

SENSORY ACCEPTABILITY OF A DEEP-FRIED CARROT CHIP PRODUCT AS EVALUATED BY AMERICAN AND SOUTHEAST ASIAN CONSUMER PANELS

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ABSTRACT

Following development of deep-fried carrot chips, a high provitamin A carotenoid-snack, consumer acceptances for color, uniformity, overall appearance, odor, saltiness, sweetness, overall flavor, crispiness, oiliness, overall texture, and overall acceptability of the product were evaluated. Eighty-nine consumer panelists consisting of Americans from the Plains states of the United States (n = 45) and Southeast Asians (n = 44), males and females, 19-45 years, participated in this study. Color, uniformity, and odor were rated as good. Saltiness and sweetness were rated as nearly about right. Crispiness was rated as good, and oiliness as slightly oily. Generally, the product was acceptable to both types of consumer panelists, American and Southeast Asian, as shown by their ratings on overall appearance, overall flavor, overall texture, and overall acceptability. The differences in acceptance among country, gender, and country × gender groups were statistically not significant (P ≥ 0.05).

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INTRODUCTION

Vitamin A deficiency is a problem of public health significance in over 70 countries (Chakravarty 2000), including Southeast Asia (Combs *et al.* 1998). In 1995, it was estimated that 3 million children worldwide annually exhibited xerophthalmia, that is, they were clinically vitamin A-deficient and at risk of blindness. An additional 250 million children under 5 years of age were estimated to be subclinically vitamin A-deficient and at risk of severe morbidity and premature death (Howson *et al.* 1998). Depending on the criteria used, the number of people with vitamin A deficiency in the world could be of the order of 500 million (West 1998). With regard to North Americans, the Institute of Medicine (2001) stated that "current dietary patterns appear to provide sufficient vitamin A to prevent deficiency symptoms such as night blindness". However, some North American adults do consume less than recommended quantities of vitamin A (Institute of Medicine 2002). Americans are at risk of many degenerative and chronic diseases like cardiovascular/coronary heart disease (Mark 1997), cancer, and hypertension (Centers for Disease Control and Prevention 2001), and evidence exists that consumption of several of the carotenoids, especially β -carotene, is associated with lower risk of these diseases (Törrönen *et al.* 1996; Van Poppel 1996; Kritchevsky 1999).

Deep-fried carrot chips that are high in provitamin A carotenoids have been developed as an alternative for intervention programs in alleviating vitamin A deficiency as well as a healthful snack (Sulaeman *et al.* 2001a). Sensory evaluations utilizing trained panelists indicated that this product was acceptable (Sulaeman *et al.* 2001a, b), and perhaps marketable. Shelf-life studies also showed a high retention of carotenoids during storage (Sulaeman *et al.* unpublished observations). An animal study indicated that the carotenoids contained in these chips were biologically available and were able to reverse vitamin A deficiency in Mongolian gerbils (Sulaeman *et al.* 2002).

Snack chips can serve as vehicles for important nutrients, while being readily accepted by the population (Almieda-Domingues *et al.* 1990). Snack chips are becoming widely consumed by most of the people around the world including Southeast Asian countries. According to a Snack Food Association News Release (Snack Food Association 2000), total pounds of savory snacks (potato chips, tortilla chips, pretzels, popcorn, cheese snacks, and meat snacks) sold in 1999 grew by 4.4% to reach 6.17 billion pounds. Sales of potato chips, likely America's favorite savory snack, experienced steady growth in 1999 to reach \$4.69 billion, or 2.2% more than in 1998. Sales of America's second favorite savory snack, tortilla chips, increased to \$3.75 billion, or 5.5% growth in 1999 (Snack Food Association 2000). Frito-Lay, the largest snack chip company in the world, had a snack chip sales of \$5.9 billion outside North America in 1999 (Pepsico 2001). The introduction of snack chips high in

micronutrient (vitamins and minerals) content may help consumers meet their needs for a specific or several of the vitamins and minerals.

Deep-fried carrot chips contain the important nutrients α -, β -, cis-9- β -carotene, and lutein (Sulaeman *et al.* 2001a). α -, β -, and cis-9- β -carotene are provitamin A compounds, which can be converted into vitamin A in the human body (Institute of Medicine 2000), while lutein functions as an antioxidant like the other carotenes. Carrot chips developed in our laboratory and prepared by the most optimal treatment had vitamin activities of 3661-4266 μ g RAE (retinol activity equivalent) per 100 g (Sulaeman *et al.* 2001b). Due to its antioxidant activity, foods rich in provitamin A carotenoids and other carotenoids may also be beneficial in prevention of major health problems (Kohlmeier and Hasting 1995; Törrönen *et al.* 1996; Kritchevsky 1999). The introduction of carrot chips to Southeast Asians as well as to Americans, therefore, would be a food-based vehicle for increasing the consumption of carotenoids.

