

Article

Assessing the Adoption Level and Factors Influencing Circular Economy Adoption Among Adult Consumers in the Eastern Province of Saudi Arabia

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Abstract

Food-related circularity reduces food waste, enhances food security, and promotes sustainable food management. This study assessed the extent of food-related circularity adoption among adult consumers in the Eastern Province of Saudi Arabia and identified its associated socioeconomic, behavioral, and attitudinal factors. Primary data were collected from 384 Saudi adults (≥ 18 years) using a structured questionnaire in a cross-sectional survey. The data analysis included descriptive statistics and an ordinal logistic regression model (OLRM). The food-related circularity adoption index was constructed from 40 items that assessed individual practices related to recyclable or reusable food items, including bread, dates, cooked rice, cooked pasta, stewed vegetables, stewed meat, and fruit, with a Cronbach's alpha of 0.931. Based on tertile classification, the food-related circularity adoption levels were distributed as follows: 3.1% low; 34.4% middle; and 62.5% high. The OLRM indicated that regular use of CE-related digital tools was positively associated with higher food-related circularity adoption. The respondents who disagreed that unwillingness to store leftovers contributes to food waste had significantly higher odds of high food-related circularity adoption ($OR = 8.47, p < 0.01$), and those who did not shop out of boredom had 4.87 times higher odds of high food-related circularity adoption ($p < 0.01$). The findings indicated that, given the use of convenience sampling and recruitment through social media, the reported prevalence of high food-related circularity adoption (62.5%) reflects the surveyed sample and should not be generalized to the broader population. Accordingly, CE-related digital platforms should clearly communicate the environmental, economic, and social benefits of food-related circularity practices; link individual and household actions to broader sustainability and food-security goals; and reinforce users' sense of impact.

Keywords: circular economy (CE); food waste; food-related circularity adoption; ordered logistic regression model (OLRM); rationalization of food consumption



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1. Introduction

The circular economy (CE) has recently emerged as a critical research topic, garnering heightened attention due to its substantial solutions for mitigating food waste issues. The authors of [1] define the circular economy (CE) as a regenerative system that minimizes resource input and waste, emissions, and energy leakage by slowing, closing, and narrowing material and energy loops. This can be accomplished by durable design, maintenance, repair, reuse, remanufacturing, refurbishing, and recycling. Consequently, the circular economy (CE) is a process designed to maintain value via maintenance, reuse, refurbishment,

remanufacturing, recycling, and composting [2]. Furthermore, the circular economy (CE) is predominantly depicted as an alternative framework that provides both economic and environmental benefits, as analyzed in [1]. The circular economy (CE) has experienced a paradigm shift, and currently prioritizes sustainable development at three levels: micro (businesses and customers), meso (economic actors involved in industrial symbiosis), and macro (cities, regions, and governments) [3].

Consumers play a crucial role in the circular economy (CE) loop [4–6]. They put circular economy ideas into action by making choices and acting in ways that extend the life of products, reduce waste, and use fewer resources. This is how consumers are managed from a circular economy point of view [7]. The CE helps consumers by making products that last longer and are more useful, which improves their quality of life and saves them money in the long run. However, adopting the circular economy is not easy. Recent research has underscored several critical factors that affect consumer behavior in this context: economic considerations, the congruence of consumer demands with market offerings, information accessibility, social influences, and personal preferences and beliefs. Consumer decision-making is a fundamental process that influences behavior [8]. Consequently, it is imperative to identify the variables that motivate consumers to adopt more circular habits, especially when such changes may require significant lifestyle adjustments [6]. Therefore, understanding how consumers make decisions is important because it affects how long and how often they use goods that are meant to be used for a long time; this outcome ultimately depends on the users themselves [9,10]. Therefore, understanding customer engagement in circular processes is crucial, as consumer empowerment is integral to the circular economy framework [11]. The authors of [12] recently stressed the need for more empirical research on how communities and consumers are involved in circular activities.

Presently, new methodologies are propelling the circular economy in the food sector, encompassing novel company structures and digital marketplace platforms for food sharing. These platforms, which are based on a circular model, link food producers and vendors with reuse organizations, charities, and consumers, thereby markedly diminishing food waste [13]. A circular economy approach to food waste acknowledges and maintains the value and usability of food products, nutrients, and resources for an extended duration; this reduces resource consumption while promoting the upcycling of food waste and byproducts. Thus, the food-related circular framework is essential for minimizing food waste and enhancing the overall sustainability. In line with this framework, circular food behaviors are categorized and characterized into three types: linear, transitioning, and circular behaviors [14].

