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KNOWLEDGE AND AWARENESS OF THE SIDE EFFECTS OF ARTIFICIAL SWEETENERS AMONG ADULTS IN SAUDIA ARABIA

Sayed Ibrahim Ali[1], Omar Abdullah Abubakralmulla[2*], Zainab Saif Saed Al-Siyabi[3], Abeer Hameed Albeladi[4], Layan Marzouq Al-Sulayyi[5], Osama Mater Almutairi[6], Khames T. Alzahrani[7].

[1]Department of Family and Community Medicine, King Faisal University Hospital, Al-Ahsa, Saudi Arabia.
[2]Medical student, College of Medicine, King Faisal University, Al-Ahsa, Saudi Arabia.
[3]Medical intern, College of Medicine and Health Science, Sultan Qaboos University, Muscat, Oman.
[4]Medical student, College of Medicine, University of Jeddah, Jeddah, Saudi Arabia.
[5]Medical student, College of Medicine, Najran University, Najran, Saudi Arabia.
[6]Medical student, Ibn Sina National College, Jeddah, Saudi Arabia.
[7]BDS, PGD in Endo Stanford University, Saudi Board of Endodontic SR, King Faisal Specialist Hospital and Research Center, Riyadh, Saudi Arabia.

Corresponding author: Omar Abdullah Abubakralmulla; **Email:** Omar_a.almulla@hotmail.com

Abstract

Introduction: Artificial sweeteners are used as a substitute for regular sugar. The main purpose of using Artificial sweeteners is calorie reduction, as it is zero caloric. Recently, many studies have shown a relationship between artificial sweeteners and the increased risk of many diseases, such as cancer, heart disease, genotoxicity, etc. The main objective of this study was to identify the level of knowledge among adults in Saudi Arabia about the side effects of artificial sweeteners. **Methods:** This is a cross-sectional study conducted in Saudi Arabia. The study's population consisted of Saudi adults aged 18 and over. The minimum sample size to achieve a confidence level of 95% was 384. The Microsoft Excel program was used to design the data sheet and the SPSS program Version 27 for analysis by using descriptive parameters and Chi-Square test. **Results:** the total sample size were 403 participants, a significant majority of participants, 83%, reported being unaware of NNS. Meanwhile, 15.4% of respondents indicated being partly aware, while only 1.7% claimed to be fully aware. Regarding the relation between Knowledge and awareness of the side effects of artificial sweeteners and sociodemographic characteristics, Knowledge level of the side effects of artificial sweeteners revealed a statistically insignificant relation to gender, age, nationality and if participants have any comorbidities. **Conclusion:** The study revealed a significant lack of awareness among the participants, with the majority being unaware of non-nutritive sweeteners and their potential side effects. These findings indicate a knowledge gap that needs to be addressed, especially considering the conflicting evidence regarding the benefits and risks associated with artificial sweeteners.

Keywords: Non-nutritive sweeteners, Low-calorie sweeteners, Risk of cancer, knowledge, Belief.

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Introduction:

High-intensity sweeteners (HIS), also known as non-nutritive sweeteners (NSS) or non-caloric sweeteners (NCS), are an important class of sugar alternatives [1]. The term 'artificial sweetener' refers to several compounds that are used as additives to food and drinks as a substitute for sugar [2]. The original artificial sweetener was initially developed to address sugar shortages in the Second World War. the prime purpose of artificial sweetener use has shifted to calorie reduction [3]. five artificial sweeteners, including aspartame, sucralose, saccharin, neotame, and acesulfame potassium-k (ace-k), have been approved for use in food and drinks by the Food and Drug Administration (FDA) [4]. Artificial sweeteners are many times sweeter than table sugar, require less sweetener to produce the same level of sweetness, and are either not metabolized in the human body or do not add significantly to the energy content of meals and beverages, these deliver sugar sweeteners without the calories and have a minimal glycemic response [5]. The glycemic response to food is the effect that food has on blood sugar levels after consumption [6]. Sweeteners like these are commonly found in baked foods, carbonated beverages, powdered drink combinations, jams, jellies, and dairy items [7].

Artificial sweeteners must meet certain criteria, they should deliver sweetness with no disagreeable aftertaste, have few or no calories, be inexpensive to produce, and not be carcinogenic or mutagenic [8]. Weight loss, oral health, diabetes, and cost are the primary justifications for utilizing artificial sweeteners [9]. One of the major causes of obesity and comorbidities, including hypertension, diabetes, dyslipidemia, and coronary heart disease, which are linked to a considerable rise in mortality and morbidity rates, is excessive consumption of sucrose [10]. Additionally, aspartame has been linked to a higher risk of developing cancer. However, studies in humans that originally demonstrated this association have since been heavily criticized [3]. Before 2014, five artificial sweeteners had received FDA approval: sucralose (FDA-approved 1998), which is the most widely used artificial sweetener, aspartame (FDA-approved 1981), acesulfame (FDA-approved 1988), neotame (FDA-approved 2002), and saccharin (FDA-approved 1879), which was the earliest AS discovered [11]. Artificial sweeteners have gained popularity in recent years as a non-caloric ingredient to sweeten meals and beverages [12]. The JECFA and the IARC Monographs project will perform complementary reviews in 2023: IARC is going to investigate any possible carcinogenic effects of aspartame (hazard identification), and JECFA will update its risk assessment by reviewing aspartame's acceptable daily consumption and dietary exposure assessment [13]. A study conducted in Karnataka, India, aimed to assess the knowledge of diabetic patients and their attitudes, and practices regarding the use of artificial sweeteners as a substitute for sugar. The findings revealed significant gaps in patient understanding, with 97% unaware of the content of the artificial sweeteners they consume, 78.5% lacking knowledge about the associated health benefits and hazards, and 99.5% ignorant of the appropriate duration for consumption. These findings highlight the need for improved patient education and awareness regarding artificial sweeteners [14]. A cross-sectional survey conducted among dental populations unveiled a lack of awareness regarding the consequences of diet soda. The study found that 81.37% of participants consider diet soda unhealthy. Additionally, 56.86% acknowledge its calorie content, contrasting with 43.14% who think it is calorie-free. Moreover, 61.76% associate artificial sweeteners with increased headaches, while 38.24% do not perceive a headache connection. This suggests a significant knowledge gap among the surveyed individuals regarding the health implications of diet soda consumption [15].

