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Food additive perceptions and practices among young adults in four arab countries

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ABSTRACT

Objective: This study aimed to assess consumer perceptions, purchasing behaviors, and consumption patterns related to food additives (FAs) across four Arab countries: Egypt, Jordan, Lebanon, and Oman.
Methods: A cross-sectional online survey was conducted using a snowball sampling method, yielding 2351 participants: Egypt (n = 1181), Jordan (n = 414), Lebanon (n = 342), and Oman (n = 414). Statistical analyses included exploratory and confirmatory factor analyses to validate scale structure, multi-group analysis to assess measurement invariance, and descriptive, bivariate, and multivariable methods to examine perceptions and practices.
Results: Risk perception was strongly correlated with better practice ($r = 0.76$, $p < 0.001$) and weakly with age ($r = 0.09$, $p < 0.001$). Better practice also showed a weak association with older age ($r = 0.10$, $p < 0.001$). In regression analysis, lower risk perception was significantly associated with being Egyptian (β = -4.88) and reading food labels (β = -0.55), while higher perception was associated with being Omani (β = 2.19), a nutritionist (β = 1.90), a healthcare professional (β = 0.66), having food allergies (β = 1.53), and older age (β = 0.03). Better practice was predicted by being Omani (β = 1.04), having food allergies (β = 0.65), and higher risk perception (β = 0.78), while being Egyptian (β = -2.17) or a healthcare professional (β = -0.43) were associated with poorer practice.
Conclusions: Findings reveal cross-country differences in FA perceptions and practices, emphasizing the need for culturally tailored food safety policies and communication strategies. Further research should explore underlying influences and evaluate targeted educational interventions.

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1. Introduction

Food additives (FAs) are natural or synthetic substances added during food production or processing to preserve food, improve its appearance, and enhance its taste and texture (World health Organization, 2023). The World Health Organization (WHO) categorizes FA into flavoring agents, enzyme preparations, and other additives, including colorants, sweeteners, and preservatives (World health Organization, 2023). Natural FAs originate from plant, animal, or mineral sources, and synthetic compounds from chemical processes (U.S. Food and Drug Administration, n.d.). Both categories must meet identical safety standards established by international food safety authorities ((U.S. Food and Drug Administration, n.d.; European Food Safety Authority, n.d.; European Commission, n.d.). While the European Food Safety Authority (EFSA) maintains explicit legal definitions that differentiate between natural, nature-identical, and artificial substances with corresponding labeling requirements (European Food Safety Authority, n.d.), the U.S. Food and Drug Administration focuses primarily on functional safety rather than origin, with the notable exception of natural versus artificial flavoring designations (U.S. Food and Drug Administration, n.d.). This regulatory framework ensures that both natural and synthetic additives undergo rigorous toxicological evaluation and are subject to acceptable daily intake limits (U.S. Food and Drug Administration, n.d.; European Food Safety Authority, n.d.; European Commission, n.d.). However, the legal distinction becomes particularly relevant in organic food regulations and consumer labeling requirements (U.S. Food and Drug Administration, n.d.; European Food Safety Authority, n.d.). While FAs are integral to the food industry, they have become a growing health concern, particularly for children (Bearth et al., 2014; Osaili et al., 2023; Trasande et al., 2018; Savin et al., 2022; Shim et al., 2011; Buchler et al., 2010).

Despite regulatory assurance of safety when used within acceptable limits (Pomeranz et al., 2024), recent studies indicate that many consumers have negative attitudes and misconceptions about FAs (Melios et al., 2025; Van Gunst & Roodenburg, 2019). A survey in the United Arab Emirates (UAE) found that approximately 61 % of respondents believed FAs were harmful to human health (Osaili et al., 2023), aligning with previous research indicating widespread consumer apprehension about their potential long-term health effects (Parke & Lewis, 1992; Silva & Lidon, 2016)

Risk perception is affected by socio-cultural factors, including knowledge level (Osaili et al., 2023; Borda et al., 2021; Esfahani et al., 2021; Miao et al., 2020; Gökce et al., 2017; Nadia Shaheen Koyratty & Aumjaud, 2014), education level (Esfahani et al., 2021; Gökce et al., 2017; Hoteit et al., 2022), gender (Esfahani et al., 2021), age group (Kotb et al., 2025), FA sources (natural or synthetic) (Evans et al., 2010; Rozin & Fischler, 2012), reports on social media (Osaili et al., 2023), and the level of trust in regulators (Bearth et al., 2014). Research showed that knowledge about FAs is crucial in mitigating biased judgments associated with risk perception (Miao et al., 2020). However, according to recent studies, significant gaps persist in consumer understanding of the topic, particularly regarding the identification of which food products contain FAs (Osaili et al., 2023; Borda et al., 2021; Miao et al., 2020; Gökce et al., 2017). Many consumers lack awareness of which food contains FAs. A survey showed that over half of respondents mistakenly believed that foods like pickles, yogurt, and natural cheeses are additives-free (Osaili et al., 2023). Such misconceptions influence purchasing behavior, such as avoidance of food containing FAs and preference for natural foods (Evans et al., 2010; Rozin & Fischler, 2012). Food choices are further influenced by physiological, psychological, social, environmental, and technological factors (Martín-Rodríguez et al., 2024), creating complex interplays between perception, knowledge, and behavior that warrant further investigation.

Another factor affecting risk perception and purchasing behavior is trust in regulations (Osaili et al., 2023). In Arab countries, FA regulations reflect a blend of international standards and localized adaptations. In Egypt, Decision 4/2020 established the National Food Safety Authority (NFSA) as the sole authority for amending the positive list of additives, drawing on the Codex Alimentarius (GSFA–JECFA) and EU standards (Codex Alimentarius, 2025; U.S. Department of Agriculture Foreign Agricultural Service, 2020). The Gulf Cooperation Council (GCC) states operate under GSO 2500:2022, which aligns with Codex frameworks and the International Numbering System (INS) for additives while also incorporating regional bans like that on Titanium Dioxide (TiO_2) (Gulf Food standards, 2023; Faour-Klingbeil & Todd, 2018). The Sultanate of Oman commits to Codex Alimentarius and international food safety standards (Codex Alimentarius, 2025). Jordan's food additive regulations, implemented by the Jordan Food and Drug Authority (JFDA), reference Codex, EU standards, and local technical regulations (JS 94:2017) (Faour-Klingbeil & Todd, 2018; Faour-Klingbeil et al., 2022), whereas Lebanon follows a dual Codex-EU framework under its Ministry of Public Health (NL 761:2016) (Faour-Klingbeil & Todd, 2018; Faour-Klingbeil et al., 2022). Despite these frameworks, food exports from several Arab nations (e.g., Egypt, Lebanon, Jordan) have faced USFDA rejections and UAE bans due to non-compliance with safety standards, particularly concerning excessive pesticide residues and additives (Faour-Klingbeil & Todd, 2018). These incidents highlight persistent challenges in harmonizing regulations with international safety expectations.

The growing consumption of ultra-processed foods (UPFs), as industrially manufactured products containing additives like emulsifiers and artificial preservatives (Cediel et al., 2021), exacerbates these concerns. In Lebanon, UPFs contribute 47 % of daily energy intake in children under five, with higher consumption linked to overweight/obesity (Chokor et al., 2025). Globally, UPF intake correlates with younger age, urban residence, and socioeconomic disparities (Dicken et al., 2023), indicating the need for targeted interventions.

By examining these dynamics within the context of divergent regulatory frameworks and rising UFP consumption, the study aims to investigate consumers' risk perceptions of FAs, purchasing behavior practice, and actual consumption frequency of foods containing FAs. The findings can improve food policy reforms and consumer education to bridge the gaps between regulation, knowledge, perception, and behavior.