A major reason why food goes to waste is that home food distribution is not managed well. Making plans for obtaining and storing food is not easy. A common behavior is buying too much food without thinking about how it will spoil [15]. Even if customers try to follow producers' advice, some food spoils because the date labels on the products are unclear. There are also other problems in the home that make it hard to manage the pantry well, such as family members having different tastes in food and unexpected social events. Food-related circularity models are a good way to reduce food waste, which is currently at a high level [16,17]. Additionally, the deployment of consumer-engaging food-related circularity systems would capitalize on the shifting consumer perceptions about sustainable living [18]. Nonetheless, tackling the consumer aspect of the circular economy related to food remains difficult [19]. People also need to become used to new technology that is meant to recycle biological materials and close the food waste loop. Food-related circularity offers new methods and technologies for recycling materials, but these technical solutions do not work unless people adopt them. To manage food waste at the consumer level, consumers need to be actively involved in making decisions about how to buy and

throw away food [19]. Additionally, consumers are more likely to adopt circular economy practices if they have knowledge of the circular food supply chain [20].

Saudi Arabia has limited land and water for growing food, which means that a lot of food goes to waste and these limited resources are spent on food that is not eaten. Because of this, the country relies heavily on imports and food subsidies to meet its food needs [21]. Food waste is a major risk to the safety of the food supply in the country [21,22]. The authors of [23] identified the primary factors contributing to food waste in Saudi Arabia as insufficient social awareness, the conduct of dinner hosts, and a propensity to display extravagant cuisine to guests. A strong economy, cultural traditions that link celebrations to food waste, and limited awareness of the consequences of food waste are key national factors associated with food waste.

The authors of [22] discovered that food waste is an issue due to insufficient laws, policies, or distinct collection systems for various types of solid waste. They found that people do not like food waste, do not know much about it, and do not want to use food waste byproducts. They also learned that pre-treatment before landfilling is not a common way to manage waste. This reflects why food-related circularity is an important way to cut down food waste in Saudi Arabia. The government still lacks a clear plan for food-related circularity, which makes it harder to deal with important issues such as waste management and over-consumption [24]. The authors of [25] conducted research that highlighted the potential implementation of circular economy principles to enhance the sustainability across supply chains.

The mentioned literature reveals that many studies recognize food waste as a critical concern in terms of food security and sustainability; however, there is a lack of research on the implementation of the food-related circularity as an essential strategy to reduce food waste in Saudi Arabia's food sector. The principal shortcoming in research regarding consumer adoption of food-related circularity practices in Saudi Arabia is the absence of studies assessing the extent of this adoption and the impact of socioeconomic characteristics and consumer behavior on the actual implementation of food-related circularity practices among diverse adult consumers in Saudi Arabia.

Although the existing literature recognizes food waste as a major food-security, environmental, and resource-efficiency concern in Saudi Arabia, much of the available evidence has focused on the scale and determinants of food waste, institutional and regulatory barriers, and the technical potential of food-related circularity approaches. Comparatively limited attention has been paid to the consumer as an active participant in food-related circular practices, including planned purchasing, appropriate food storage, leftover utilization, waste avoidance, recycling, and the use of digital platforms that support resource recovery or food sharing. Moreover, empirical evidence remains limited regarding the extent to which Saudi consumers report adopting these food-related circularity practices and how such adoption is associated with socioeconomic characteristics, food-purchasing and food-management behaviors, consumer attitudes, and engagement with CE-related applications and platforms. Evidence from other countries cannot be directly generalized to Saudi Arabia because food consumption and waste practices are shaped by local cultural traditions, income conditions, food-subsidy arrangements, retail environments, digital access, and waste-management infrastructure. By addressing this evidence gap, the present study examined the self-reported food-related circularity adoption among adult consumers in the Eastern Province of Saudi Arabia and its statistical associations with selected socioeconomic, behavioral, attitudinal, and digital-use characteristics.

Therefore, this study used a framework linking socioeconomic characteristics to food-related attitudes and behaviors that shape food-related circularity adoption. Family size, income, occupation, and marital status; food-purchasing motives; leftover management; the

use of CE platforms; and recycling practices together reflect a broader orientation toward sustainable consumption and resource efficiency. Because the data are cross-sectional, the framework is used to explain associations rather than causality.