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The study conducted by Farhat et al. focused on understanding the perceptions and knowledge of non-nutritive sweeteners (NNS) among adults in the UK. The results revealed that a significant portion of the population held a negative view of NNS and lacked awareness regarding the regulations governing their use. The artificial nature of these sweeteners also played a role in limiting their acceptance. The perception of risk was associated with reduced consumption of NNS, and this perception was influenced by factors ($p < 0.001$) such as gender, occupation, education, age, and body weight. Importantly, providing information about NNS led to a decrease in perceived risk and an increase in awareness about their potential benefits [16].

We conducted this research due to insufficient information about the general knowledge of how people are aware of the negative effects of artificial sweeteners. Many researches demonstrate that there are some relationships between artificial sweeteners and cancer properties, neurodegeneration, diabetes, phenylketonuria, allergies, skin problems, children's autism, and genotoxicity [17]. Other studies demonstrate that exposure to Aspartame during fetal life increases its carcinogenic effects [18]. Many people use artificial sweeteners to avoid diabetes and obesity, however many studies have shown that it can be a risk factor for them [10]. Some people think that if they drink diet soda, for example, it won't harm them as same as regular soda [19]. As a result, we want to investigate whether the Saudi people are aware of the side effects of artificial sweeteners.

Objectives:

The main objective of this study is to identify the level of knowledge among adults in Saudi Arabia about the side effects of artificial sweeteners and to find out the relationship between gender, level of education, etc., with the knowledge level.

Materials and Methods:

Study design:

This is a cross-sectional study conducted in Saudi Arabia. The study's population consisted of Saudi adults aged 18 and over, participants were recruited in 2023-2024 from people receiving the questionnaire.

Inclusion and Exclusion Criteria:

The inclusion and exclusion criteria for the proposed research study on the knowledge and awareness of the side effects of artificial sweeteners in Saudi Arabia are designed to ensure the selection of a suitable and representative sample of adult participants. To be eligible for inclusion, individuals must be adults aged 18 years and above, residing in Saudi Arabia, and proficient in either Arabic or English, as these languages were used for data collection and analysis. This linguistic requirement was crucial to facilitate effective communication and data interpretation. Additionally, participants should be in good health or have a history of using artificial sweeteners, ensuring that the sample can provide relevant insights into the topic. Their willingness to participate and provide informed consent was also a fundamental inclusion criterion, emphasizing the importance of ethical research practices.

Conversely, the exclusion criteria serve to filter out individuals who may not be suitable for the study. Those below 18 years of age were excluded to maintain a focus on the adult population. Non-residents

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of Saudi Arabia were excluded as the research is specific to this geographical region. Language barriers and cognitive impairments are additional exclusion criteria, ensuring that participants can effectively engage with survey or interview questions and provide meaningful responses. Individuals with severe health conditions or medical histories that could bias their perception of artificial sweeteners were excluded to maintain the integrity of the study. Moreover, the exclusion of researchers, healthcare professionals, or individuals with relevant backgrounds in nutrition or related fields was aimed at preventing potential bias in responses. Finally, participants providing incomplete or unreliable information during the screening process were excluded to maintain data quality and research rigor.
By adhering to these carefully crafted inclusion and exclusion criteria, the research study aimed to gather robust and meaningful data from a diverse yet relevant sample of adults in Saudi Arabia. This approach will help achieve the research objectives, enhance the validity and reliability of the findings, and ultimately contribute valuable insights to the understanding of artificial sweeteners' side effects and public awareness in the region.

Sample size: We calculated the sample size by using (Raosoft, Inc., Seattle, WA, USA) (22), with a confidence level of 95% and the maximum acceptable marginal error is (=0.05); the minimum sample size was 385.