2. Materials and methods

2.1. Study design

A cross-sectional analytical study was conducted online from January 1, 2024, to June 30, 2024. The research proposal was sent to international research groups in Arab countries to invite interested parties to join the study. Researchers from Egypt, Jordan, Lebanon, and Oman agreed to collaborate on this research project. Google Forms, a cloud-based survey powered by Google for online surveys, was used to develop the questionnaire. Data were collected throughout the six-month study period using the snowball technique (Parker et al., 2019). University students were recruited as initial participants and asked to share the survey link with their social networks using various social media platforms (WhatsApp, Facebook, and LinkedIn). The selection of the non-probabilistic sampling method is due to practical constraints, including limited resources for probability sampling across multiple countries, the need for rapid data collection during the specified timeframe, and the challenge of accessing diverse populations across four countries simultaneously. We acknowledge that this approach introduces inherent selection bias, likely resulting in overrepresentation of educated, urban, and younger participants with similar sociodemographic characteristics and social networks.

2.2. Participants

Eligible participants were young adults between the age of 20 to 35 years (World Medical Association, 2013), residing in their respective countries, regardless of their level of education, profession, or gender. All participants provided informed consent before taking part in the survey. The survey was conducted in English or Arabic, ensuring that respondents could understand one of these languages. The initial contact with participants was done through university students in each country who were trained and informed about the content and aim of the survey. A total of 2351 respondents participated from the four countries: 1181 from Egypt, 414 from Jordan, 342 from Lebanon, and 414 from Oman.

2.3. Sample size calculation

The minimum sample size was calculated using the G-Power software, version 3.0.10. The calculated effect size was 0.0526, expecting squared multiple correlations of 0.05 (R2 deviation from 0) related to the Omnibus test of multiple regression. The minimum necessary sample was $n = 400$, considering an alpha error of 5 %, a power of 80 %, and allowing 20 predictors in the model. The 20 predictors included the sociodemographic characteristics (age, gender, marital status, education level, nutritionist status), self-perceived FA knowledge level, preferred information communication method, risk perception items (harmfulness, quality concerns, allergy risk, cancer risk, child safety, natural preference), practice items (willingness to pay more, natural FAs preference, shopping attention, quality beliefs, cooking preference, government trust, colorant avoidance, aspartame avoidance, manufacturer trust), and consumption frequency of high-FA foods and beverages.

2.4. Questionnaire

The questionnaire consisted of four parts, in addition to the introduction to the survey that encompasses the study topic, objectives, and a statement of consent. It was initially formulated in English and adopted from previous validated scales (Bearth et al., 2014; Osaili et al., 2023; Shim et al., 2011; Melios et al., 2025). The questionnaire was translated to Arabic and back-translated to English. English versions were compared, with minor discrepancies corrected by consensus between the translators and principal investigator in each country. The questionnaire was pilot-tested with a small sample ($n = 20$) of participants representing the target population. The pilot study assessed question clarity, identified ambiguous items, estimated completion time, and evaluated the reliability of measurement scales. Based on pilot feedback, minor wording adjustments were made to improve comprehension while maintaining the original meaning of items.

The first part included the socio-demographic characteristics of participants, such as age, gender, marital status, being a nutritionist, and education level. The second part examined the consumer's self-perceived level of information about FAs and food labels, in addition to the preferred method of FA information communication. The third part entailed 15 questions evaluating FAs' risk perception and practice. This part was divided into two sub-sections: Section 1 examined the consumer risk perception of FAs (Cronbach's alpha =0,91). Participants were asked to rate each item using a 5-point Likert scale, ranging from 1 for strongly disagree to 5 for strongly agree. Higher scores indicated higher risk perception. Perception questions were as follows: 1) Foods containing additives are harmful to human health, 2) Foods containing additives are of low quality, 3) Food additives may cause allergy, 4) Food additives may cause cancer, 5) I consider that food additives are more harmful to children, 6) Natural foods are better for my health. Whereas, Section 2 evaluated the practice toward FAs and choices made between natural products and those containing FAs (Cronbach's alpha =0,92). The same Likert scale was used as above. Practice questions were as follows: 1) I don't mind paying more for additive-free food, 2) I choose natural food additives because they are safer than artificial ones, 3) I pay attention during grocery shopping to ensure that the foods are as natural as possible, 4) The more natural the products are, the higher the quality of nutrients and vitamins, 5) I prefer cooking for my family to avoid purchasing product that contains food additives, 6) I don't worry about food additives because I trust that the government will not allow the marketing of any harmful, 7) I avoid purchasing any product containing colorant, 8) I avoid purchasing any product containing Aspartame (artificial sweetener) for my children, 9) Trust that food manufacturers do not add too many permitted food additives to their products.

The fourth part included a list of sweet, savory foods and beverages with high to moderate FAs levels. Consumers were asked to indicate the frequency of consumption based on a six-item Likert scale ranging from none, once or less monthly, once per month, more than once per week, once per week, once per day, and more than once per day.

2.5. Ethical consideration

The study received ethical approval from the Ethics and Research Committee at the Lebanese International University (LIU) under the code 2023ERC-129-LIUSOP. The study adheres to the principles outlined in the Declaration of Helsinki (Goodyear et al., 2007). Before proceeding with the survey, participants provided informed consent by clicking a box, which confirmed their understanding of the study objectives and their freedom to withdraw at any time. Consent was further implied through the completion and submission of the online survey. All collected data were anonymous.

2.6. Statistical analysis

We used the FACTOR program v.12.04.01 (Lorenzo-Seva & Ferrando, 2006) to perform the Exploratory Factor Analysis (EFA). A minimum sample between 60 participants was deemed necessary based on ten participants per scale's item. We carried out an EFA in the first subsample, made up of 33 % (1/3) of the total sample (762 subjects). The Kaiser-Meyer-Olsen (KMO) and Bartlett's p values were used to confirm the adequacy of the data for EFA. The Measure of Sampling Adequacy (MSA) values were verified to check if any item needs to be eliminated if MSA < 0.5 (Kaiser & Rice, 1974). Moreover, the Expected Residual correlation direct Change (EREC) index was used to assess the residual correlation between two items (i.e. doublets); items appearing in different doublets were removed (Ferrando et al., 2022). The polychoric correlations were applied too since the data had an ordinal nature. The Unweighted Least Squares (ULS) method was used to extract the factors (Lloret-Segura et al., 2014) with no rotation applied, whereas the Parallel Analysis was used to determine the number of factors to be extracted (Timmerman & Lorenzo-Seva, 2011; Garrido et al., 2019) the latter was conducted based on 500 random datasets using permutation of the raw data.

Subsequently, we conducted a Confirmatory Factor Analysis (CFA) to verify the factor structure obtained in the EFA, on the remaining 66 % (2/3) of the sample ($n = 1589$) using the SPSS AMOS v.30. The minimum sample size to perform a CFA ranges from 3 to 20 times the number of items of the scale (Mundfrom & Shaw, 2005). Thus, a minimum sample of 120 participants was assumed as required to have enough statistical power. To check the adequacy of the model, several fit indices were calculated: the root mean square error of approximation (RMSEA; ≤ 0.08), the normed model chi-square (χ^2/df; ≤ 5), the comparative fit index (CFI), the Tucker-Lewis Index (TLI) (≥ 0.90 for both), and standardized root mean square residual (SRMR; ≤ 0.05) (Hu & Bentler, 1999). Multivariate normality was not verified at first (Bollen-Stine bootstrap $p = 0.002$); thus, we conducted non-parametric bootstrapping procedure. Evidence of convergent validity was confirmed via the calculation of the Average Variance Extracted (should be > 0.5).

To test measurement invariance of the perception and practice scores between genders and countries, we performed multi-group CFA (Chen, 2007) using the total sample. Measurement invariance was evaluated at the configural, scalar, and metric levels (Vadenberg & Lance, 2000) We accepted ΔCFI ≤ 0.010 and ΔRMSEA ≤ 0.015 or ΔSRMR ≤ 0.010 as evidence of invariance (Swami et al., 2022).