Prior to marketing this new product, its acceptability must be determined. The objectives of this study were to evaluate the consumer acceptance of the deep-fried carrot chip product, and to assess the differences in acceptance of the carrot chip product between American and Southeast Asian consumer panelists and between males and females.

MATERIALS AND METHODS

Deep-fried Carrot Chip Preparation and Packaging

Deep-fried carrot chips were prepared according to the most optimal method developed by Sulaeman *et al.* (2001b) from fresh jumbo carrots (*Daucus carota* cv. Navaio) (Grimmway Farms, Bakersfield, CA) using partially hydrogenated soybean oil (PHSO) (Bunge Food, Bradley, IL) as the frying oil. Briefly, carrots were trimmed and cut into 55 mm lengths and mechanically peeled using the Hobart Peeler Machine (Hobart Manufacturing Co., Troy, OH) at the lowest speed for 1 min and sliced into 1.5 mm thickness using the Dito Dean Slicer Model TR-22 (Dean Food Preparation, Los Angeles, CA). The carrot slices were steam-blanching for 4 min, cooled under running tap water for 4 min, soaked in sodium metabisulfite 0.2% (w/v) solution for 15 min, drained, and deep-fried in PHSO using a Toastmaster Fryer Model 1427 (Elgin, IL) at 165C for 5 min or until there were no visible bubbles due to residual water. The fried carrot chips were drained on paper towels, and shaken with 1.0% (w/w) salt. The carrot chip product was packaged (15 g per bag) in layered film (2.5 mil, metallized polyester and linear low density polyethylene) pouches (16.5 cm \times 20.3 cm O.D.) (Kapak Co., Minneapolis, MN) using a Multivac AG 500/AG 900 (Multivac Inc., Kansas City, MO). The moisture and oxygen permeabilities

of this pouch were 0.837 g/m²/24 h (at 37.8C, 100% RH) and 1.2 cc/m²/24 h (at 22.8C, 0% RH and 100% O₂), respectively, according to the manufacturer. The pouches were partially vacuumed and flushed with nitrogen gas until the O₂ concentration in the pouches was < 1% (Emenheiser *et al.* 1999), and stored at -50C until ready for sensory analyses.

Evaluation of Consumer Acceptance

Prior to the evaluation, the study was approved by the university's Institutional Review Board for research involving human subjects. Both sets of the consumer panelists were volunteers from our university's students, faculty, staff, and their families. The panelists consisted of Americans from the Plains states of the United States (n = 45) and Southeast Asians (n = 44), males and females, aged between 19-45 years. The Southeast Asian panelists were originally from Indonesia, Malaysia, Thailand, and Singapore, and had lived in the United States less than three years. Since the population of these countries may represent the population of all Southeast Asian countries (more than 70%) (Population Reference Bureau 2001), they were all grouped into one group. In our opinion, similarities in culture, especially in language and in the types of foods they usually consumed, exist in these Southeast Asian countries. Prior to sensory evaluation, the panelists were asked to provide demographic information including age, gender, race, cigarette smoking, any allergy to certain foods, special diet, illness, and information about their general preferences for chip products.

The packaged carrot chips were removed from the freezer 18 h prior to evaluation and the product was at room temperature when the tests were performed. Panelists were asked to evaluate two packaged samples (from the same product) with different code numbers to decrease consumer panelists' biases. The samples were given one at a time, and water was provided to cleanse panelists' palates before evaluating the second sample. Evaluations were performed in a conference room or at panelists' homes (Lawless and Heymann 1999). The panelists were asked to test individually, so they did not influence each other.