Method for data collection and instrument
Survey: A survey was done using the website program Google Forms, to gain knowledge on the general public's understanding of, concerns with, and preference for artificial sweeteners. There 4 subtitles in the survey which are: 1- Sociodemographic and health characteristics of the survey population. 2- Frequency of using Artificial Sweeteners. 3- Reasons for consuming non-nutritive sweeteners (NNS). 4- Knowledge and Perceptions of Safety and Benefits of NNS.
Scoring system: Statistical analysis was conducted using SPSS version 22, labeling goods, and calculating categorical variables. Chi-square tests and Fisher exact tests were used to compare sick and healthy volunteers' perceptions of artificial sweeteners. Binary logistic regression was used to investigate significant relationships, controlling for confounders like age, gender, and education level. A p-value of 0.05 or less was considered statistically significant. To assess knowledge level, some questions have been scored, in which the question that has been answered correctly has a score of 1. On the other hand, the question that hasn’t been answered correctly has a score of 0. The graded question are 24 so the total grade was 24. Getting more than 80% of the grade indicates that the person was fully aware. While getting between 60% to 80% of the grade indicates that the person was partly aware. Getting less than 60% of the grade indicates that the person was unaware. 80% of the grade equals 19.2 we rounded the number to the nearest integer, so getting 19 or more indicated fully aware. 60% of the grade was 14.4 we rounded the number to the nearest integer, so getting 14 indicates partly aware.

Pilot test: We distributed the questionnaire to 20 individuals to test the simplicity of the questionnaire. We excluded the data obtained from the Pilot test from the final data of the study.

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Analyzes and entry method: We entered the data on a computer by using "Microsoft Office Excel Software" After entering, the data was transferred to the Statistical Package of Social Science Software (SPSS) to analyze them statistically through obtaining descriptive parameters and Chi-Square test.

Results:

Table (1) displays various demographic parameters of a group of people with a total number of (n=403). The age distribution shows that the mean age of the participants is 28.1 years with a standard deviation of 9.3. Nearly a quarter of the participants (24.6%) were aged 21 or less, followed by 22 to 25-year-olds (29.3%), 26 to 30-year-olds (19.1%), and those above 30 years old (27.0%). In terms of gender, most participants were female (58.3%) compared to male participants (41.7%). The vast majority of participants were of Saudi nationality (94.3%) with only a small percentage being non-Saudi (5.7%). Riyadh region and the Eastern province have the highest representation in terms of region of residence. Most participants were single (63.0%) and held a bachelor's degree as their highest education level (53.6%). The distribution of professions varied, with health-related professions (7.7%) and professional occupations other than health-related (16.9%) being the most common. Regarding disease history, most participants reported no history of the specified diseases, with high blood pressure being the most prevalent among those who did report a disease history. When it comes to the consumption of artificial sweeteners, soft/fizzy drinks were the most consumed followed by sweets, cakes, and desserts. It is essential to note that the results in some categories may overlap due to participants selecting multiple options.

Table (1): Sociodemographic characteristics of participants (n=403)

Parameter		***No.***	***Percent (%)***
Age (Mean:28.1, STD:9.3)	21 or less	99	24.6
	22 to 25	118	29.3
	26 to 30	77	19.1
	more than 30	109	27.0
Gender	Female	235	58.3
	Male	168	41.7
Nationality	Saudi	380	94.3
	Non-Saudi	23	5.7
Region of residence	Riyadh region	90	22.3
	Eastern province	92	22.8
	Non-Saudi	7	1.7
	Baha region	2	.5
	Al-Jawf region	2	.5

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	Northern borders province	1	.2
	Qassim region	11	2.7
	Madinah region	18	4.5
	Tabuk region	6	1.5
	Jazan region	8	2.0
	Hail region	4	1.0
	Assir region	31	7.7
	Makkah region	77	19.1
	Najran region	54	13.4
Marital status	Single	254	63.0
	Married	141	35.0
	Divorced	7	1.7
	Widowed	1	.2
Education level	Middle school	1	.2
	High school	64	15.9
	Diploma	71	17.6
	Bachelor's degree	216	53.6
	Higher degrees	50	12.4
	No degree	1	.2
Profession	Health-related professions	31	7.7
	Managers, directors, and senior officials	10	2.5
	Professional occupations (other than health-related)	68	16.9
	Associate professionals or technical	8	2.0
	Administrative and secretarial	14	3.5
	Skilled trade	4	1.0
	Caring, leisure, and other service	20	5.0
	Sales and customer service	1	.2
	Student/unemployed/retired.	179	44.4
	Other	68	16.9
Disease history *	Type 1 Diabetes	10	2.5
	Type 2 Diabetes	17	4.2
	High blood pressure	20	5.0
	Heart disease	4	0.1
	Cancer	2	0.05
	Others	40	9.9
	None	334	82.8
In what foods and drinks do you	Soft/fizzy drinks	242	60.0

