuming fried banana chips, their preferred seasonings and the corresponding optimum coating amount. The seasoning application technology for banana chips also needs to be improved. The amount of seasoning and the adhesion of powder to the food product is the key for successful snacks. Generally, excess seasonings are usually over applied to ensure an adequate amount of coating on products through the shelf life. In electrostatic coating, however, 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, which is the food product in this case, resulting in more coating amount on the product and less on the equipment or dust generation [1, 2, 3]. Electrostatic coating achieves a smaller standard deviation in the amount of coating per piece than that of non-electrostatic coating [4]. Electrostatic powder coating of crackers with salt reduced the standard deviation of coating amount to almost half of that produced by the non-electrostatic coater [5]. A smaller amount of seasoning coating on food products is needed when electrostatic coating is applied [6], because the electrostatic process resulted in higher coating efficiency and less dust generation [7, 8]. Therefore, electrostatic coating has high potential as an alternative method for applying seasoning to fried banana chips based on the theory that it should improve product quality and process efficiency. Thus this study investigates the consumer perception of seasoned snacks and the effects of electrostatic coating on improving consumer acceptances and coating process efficiency.

Materials and Methods

Consumer Survey and Seasoning Optimization

There were 122 consumers participating in the survey; 61% female and 39% male, with the age range from 15 to older than 45 years. They were asked about their snacking behaviour regarding banana chips and their 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 preferred seasonings from the consumer survey, including barbeque-BBQ, sour cream and onion-SCO, paprika-PP (International Flavors and Fragrances, Bangkok, Thailand) and sodium chloride-salt (Morton Salt, Chicago, IL, USA) were selected to determine the coating amounts for banana chips. 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 [4]. 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 sample for the sensory evaluation was controlled to be within $\pm 1\%$ as suggested by Ratanatriwong *et al* [4].

The optimum coating amount for each seasoning was determined by a sensory acceptance test using the hedonic rating scale. Product acceptance was based on colour, odor, flavour, taste and overall acceptance attributes. There were 40 panelists participating in the sensory evaluation of each seasoning. Following this, 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. They then 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 evaluations were coated on banana chips at 0 and 25 kV by a belt conveyor electrostatic coater (Terronics Co., IN, USA) for non-electrostatic (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 $\pm 1\%$ [4], so each panelist received a sample with an equal amount of coating per piece. In this manner, 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 electrostatically and non-electrostatically coated banana chips for product acceptance using 9-point hedonic and just-about-right (JAR) scales based on coating evenness, flavour intensity, crispness and overall acceptance.

Comparison of process efficiency by different coating methods

The process efficiency of electrostatic and non-electrostatic 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 15g each by non-electrostatic (0 kV) and electrostatic (25 kV) methods. 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 Equation 1. The transfer efficiency improvement was the difference between transfer efficiency of electrostatic and non-electrostatic coatings.

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

The dust generated during seasoning coating was also collected from the air in a cassette/PVC filter (SKC, Inc. Eighty Four, PA, USA) for 3 min. Air was pumped at a rate of 5l/min by a model HFS 513A Gilian air pump (Wayne, NJ, USA). 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 colour reading (L^* , a^* , b^*) of samples taken by a Minolta colorimeter model CR-300 (Minolta Co., LTD, Ramsey, NJ, USA). Hue angle expressed in degrees was calculated using Equation 2.

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

Colour was measured in 4 quadrant positions per chip of 3 banana chips. The standard deviation from each chip was used to determine whether electrostatically and non-electrostatically coated samples were significantly different in terms of coating evenness. Samples with smaller standard deviation were considered as more evenly coated.

Statistical Analysis

The sensory results from the hedonic scale were 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 were used to analyze whether electrostatic coating could improve the product acceptances from the sensory test using 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, USA).