The panelists were asked to evaluate the sample's appearance (color, uniformity, overall liking in appearance), texture (crispiness, oiliness, overall liking in texture), flavor (odor, saltiness, sweetness, overall liking in flavor), and overall acceptance using a questionnaire modified from that of Lawless and Heymann (1999). Overall liking in appearance, texture, flavor, and overall acceptability was rated using a 9-point hedonic scale (1 = dislike extremely, 5 = neither like nor dislike, 9 = like extremely). Other factors were evaluated using 9-point rating scales: color and uniformity (1 = very poor, 9 = very good), crispiness (1 = very tough, 9 = very crispy), oiliness (1 = not at all,

9 = very oily), odor (1 = very poor, 9 = very good), saltiness (1 = not salty at all, 5 = just about right, 9 = too salty), and sweetness (1 = not sweet at all, 9 = very sweet). Color, uniformity, crispiness, oiliness, and odor scores >6 were interpreted as being good. Using an open-ended question format, panelists were also requested to give their opinions on what they liked most about the product.

Statistical Analyses

Data were analyzed using the General Linear Model (GLM) procedure of SAS version 6 (SAS Institute, Cary, NC). Duncan's multiple range tests were performed for multiple comparisons to test if there were any differences between American and Southeast Asian consumer panelists and between male and female consumer panelists. Differences were considered significant at $P < 0.05$. Correlation coefficients between selected sensory attributes were also determined.

RESULTS

Profile of Consumer Panelists

The characteristics of the consumer panelists are described in Table 1. Approximately 91% of the consumer panelists indicated that they liked any kind of chips, particularly potato chips. Most consumer panelists indicated that they liked chip products moderately (44.9%) or liked them very much (28.1%).

Appearance

Consumer panelists' ratings for color (mean = 6.5) and uniformity (mean = 6.6) attributes as well as for overall liking of the appearance (mean = 6.2) of carrot chips indicated that the appearance of carrot chips was acceptable (Table 2). No significant differences ($P \geq 0.05$) were found in color, uniformity, or by overall liking of the appearance of the product by country, gender, and country \times gender, and the product was rated as good. Based on the percentage of consumer panelists who rated the overall appearance above 6 (like slightly), the majority (70.0%) of these consumer panelists liked the carrot chip appearance (Fig. 1). Significant correlations ($P < 0.05$) were noted between consumer panelists' liking of the appearance and their ratings on color ($r = 0.79$) and uniformity ($r = 0.43$) of the carrot chips. The better the color and the more uniform the carrot chips, the better the consumer liking on the overall appearance.

TABLE 1.
PROFILE OF CONSUMER PANELISTS AND THEIR LIKING OF CHIP PRODUCTS

Variable	Category	N	Percentage
Ethnic/Country origin	American	45	50.6
	Southeast Asian	44	49.4
Gender	Male	44	49.4
	Female	45	50.6
Age	19-24 y	71	79.8
	25-34 y	8	9.0
	35-45 y	10	11.2
Cigarette smoking	No	76	85.4
	Yes	13	14.6
Food allergy	No	79	88.8
	Yes	10	11.2
Special diet	No	86	96.6
	Yes	3	3.4
Liking of chip products in general	No	8	9.0
	Yes	81	91.0
Kind of chip product liked	Potato chips	66	81.5
	Tortilla chips	57	70.4
	Corn chips	44	54.3
	Other chips	13	16.0
Degree of liking chip products in general	4 = Dislike slightly	2	2.3
	5 = Neither like nor dislike	11	12.4
	6 = Like slightly	5	5.6
	7 = Like moderately	40	44.9
	8 = Like very much	25	28.1
	9 = Like extremely	6	6.7

Texture

Both ethnic groups of consumer panelists indicated that they 'liked slightly' the overall texture (mean = 6.1) of the product (Table 3). Both ethnic groups of consumer panelists rated crispiness as good. The mean oiliness score for all subjects was 4.4 (1 = not oily at all, 9 = very oily); this was interpreted as being slightly oily. The differences by country, gender, and country \times gender were not statistically significant ($P \geq 0.05$). A significant correlation was observed between consumer panelist acceptance ratings on overall texture and crispness ($r = 0.57$, $P < 0.05$). In general, the texture of carrot chips was

TABLE 2.
MEAN RATINGS AND STANDARD DEVIATIONS FOR APPEARANCE OF DEEP-FRIED CARROT CHIPS AND PROBABILITIES OF F VALUES FOR COUNTRY, GENDER, AND COUNTRY × GENDER