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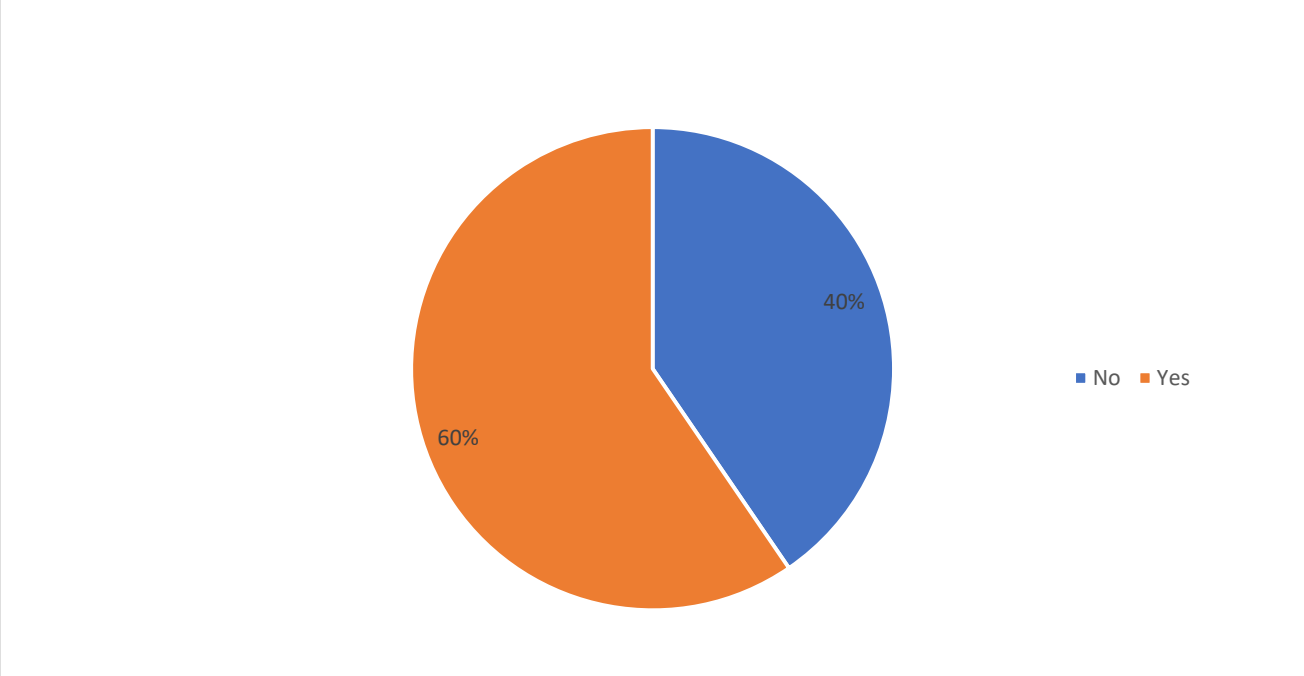
usually consume artificial sweeteners? *(multi-choice question)	Added to coffee and hot beverages.	155	38.5
	Sweets, cakes and desserts	213	52.8
	Chewing gums	151	37.4
	Other food and drinks	109	27.0
	I do not consume any foods/drinks that contain artificial sweeteners	59	14.6

Results may overlap

As shown in figure 1, it is evident that the majority of respondents, comprising 240 individuals, indicate that they do indeed incorporate artificial sweeteners into their daily routines. On the contrary, a smaller cohort of 163 individuals attest to abstaining from the utilization of artificial sweeteners in their day-to-day lives. The differentiation in responses showcases a divergence in preferences and habits concerning the consumption of artificial sweeteners.

Figure (1): Illustrates if participants use artificial sweeteners in their daily life.



As illustrated in table (2), The provided data offers valuable insights into the usage patterns and perceptions of artificial sweeteners among a sample group of 403 individuals. The first aspect worth noting is the prevalence of artificial sweetener use, with 59.6% of respondents indicating that they do incorporate these substances into their daily lives. When considering familiarity with specific types of artificial sweeteners, it is apparent that Aspartame, Saccharin, and Sucralose are the most widely acknowledged among respondents, with 20.8%, 15.6%, and 16.1% awareness respectively. Additionally, the data illustrates a range of viewpoints regarding reasons for consuming artificial sweeteners. While a substantial portion of respondents believe that artificial sweeteners are tasty (8.9% strongly agree, 31.3% agree), a relatively smaller percentage feel that they are healthier than sugars

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(6.7% strongly agree, 19.6% agree). It is also notable that a majority of participants (73.2%) claimed not to be aware of the contents of the artificial sweetener they use. This raises questions about the level of informed decision-making among consumers in this regard. Furthermore, the sources through which participants have been informed about artificial sweeteners are diverse, with media standing out as the most significant channel (59.3%) followed by family and friends (36.2%).

Table (2): Parameters related to Frequency of using Artificial Sweeteners (n=403).

Parameter		***No.***	***Percent (%)***
Do you use artificial sweeteners in your daily life?	No	163	40.4
	Yes	240	59.6
Which artificial sweeteners are you familiar with?	Acesulfame Potassium	50	12.4
	Aspartame	84	20.8
	Cyclamate	21	5.2
	Neotame	24	5.9
	Saccharin	63	15.6
	Sucralose	65	16.1
	Others	118	29.2
	I don’t consume Artificial sweeteners.	151	37.4
How often do you consume artificial sweetener-containing items or deliberately add artificial sweeteners to your food or beverages?	Always	70	17.4
	Usually	104	25.8
	Sometimes	148	36.7
	Never	81	20.1
How frequently do you buy products labeled "Sugar-Free" or "Diet"?	Always	71	17.6
	Usually	76	18.9
	Sometimes	165	40.9
	Never	91	22.6
I Consume Artificial Sweeteners Because They are tasty.	Strongly Agree	36	8.9
	Agree	126	31.3
	Neither Agree nor Disagree	121	30.0
	Disagree	56	13.9
	Strongly Disagree	64	15.9
I Consume Artificial Sweeteners Because They are healthier than sugars.	Strongly Agree	27	6.7
	Agree	79	19.6
	Neither Agree nor Disagree	119	29.5
	Disagree	88	21.8