This research aimed to fill this gap by (1) evaluating the extent of consumer adoption of food circular economy practices as a method for minimizing food waste and (2) identifying the elements that affect this adoption, encompassing socioeconomic characteristics, consumer behaviors, and attitudes towards the circular economy. The study also sought to furnish policymakers with actionable strategies to reduce food waste and increase consumer engagement in circular economy initiatives, thereby improving food security and attaining food sustainability.

2. Materials and Methods

2.1. Sampling Size

The sample was taken from the Eastern Province between August and September 2025. The Eastern Province has a diverse range of economic activities, including agriculture, trade, and manufacturing. Indigenous traditions and globalization are closely associated with the attitudes and behaviors of people in the Eastern Province. The participants were recruited on social media using a convenience sampling method and the sample size was estimated using the Stephen Thompson technique [26]. The Stephen Thompson equation can be expressed as follows:

$$n = \frac{N \times p(1 - p)}{\left[\left[N - 1 \times \left(\frac{d^2}{z^2} \right) \right] + p(1 - p) \right]} \quad (1)$$

where

n: sample size.

N: the size of the study community.

Z: the normative degree corresponding to a level of significance of 0.95, which is equal to 1.96.

d: the error ratio, which is equal to 0.05.

p: the ratio of the availability of property, which is neutral and equal to 0.50.

$$n = \frac{2,949,854 \times 0.50(1 - 0.50)}{\left[\left[2,949,854 - 1 \times \left(\frac{(0.05)^2}{(1.96)^2} \right) \right] + 0.50(1 - 0.50) \right]}$$

The total population size is about 2,949,854 individuals according to [27]. Thus, the study sample consisted of 384 individuals [28].

2.2. Data Collection

A cross-sectional study was carried out using primary data with the help of a structured questionnaire to determine the level of food-related circularity adoption and to identify the factors influencing the adoption of the food-related circularity among adult consumers of the Eastern Province of Saudi Arabia. There were four key parts to the questionnaire. The first part asked questions about sex, age, marital status, education level, occupation, and monthly income. The second part recorded information about how people buy food, such as how they shop for it, how much they spend on it, and why they buy it. The third section included questions on the behavior of individuals towards food-related practices, and how individuals rationalize their food consumption. In this section, the participants were asked about their practices regarding the recycling of leftover food, their familiarity with the term “circular economy,” their home recycling habits, the use of ap-

plications for food recycling, and the motivations behind rationalizing food consumption within the food-related circularity framework. There were five reasons for utilizing the food-related circularity to rationalize food consumption, and then the participants were asked to rate their motivation for doing so on a five-point Likert scale (strongly disagree, disagree, neutral, agree, highly agree). Section four records information on how the food-related circularity system helped people rationalize their dietary choices. The participants were encouraged to think about how they may use food-related circularity practices to make their food choices more reasonable. It featured the recycling of important items, including bread, dates, cooked rice, cooked pasta, stewed vegetables, stewed meat, and fruit. We chose a graded scale (yes/sometimes/no) because it is simple to grasp and apply, and it gives people more freedom to appropriately express their ideas. The “sometimes” option helps to decrease bias and deliver more detailed data by showing the difference in views instead of requiring participants to give a clear answer. This scale also makes it easier to analyze data without the complications that more detailed scales can bring. This makes it a good choice for gathering clear and easy-to-understand data, as pointed out in [29].

The questionnaire was checked by a group of experts before being distributed to ensure that it was well-organized and met the study’s goals. The questionnaire had certain requirements that needed to be met in order to verify that the participants belonged to the correct demographic category. To be eligible, Saudi citizens needed to be at least 18 years old and live in the Eastern Province. A pilot test of the questionnaire was conducted with 25 individuals who met the eligibility criteria for the main survey. The pilot used the same administration mode as the main study (online) and included a brief debrief in which participants were asked about clarity, wording, response options, and completion time. Participants reported an average completion time of approximately 15 min. Feedback indicated that several items on food-related circular economy practices and food waste behaviors were ambiguous or difficult to interpret, particularly the distinction between reusing and recycling food leftovers. Some respondents also noted that 5-point frequency scale labels were confusing and that two questions on rationalization motivations for utilizing the circular economy (CE) system felt repetitive. Based on these findings, we (i) reworded five items to improve clarity, (ii) revised the response scale from a 5-point frequency scale (Never to Always) to a 5-point agreement scale (Strongly disagree to Strongly agree), and (iii) merged five overlapping questions on motivations and practices to reduce redundancy. No items showed systematic non-response in the pilot, and no additional eligibility issues were identified. The revised questionnaire was then used in the main survey.