Country	Gender	n	Appearance					
			Color ^a		Uniformity ^a		Overall liking ^b	
			Mean	S.D.	Mean	S.D.	Mean	S.D.
American		45	6.6	1.1	6.5	1.1	6.2	1.3
	Male	22	6.6	1.2	6.6	1.5	6.3	1.3
	Female	23	6.6	1.1	6.4	1.1	6.2	1.3
Southeast Asian		44	6.4	1.6	6.7	1.3	6.1	1.4
	Male	22	6.3	1.6	6.8	1.1	6.0	1.3
	Female	22	6.6	1.7	6.7	1.5	6.2	1.6
American + Southeast Asian		89	6.5	1.4	6.6	1.2	6.2	1.4

Source of variation	Probabilities of F Values		
	Color	Uniformity	Overall liking of appearance
Country	0.666	0.502	0.666
Gender	0.485	0.541	0.917
Country x Gender	0.576	0.744	0.492

^a1=very poor, 9=very good; ^b1=dislike extremely, 9=like extremely.

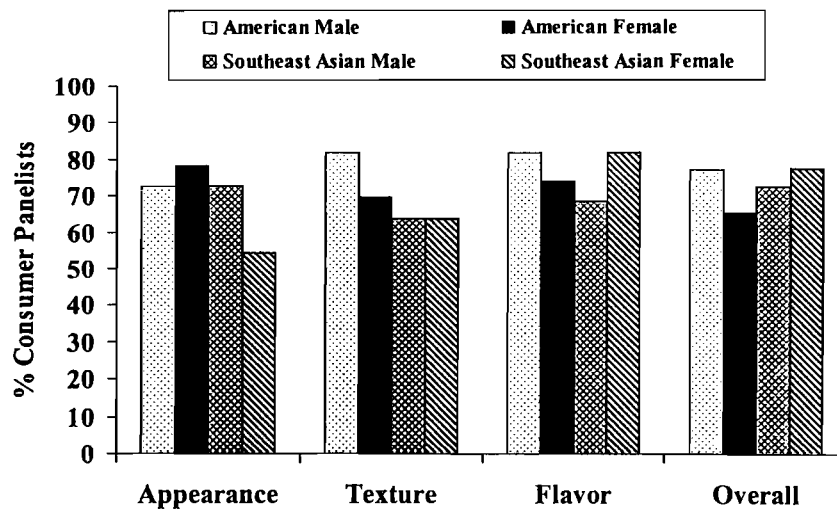


FIG. 1. PERCENTAGE OF AMERICAN AND SOUTHEAST ASIAN CONSUMER PANELISTS GIVING GOOD ACCEPTANCE RATINGS^a OF THE DEEP-FRIED CARROT CHIP PRODUCT

^aGood acceptability scores were deemed to be those that were 6 and above.

TABLE 3.
MEAN RATINGS AND STANDARD DEVIATIONS FOR TEXTURE OF DEEP-FRIED
CARROT CHIPS AND PROBABILITIES OF F VALUES FOR COUNTRY, GENDER,
AND COUNTRY \times GENDER

Country	Gender	N	Texture					
			Crispiness ^a		Oiliness ^b		Overall liking ^c	
			Mean	S.D.	Mean	S.D.	Mean	S.D.
American		45	6.2	1.3	4.6	1.2	6.1	1.2
	Male	22	6.3	1.4	4.9	1.7	6.2	1.2
	Female	23	6.2	1.3	4.4	1.5	5.9	1.2
Southeast Asian		44	6.1	1.1	4.1	1.7	6.0	1.2
	Male	22	6.2	1.0	4.4	2.9	6.0	1.1
	Female	22	6.0	1.2	3.9	1.5	6.0	1.3
American + Southeast Asian		89	6.2	1.2	4.4	1.5	6.1	1.2

Source of variation	Probabilities of F Values		
	Crispiness	Oiliness	Overall liking of texture
Country	0.619	0.140	0.758
Gender	0.583	0.171	0.629
Country \times Gender	0.937	0.916	0.519

^a1=very tough, 9=very crispy; ^b1=not at all, 9=very oily; ^c1=dislike extremely, 9=like extremely.

acceptable for almost all of the consumer panelists (93.3%), and about 70% of the consumer panelists rated this chip product as ≥ 6 (Fig. 1).

Flavor

The odor was rated good, while the saltiness and sweetness were rated nearly about right (Table 4). Consumer panelists indicated that they liked slightly the overall flavor (mean = 6.1) of the product. No significant differences ($P \geq 0.05$) were observed in odor, saltiness, sweetness, and overall liking of flavor by country, gender, and country \times gender. Positive correlations ($P < 0.05$) were observed between the consumer panelist acceptance ratings on overall flavor and the ratings of odor ($r = 0.43$), saltiness ($r = 0.24$), and sweetness ($r = 0.36$). In general, the flavor of carrot chips was acceptable to the majority of consumer panelists (89.9%), and about 76.4% of the consumer panelists rated this product as good (score ≥ 6) (Fig. 1).