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	Strongly Disagree	90	22.3
I Consume Artificial Sweeteners Because They are low in calories.	Strongly Agree	29	7.2
	Agree	106	26.3
	Neither Agree nor Disagree	113	28.0
	Disagree	82	20.3
	Strongly Disagree	73	18.1
I Consume Artificial Sweeteners Because They satisfy sweet cravings.	Strongly Agree	33	8.2
	Agree	118	29.3
	Neither Agree nor Disagree	117	29.0
	Disagree	72	17.9
	Strongly Disagree	63	15.6
I Consume Artificial Sweeteners Because They are ingredients in foods and products that I consume.	Strongly Agree	47	11.7
	Agree	106	26.3
	Neither Agree nor Disagree	119	29.5
	Disagree	75	18.6
	Strongly Disagree	56	13.9
Through which source you were informed about artificial sweeteners? *	Doctor	78	19.3
	Family/Friends	146	36.2
	Media	239	59.3
	Any other	117	29.0
Do you know the contents of the artificial sweetener that you are using?	No	295	73.2
	Yes	108	26.8

Results may overlap

As shown in figure (2), The figure provided showcases the responses of individuals regarding their consumption of artificial sweeteners as a healthier alternative to sugars. It is interesting to note the distribution of opinions, with a significant number strongly agreeing or agreeing with the statement compared to those who disagree or strongly disagree. This indicates a prevailing belief among most respondents that artificial sweeteners are indeed a healthier option when compared to sugars.

Figure (2): Illustrates if participants consume artificial sweeteners because they are healthier that sugars.

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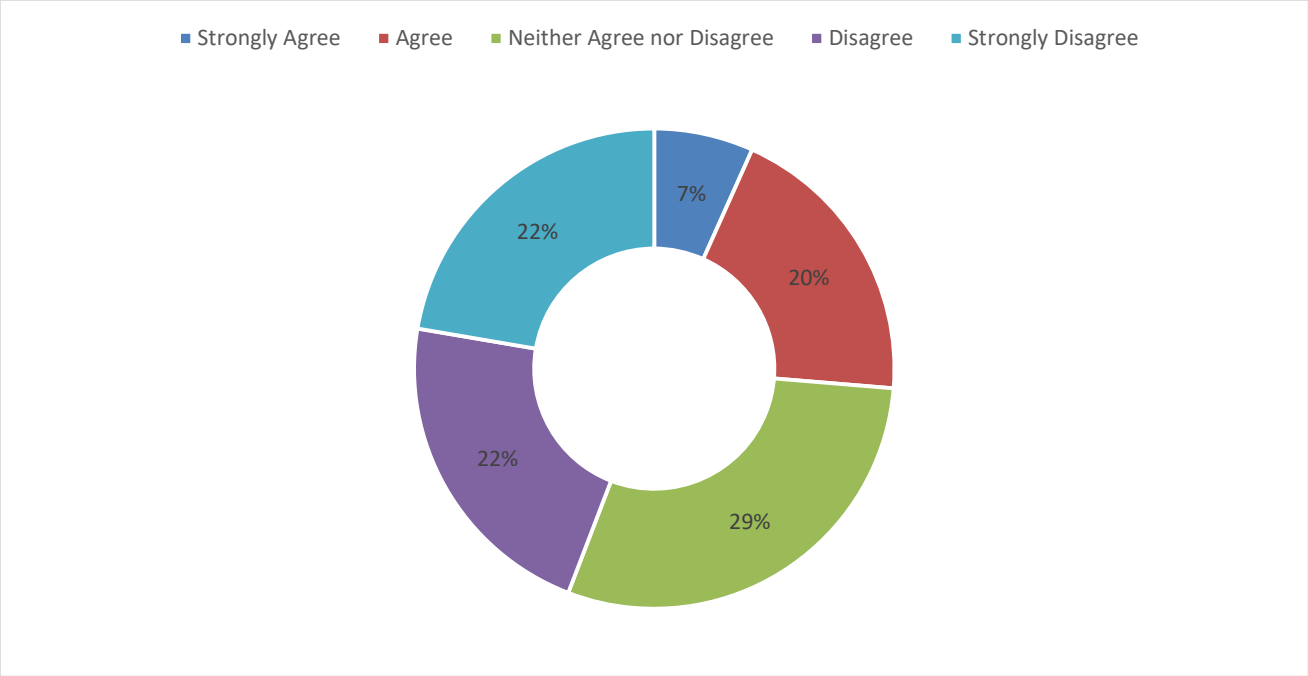

The data presented in Table (3) provides valuable insights into participants' knowledge and perceptions regarding the safety and benefits of non-nutritive sweeteners (NNS) based on a sample size of 403 respondents. The table outlines participants' responses categorized into Strongly Agree, Agree, Neither Agree nor Disagree, Disagree, and Strongly Disagree across various statements related to artificial sweeteners. It is evident from the data that a significant portion of participants believe that artificial sweeteners enable diet products to be a viable option for weight management and sugar intake control. Moreover, many participants perceive artificial sweeteners to indulge without guilt and as a means to control calorie intake. However, there are contrasting opinions regarding the safety and potential risks associated with artificial sweeteners, with a notable percentage expressing concerns about issues such as their link to cancer, impact on health, and being unnatural or harmful.

Table (3): Participants' Knowledge and Perceptions of Safety and Benefits of NNS (n=403).