The primary data were gathered by distributing the questionnaire electronically through social media [28]. To minimize duplicate responses, the survey was restricted to one submission per participant, and the link included instructions for single completion. The final dataset was screened for duplicate or highly similar entries, and suspicious cases were removed when necessary. The study also incorporated secondary data from relevant national and international sources on food waste and circular economy practices.

Missing data were examined prior to analysis. Less than 5% of values per indicator were missing, and the pattern of missingness showed no systematic concentration in specific indicators or respondent groups. Given the low level of missingness (<5% per variable), missing values were handled using mean replacement. This approach is consistent with common practice in partial least squares structural equation modeling (PLS-SEM) when missing data are minimal and plausibly missing completely at random.

2.3. Data Analysis

2.3.1. Assessing the Extent of Circular Economy Implementation

The extent of CE implementation in this study was based primarily on individual food-related circularity behaviors rather than the full breadth of circular economy adoption. Specifically, the index captures food waste prevention, leftover management, the reuse of edible food, and related individual practices that align with circular principles. Although the CE is a broader concept that also encompasses reduction, repair, sharing, recycling, resource recovery, and product life extension across multiple waste streams, food-related behaviors provide a practical and observable entry point for examining consumer participation in circular practices in the Saudi context. Therefore, the results should be interpreted as a reflection of the associations with food circularity practices, not with CE adoption in its entirety. In this study, food leftover management was used as a proxy for CE adoption at the individual level, with the understanding that this operationalization captures a specific, behaviorally actionable domain of the broader CE framework.

To assess the level of circular economy practices, the participants were asked how they justified their dietary choices with respect to the CE system and their own beliefs, using a graded scale (yes/sometimes/no) as examined by [28]. We asked the participants about their method of recycling seven food items: bread, dates, cooked rice, cooked pasta, stewed vegetables, stewed meat, and fruit. The participants' responses about food recycling were expressed as follows:

Firstly, some questions were answered with one of three responses (yes, sometimes, or no) on a scale of 1 to 3. For example, "I throw it away in the trash" is one of seven questions like this.

Secondly, positive phrases were responded to with one of three answers—"yes," "sometimes," or "no,"—on a scale of 3 to 1, such as the following: sorted and ground to make different recipes, used to make other dishes, turned stale bread into breadcrumbs (rusks), and used expired products as feed for animals. The total number of questions answered in this way was 40.

Thirdly, the score was calculated, with the highest possible score being 120 degrees (40×3) and the lowest possible score being 40 degrees (40×1).

Before identifying the food-related circularity index, a reliability test for the 40 questions that were used to construct the food-related circularity level (index) was applied using Cronbach's alpha. The reliability coefficient of Cronbach's alpha was equal to 0.931, indicating a satisfactory internal consistency among all questions (see Appendix A Table A1).

Fourthly, percentage thresholds were chosen to provide an interpretable grouping of respondents into low, middle, and high categories, as indicated by the study in [28]. The food-related circularity adoption index was categorized into three ordered levels: low (<50%), middle (50–70%), and high (>70%). These thresholds reflect substantive levels of behavioral engagement: scores below 50% indicate limited adoption (fewer than half of the circular behaviors endorsed), 50–70% indicate partial or transitional adoption, and above 70% indicate established circularity practices (consistent endorsement of most behaviors). Although not based on external normative benchmarks, this tripartite classification aligns with common practice in behavioral research for distinguishing low, middle, and high levels of practice adoption and facilitates interpretation of the ordinal outcome in regression models. The selected cutoffs provided a straightforward way to summarize variation in the intensity of reported circular behaviors across the sample and were consistent with the descriptive aim of the index.