Results and Discussion

There were 122 consumers participating in the survey; 61% female and 39 % male. The average ages of consumers were divided into 4 categories from 15 to >45 years. The consumer salaries per month were divided into 7 categories from <4,000 to >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 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 ($p \leq 0.05$). Nori-seaweed, hot chili, wasabi and roasted chili paste were less preferred by consumers. According to the coating levels, the preferred coating amount of each seasoning was selected from the acceptances of panelists based on colour, odor, taste, flavour and overall acceptance. The optimum coating amount of salt, paprika, barbeque and sour cream and onion were 2, 8, 6 and 8%, respectively ($p \leq 0.05$). The

results from the acceptance and ranking test of seasoned banana chips are 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. Acceptance of banana chips coated with various seasonings.

Seasoning	Colour	Odor	Taste	Flavour	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 ($p \leq 0.05$).

The results showed that some attributes may be the important factors driving the overall acceptance of consumers toward banana chips for each seasoning (Table 2). For barbeque, colour, odor, taste and flavour showed their effects on overall acceptances with the correlation of 79%. However, colour did not drive the overall acceptance of salt and sour cream and onion banana chips, whereas taste was not a major factor for paprika and sour cream and onion banana chips. Only odor, taste and flavour indicated their effects on overall acceptance of salted banana chips with the correlation of 81%. For paprika, colour, odor and flavour showed the effect on banana chip acceptances with the correlation of 80%. However, only flavour 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 received an average score of 5 in every attribute, 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 the two different methods in the acceptance test using hedonic test for overall acceptance and the JAR scale for coating evenness, flavour intensity and crispness.

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

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

* Significantly different ($p \leq 0.05$).

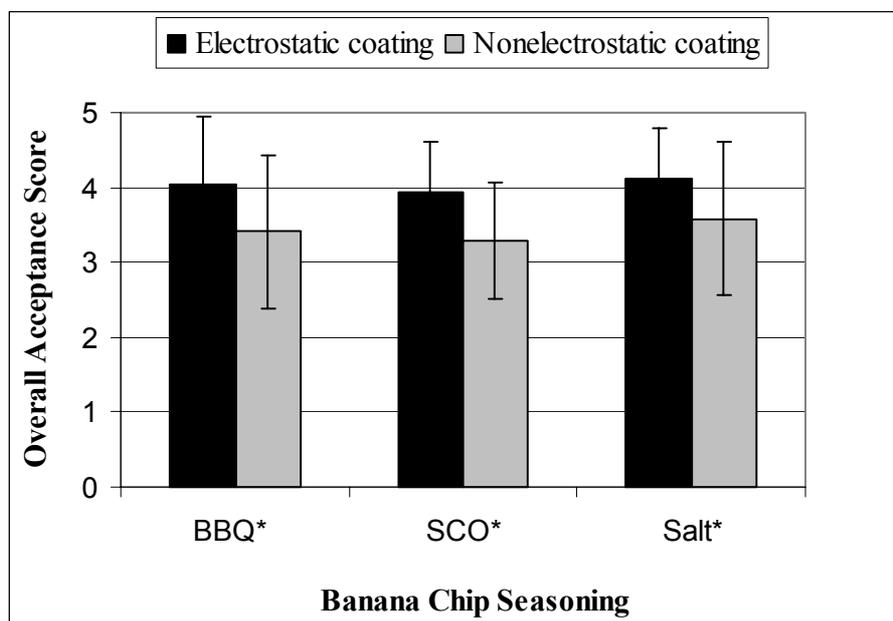


Figure 1. E coated banana chips were significantly preferred over NE banana chips in all seasonings. * Significantly different ($p \leq 0.05$).

For all seasonings, E coated banana chips were significantly preferred (Fig. 1) and were more evenly coated than NE coated samples ($p \leq 0.05$) (Fig. 2). All electrostatically coated samples were located in the coating evenness preference map closer to ideal (just-right) than those of non-electrostatic ones (Fig. 3). This result agreed with the information reported on electrostatically coated potato chips [4].