SPSS software version 27 was used to analyze the data. McDonald's ω coefficient and Cronbach's α coefficient were used to test reliability. The perception and practice scores were considered normally distributed according to its kurtosis and skewness values (between ±1). The Student's *t*-test was employed to compare two means, while the ANOVA test was used for comparing three or more means. The Pearson correlation test assessed the relationship between two continuous variables. Subsequently, two linear regressions were performed, with "risk perception score" and "practice score" taken as the dependent variables. Independent variables entered in the models were those that showed a $p < 0.25$ in the bivariate analysis (Bursac et al., 2008). $P < 0.05$ was considered statistically significant.

3. Results

3.1. Descriptive analysis

A total of 2351 participants were enrolled in the study from four Arab countries (Egypt, Jordan, Lebanon, and Oman). The sample was predominantly female (62.1 %), single (76.3 %), with a mean age of 27.27 ± 9.66 (years) and university degree (83.6 %). A number of participants were healthcare professionals (33.3 %) including nutritionists (11.4 %) (Table 1).

Data comparison of the four Arab countries revealed distinct patterns in food label reading, food labeling awareness, information about FA, and communication preferences. (Fig. 1 and Table 2). More than half of the participants stated that they read the food label. Jordan showed the highest rate of food label reading (79 %) and significant concern for insufficient FA education (61.6 %). Lebanon scored the lowest rates of food label reading (57 %), insufficient FA education (26.6 %), and difficulties understanding FA information (8.2 %), suggesting either higher nutritional literacy or lower awareness of FA-related issues. Egypt aligned closely with overall averages but showed the highest rates of perceived insufficient FA labeling (59.4 %) and difficulties understanding FA information (28.8 %). Oman expressed the most concern for insufficient FA education (65.7 %) (Table 2).

Regarding preferred communication methods, small booklets were most favored overall (21.7 %), with Jordan showing the highest preference (24.4 %). Phone apps were the second most popular method (21.3 %), particularly in Oman (23.2 %), while online education was most preferred in Lebanon (22.8 %). Notably, Lebanon also showed a higher preference for posters (20.5 %) compared to other countries (Table 2).

Oman exhibited the highest risk perception (22.82 ± 3.54) and practice mean scores (33.79 ± 4.81), indicating heightened awareness and more cautious behaviors towards FAs. In contrast, Egypt showed the lowest mean scores in both risk perception (16.40 ± 5.78) and practices (25.38 ± 8.12), suggesting lower concern and less stringent behaviors. Jordan and Lebanon demonstrated intermediate levels, with Jordan scoring slightly higher in practices (31.79 ± 4.81) compared to Lebanon (29.83 ± 5.74), despite similar risk perception mean scores (Table 2).

Analysis of data from the food frequency questionnaire showed various consumption patterns across various food and beverage categories. These results reveal complex relationships between consumer behavior and potential concerns about FAs. While some products showed high rates of daily consumption, such as chips (36.4 %), chocolate (36.3 %), and bottled juice (40.7 %), others demonstrated notable avoidance, particularly artificial sugar substitutes (27.6 % never consume) and energy drinks (32.4 % never consume). Most categories exhibited peak consumption frequencies of once per week, suggesting a trend towards moderation (Fig. 2, Fig. 3).

3.2. Exploratory and confirmatory factor analyses results

Model 1: Perception scale

Table 1
Sociodemographic characteristics of participants ($n = 2351$).

	All countries $n = 2351$	Egypt $n = 1181$	Jordan $n = 414$	Lebanon $n = 342$	Oman $n = 414$
Gender					
Male	892 (37.9 %)	444 (37.6 %)	190 (45.9 %)	191 (55.8 %)	67 (16.2 %)
Female	1459 (62.1 %)	737 (62.4 %)	224 (54.1 %)	151 (44.2 %)	347 (83.8 %)
Marital status					
Single	1793 (76.3 %)	943 (79.8 %)	335 (80.9 %)	182 (53.2 %)	333 (80.4 %)
Married	558 (23.7 %)	238 (20.2 %)	79 (19.1 %)	160 (46.8 %)	81 (19.6 %)
Have children					
No	1890 (80.4 %)	958 (81.1 %)	370 (89.4 %)	192 (56.1 %)	370 (89.4 %)
Yes	461 (19.6 %)	223 (18.9 %)	44 (10.6 %)	150 (43.9 %)	44 (10.6 %)
University degree					
No	386 (16.4 %)	119 (10.1 %)	122 (29.5 %)	116 (33.9 %)	29 (7 %)
Yes	1965 (83.6 %)	1062 (89.9 %)	292 (70.5 %)	226 (66.1 %)	385 (93 %)
Nutritionist					
No	2082 (88.6 %)	970 (82.1 %)	375 (90.6 %)	331 (96.8 %)	405 (97.8 %)
Yes	269 (11.4 %)	211 (17.9 %)	38 (9.2 %)	11 (3.2 %)	9 (2.2 %)
Healthcare professional					
No	1566 (66.7 %)	610 (51.7 %)	306 (73.9 %)	266 (78.2 %)	384 (92.8 %)
Yes	783 (33.3 %)	571 (48.3 %)	108 (26.1 %)	74 (21.8 %)	30 (7.2 %)
Food allergy					
No	1963 (83.5 %)	982 (83.1 %)	354 (85.5 %)	309 (90.4 %)	318 (83.5 %)
Yes	388 (16.5 %)	199 (16.9 %)	60 (23.2 %)	33 (9.6 %)	96 (23.2 %)
			mean ±SD		
Age (years)	27.27 ± 9.66	25.14 ± 8.36	32.05 ± 8.90	33.68 ± 12.14	22.87 ± 6.07

SD: standard deviation.

Firstly, the suitability of the data for EFA was confirmed via Bartlett's test ($p \leq 0.001$) and the KMO test (KMO = 0.880). None of the items was removed because of low communality (< 0.3) or low MSA (< 0.5) or because of the presence of doublets. Findings showed an adequate fit to a one-dimensional solution supported by the parallel analysis, the GFI (GFI = 0.99) being higher than 0.95, the explained variance being of 70.10 %, the I-ECV (I-ECV = 0.88) being higher than 0.85, the UniCo index (UniCo = 0.98) being higher than 0.95, and the MIREAL (MIREAL = 0.26) being lower than 0.30.

The unidimensional model was tested via a CFA on subsample 2. Results showed that fit of the single-factor model of the perception scale was modest (SRMR = 0.062, CFI = 0.918, TLI = 0.864 and RMSEA = 0.180 [0.167, 0.194]) but improved after adding a correlation between residuals of items 1 and 2 due to high modification indices (= 269.86) (SRMR = 0.030, CFI = 0.969, TLI = 0.942 and RMSEA = 0.118 [0.103, 0.133]). Results showed that fit of the single-factor model of the perception scale was poor (SRMR = 0.062, CFI = 0.918, TLI = 0.864 and RMSEA = 0.180 [0.167, 0.194]) but improved after adding a correlation between residuals of items 1 and 2 due to high modification indices (=

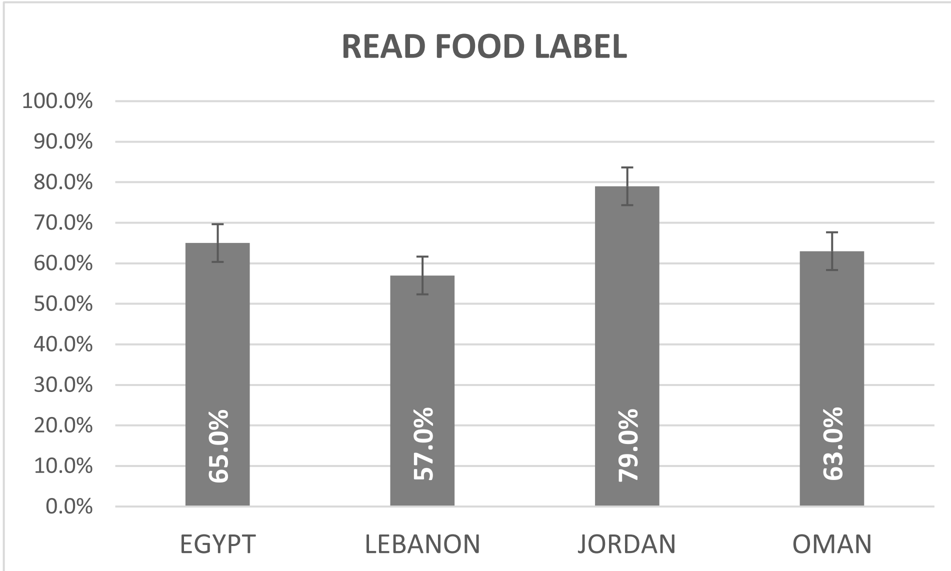

Fig. 1. Percentage of participants that read the food label per country.