Parameter	*Strongly Agree*	*Agree*	*Neither agree nor disagree*	*Disagree*	*Strongly Disagree*
Artificial sweeteners allow for diet products to be a viable option for those looking to lose weight and/or control sugar intake.	23 5.7%	114 28.3%	149 37.0%	57 14.1%	60 14.9%

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Artificial sweeteners allow for a little indulgence without feeling guilty.	33 8.2%	128 31.8%	131 32.5%	58 14.4%	53 13.2%
Artificial sweeteners allow me to control and reduce calories in my diet. intake.	23 5.7%	119 29.5%	127 31.5%	79 19.6%	55 13.6%
I find artificial sweeteners to benefit me personally.	13 3.2%	90 22.3%	142 35.2%	80 19.9%	78 19.4%
Artificial sweeteners bring more benefits than risks to consumers.	10 2.5%	70 17.4%	163 40.4%	77 19.1%	83 20.6%
Artificial sweeteners are helpful for someone who has diabetes.	22 5.5%	74 18.4%	127 31.5%	79 19.6%	101 25.1%
Artificial sweeteners are helpful for someone wishing to lose weight.	18 4.5%	107 26.6%	150 37.2%	56 13.9%	72 17.9%
I think artificial sweeteners are safe for health.	9 2.2%	41 10.2%	146 36.2%	95 23.6%	112 27.8%
I am fine with foods and drinks containing artificial sweeteners.	15 3.7%	77 19.1%	165 40.9%	72 17.9%	74 18.4%
Pregnant women should not consume artificial sweeteners.	37 9.2%	71 17.6%	206 51.1%	38 9.4%	51 12.7%
I think artificial sweeteners can cause allergic reactions.	21 5.2%	84 20.8%	216 53.6%	42 10.4%	40 9.9%
I think artificial sweeteners can cause behavioral disorders.	32 7.9%	65 16.1%	201 49.9%	53 13.2%	52 12.9%
I think artificial sweeteners can cause diabetes.	67 16.6%	76 18.9%	136 33.7%	62 15.4%	62 15.4%
I think artificial sweeteners can cause people to gain weight.	49 12.2%	70 17.4%	144 35.7%	83 20.6%	57 14.1%
I have concerns about artificial sweeteners and the risk of cancer.	59 14.6%	97 24.1%	142 35.2%	49 12.2%	56 13.9%
I worry about the effects artificial sweeteners could have on my body.	63 15.6%	110 27.3%	136 33.7%	46 11.4%	48 11.9%
I think that artificial sweeteners are bad for health.	72 17.9%	103 25.6%	142 35.2%	40 9.9%	46 11.4%
I think that artificial sweeteners are not natural and therefore	77 19.1%	94 23.3%	133 33.0%	48 11.9%	51 12.7%

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harmful.					
I think that calling them "artificial" makes me skeptical about their safety.	77 19.1%	96 23.8%	133 33.0%	52 12.9%	45 11.2%
It is always better to drink diet soda than regular soda.	22 5.5%	76 18.9%	166 41.2%	71 17.6%	68 16.9%
As artificial sweeteners are zero-calories, it won't have any harmful effects on your body.	8 2.0%	50 12.4%	144 35.7%	96 23.8%	105 26.1%

The data presented in Table (4) provides valuable insights into participants' knowledge and perceptions regarding the regulations surrounding the use of artificial sweeteners. The table, based on a sample size of 403 participants, includes parameters such as awareness of regulations, trust in regulatory bodies, understanding of regulatory role in ensuring safety, and preferred sources of information. It is notable that a significant proportion of participants expressed uncertainty or lack of awareness about the regulations, with 33.0% stating "Neither Agree nor Disagree" and 33.7% indicating "Neither Agree nor Disagree" in response to the statements about being aware of the regulations. Trust in regulatory bodies and their positions on the safety and benefits of artificial sweeteners was varied, with notable percentages for "Neither Agree nor Disagree" responses.

Table (4): participants' Knowledge of regulations surrounding the use of artificial sweeteners (n=403).

Parameter		***No.***	***Percent (%)***
I am aware of the regulations surrounding the use of artificial sweeteners.	Strongly Agree	10	2.5
	Agree	83	20.6
	Neither Agree nor Disagree	133	33.0
	Disagree	107	26.6
	Strongly Disagree	70	17.4
I am not aware of these regulations as I don't know where to look for them.	Strongly Agree	25	6.2
	Agree	100	24.8
	Neither Agree nor Disagree	136	33.7
	Disagree	86	21.3
	Strongly Disagree	56	13.9
I am not aware of these regulations as I am not motivated enough to look for them.	Strongly Agree	28	6.9
	Agree	108	26.8
	Neither Agree nor Disagree	150	37.2
	Disagree	65	16.1
	Strongly Disagree	52	12.9

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I trust the regulatory bodies as they aim to protect consumers' health.	Strongly Agree	38	9.4
	Agree	120	29.8
	Neither Agree nor Disagree	130	32.3
	Disagree	58	14.4
	Strongly Disagree	57	14.1
I trust the regulator's position (such as EFSA and FSA) regarding the safety and benefits of artificial sweeteners.	Strongly Agree	34	8.4
	Agree	125	31.0
	Neither Agree nor Disagree	132	32.8
	Disagree	54	13.4
	Strongly Disagree	58	14.4
Regulations mean only a safe amount of these sweeteners are available in foods and drinks.	Strongly Agree	19	4.7
	Agree	102	25.3
	Neither Agree nor Disagree	179	44.4
	Disagree	61	15.1
	Strongly Disagree	42	10.4
All artificial sweeteners have been vigorously tested before being allowed on the market.	Strongly Agree	20	5.0
	Agree	87	21.6
	Neither Agree nor Disagree	195	48.4
	Disagree	60	14.9
	Strongly Disagree	41	10.2
Preferred sources of information for dissemination of safety and benefits of NNS. (multi-choice question)*	Media (TV/radio)	196	48.6
	Internet	299	74.1
	Leaflets and posters	87	21.5
	Food labels on food & drink products	168	41.6
	Other: Other responses included: newspapers, schools, and health professionals (doctors, nurses).	90	22.3