The instrumental result of coating evenness also correlated well with sensory data. The b-value standard deviation 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 [5] found that an electrostatic salting machine produced salted crackers that had a lower average standard deviation of salt than those coated with the conventional method. Ratanatriwong, *et al* [4] reported the advantage of more-even coating on potato chips by electrostatic coating as well.

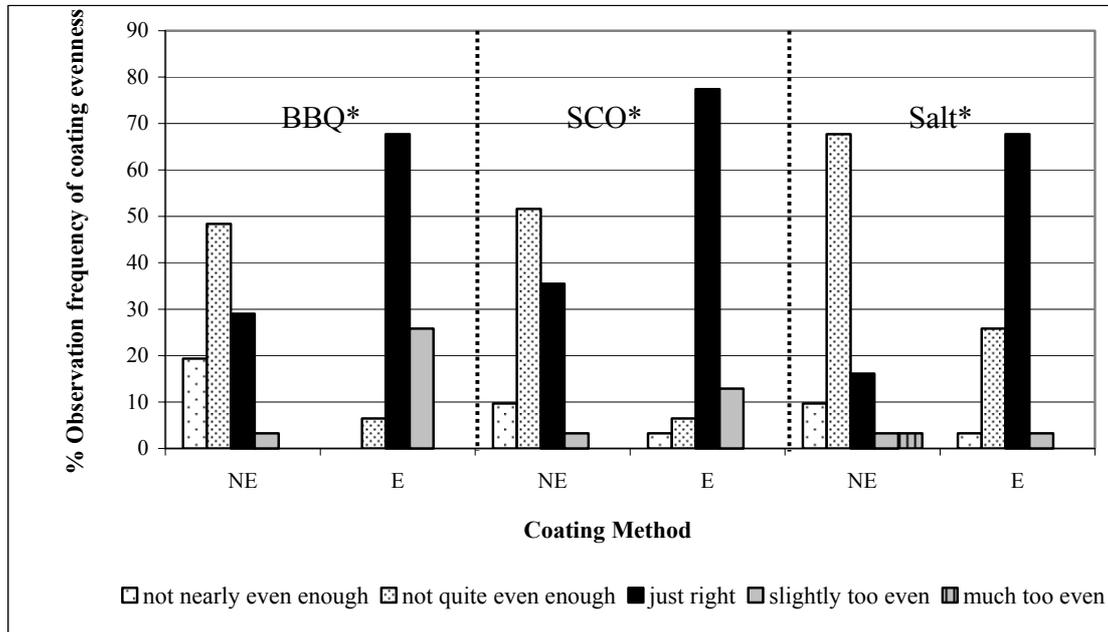


Figure 2. Electrostatically coated banana chips were rated as more even than non-electrostatically coated samples for all seasonings based on JAR scale. * Significantly different ($p \leq 0.05$).