Table 2
Information about FAs and preferred method of communication.

	All countries n = 2351	Egypt n = 1181	Jordan n = 414	Lebanon n = 342	Oman n = 414
Information about food additives					
Insufficient education*	1256 (53.4 %)	638 (54 %)	255 (61.6 %)	91 (26.6 %)	272 (65.7 %)
Insufficient food labeling *	1219 (51.9 %)	701 (59.4 %)	164 (39.6 %)	181 (52.9 %)	173 (41.8 %)
Difficulties understanding *	556 (23.6 %)	340 (28.8 %)	95 (22.9 %)	28 (8.2 %)	93 (22.5 %)
Preferred method for information communication*					
Small booklet (leaflet)	511 (21.7 %)	268 (22.7 %)	101 (24.4 %)	48 (14.8 %)	94 (22.7 %)
Sales person	237 (10.1 %)	115 (9.7 %)	52 (12.6 %)	38 (11.1 %)	32 (7.7 %)
Animation	332 (14.1 %)	168 (14.2 %)	70 (16.9 %)	35 (10.2 %)	59 (14.3 %)
Poster	350 (14.9 %)	168 (14.2 %)	47 (11.47 %)	70 (20.5 %)	65 (15.7 %)
A phone app	501 (21.3 %)	263 (22.3 %)	69 (16.7 %)	73 (21.3 %)	96 (23.2 %)
Online education	420 (17.9 %)	199 (16.9 %)	75 (18.1 %)	78 (22.8 %)	68 (16.4 %)
			mean ±SD		
Risk perception	19.03 ± 5.89	16.40 ± 5.78	21.03 ± 5.85	21.10 ± 3.99	22.82 ± 3.54
Practice of food additives	28.63 ± 8.02	25.38 ± 8.12	31.79 ± 4.81	29.83 ± 5.74	33.79 ± 4.81

* Answer: Yes; SD: standard deviation.

269.86) (SRMR = 0.030, CFI = 0.969, TLI = 0.942 and RMSEA = 0.118 [0.103, 0.133]). While the RMSEA remained above the recommended threshold of 0.08, other fit indices (CFI, TLI, SRMR) demonstrated acceptable fit.

Besides, the AVE value was appropriate = 0.58. The reliability of the items was good for the perception scale in the total sample (α = 0.89 / ω = 0.90), sample 1 (α = 0.89 / ω = 0.90) and sample 2 (α = 0.89 / ω = 0.90).

Model 2: Practice scale

Two items (Osaili et al., 2023; Shim et al., 2011) were removed because of low communality (< 0.3) in the first EFA. Consequently, the suitability of the data for the second EFA was confirmed via Bartlett's test ($p \leq 0.001$) and the KMO test (KMO = 0.921). Findings showed an adequate fit to a one-dimensional solution supported by the parallel analysis, the GFI (GFI = 0.99) being higher than 0.95, the explained variance being of 74.45 %, the I-ECV (I-ECV = 0.94) being higher than 0.85, the UniCo index (UniCo = 0.99) being higher than 0.95, and the MIREAL (MIREAL = 0.19) being lower than 0.30.

The unidimensional model was tested via a CFA on subsample 2. Results showed that fit of the single-factor model of the practice scale was modest (SRMR = 0.043, CFI = 0.942, TLI = 0.913 and RMSEA = 0.138 [0.127, 0.149]) but improved after adding a correlation between residuals of items 7 and 8 due to high modification indices (= 243.70) (SRMR = 0.026, CFI = 0.978, TLI = 0.964 and RMSEA = 0.089 [0.078, 0.101]). The AVE value was appropriate = 0.61. The RMSEA approached but slightly exceeded the recommended threshold of 0.08, while other fit indices indicated good model fit. The reliability of the items was good for the practice scale in the total sample (α = 0.92 / ω = 0.92), sample 1 (α = 0.93 / ω = 0.93) and sample 2 (α = 0.92 / ω = 0.92). The standardized estimates of factor loadings of the EFA and CFA for both scales were appropriate (Table 3).

3.3. Measurement invariance

The results of measurement invariance between genders at the configural, metric and scalar levels and between countries at the configural and metric levels are shown in Table 4. The results showed that there was no significant difference between males and females in terms of perception (18.92 ± 5.92 vs 19.09 ± 5.87, $t(2349) = -0.68$, $p = 0.495$, Cohen's $d = 0.029$) and practice (22.52 ± 6.82 vs 22.55 ± 7.10, $t(2349) = -0.10$, $p = 0.922$, Cohen's $d = 0.004$) scores.

Measurement invariance testing revealed that both perception and practice scales achieved configural and metric invariance across countries, indicating that the factor structure and item loadings are comparable. However, scalar invariance was not supported (ΔCFI = 0.146 for perception; ΔCFI = 0.061 for practice), suggesting that item intercepts differ across countries. This lack of scalar invariance indicates that observed mean differences across countries may partially reflect

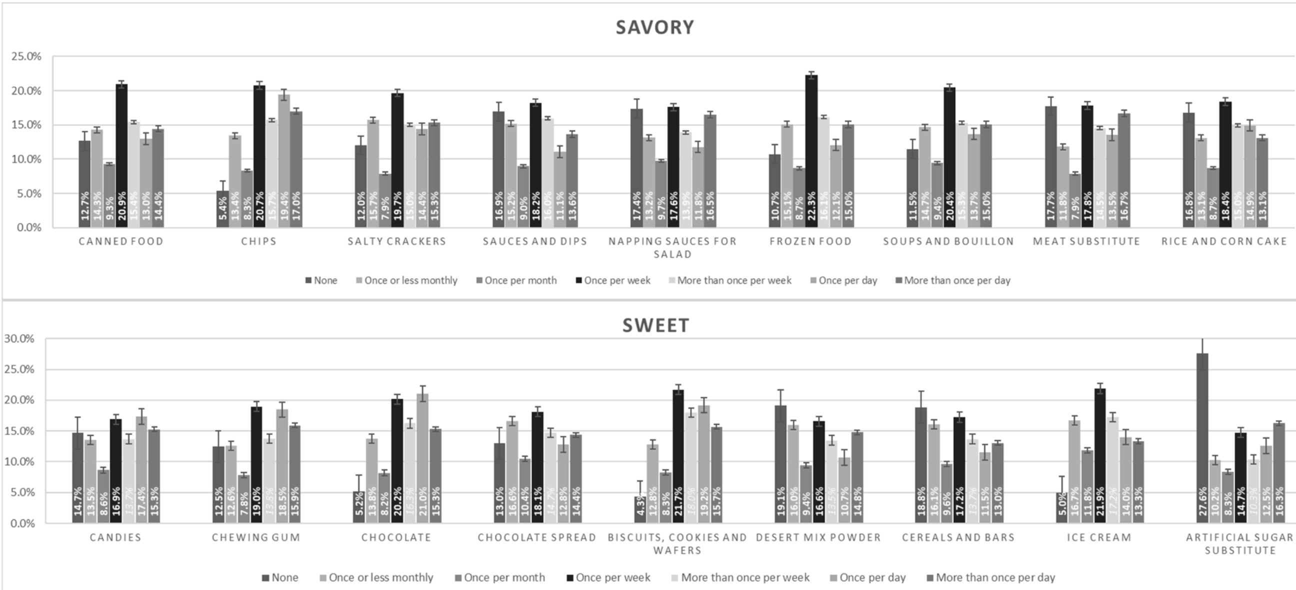

Fig. 2. Consumption frequency of FA-containing sweets and savory in four Arab countries.