2.3.2. Ordered Logistic Regression Model (OLRM)

Ordered logistic regression is a statistical method for modeling an ordinal dependent variable with categorical outcomes—such as low, middle, and high—that have a natural order, but no clear lines between categories. The model demonstrates the influence of predictors on the likelihood of classification into higher or lower result categories, based on the proportional odds assumption. The proportional odds logistic regression model was used to analyze the ordinal dependent variables [30,31].

The model posits the presence of a continuous latent variable y^* that regulates the observed ordinal categories y , as delineated in [32].

$$Y^* = \beta_i X_i + \varepsilon_i \quad (2)$$

where X_i represents the predictors, β_i denotes the coefficients, and ε follows a conventional logistic distribution as the standard error. The observable Y^* is defined by thresholds (cut point) μ_j :

$$Y = \begin{cases} 1 & \text{if } y^* \leq \mu_1 \\ 2 & \text{if } \mu_1 < y^* \leq \mu_2 \\ \vdots & \\ \vdots & \\ J & \text{if } y^* > \mu_{J-1} \end{cases} \quad (3)$$

For J ordered categories, the model estimates cumulative logits:

$$\log \left(\frac{P(Y \leq j)}{P(Y > j)} \right) = \alpha_j + \beta_i X_i \text{ for } j = 1, 2, \dots, J-1 \quad (4)$$

$\alpha_j = \mu_j$ are category cutpoints (intercepts; one fewer than the number of categories).

The β variables are the shared regression coefficients (one per predictor).

The formulas showed that the ordered logistic model can use the estimated value of the latent variable and the assumed logistic distribution of the disturbance term to figure out the chance that the unobserved variable Y^* falls within certain threshold limits [33]. When using ordinal data, ordered logistic regression estimation uses maximum likelihood estimation (MLE) to estimate both the regression coefficients (β) and the category cutpoints α_j at the same time.

In our research, the dependent variable (y) represents the extent of food-related circularity adoption, classified into three categories: low level, middle level, and high level. The low level was less than 50% of the maximum degree (less than 60 degrees), the middle level was between 50% and less than 70% of the maximum degree (from 60 degrees to less than 72 degrees), and the high level was more than 70% of the maximum degree (greater than 72 degrees). The explanatory elements included socioeconomic characteristics, consumer habits, and attitudes toward the adoption of food-related circularity. In this way, the model specification can be stated as follows:

$$\text{Logit} [\Pr(Y \leq j | X)] = \alpha_j + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5 + \beta_6 X_6 + \beta_7 X_7 + \beta_8 X_8 + \beta_9 X_9 + \varepsilon_i \quad (5)$$

where

Y : the level of food-related circularity adoption (1 = low level, 2 = middle level, 3 = higher level).

α_j : the cutpoints.

$X_1, X_2, \dots, X_9$: the explanatory variables.

$\beta_1, \beta_2, \dots, \beta_9$: the shared regression coefficients.

ϵ_i : the standard error, which followed a standard logistic distribution.

Table 1 delineates the explanatory variables utilized in the ordered logistic regression model (OLRM), along with their corresponding codes and symbols employed in the model. Nine independent variables were employed to evaluate the extent of food-related circularity adoption. The nine predictors were selected because they were the most theoretically and empirically relevant variables available for the model. This limited set was chosen to maintain model parsimony, avoid unnecessary complexity, and improve the stability and interpretability of the results.

Table 1. Description of the explanatory variables used in the ordered logistic regression model (OLRM).

Symbol of Variable in Model	Name of Variable	Type of Variable	Variable Code
X1	Family size	Continuous variable	FS
X2	Individual monthly income	1 = $\leq$ 2000 SR 2 = >2000–4000 SR 3 = >4000–6000 SR 4 = >6000–8000 SR 5 = >8000–10,000 SR 6 = >10,000 SR	INC
X3	Occupation	1 = Employee 0 = Other occupational status	OCCU
X4	Marital status	1 = Married 0 = Otherwise	MS
X5	Recycling of foodstuffs	1 = No 2 = Sometimes 3 = Yes	RFS
X6	Use of applications and platforms for the circular economy	1 = No 2 = Sometimes 3 = Yes	APCE
X7	Belief that unwillingness to keep leftover food is a major reason for food waste	0 = No 1 = Yes	UWKF
X8	Boredom as a motivator for purchasing food	0 = No 1 = Yes	MBFP
X9	Average rationalization motivations for utilizing the CE system	Continuous variable	ARMCE

Items measuring beliefs about food waste causes (e.g., unwillingness to store leftovers causes food waste) were recorded as binary responses (Yes/No). For these belief items, ‘Yes’ indicates agreement that the stated factor causes food waste, and ‘No’ indicates disagreement. Items measuring rationalization motivations for using the circular economy system were recorded on 5-point agreement scales (Strongly disagree to Strongly agree). For the rationalization items, higher scores indicate stronger agreement with the stated motivation. No items were reverse coded in these scales. The dependent variable (food-related circularity adoption) was constructed so that higher scores reflect greater adoption of circular practices.