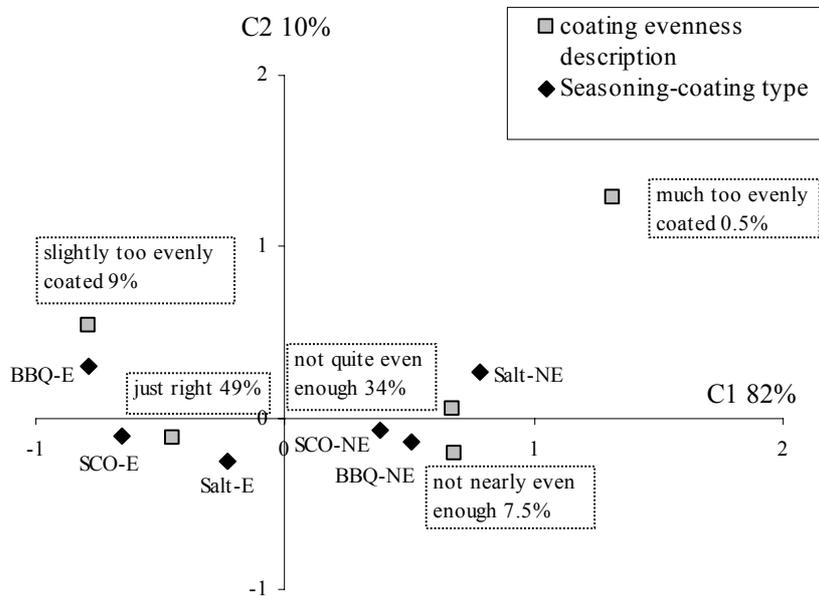


Figure 3. The coating evenness of electrostatically coated banana chips for all seasonings were close to ideal (just-right) while non-electrostatically coated samples were not uniform enough.

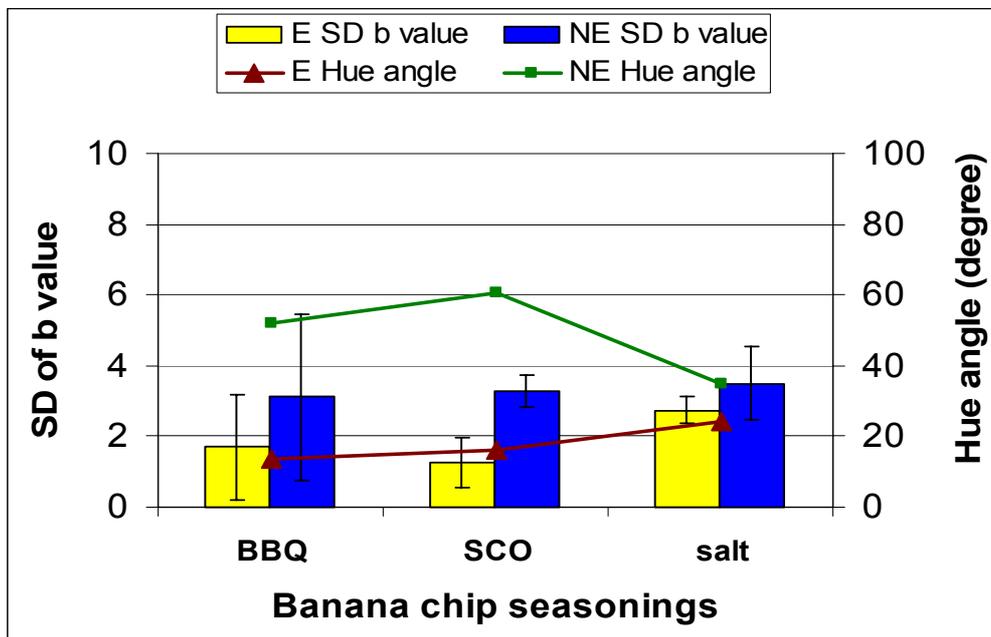


Figure 4. E coated banana chips were coated more evenly than NE coated samples because of lower standard deviation of colour parameter values ($p \leq 0.05$).

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

The effect of electrostatic coating on flavour intensity found in this study agreed with the assumption previously reported that electrostatic processing may enhance flavour intensity. Due to the fact that more even coating covers a larger surface area, it may result in more flavour distribution [9, 10]. In contrast, this phenomenon was not found in electrostatically coated potato chips [4]. Only coating uniformity seems to be the most important effect that drives consumer preference since no significant difference in flavour intensity was found between electrostatically and non-electrostatically coated samples in that study. However, since electrostatically coated banana chips were more evenly coated than non-electrostatic samples as discussed earlier, the surface area of seasoning should be larger which would result in greater flavour distribution when panelists assessed the samples.

There was, however, no significant difference between coating methods based on crispness. This attribute was suggested just to verify the panelist accuracy [4]. Given the results shown above, it indicates that the panelists did not guess their answers because different coating types should not affect the crispness.