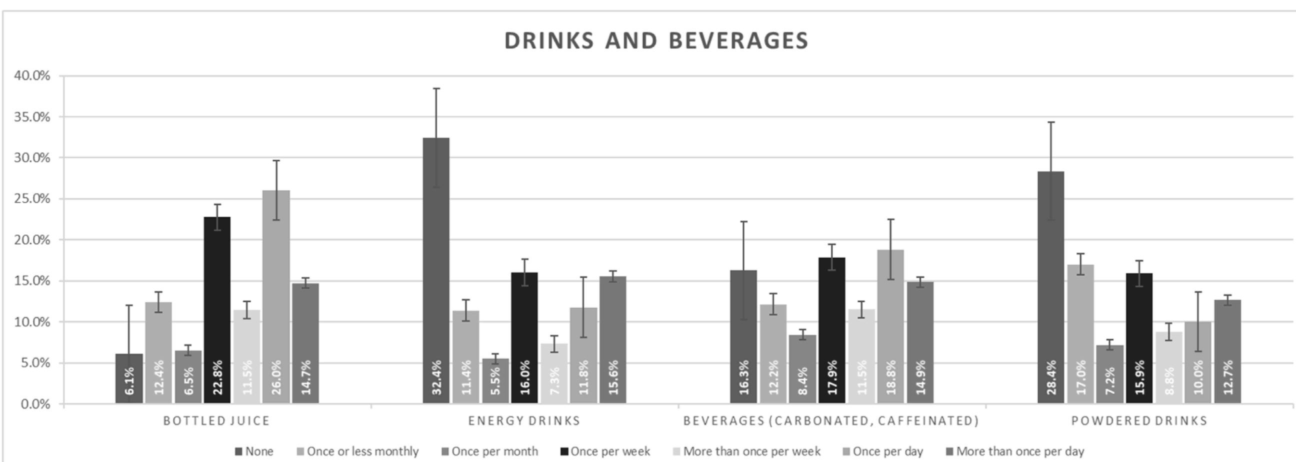

Fig. 3. Consumption frequency of FA-containing drinks and beverages in four Arab countries.

differences in response styles or item interpretation rather than true differences in the underlying constructs. Therefore, cross-country mean comparisons should be interpreted with caution.

Accordingly, descriptive comparisons showed a higher mean perception score was significantly found in Oman (22.82 ± 3.54), followed by Lebanon (21.10 ± 3.99), Jordan (21.03 ± 5.85) and Egypt (16.40 ± 5.78), F (3, 2347) = 210.51, $p < 0.001$ (where: 3 = degrees of freedom between groups (4 countries - 1), 2347 = degrees of freedom within groups (your total sample size - 4)). The post-hoc analysis revealed that this difference was significant between Lebanon and Egypt ($p < 0.001$), Lebanon and Oman ($p < 0.001$), Jordan and Egypt ($p < 0.001$), Egypt and Oman ($p < 0.001$) and Jordan and Oman ($p < 0.001$). A higher mean practice score was significantly found in Oman (27.62 ± 4.36), followed by Lebanon (25.19 ± 5.17), Jordan (24.88 ± 6.09) and Egypt (19.17 ± 6.76), F (3, 2347) = 260.98, $p < 0.001$. The post-hoc analysis revealed that this difference was significant between Lebanon and Egypt ($p < 0.001$), Lebanon and Oman ($p < 0.001$), Jordan and Egypt ($p < 0.001$), Egypt and Oman ($p < 0.001$) and Jordan and Oman ($p < 0$ 0.001).

3.4. *Concurrent validity*

Higher risk perception scores were significantly and strongly correlated with better practice ($r = 0.76$; $p < 0.001$) and weakly with older age ($r = 0.09$; $p < 0.001$), whereas better practice was significantly and weakly associated with older age ($r = 0.10$; $p < 0.001$) (Table 5).

3.5. *Bivariate analyses*

Higher risk perception and practice scores were significantly found in Omani participants compared to other countries, in those who do not hold a university degree, who are not healthcare professionals, who have food allergy, who do not acknowledge insufficient labeling about food additives and in those who do not have difficulties understand FA information (Table 6).

3.6. *Multivariable analysis*

The results of the linear regression that considered risk perception as the dependent variable, showed that Egyptians vs Lebanese (Beta = −4.88; CI= −5.57; −4.19) and reading food labels (Beta = −0.55; CI=

Table 3
English items of the perception and practice scores, and standardized estimates of factor loadings from the exploratory (EFA) and confirmatory factor analysis (CFA).

Items	EFA	CFA
Model 1: Perception scale		
1. Foods containing additives are harmful to human health	0.74	0.64
2. Foods containing additives are of low quality	0.64	0.52
3. Food additives may cause allergies	0.87	0.83
4. Food additives may cause cancer on the long-term	0.88	0.84
5. Food additives are more harmful to children	0.90	0.87
6. Natural foods are better for my health	0.77	0.81
Model 2: Practice scale		
1. I don't mind paying more for additive-free food	0.73	0.67
2. I choose natural food additives because they are safer than artificial ones	0.88	0.86
3. I pay attention during grocery shopping to ensure that the foods are as natural as possible	0.89	0.80
4. he more natural the products are, the higher the quality of nutrients and vitamins	0.87	0.87
5. I prefer cooking for my family to avoid purchasing product that contains food additives	0.89	0.86
6. I don't worry about food additives because I trust that the government will not allow the marketing of any harmful	-	-
7. I avoid purchasing any product containing colorants	0.78	0.66
8. I avoid purchasing any product containing Aspartame (artificial sweetener) for my children	0.82	0.70
9. I trust that food manufacturer do not add too many permitted food additives to their products	-	-

EFA = Exploratory Factor Analysis; CFA = Confirmatory Factor Analysis. Factor loadings ≥ 0.40 considered adequate. Model fit for perception scale after modification: CFI = 0.969, TLI = 0.942, RMSEA = 0.118 [0.103, 0.133], SRMR = 0.030. Model fit for practice scale after modification: CFI = 0.978, TLI = 0.964, RMSEA = 0.089 [0.078, 0.101], SRMR = 0.026. Items 6 and 9 were removed from the practice scale due to low communality (<0.3).

−1.01; −0.09) were significantly associated with lower risk perception, whereas Omani vs Lebanese (Beta = 2.19; CI= 1.36; 3.01), being a nutritionist (Beta = 1.90; CI= 1.19; 2.61) or a healthcare professional (Beta = 0.66; CI= 0.16; 1.16), having food allergy (Beta = 1.53; CI= 0.94; 2.11) and older age (Beta = 0.03; CI= 0.01; 0.06) were significantly associated with higher risk perception (Table 7, Model 1).

The results of the linear regression that considered practice as the dependent variable, showed that Egyptians vs Lebanese (Beta = −2.17; CI= −2.78; −1.55) and being a healthcare professional (Beta = −0.43; CI= −0.85; −0.01) were significantly associated with worse practice, whereas Omani vs Lebanese (Beta = 1.04), having food allergy (Beta = 0.65; CI= 0.15; 1.16) and higher risk perception (Beta = 0.78; CI= 0.75; 0.82) were significantly associated with better practice (Table 7, Model 2).

4. Discussion

This study provides distinct insights into consumer perceptions and behaviors regarding FAs across four Arab countries. Results showed that national differences dominated individual factors, healthcare professionals demonstrated a disconnected risk perception and purchasing behavior, and label reading was associated with lower risk perception.