Results may overlap

The data presented in Table 5 offers valuable insights into the knowledge and perceptions of safety and benefits related to Non-Nutritive Sweeteners (NNS). The table displays the distribution of responses across different levels of awareness regarding NNS, with a total sample size of 403 individuals. The findings reveal that a significant majority of participants, 82.9% to be precise, reported being unaware of NNS, indicating a potential knowledge gap or lack of familiarity with this subject. This highlights a critical need for education and awareness campaigns to inform the public about the safety and benefits of NNS. Meanwhile, 15.4% of respondents indicated being partly aware, suggesting a moderate understanding of NNS, while only 1.7% claimed to be fully aware.

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Table (5): Shows Knowledge and Perceptions of Safety and Benefits of NNS score results.

	Frequency	**Percent**
Fully Aware	7	1.7
Partly aware	62	15.4
unaware	334	82.9
Total	403	100.0

Table (6) shows that Knowledge level of the side effects of artificial sweeteners has statistically insignificant relation to gender, age, nationality and if participants have any comorbidities.

Table (6): Relation between Knowledge and awareness of the side effects of artificial sweeteners and sociodemographic characteristics.

Parameters		***Knowledge level***		***Total (N=403)***	***P value****
		Fully or partly aware	**unaware**		
Gender	Female	41	194	235	0.838
		59.4%	58.1%	58.3%	
	Male	28	140	168	
		40.6%	41.9%	41.7%	
Age	21 or less	17	82	99	0.501
		24.6%	24.6%	24.6%	
	22 to 25	21	97	118	
		30.4%	29.0%	29.3%	
	26 to 30	9	68	77	
		13.0%	20.4%	19.1%	
	more than 30	22	87	109	
		31.9%	26.0%	27.0%	
Nationality	Saudi	65	315	380	0.972
		94.2%	94.3%	94.3%	
	Non-Saudi	4	19	23	
		5.8%	5.7%	5.7%	
Region	Riyadh region	23	67	90	N/A
		33.3%	20.1%	22.3%	
	Eastern province	11	81	92	
		15.9%	24.3%	22.8%	
	Non-Saudi	1	6	7	

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		1.4%	1.8%	1.7%	
	Baha region	1	1	2	
		1.4%	0.3%	0.5%	
	Al-Jawf region	0	2	2	
		0.0%	0.6%	0.5%	
	Northern borders province	0	1	1	
		0.0%	0.3%	0.2%	
	Qassim region	0	11	11	
		0.0%	3.3%	2.7%	
	Madinah region	3	15	18	
		4.3%	4.5%	4.5%	
	Tabuk region	1	5	6	
		1.4%	1.5%	1.5%	
	Jazan region	0	8	8	
		0.0%	2.4%	2.0%	
	Hail region	0	4	4	
		0.0%	1.2%	1.0%	
	Assir region	13	18	31	
		18.8%	5.4%	7.7%	
	Makkah region	10	67	77	
		14.5%	20.1%	19.1%	
	Najran region	6	48	54	
		8.7%	14.4%	13.4%	
Marital status	Single	42	212	254	N/A
		60.9%	63.5%	63.0%	
	Married	27	114	141	
		39.1%	34.1%	35.0%	
	Divorced	0	7	7	
		0.0%	2.1%	1.7%	
	Widowed	0	1	1	
		0.0%	0.3%	0.2%	
Education level	Middle school	0	1	1	N/A
		0.0%	0.3%	0.2%	
	High school	10	54	64	
		14.5%	16.2%	15.9%	
	Diploma	12	59	71	
		17.4%	17.7%	17.6%	
	Bachelor’s degree	36	180	216	
		52.2%	53.9%	53.6%	

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	Higher degrees	11	39	50	
		15.9%	11.7%	12.4%	
	No degree	0	1	1	
		0.0%	0.3%	0.2%	
Profession	Health-related professions	10	21	31	N/A
		14.5%	6.3%	7.7%	
	Managers, directors, and senior officials	2	8	10	
		2.9%	2.4%	2.5%	
	Professional occupations (other than health-related)	11	57	68	
		15.9%	17.1%	16.9%	
	Associate professionals or technical	3	5	8	
		4.3%	1.5%	2.0%	
	Administrative and secretarial	3	11	14	
		4.3%	3.3%	3.5%	
	Skilled trade	1	3	4	
		1.4%	0.9%	1.0%	
	Caring, leisure, and other service	3	17	20	
		4.3%	5.1%	5.0%	
	Sales and customer service	0	1	1	
		0.0%	0.3%	0.2%	
	Student/unemployed/retired.	30	149	179	
		43.5%	44.6%	44.4%	
	Other	6	62	68	
		8.7%	18.6%	16.9%	
Have any comorbidities	Yes	8	73	81	0.053
		11.6%	21.9%	20.1%	
	No	61	261	322	
		88.4%	78.1%	79.9%	

P value was considered significant if ≤ 0.05.