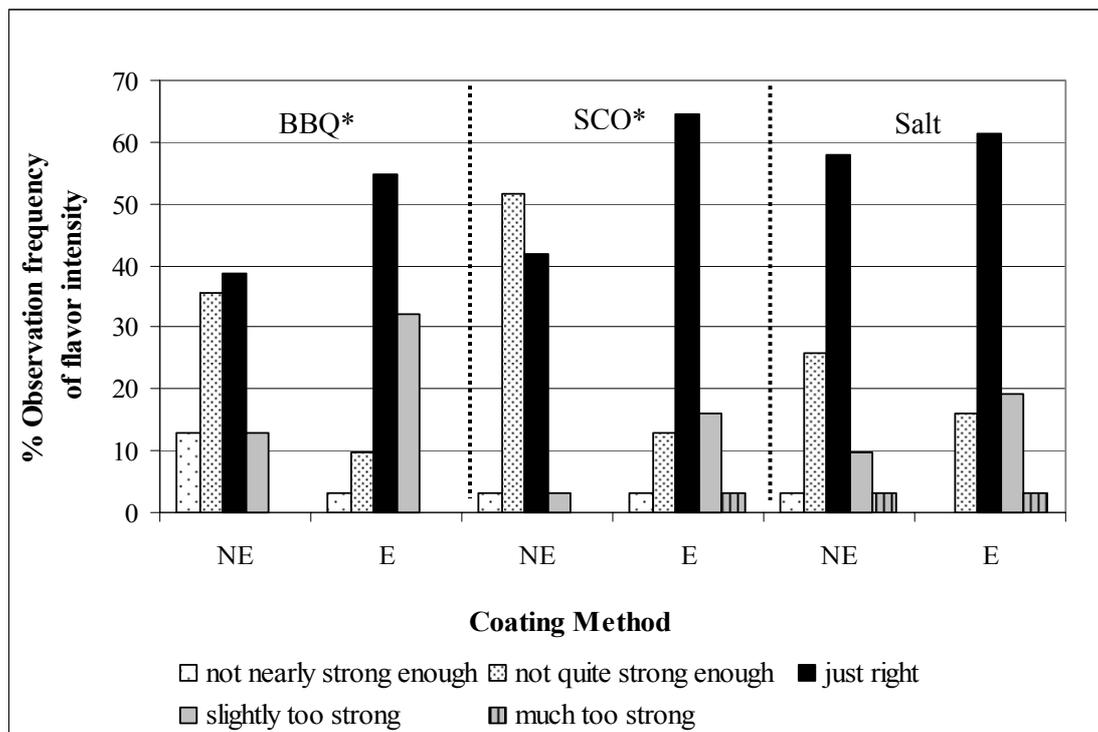


Figure 5. E coated banana chips were rated as higher flavour intensity than NE coated samples in all seasonings except salt based on JAR scale. * Significantly different ($p \leq 0.05$).