4.1. Cross-national variations and demographic influences

Data analysis revealed notable cross-national differences in risk perception and practices with Oman exhibiting the highest risk perception (β=2.19 vs Lebanon, $p < 0.001$) and practice (β=1.04, $p = 0.004$) scores, while Egypt showed the lowest (β=−4.88 and −2.17 respectively, $p < 0.001$). However, the lack of scalar invariance in our measurement models limits definitive conclusions about whether these differences reflect true variation in underlying attitudes or differences in how participants across countries interpreted and responded to survey items. These findings, supported by robust model fits (Nagelkerke $R^2 = 0.252$ for perception and 0.606 for practice), suggests that country level factors, such as stringent regulations and public health campaigns as observed in some studies (Johnson & Swedlow, 2020), may outweigh individual demographic factors in shaping FA-related behaviors, though cultural differences in response styles cannot be ruled out. The stronger predictive power for practices ($R^2 = 0.606$) indicates that risk perception (β=0.78, $p < 0.001$) is the dominant behavioral driver. This finding aligns with the theory of planned behavior where perceived risk acts as a key motivator for behavioral change (Chen, 2017). However, residual variance implies unmeasured influences (e.g., media exposure, cultural trust in food systems), particularly in Egypt where risk perception was markedly lower. Although all participants fell within the target age range of 20–35 years, substantial differences in mean age existed between countries (Oman: 22.87 years vs Lebanon: 33.68 years). While age

Table 5
Correlations between age, risk perception and practice toward food additives.

	Risk perception scale	Practice scale	Age
Risk perception scale	1		
Practice scale	0.76***	1	
Age	0.09***	0.10***	1

*** $p < 0.001$.

Table 4
Measurement invariance across genders and countries in the total sample.

Model	CFI	RMSEA	SRMR	Model Comparison	ΔCFI	ΔRMSEA	ΔSRMR
Perception scale							
Model 1a: Genders							
Configural	0.974	0.076	0.028				
Metric	0.972	0.069	0.039	Configural vs metric	0.002	0.007	0.011
Scalar	0.970	0.064	0.039	Metric vs scalar	0.002	0.005	<0.001
Model 2a: Countries							
Configural	0.948	0.067	0.047				
Metric	0.937	0.062	0.067	Configural vs metric	0.011	0.005	0.020
Scalar	0.791	0.099	0.098	Metric vs scalar	0.146	0.037	0.031
Practice scale							
Model 1b: Genders							
Configural	0.976	0.066	0.029				
Metric	0.976	0.060	0.033	Configural vs metric	<0.001	0.006	0.004
Scalar	0.975	0.057	0.033	Metric vs scalar	0.001	0.003	<0.001
Model 2b: Countries							
Configural	0.978	0.040	0.041				
Metric	0.972	0.039	0.054	Configural vs metric	0.006	0.001	0.013
Scalar	0.911	0.062	0.077	Metric vs scalar	0.061	0.023	0.023

Note. CFI = Comparative fit index; RMSEA = root mean square error of approximation; SRMR = Standardized root mean square residual.

Table 6
Bivariate analysis of factors associated with perception and practice toward food additives.

	Risk perception					Practice				
	mean ± *SD*	t / F	df / df1,df2	*p*	Effect size	*mean* ± *SD*	t / F	df / df1,df2	*p*	Effect size
Country		210.51	3, 2347	**<0.001**	0.184	260.98	260.98	3, 2347	**<0.001**	**0.250**
Lebanon	21.10 ± 3.99					25.19 ± 5.17				
Egypt	16.40 ± 5.78					19.17 ± 6.76				
Jordan	21.03 ± 5.85					24.88 ± 6.09				
Oman	22.82 ± 3.54					27.62 ± 4.36				
Gender		−0.68	2349	0.495	0.029		−0.10	2349	0.922	0.004
Male	18.92 ± 5.92					22.52 ± 6.82				
Female	19.09 ± 5.87					22.55 ± 7.10				
Marital status		−1.46	2349	0.144	0.071		−1.85	2349	0.065	0.089
Single	18.93 ± 5.90					22.39 ± 6.94				
Married	19.35 ± 5.84					23.01 ± 7.15				
Have children		0.78	2349	0.434	0.042		0.50	2349	0.621	0.026
No	19.08 ± 5.82					22.57 ± 6.94				
Yes	18.83 ± 6.14					22.39 ± 7.23				
University degree		2.82	2349	**0.005**	0.157		3.50	2349	**<0.001**	0.180
No	19.80 ± 5.64					23.59 ± 6.30				
Yes	18.88 ± 5.92					22.33 ± 7.11				
Dietitian		−1.51	2349	0.122	0.100		0.11	2348	0.914	0.007
No	18.96 ± 5.86					22.54 ± 6.95				
Yes	19.54 ± 6.06					22.49 ± 7.40				
Healthcare professional		4.35	2347	**<0.001**	0.190		7.50	2347	**<0.001**	0.328
No	19.40 ± 5.80					23.29 ± 6.80				
Yes	18.28 ± 6.00					21.02 ± 7.16				
Read food label		1.57	2349	0.117	0.068		0.004	2349	0.997	<0.001
No	19.29 ± 5.77					22.54 ± 6.57				
Yes	18.89 ± 5.94					22.54 ± 7.21				
Food allergy		−5.38	2349	**<0.001**	0.299		−5.04	2349	**<0.001**	0.296
No	18.74 ± 5.80					22.20 ± 6.85				
Yes	20.49 ± 6.10					24.26 ± 7.45				
Insufficient labeling about FAs		4.09	2349	**<0.001**	0.169		4.67	2349	**<0.001**	0.192
No	19.54 ± 5.65					23.23 ± 6.63				
Yes	18.55 ± 6.06					21.89 ± 7.26				
Insufficient education about FAs		0.58	2349	0.563	0.024		1.78	2349	0.075	0.074
No	19.10 ± 5.86					22.81 ± 6.97				
Yes	18.96 ± 5.91					22.30 ± 7.01				
Difficulties understanding FAs information		3.95	2348	**<0.001**	0.192		4.02	2349	**<0.001**	0.202
No	19.29 ± 5.83					22.87 ± 6.86				
Yes	18.17 ± 5.98					21.46 ± 7.33				

SD: standard deviation; FAs: food additives; numbers in bold indicate significant p values.

showed only weak correlations with outcomes ($r = 0.09–0.10$) and was controlled in multivariable models (β=0.03, $p = 0.014$ for perception), the unequal age distribution across countries may introduce some confounding. Notably, Oman's younger sample paradoxically showed the highest risk perception despite younger age sometimes being associated with lower health consciousness in the literature. This pattern may reflect cohort-specific experiences, such as differential exposure to recent food safety education or social media campaigns targeting younger demographics, rather than purely national differences. Contrary to studies demonstrating the age and gender influence on FA risk perception and practice (Osaili et al., 2023; Rozin & Fischler, 2012; Chen, 2017; Oakes & Slotterback, 2001; Sameshima & Akamatsu, 2023; Gundala et al., 2022; Bayram & Ozturkcan, 2023; Grunert et al., 2001; Harnack et al., 1997), our results showed negligible gender associations and only weak age correlations. This discrepancy may partially reflect restricted demographic variance resulting from our snowball sampling approach, which produced a sample with marked homogeneity (83.6 % university-educated, mean age 27.27 years). This sampling approach likely created clusters of participants with similar characteristics and limited variance in key demographic variables, potentially masking associations that would be observable in more heterogeneous populations. On the other hand, the relationship between the level of education and FA knowledge, perception and attitude showed variable results in the literature (Bearth et al., 2014; Osaili et al., 2023; Shim et al., 2011; Wu et al., 2013; Kayışoğlu & Coşkun, 2016). Interestingly, being a nutritionist was positively associated, in this study, with a high-risk perception (β=1.90, $p < 0.001$), whereas general education level (university degree) showed no significant effect. Healthcare professionals exhibited a mismatched risk perception and practice behavior (β=−0.43, $p = 0.045$), suggesting that knowledge alone may not translate into behavior. Healthcare professionals may prioritize convenience due to time constraints, or they may trust regulatory standards despite awareness of risks. The disconnect among healthcare professionals suggests that subjective norms (e.g., workplace culture) may override personal attitudes (Chen, 2017). However, careful interpretation of this finding may be warranted because our sampling method may have captured a specific subset of younger, digitally engaged healthcare professionals whose time constraints and workplace circumstances may differ from the broader professional population.

