Original Article

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Exploring Alternative Sweeteners: Consumer Perspectives and Product Development for Healthier and Affordable Choices

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Abstract:

Objective: This study aimed to evaluate the consumption, consumer experiences, and expectations of alternative sweeteners (AS) among adults. It also developed and assessed a prototype alternative sweetener product (ASP) in terms of acceptability and willingness-to-pay compared to sugar.

Material and Methods: Two studies were conducted. In Study I, a cross-sectional survey assessed consumer experiences and expectations of AS. In Study II, a prototype ASP was developed using erythritol, stevia and sucralose via a geometric dilution method. The ASP was then compared to sugar in snacks and beverages through a single-blinded experiment.

Results: The survey revealed that 63.6% disliked the taste of AS, expecting a sugar-like taste and affordable price. The single-blinded experiment showed no significant differences in overall liking between the ASP and sugar. The cost of the ASP prototype was 88% cheaper than the average marketed AS available in physical markets.

Conclusion: These findings indicate consumer readiness to accept AS, although current market products do not fully meet consumer expectations. The ASP prototype, being more affordable and acceptable, has the potential to reduce barriers related to the affordability and acceptability of AS. The simplicity of the technique used to prepare the ASP prototype also facilitates the transfer of this technology to consumers for home use.

Keywords: alternative sweetener, consumer preference, non-nutritive sweetener, sugar substitute, willingness-to-pay

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Introduction

High sugar consumption is a major public health concern worldwide[1,2]. Research indicates that individuals who consume excessive amounts of sugar are more likely to gain weight and have a higher risk of obesity, type 2 diabetes, dyslipidemia, hypertension, and cardiovascular diseas[3]. The World Health Organization (WHO) recommends reducing sugar intake to no more than 25 grams per day[4]. However, in 2021, the average daily sugar consumption in Thailand was 100 grams per day; four times the WHO recommendation[5].

In this study, alternative sweetener (AS) refers to any single non-nutritive sweetener used as a sugar substitute, and alternative sweetener product (ASP) refers to a product composed of a blend of more than one AS. Currently, alternative sweeteners are increasingly popular among consumers[6,7]. These are found coffee, sugar-free sodas, sugar-free tea and coffee, and sugar-free jelly[6,8–10]. Despite the variety of these products within the Thai market, their usage prevalence is unknown. In addition, there may be some barriers using them. For example, while products completely replacing sugar with an alternative sweetener may be convenient to use, consumers do not gain control over the level of sweetness. Theoretically, products partially substituting sugar with alternative sweeteners can help reduce the amount of sugar and calories consumed. However, these products still contain some form of sugar, meaning that they still provide energy and affect blood sugar levels, which may not make them the best choice for those needing to control their blood sugar.

Based on our review, the results show there were limited studies on the health benefits; additionally the results shown were inconclusive[11–14]. However, a recent meta-analysis has shown that some alternative sweeteners have the potential to be used by people wanting to control their weight or blood sugar level[10], such as erythritol, stevia, and sucralose. Based on our extensive literature review, there is no evidence indicating whether Thai consumers reject or welcome these products. Additionally, certain alternative sweetener brands, whether they be a single alternative sweetener or blended that are intended to replace sugar in amounts preferred by consumers, still have limitations in their usage. For instance, some; such as aspartame, cannot be used in cooking, as they cannot withstand high heat. To enhance consumer accessibility and encourage product usage, it is vital to develop an alternative sweetener product that aligns with consumer preferences. Therefore, understanding consumers' experiences and expectations before initiating the development of a new product is a critical step.

However, recent meta-analyses suggest sweeteners like erythritol, stevia, and sucralose can aid in weight and blood sugar control[10]. There is no evidence on whether Thai consumers accept these products. Some sweeteners, like aspartame, have usage limitations, such as notwithstanding high heat[11–14]. To enhance accessibility and usage, it's crucial to develop a sweetener that meets consumer preferences. Understanding consumer experiences and expectations is essential before developing a new product.

Material and Methods

Two studies were conducted. Study I aimed to identify the experiences associated with AS consumption and expectations regarding AS. Study II aimed to identify consumers' acceptance, estimate the cost of snacks and beverages using our developed AS prototype, and gauge consumers' willingness to pay, and compare the cost of ASP prototype with the price of ASPs available in the market.