TABLE 4.
MEAN RATINGS AND STANDARD DEVIATIONS FOR FLAVOR OF DEEP-FRIED
CARROT CHIPS AND PROBABILITIES OF F VALUES FOR COUNTRY, GENDER,
AND COUNTRY × GENDER

Country	Gender	n	Flavor						Overall liking ^d	
			Odor ^a		Saltiness ^b		Sweetness ^c		Mean	S.D.
			Mean	S.D.	Mean	S.D.	Mean	S.D.		
American		45	5.7	1.3	4.3	1.1	4.8	1.5	6.2	1.2
	Male	22	5.9	1.3	4.3	1.3	5.1	1.4	6.4	1.1
	Female	23	5.5	1.3	4.4	1.1	4.6	1.5	6.0	1.2
Southeast Asian		44	6.0	1.7	4.3	1.3	4.6	1.2	6.0	1.4
	Male	22	5.8	1.6	4.1	1.4	4.8	1.2	5.7	1.2
	Female	22	6.3	1.8	4.5	1.3	4.5	1.3	6.3	1.6
American + Southeast Asian		89	5.9	1.5	4.3	1.2	4.7	1.4	6.1	1.3

Source of variation	Odor	Probabilities of F Values		
		Saltiness	Sweetness	Overall liking of flavor
Country	0.320	0.965	0.4475	0.464
Gender	0.830	0.476	0.1624	0.677
Country x Gender	0.200	0.662	0.779	0.082

^a1=very poor, 9=very good; ^b1=not salty at all, 5=just about right, 9=too salty; ^c1=not sweet at all, 9=very sweet; ^d1=dislike extremely, 9=like extremely.

Overall Acceptance

The consumer panelists rated the carrot chip product as like slightly to like moderately (mean = 6.2) with regard to overall acceptability (Table 5). No significant differences ($P \geq 0.05$) were noted between country, gender and country × gender on the consumer panelist rating of overall acceptance of the deep-fried carrot chip product. About 91.0% of consumer panelists indicated that the carrot chip product was acceptable, and about 73% of consumer panelists rated this carrot chip product with a score ≥ 6 or good (Fig. 1).

Consumer Panel Comments

Table 6 summarizes the comments made by the Southeast Asian and American consumer panelists about the product to the open-ended question "what do you like most about the product". The comments made by both

country groups were generally similar. The comment given most often (by 60.5% of consumer panelists) was that the carrot chips had a good but different taste and flavor; the product was sweet and salty with a typical carrot odor. Forty-four percent of the consumer panelists indicated that they liked the crunchy, crispy texture of the product, and 34.6% indicated liking the color and appearance of the product. Some (27.2%) of our consumer panelists commented on the uniqueness of the product. The product was viewed as "nutritious" and as a "healthy snack" by 21.0% of consumer panelists.

TABLE 5.
MEAN RATINGS AND STANDARD DEVIATIONS FOR OVERALL ACCEPTANCE OF
DEEP-FRIED CARROT CHIP PRODUCT AND PROBABILITIES OF F VALUES FOR
COUNTRY, GENDER, AND COUNTRY \times GENDER

Country	Gender	N	Overall Acceptance ^a	
			Mean	S.D.
American		45	6.1	1.4
	Male	22	6.3	1.3
	Female	23	6.0	1.4
Southeast Asian		44	6.2	1.3
	Male	22	6.0	1.0
	Female	22	6.4	1.5
American + Southeast Asian		89	6.2	1.4

Source of variation	Probabilities of F Values
Country	0.8574
Gender	0.9809
Country \times Gender	0.1890

^a1=dislike extremely, 9=like extremely.