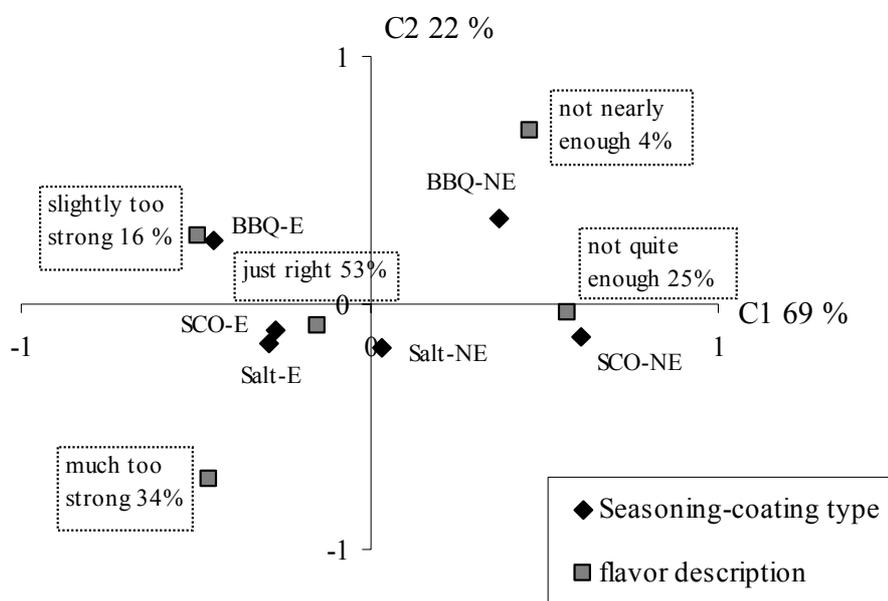


Figure 6. The flavour intensity of electrostatically coated banana chips were close to ideal (just-right) or slightly too strong, while that of non-electrostatically coated samples were not strong enough, except salt.

Table 3. Comparison of coating efficiency between non-electrostatic (NE) and electrostatic (E) coating by the transfer efficiency and the electrostatic coating improvement.

Seasoning	Transfer efficiency (%)		E Coating improvement* at 25 kV (%)
	Non-electrostatic	Electrostatic	
Barbeque	56	78*	41
Sour cream & onion	37	58*	58
Salt (NaCl)	40	74*	84

* Significantly different (p≤0.05).

Table 4. Comparison of the coating efficiency between non-electrostatic (NE) and electrostatic (E) coating by dustiness and the electrostatic coating improvement on dust reduction.

Seasoning	Dustiness (mg/l)		E Dust Reduction*
	Non-electrostatic	Electrostatic	at 25 kV (%)
Barbeque	0.00079	0.00033*	50
Sour cream & onion	0.00085	0.00029*	46
Salt (NaCl)	0.0022	0.00031*	37

* Significantly different ($p \leq 0.05$).

According to the preliminary study of electrostatic coating application on fried banana chips, the comparison of the coating efficiency between non-electrostatic (NE) and electrostatic (E) coating by the transfer efficiency, dustiness and electrostatic coating improvement and dust reduction were determined. 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 with average dust reduction of 44% (Tables 3&4). Electrostatic coating is credited with its benefit on improving coating quality of product [6], and process coating efficiency, including transfer efficiency (coating amount) and dust reduction [7, 8, 11].

In electrostatic coating, when powder particles fall through an intense electromagnetic field, they are charged. These charged particles form clouds due to the similar-charge repulsion and coat on the nearest ground target (food surface). This results in more coating amount and less dust because powders seek the target object rather than staying suspended [1, 3]. The charges on the powder induce opposite charges in the food target, producing strong adhesion for as long as the charges last [1]. Adhesion force between the charged particle and the object overcomes powder-coating loss as waste [12]. Therefore, electrostatic coating as compared to traditional coating gives higher transfer efficiency, less seasoning usage, less waste, less clean up time and less dust [1, 3]. Biehl and Barringer [7] reported a 15% improvement of coating efficiency by electrostatic coating. Similarly, this study found that electrostatic coating significantly improved transfer efficiency and dust reduction over NE coating with the average from all seasonings of 61 and 54%, respectively (Fig. 7-8).