Ethics

Both study I and II were conducted in accordance with the Declaration of Helsinki and approved by the Center for Ethics in Human Research, Khon Kaen University HE

662171, HE HE642186. Written informed consent was obtained from all participants in the study.

Study I

Study design and participant

This study employed a survey design targeting adult consumers. A sample size of 180 was estimated using the formula $n= [(Z_{\alpha/2})^2P(1-P)]/e^2$, based on a 13.34% proportion of AS consumption from a previous study[15], with a 5% margin of error and a 0.05 alpha level. Inclusion criteria were participants whom visited the main university canteen; aged 18–65, Thai speakers, and voluntary participants. Exclusion criteria included participants whom declined, or had disabilities or severe illnesses that could cause harm by providing information.

Data collection

A self-developed, semi-structured questionnaire was used to collect data. The questionnaire was written in the Thai language and was divided into three parts. The questionair's validity was assessed by five experts whom met the following criteria: 1) hold a PhD, 2) have experience in conducting research and developing questionnaires, and 3) have experience in publishing peer review papers regarding diabetes prevention or health promotion. The first part concerned demographic information. The second part concerned experience from consumption of products containing AS. Question A was an open-ended question: "Have you ever consumed AS? Question B: If so, could you tell us about your experiences?", and the third was also an open-ended question; "If there is a product that provides sweetness, but does not have calories, how would you like it to be?," was used to identify participants' expectation of ASP. Prior to data collection, the research objective, participants' rights, and confidentiality were informed to the potential participants. After the potential participants agreed to participate, consent was sought. The questions in the questionnaire were read to the participant and the researcher filled in the answers according to the participants' responses.

Statistical analysis

Descriptive statistics were used to present participants' demographic information. Content analysis identified emerging themes from responses about experiences and expectations for ASP.

Study II

Study design for the assessment of consumer acceptance

A brief development of an alternative sweetener product prototype is mentioned in previous publications[16]. The selected ASP prototype was used in pancake recipes and hot coffee, replacing sugar at a 0.5:1 ratio to match sweetness. These were tested in controlled, single-blinded trials.

Participants for the consumer acceptance test were aged 18–65, visiting the main university canteen at Khon Kaen University between 8:30 am and 7:00 pm. A sample size of at least 80 subjects was determined using the formula for comparing means: n/group= , with a significance level (α) of 0.05 and a power of 90%. Based on previous study data, the mean overall liking scores for the product with the sweetener substitute (μ1) and sugar (μ2) were 37.8 and 53.4, respectively, with a standard deviation of 29.3[14]. This calculation required a minimum of 40 subjects per group, leading to a total of at least 80 subjects for the two-arm design. To achieve the desired response rate, we increased the number of subjects to 100.

Inclusion criteria were: 1) having visited the main university canteen during data collection, 2) being aged 18–65 years, 3) having voluntarily consented and provided a signed consent form, and 4) being proficient in Thai listening, speaking, reading, and writing. Exclusion

criteria were: 1) pregnant or breastfeeding individuals, 2) allergies or non-consumption of coffee, wheat flour, cow's milk, or eggs, 3) unwilling or uncomfortable providing information after recruitment, 4) disabilities or severe illnesses posing information-provision risks, 5) smokers, 6) taking medications affecting taste perception (e.g., high blood pressure medications, cancer treatments, vitamins), 7) neurological disorders altering taste perception (e.g., Parkinson's disease, multiple sclerosis, Alzheimer's disease, bacterial or viral infections), 8) groups at risk from sugar consumption (e.g., individuals with diabetes, kidney disease, liver disease, central obesity, cancer, cardiovascular and hepatic diseases), and 9) groups at risk from erythritol, stevia, and sucralose consumption.

Quota randomization was applied to 25 subjects per day over 5 days, total of 100 subjects. After giving consent, participants picked a card indicating a number. Those who received number one tasted sugar before ASP, while those with number two tasted ASP before sugar. Each participant received a box set, with food items labeled to indicate the tasting sequence. Participants were blinded to which pancakes and coffee contained ASP or sugar, with only the researcher (the first author) knowing the formula of each.