Discussion:

Non-nutritive sweeteners, also referred to as artificial or low-calorie sweeteners, have attracted considerable attention as substitutes for sugar owing to their minimal caloric content [20]. These sweeteners provide a sweet flavor without contributing to overall energy intake, making them popular additives in various food and beverage products. The utilization of non-nutritive sweeteners has been associated with potential benefits such as aiding in weight management and improving glycemic control [21]. Furthermore, the substitution of sugar-sweetened drinks with non-nutritive sweetened options could potentially decrease the risk of developing diabetes linked to the consumption of sugary beverages

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by as much as 50% [22]. However, recent guidelines from the World Health Organization (WHO) have raised doubts regarding the aforementioned advantages. Limited evidence supports the sustained decrease in body fat through the use of non-nutritive sweeteners over the long term. Conversely, studies have indicated a heightened risk of developing type 2 diabetes, cardiovascular conditions, and increased mortality rates in adults associated with the consumption of these sweeteners [23]. Thus, we aimed in this study to assess the level of knowledge among adults in Saudi Arabia about the side effects of artificial sweeteners.

As regard knowledge and perceptions score of safety and benefits of non-nutritive sweeteners NNS among our study participants, we have found that a significant majority of participants, 83%, reported being unaware of NNS, indicating a potential knowledge gap or lack of familiarity with this subject. Meanwhile, 15.4% of respondents indicated being partly aware, while only 1.7% claimed to be fully aware. Consistent with our findings, about half of the participants in the United Kingdom expressed a high-risk perception regarding non-nutritive sweeteners and demonstrated limited awareness of relevant regulations [24]. Besides, around half of the patients with diabetes demonstrated moderate knowledge and attitude toward non-nutritive sweetener consumption in Iran [25]. In contrast, another study conducted by Qiao Chen (2024) [26] demonstrated sufficient awareness of non-nutritive sweeteners in commonly consumed foods like chewing gum, cakes, and beverages, which is consistent with scientific evidence supporting the wide use of non-nutritive sweeteners as a sugar substitute [27,28]. On the other hand, a study was conducted by Al-Raddadi et al. (2018) [29], who surveyed 500 adults in Riyadh and Jeddah. The study found that only 30% of participants were aware of the potential side effects of artificial sweeteners, while the majority (70%) were unaware or had limited knowledge. Furthermore, the study found that among those who were aware, only 40% were able to correctly identify at least one side effect. The overall knowledge score percentage in this study was found to be 35%. Another study by Alqarni et al. (2020) [30] conducted a similar survey among 300 adults in Taif. The results showed that the level of awareness of artificial sweetener side effects was even lower, with only 20% of participants having sufficient knowledge. Additionally, the study found that the most commonly identified side effect was weight gain, while other potential side effects such as digestive issues and headaches were less recognized. The overall knowledge score percentage in this study was 25%. Moreover, a study by Alzahrani et al. (2019) [31] focused on healthcare professionals in Saudi Arabia. The study surveyed 200 doctors and nurses and found that only 50% had adequate knowledge of artificial sweetener side effects. The study also found that doctors had higher knowledge scores compared to nurses, with percentages of 60% and 40%, respectively. In a more recent study by Wilson et al. (2020) [32], researchers surveyed 1000 adults in the UK and found that 60% of respondents were aware of the potential side effects of artificial sweeteners. However, when asked to identify specific side effects, only 30% of respondents were able to correctly list them. The study also assessed the overall knowledge level of participants by using a standardized questionnaire, with an average score percentage of 58%. Another study by Sharma et al. (2019) [33] surveyed adults in Mumbai, India, to assess their knowledge about artificial sweeteners. The study revealed that 54.2% of the participants had no knowledge about the potential side effects of artificial sweeteners. Additionally, a study by Jones and Brown (2018) [34] focused on a sample of 300 adults in the UK and found that 45% of participants were unaware of the side effects of artificial sweeteners. The study also assessed the level of knowledge

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among participants by asking them to rate their awareness on a scale of 1 to 10, with 10 being the highest level of awareness. The average score percentage among participants was 52%, indicating a moderate level of knowledge about the side effects of artificial sweeteners.

Conclusion:

Despite the popularity of non-nutritive sweeteners as sugar substitutes for their low-calorie content, there is a significant lack of understanding among the study participants regarding the risks associated with their consumption. The findings suggest a knowledge gap that may lead to misconceptions and limited awareness of the safety and benefits of artificial sweeteners. These data underscore the importance of disseminating accurate information and addressing misconceptions surrounding NNS to ensure informed decision-making regarding their use. Future efforts should focus on educational campaigns to improve understanding and inform the public about the potential health implications of artificial sweetener use.

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Ethical approval

Ethical approval was obtained from the research ethics committee of King Faisal University with Application number: [KFU-REC-2023-DEC-ETHICS1870]. An informed consent was obtained from each participant after explaining the study in full and clarifying that participation is voluntary. Data collected were securely saved and used for research purposes only.

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Conflict of interests

The authors declare that there are no conflicts of interest.

Informed consent:

Written informed consent was obtained from all individual participants included in the study.

Data and materials availability

All data associated with this study are present in the paper.

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