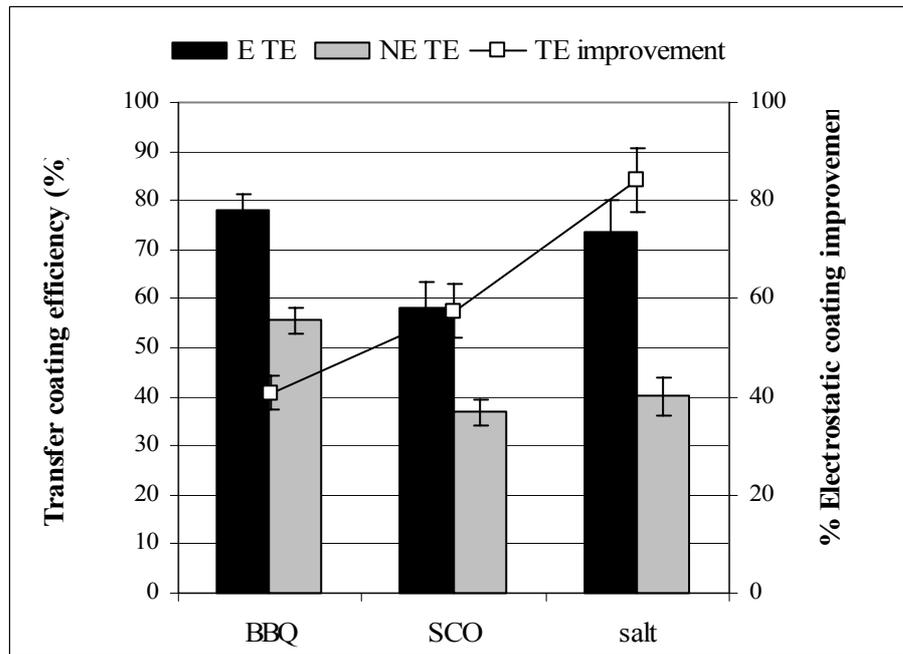


Figure 7. Electrostatic process achieved significantly greater transfer coating efficiency on banana chips where salt had the highest Electrostatic transfer efficiency improvement. * Significantly different ($p \leq 0.05$).

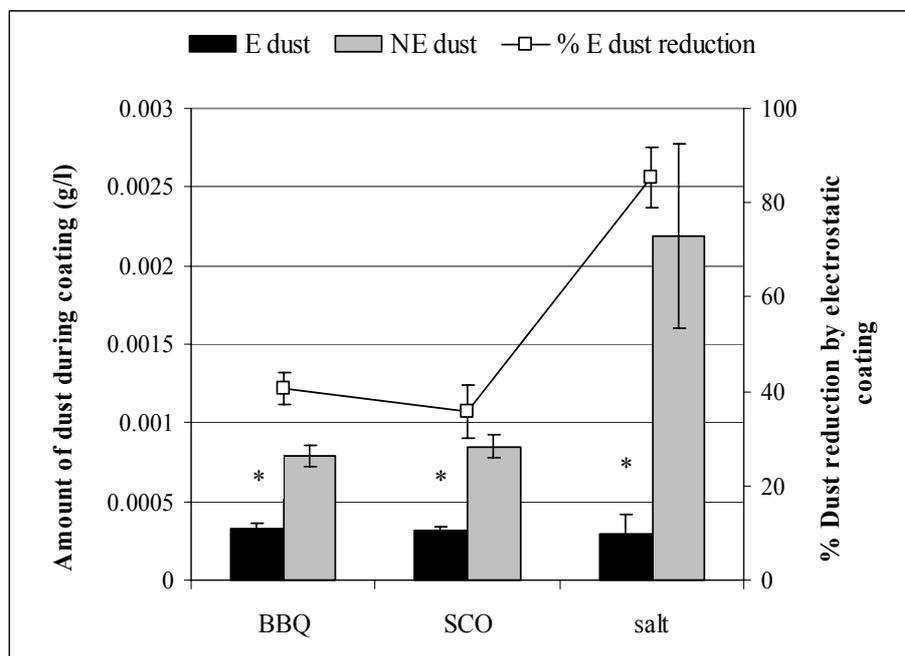


Figure 8. Electrostatic process resulted in significantly lower amount of dust during coating where salt showed the highest improvement by electrostatic coating on dust reduction. * Significantly different ($p \leq 0.05$).

Conclusion

Banana-chip seasonings considered desirable by consumers and their optimum coating amounts were determined. E-coated banana chips were preferred based on coating evenness, flavour intensity and overall acceptance. E coating achieved greater coating process efficiency (%TE and dust) and product quality (coating evenness). Thus, E coating is a promising process for seasoned banana chips with better product quality, less cost and less waste.

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