Each participant initially received a 2x2 cm pancake. After a 5-minute water break, they tasted a second pancake and assessed the overall liking and sweetness of both. Following another 5-minute water break, participants tasted one teaspoon of the first hot coffee, took another 5-minute water break, and paused for 5 minutes before sampling the second hot coffee. They then assessed the overall liking and sweetness of both coffees.

Tool and data collection

After verifying criteria, explaining the tasting protocol, and obtaining consent, participants completed part 1 of the questionnaire on general information. They then tasted the pancakes and coffee and completed part 2; assessing overall and sweetness liking using an 11-point scale (0="dislike extremely" to 10="like extremely"). The questionnaire, validated by three experts, included the question: "How much more are you willing to pay for food products in the same quantity that uses ASP instead of sugar?" was used to measure participants' willingness to pay. A question on how much more participants were willing to pay for products using ASP instead of sugar.

Statistical analysis

Descriptive statistics were used to present participants' demographic information. Paired t-tests were used for overall liking scores between ASP and sugar. Willingness to pay, presented as median and interquartile range (Q1, Q3), was used due to non-normal data distribution. The ASP prototype cost was based on the prices of the AS used, with the average price for an ASP equivalent to the sweetness of 1 kg of sugar calculated from three ASPs commonly found in Thai supermarkets.

Results

Study I

Demographic information

The majority of the participants were female government employees. In study I (n=180), the mean age was 39.8±12.8 (min:18, max:65) years old. In study II (n=100), the mean age was 36.8±13.7 (min:18, max:65) years old. Details of demographic information are shown in Table 1.

Experiences of alternative sweetener products

Most of the participant (63.6%) expressed from their experience with consuming AS that, in terms of taste, these AS are sweet but have an unfamiliar sweetness that is not like regular sugar. Additionally, most of the sample group found the price of sugar substitutes was too expensive (45.6%), reasonable and appropriate (40.3%), and the same price as sugar (14.1%).

Expectations of alternative sweetener product

Five themes emerged: taste, preparation, form, packaging, and price (Figure 1). For taste, consumers preferred an ASP with a round, sugar-like taste and no bitter aftertaste that enhanced the food's mellow and full flavor. The preferred form was powder in small, portable packaging. Moreover, the price should be comparable to sugar.

Study II

Overall liking of alternative sweetener product prototype

There was no difference in the overall liking of pancakes made with sugar or ASP. However, the overall liking of coffee made with ASP was higher than that of coffee made with sugar. This difference was statistically significant. (Table 3)

Table 1 Demographic information of the participants

Demographic data	Study I (n=180) n	Study II (n=100) n
Gender		
Female	120	60
Male	60	40
Income (Baht/month)		
≤10,000	25	48
10,001-20,000	47	28
20,001-30,000	35	15
30,001-40,000	34	6
40,001-50,000	13	2
>50,000	26	1
Occupation		
Government employees	118	32
Students	27	28
Self employed	22	25
Company employees	13	15

Table 2 Types of products containing alternative sweeteners consumed by participants

Product Type	number (%)
Products containing alternative sweeteners	
Flavored carbonated drinks	68 (27.1)
Sugar-free chewing	68 (27.1)
Sugar-free herb lozenges	33 (13.2)
Monkfruit and monkfruit sweeten drinks	18 (7.2)
Alternative sweetener	
Erythritol	37 (14.7)
Stevia and maltitol syrup	17 (6.8)
Sucralose and erythritol	10 (3.9)

Willingness to pay

The participants were willing to pay not more than 15% more (Q1: 5, Q3: 50) for food products with ASP when compared with food products that contain regular sugar. The comparison of the cost of hot coffee and pancakes using sugar and the ASP prototype indicated that the increasing cost would not significantly affect the price of the coffee or pancakes (Table 4).

Discussion

Consumer feedback on AS products indicates that current options often fail to meet taste expectations. Nearly half of the participants reported dissatisfaction with the taste of AS and ASP, highlighting the challenge of balancing health benefits with sensory satisfaction. This feedback is essential for the food industry and health policymakers to promote healthier eating without compromising taste.