Participants with food allergies reported significantly higher FA perception and practice scores, reflecting their enhanced awareness and caution about food additives in their diets. This finding aligns with the broader context of health concerns about food additives (Bearth et al., 2014; Osaili et al., 2023; Trasande et al., 2018; Savin et al., 2022; Shim et al., 2011; Buchler et al., 2010; Pomeranz et al., 2024; Eiser et al., 2002; Warner, 2024; Hauser et al., 2011; Choe et al., 2005; Ismail et al., 2017). Our results strongly support the Theory of Planned Behavior (TPB), as demonstrated by the significant association between risk perception and practices.

However, the substantial residual variance indicates that subjective norms and perceived control may exert independent influences.

Cross-national differences exemplify varying subjective norms. Oman's higher practice scores may reflect stronger social norms favoring additive avoidance, shaped by stricter regulations, public health

Table 7
Multivariable analyses.

	Unstandardized beta	Standardized beta	p value	95 % CI
Model 1: Linear regression taking the risk perception score as the dependent variable (Nagelkerke $R^2 = 0.252$)				
Egypt vs Lebanon*	−4.88	−0.41	**<0.001**	−5.57; −4.19
Jordan vs Lebanon*	0.20	0.01	0.612	−0.57; 0.97
Oman vs Lebanon*	2.19	0.14	**<0.001**	1.36; 3.01
Marital status (married vs single*)	−0.26	−0.02	0.372	−0.84; 0.31
University degree (yes vs no*)	−0.18	−0.01	0.581	−0.81; 0.46
Nutritionist (yes vs no*)	1.90	0.10	**<0.001**	1.19; 2.61
Healthcare professional (yes vs no*)	0.66	0.05	**0.010**	0.16; 1.16
Read food label (yes vs no*)	−0.55	−0.04	**0.019**	−1.01; −0.09
Food allergy (yes vs no*)	1.53	0.10	**<0.001**	0.94; 2.11
Insufficient labeling (yes vs no*)	−0.10	−0.01	0.655	−0.53; 0.34
Difficulties understanding FAs info (yes vs no*)	−0.41	−0.03	0.115	−0.92; 0.10
Age	0.03	0.06	**0.014**	0.01; 0.06
Model 2: Linear regression taking the practice score as the dependent variable (Nagelkerke $R^2 = 0.606$)				
	Unstandardized beta	**Standardized beta**	**p value**	**95 % CI**
Egypt vs Lebanon*	−2.17	−0.16	**<0.001**	−2.78; −1.55
Jordan vs Lebanon*	−0.23	−0.01	0.489	−0.89; 0.42
Oman vs Lebanon*	1.04	0.06	**0.004**	0.33; 1.75
Marital status (married vs single*)	−0.10	−0.01	0.678	−0.60; 0.39
University degree (yes vs no*)	0.02	0.001	0.954	−0.52; 0.55
Healthcare professional (yes vs no*)	−0.43	−0.03	**0.045**	−0.85; −0.01
Food allergy (yes vs no*)	0.65	0.03	**0.011**	0.15; 1.16
Insufficient labeling (yes vs no*)	−0.11	−0.01	0.549	−0.49; 0.26
Difficulties understanding FAs info (yes vs no*)	−0.19	−0.01	0.388	−0.63; 0.25
Age	0.02	0.02	0.188	−0.01; 0.04
Risk Perception	0.78	0.66	**<0.001**	0.75; 0.82

* Reference group; numbers in bold indicate significant *p* values.

campaigns, and cultural discourse emphasizing food purity. Conversely, Egypt's lower scores may indicate permissive norms where processed food consumption faces less social scrutiny.

The healthcare professional paradox indicates how low perceived behavioral control overrides attitudes. Time scarcity, limited workplace food options, and competing professional demands may reduce actual control over food choices despite knowledge and concern. This finding highlights those interventions targeting healthcare workers need to address structural barriers.

Food allergy status strengthened both attitudes and behaviors, illustrating that personal health relevance enhances attitude-behavior consistency by simultaneously increasing motivation and perceived necessity of control.

The negative association between label reading and risk perception challenges simple knowledge-deficit models. Within TPB, this may reflect enhanced perceived control: as label literacy increases, confidence in navigating food choices may reduce anxiety despite unchanged objective risks. Alternatively, it may indicate that current labels function as subjective norm cues signaling regulatory approval rather than risk warnings.

This theoretical lens reveals that effective interventions must address all three TPB components: enhancing risk awareness (attitudes), establishing social norms favoring additive avoidance through media campaigns and peer modeling (subjective norms), and removing structural barriers through improved product availability, clear labeling, and reduced cost differentials (perceived control).

4.2. Risk perception, behavioral patterns, and information processing

Contrary to expectations, frequent food label readers exhibited lower risk perception scores ($\beta = -0.55$, $p = 0.019$), a finding that persisted even after accounting for covariates in the high-fit model (Nagelkerke $R^2 = 0.252$). This finding indicates that label engagement may foster false reassurance, possibly due to insufficient hazard warnings or cognitive biases (e.g., 'label literacy' equated with safety). The negative association between label reading and risk perception may be related to optimism bias, whereby consumers assume that regulated and labeled products are inherently safe (Weinstein, 1980; Shepperd et al., 2013), or to information overload, where complex nutritional labels lead to cognitive disengagement and reduced risk sensitivity (Miller & Cassady, 2015; Grunert & Wills, 2007). Additionally, higher health literacy among frequent label readers may paradoxically reduce perceived risk through enhanced confidence in their ability to navigate food choices safely (Carbone & Zoellner, 2012). Revising labeling formats to highlight additive-related risks, particularly in high-consumption products like chips and bottled juice (Fig. 2), could mitigate this gap. This finding might indicate that current labeling practices may not effectively communicate potential risks or that increased familiarity with FAs through label reading might lead to decreased risk perception. Food label reading habits varied across the four Arab countries. The high rate of food label reading in Jordan, coupled with concerns about insufficient FA education, contrasts with lower rates of label reading and difficulties in understanding FA information in Lebanon. This variability suggests diverse levels of nutritional literacy and awareness across countries. The results in Egypt align with overall averages but show high perceived insufficiency in FA labeling. Concern for FA education in Oman underscores the need for more information on food additives. This finding indicates the need for improved clarity and information accessibility in food labels and aligns with global research on FA and food label understanding that showed varying levels of consumer literacy (Osaili et al., 2023; Shim et al., 2011; Kayışoğlu & Coşkun, 2016; Ajzen, 2011). In the UAE, Osaili (2023) (Osaili et al., 2023) showed that one-fourth of the respondents confirmed always reading the food label, and more than half of the participants reported that food labels provide insufficient information about FAs. In Turkey, Kayışoğlu (2016) (Kayışoğlu & Coşkun, 2016) found that only 13.3 % of participants could easily understand and interpret food labels. In korea, Shim et al. (2011) highlighted the widespread difficulty in understanding FAs, with most respondents reporting challenges in comprehending information about food additives. These findings point to the global nature of the issue, indicating significant variation in food literacy across different countries and cultures.

Nevertheless, the negative association between label reading and risk perception observed in our study warrants cautious interpretation, given the potential overrepresentation in our sample of individuals with higher baseline nutritional literacy who may interpret food labels differently than the general population.

The high Nagelkerke R^2 values for multivariable models (0.252 for perception; 0.606 for practice) suggest that the selected covariates, particularly country of residence, profession, and food allergy status, collectively explain a substantial proportion of variance in outcomes. The stronger fit for practices ($R^2 = 0.606$) highlights the centrality of risk perception ($\beta = 0.78$, $p < 0.001$) as a behavioral driver, consistent with the theory of planned behavior (Lloret-Segura et al., 2014). However, the residual variance implies unmeasured influences, such as media exposure or prior adverse experiences with additives, which future studies should address.