TABLE 6.
WHAT CONSUMERS PANELISTS LIKED ABOUT THE DEEP-FRIED
CARROT CHIP PRODUCT

Category	Percentage of panelists making comment			Quoted consumer comments
	American	Southeast Asian	Total	
Taste/Flavor	56.1	65.0	60.5	Tastes good, interesting flavor, different and unique taste, nice sweet and salty taste, good carrot taste
Texture/Crispiness	56.1	32.5	44.4	Excellent texture, crunchy, crispy
Color/Appearance	34.0	35.0	34.6	Great color, nice color, appealing, nice bright color
Uniqueness	31.7	22.5	27.2	Unique, great idea, original, cute, different
Nutrition/Health	19.5	22.5	21.0	Seems more nutritious, healthy snack, healthy choice

DISCUSSION

Based on the profile of consumer panelists (Table 1), both American and Southeast Asian panelists indicated generally liking any kind of chip product. The degree of liking chip products was also high; more than 80% liked slightly to liked extremely. This indicated that all the consumer panelists, including Southeast Asians, were familiar with chip products. This is reasonable because potato chips are available and popular worldwide. According to the report of Pepsico (2001), Frito-Lay International has operations in 45 countries (including Indonesia and Thailand) and makes chip products available in 120 countries. In addition, we believe that the people in Southeast Asian countries are also familiar with their traditional chips like those from banana, cassava, sweet potato, rice, and taro. Therefore, a new type of chip like carrot chips likely would also be acceptable to this community.

Deep-fried carrot chip products that are high in provitamin A carotenoids and antioxidants cannot provide these important nutrients unless the product is liked and accepted by consumers (Szczesniak 1987). Sensory attributes, i.e., color, aroma, flavor, and texture, and the consumer responses they evoke play a role in whether consumers will purchase and consume a product (Szczesniak 1987).

The majority of our consumer panelists, regardless of country or gender, indicated liking (evaluation score of ≥ 6) the overall appearance, overall texture, overall flavor, and overall acceptance of the carrot chip product (Fig. 1). The comments our panelists made to the open-ended question about what they most liked about the product also indicated that they liked the product's color and appearance, crispiness, taste and flavor, uniqueness, and its possible nutrition or health contributions. MacDougall (1987) reported that consumer acceptance of foods and manufactured food products is influenced predominantly by the intrinsic appeal of their appearance. Studies have shown that the color of a product influences the perception of other sensory attributes, such as aroma, taste, and flavor (Lawless and Heymann 1999). Our consumer panelists' evaluations of the carrot chip product may be taken as indicating that the product can be marketed and sold to consumers.

Published literature related to sensory differences by gender groupings are limited, as is that related to differences by the region of the world from which individuals originate are lacking. Suknark *et al.* (1998) found that there were no significant differences in ratings for all sensory attributes and overall acceptance of peanut snack products by Asian and American consumer panelists. The results of the present consumer study indicate that there were no significant differences in the sensory attributes, including overall acceptance, of the deep-fried carrot chip product between a group of consumer panelists from the plains areas of the United States and those from Southeast Asia. This carrot chip product may be used in both Southeast Asian and North American countries as a vehicle for increasing provitamin A carotenoid intakes as well as antioxidant intakes to possibly overcome nutrition and health problems in these countries.

Our observations are that carrots are available, relatively inexpensively, in Southeast Asian countries, and that individuals in these countries currently consume carrots as components of soups or stews. Proper processing of the carrots, especially methods involving cooking, improves the bioavailability and bioconversion of the provitamin A carotenoids (Rock *et al.* 1998). Some concerns exist regarding the fat content of the developed deep-fried carrot chips. The fat content in this product may increase the carotenoid bioavailability (Jalal *et al.* 1998). Many populations in the world do not consume diets high in fat, and the addition of some fat to their diets may be beneficial. Fat constitutes 16 to 17% of the caloric intake of individuals residing in Indonesia, and their recommended fat intake is at least 20% of calories (Muhilal *et al.* 1994).

CONCLUSIONS

This study shows that the deep-fried carrot chip product is organoleptically acceptable to both the American and Southeast Asian consumer panelists

included in this study, and likely is marketable. It is likely the Southeast Asian consumer panelists included in this study are representative of those residing in Southeast Asia; the same is also likely true with regard to the American consumer panelists. Using the factors for conversion of provitamin A carotenoids to vitamin A recently given by the Institute of Medicine (2001), this deep-fried carrot chip product had a mean vitamin A activity of 3964 μg retinol activity equivalents (RAE) per 100 g chips. Therefore, the consumption of 20 to 25 g of the product would provide enough provitamin A carotenoids to satisfy the human adult daily need for vitamin A. If the deep-fried carrot chip product is organoleptically acceptable to consumers in Southeast Asia and America, and likely it is, then the deep-fried carrot chips may be used as a vehicle for increasing the consumption of provitamin A carotenoids as well as antioxidants to overcome nutrition and health problems in both countries, and perhaps worldwide.

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