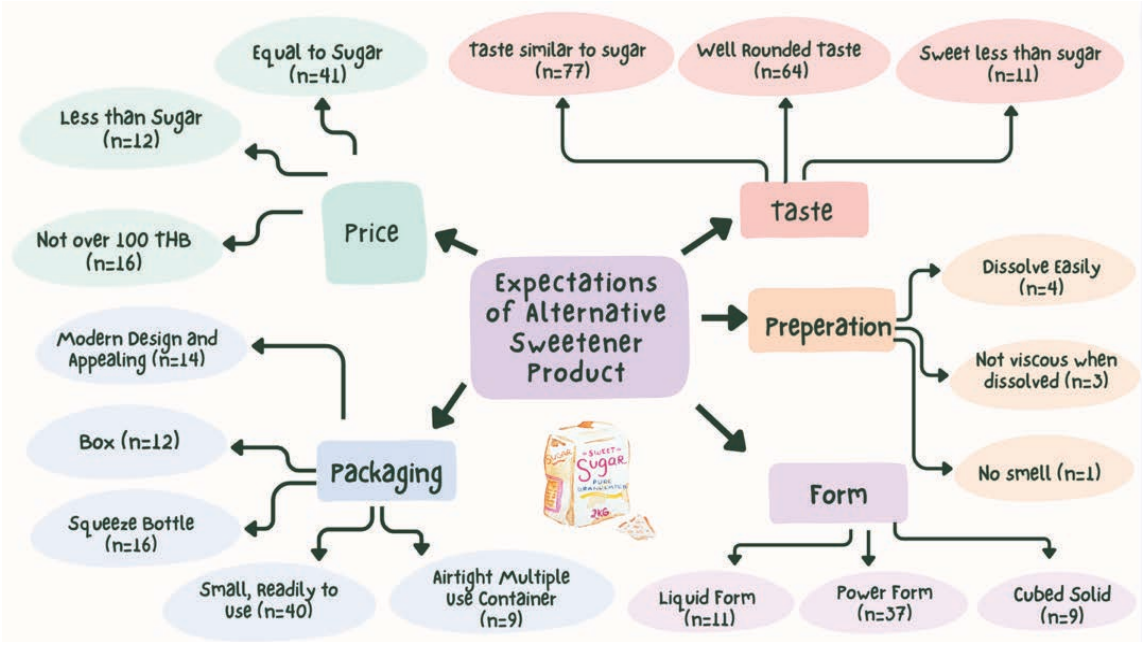

Figure 1 Participant's expectation of alternative sweetener product

Table 3 Overall liking consumer preference assessment for sugar and sweeteners in food and beverages (n=100)

Type	Overall liking
Pancake	
Sugar (mean±S.D.)	6.58±2.64
ASP (mean±S.D.)	6.57±1.99
Mean Difference (95% CI)	0.01 (–0.42, 0.44)
Coffee	
Sugar (mean±S.D.)	6.29±2.09
ASP (mean±S.D.)	6.87±2.30
Mean Difference (95% CI)	–0.58 (–1.08, –0.09)[a]

S.D.=stansard deviation, ASP=alternative sweetener product, 95% CI =confidence interval, [a]p-value<0.05

Table 4 Cost (THB) of each food product when comparing at the same sweetness

Type	Sugar	ASP
Raw Ingredient (Equivalent sweetness to sugar 1 kg)	35.00	66.00
Coffee (per serving)	10.02	10.80
Pancake (per serving)	6.62	7.08

ASP=alternative sweetener product, THB=Thai Baht, Note: $1.00 USD is approximately 37 THB

Insights on consumer expectations regarding taste, texture, form, packaging, and price is invaluable for product development. The demand for a calorie-free sweetener that tastes like sugar shows market potential; however, it also presents a significant challenge for developers; emphasizing the need for innovation aligned with consumer preferences.

Several sweeteners, such as erythritol[17], inulin[18], stevia[11] and monkfruit[13], have minimal effects on blood sugar levels. However, each has limitations: aspartame can't withstand high heat[12], erythritol has lower solubility and sweetness[19], monkfruit has a distinctive odor[13] and stevia has a bitter aftertaste[20]. Thus, market products often blend multiple sweeteners. In Thailand, only certain AS substances are permitted in food; as specified by the Ministry of Public Health and the Food and Drug Administration. The ASP in this study ensures consumer safety and compliance with FDA criteria for food and beverage products[21].