The study also found that the preferred methods for receiving information about FAs varied across countries. Small booklets were most favored overall, with Jordan showing the highest preference. Phone apps were the second most popular method, particularly in Oman. These findings provide valuable insights for developing targeted, multi-channel risk communication strategies. In the UAE, consumers preferred social media to receive information about FAs (Osaili et al., 2023), while booklets were the preferred source among consumers in Korea (Shim et al., 2011).

4.3. Consumption patterns and implications for public health

The food frequency questionnaire showed complex consumption patterns that reflect the multifaceted nature of consumer decision-making regarding food additives (FAs). The variability in the consumption trends of food containing high levels of FAs suggests that additive content alone does not dictate consumption choices. Decisions appear to be influenced by multiple factors, including taste preferences, perceived health benefits, convenience, cultural habits, and knowledge about FAs. For instance, bottled juice, often perceived as a healthier option, showed high consumption rates despite potential additive content, while artificial products, like energy drinks, were more frequently avoided. These findings align with Román et al. (2017), who highlighted the importance of perceived naturalness in food choices (Bandara et al., 2016). However, our results also indicate that this preference for naturalness is often outweighed by other factors in real-world consumption behaviors, particularly for highly palatable or convenient foods.

Osaili et al. (2023) highlighted a significant knowledge gap, with many consumers unaware of FA presence in flour/semolina/oats and natural cheeses, while correctly identifying FA-free items like fresh products (Osaili et al., 2023). This discrepancy between actual FA content and consumer awareness complicates the relationship between risk perception and practice. Moreover, the inconsistency between our findings and previous research regarding demographic influences on FA knowledge and practices suggests additional factors at play. These may include evolving consumer awareness across demographic groups, cultural or regional variations in food practices, changes in food industry regulations, and methodological differences between studies.

The complex interplay of these factors underlines the need for nuanced approaches in research and public health interventions targeting FA consumption. The study's findings are relevant to public health policies, food industry practices, and consumer education initiatives. They suggest a need for tailored approaches to cultural contexts, professional backgrounds, and individual health concerns when addressing food additive safety and risk communication in the Arab world.

4.4. Limitations

Several limitations must be acknowledged when interpreting the results of this study. Snowball sampling may have introduced selection bias, contributing to a sample skewed toward educated, urban, and young adults. Network-based recruitment likely created participant clusters with shared characteristics, information sources, and cultural values, restricting true variance in key variables. Additionally, self-selection bias may have overrepresented health-conscious individuals, potentially inflating reported protective behaviors. This limitation may explain the negligible demographic associations found in our study.

The cross-sectional design precludes causal inferences, providing only a snapshot of perceptions and practices at a single point in time. This limitation particularly affects our interpretation of the relationship between risk perception and practices, as we cannot determine whether higher risk perception leads to protective behaviors or vice versa.

Reliance on self-reported data may have introduced social desirability bias, where participants provided responses, they perceived as more socially acceptable, potentially inflating reported healthy practices and label-reading behaviors while underestimating consumption of foods high in additives. Recall bias may have affected the accuracy of FFC reporting, particularly for occasional consumption patterns, potentially leading to misclassification of dietary behaviors.

The study has limited generalizability to the broader Arab world, as the findings may reflect specific cultural, economic, or regulatory contexts of the included countries rather than universal patterns. The overrepresentation of young, educated participants, predominantly females, and single, further limits extrapolation to older or less educated populations who may exhibit different FA perceptions and practices.

The lack of objective measures of actual FA consumption and potential confounding variables not accounted for in the study design, such as income level, media exposure, or prior adverse experiences with FAs, may explain the residual variance in our models. The confirmatory factor analysis revealed model fit indices that, while improved after modifications, showed RMSEA values exceeding the conventional threshold of 0.08 for both the perception scale (RMSEA = 0.118) and practice scale (RMSEA = 0.089). Although other fit indices (CFI, TLI, SRMR) demonstrated acceptable to good fit, and convergent validity was supported by adequate AVE values (perception = 0.58; practice = 0.61), the elevated RMSEA suggests some degree of model misspecification. This may reflect the complexity of FA perceptions and practices, which may not be fully captured by unidimensional models, or could indicate cultural heterogeneity across the four countries that introduces additional variance. The lack of scalar invariance across countries represents a significant limitation in interpreting cross-national mean comparisons. While our scales demonstrated configural and metric invariance (indicating equivalent factor structures and loadings), the failure to achieve scalar invariance suggests that participants in different countries may have used response scales differently or interpreted items with varying thresholds. Consequently, observed mean differences between countries may reflect a combination of true differences in FA perceptions/practices and methodological artifacts related to cultural response styles. Future research should develop country-specific norms or employ invariance-aligned methods to enable more valid cross-cultural comparisons.

4.5. Future studies

To build upon the findings of this study and address its limitations, we propose several avenues for future research. A comparative analysis of FAs regulations across different countries could provide valuable context for the observed differences in risk perception and practices. Investigating the role of media coverage in shaping public perception of FAs in each country would offer insights into the influence of information dissemination on consumer attitudes. Future studies should also explore psychological factors, such as risk aversion or health anxiety, and their potential impact on FA risk perception and practices. Economic considerations, including food prices and disposable income, warrant examination of their influence on FA-related behaviors and choices. Conducting interventional studies is also recommended to assess the effectiveness of targeted educational programs in improving FA knowledge and influencing consumption behaviors, including randomized controlled trials (RCT) comparing educational delivery methods (mobile app vs. printed materials vs. control), cluster-randomized trial for healthcare professionals (FA training programs), and community-based intervention study (redesigned food labels). These studies could involve pre- and post-intervention assessments of FA awareness, risk perception, and consumption patterns, providing valuable data on the efficacy of different educational approaches across diverse populations. Such comprehensive research would contribute to more effective, culturally sensitive public health strategies for FA education and regulation in the Arab world and beyond.

5. Conclusion

This study highlights the complex landscape of FA perceptions and practices across four Arab countries, revealing apparent cross-national variations and challenging socio-demographic and educational associations. The findings indicate the need for culturally sensitive, country-specific food safety policies and risk communication strategies. The unexpected negative association between label reading and risk perception points to potential shortcomings in current labeling practices and highlights an opportunity for improving FAs information dissemination.

The interplay between risk perception, health consciousness, and actual consumption behaviors reflects the multifaceted nature of consumer decision-making regarding FAs. This complexity necessitates comprehensive public health interventions that address knowledge gaps and consider practical, cultural, and personal factors influencing food choices.

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Ethical statement

Ethical approval for the involvement of human subjects in this study was granted by the Ethics and Research Committee at the Lebanese International University (LIU), Reference number 2023ERC-129-LIUSOP.

The study was explained to the participants in the online questionnaire. Participants gave informed consent via the statement "I am aware that my responses are confidential, that all data will be de-identified and I agree to participate in this survey". All participants acknowledged an informed consent statement in order to participate in the study. They were able to withdraw from the survey at any time without giving a reason.

CRediT authorship contribution statement

Reham E. Kotb: Writing – original draft, Formal analysis, Conceptualization. **Souheil Hallit:** Writing – review & editing, Validation, Formal analysis. **Mai Helmy:** Writing – review & editing, Investigation. **Mohamed Bahlol:** Writing – review & editing, Investigation. **Abdallah Y.Naser:** Writing – review & editing, Investigation. **Esra' O. Taybeh:** Writing – review & editing, Investigation. **Samar Younes:** Writing – original draft, Formal analysis. **Feten Fekih-Romdhane:** Writing – review & editing, Investigation. **Michele Cherfane:** Writing – review & editing, Supervision, Methodology. **Katia Iskandar:** Writing – original draft, Project administration, Methodology, Investigation, Formal analysis, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.afres.2025.101648.

Data availability

Data will be made available on request.

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