Consumers anticipate using alternative sweeteners (AS) as sugar substitutes in foods, baked goods, and beverages, allowing them to adjust sweetness levels as desired. AS can help reduce dietary sugar intake, offering sweetness without added calories, which supports weight management and diabetes control[2,4]. Although the cost of ASP was nearly double the price of sugar for the same quantity that gives the same level of sweetness, the cost of our ASP prototype was still cheaper than the average price of the ASPs available in the market. The average price of the ASP equivalent to the sweetness of 1 kilogram of sugar was estimated to be 581.50 THB (approximately $15.72 USD).

The high cost of AS is a barrier to accessibility, as most consumers find health food prices expensive[21–23]. Homemade blended AS could reduce costs. This finding underscores the need for developing simple, non-sophisticated methods for AS production. Such approaches are essential for small-scale operators lacking advanced production facilities and technical expertise.

For the overall liking of ASP, this current study did not test any plain powder or syrup forms of ASP. This decision was because, other studies have already extensively explored the sensory attributes of AS[24–26] and have shown that the food matrix can significantly influence the perception of sweetness as well as the aftertaste of sweeteners. Additionally, complex food systems often provide a more favorable sensory experience compared to the sweeteners in their isolated form[27]. Studies in bakery products have demonstrated how the presence of fats, flours, and other ingredients can interact with sweeteners to create a more balanced and acceptable flavor profile, potentially improving the overall liking[28]. The development of this ASP is geared towards compatibility with daily consumption and integration into common food items.

For the overall liking of ASP in coffee, the findings indicate a higher approval rating compared to traditional sugar. This could be attributed to coffee's inherent bitterness, which likely masks the bitter aftertaste of stevia[11,19,26],

allowing the high-intensity sweetness to become more pronounced when paired with the beverage. On the contrary, for items like pancakes, sugar's contribution to texture[29–31] and its well-rounded flavor profile appears to enhance overall enjoyment. Therefore, ASPs may not replicate this as effectively, leading to a contrasting, less favorable response[6,8,13,28]. This suggests that ASP is suitable for sweetening foods where sugar is not a primary ingredient, like spice-heavy dishes, such as curries, highlighting their versatility in a range of culinary contexts.

Incorporating ASP into pancakes and coffee increased costs by less than 10%, which is unlikely to impact market prices significantly. ASPs are a satisfactory sugar alternative that meets consumer expectations, which is crucial for affordability in developing countries like Thailand. While urban consumers commonly consume pancakes and coffee, these items are less traditional in rural and semi-urban areas. Future research should extend to Thai herbal beverages and curries. Although ASPs are designed for ease of use, techniques like geometric dilution are required, necessitating comprehensive training for consumers and small food operators for effective technology transfer.

Limitations regarding the studied sample population should be acknowledged, as it is crucial for understanding the scope and applicability of the findings. The research primarily engaged university students and white-collar employees, which presents a specific demographic that may not accurately represent the broader population's preferences and behaviors concerning AS. This limitation underlines the need for future research to incorporate a more diverse sample that includes participants from various demographic backgrounds; including different ages, educational levels, socioeconomic statuses, and geographical locations.

Conclusion

This study's findings indicate that while consumers are generally ready to accept AS, the current market products do not fully meet their expectations. The survey revealed that 63.6% of participants disliked the taste of AS; as they expected a taste similar to sugar and at an affordable price. This single-blinded experiment demonstrated no significant differences in overall liking between the developed prototype ASP and sugar. Moreover, the ASP prototype was found to be 88% cheaper than the average marketed AS available in physical markets. These results suggest that the ASP prototype, being both affordable and acceptable, has the potential to overcome common barriers related to the affordability and acceptability of AS. Additionally, the straightforward preparation technique of the ASP prototype can be easily transferred to consumers for home use, further enhancing its practicality and appeal.

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Conflict of interest

The authors declare no conflicts of interest.

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