Therefore, the explicit hypothesis that we set out to test was whether family size, individual monthly income, occupation, marital status, the recycling of foodstuffs, the use of CE-related applications and platforms, unwillingness to keep leftover food, boredom as a motivator for food purchasing, and average rationalization motivations for utilizing the CE system were significantly associated with the level of food-related circularity adoption. The data were analyzed using IBM SPSS Statistics for Windows, version 27.

Before estimating the ordinal logistic regression model, multicollinearity among the explanatory variables was assessed using tolerance and variance inflation factor (VIF)

statistics. Because the SPSS Version 27 ordinal-regression procedure does not directly report these diagnostics, an auxiliary linear regression model was estimated using the same set of explanatory variables and coding scheme as the ordinal logistic model. The auxiliary model was used exclusively to calculate multicollinearity diagnostics; its regression coefficients were not used for substantive inference. Tolerance values ranged from 0.898 to 0.975, and VIF values ranged from 1.025 to 1.113. All tolerance values exceeded 0.20 and all VIF values were well below 5, indicating no evidence of problematic multicollinearity among the predictors. These results suggest that multicollinearity is not a concern and support the suitability of the ordinal logistic regression model for examining associations between the predictors and food-related circularity adoption (see Appendix A Table A2).

3. Results and Discussion

3.1. Socioeconomic Characteristics and Consumer Behaviors and Attitudes Toward CE

Table 2 shows the descriptive data on the socioeconomic variables, consumer behaviors, and opinions about the CE in the Eastern Province of Saudi Arabia. The statistics showed that 59.9% of the people who took part were male and 40.1% were female. There may be substantial differences between men and women when it comes to adopting circular economy techniques. For example, women are often the ones who start household habits such as reducing trash and making the most of food. The research conducted in [34] highlighted structural inequalities, illustrating how the circular economy reinforces the gender gaps inherent in the linear economy, particularly with women being disproportionately involved in informal recycling. Research conducted in [35] indicated that women demonstrate a heightened awareness of business environmental practices compared to men, as expected. About 34.6% of the people who took part were between the ages of 25 and 35, and 39.1% were between the ages of 35 and 45. Only 3.6% of the people who took part were between the ages of 55 and 65. This means that most of the people who took part were younger, and that there is a lot of opportunity for them to start implementing techniques such as recycling resources and reducing food waste.

The average family size was about five members, which could affect how much food is wasted and how much is recycled. According to the author of [36], the size of a household impacts how much waste it makes, how it is managed, how it is sorted, and how it is reused. This increases the potential for circularity. The authors of [37] found that families with more members are more likely to use circular economy approaches. On the other hand, roughly 29.9% and 32% of the people who took part in this research said their monthly income was >2000 to 4000 SR and >4000 to 6000 SR, respectively. People who make more money each month are more likely to follow circular economy practices because they can invest in new technologies and innovations that make better use of resources. Due to money problems, lower-income families often perform circular economy activities that are necessary, including fixing things or reusing them. They have trouble adopting more advanced methods [34]. The findings show that 59.6% of respondents were employed, whereas the remaining 40.4% comprised freelancers, unemployed individuals, students, and retirees.

The marital status indicated that 70.6% of the participants were married, while 29.4% were single or divorced. Marital status indirectly affects CE practices through home dynamics, shared responsibilities, and resource pooling; however, direct studies on this topic are scarce, as noted in [37]. A recent study indicated that married individuals or couples frequently exhibit greater engagement in circular economy practices due to collaborative decision-making and familial demands for sustainability. Such practices include collective trash reduction and second-hand purchases influenced by partners, particularly women who guide household behaviors. Single-person families may emphasize personal cost-

saving reuse while implementing fewer systematic innovations [38]. In this study, 45.3% of the participants reported consistently recycling their foodstuffs, whereas 47.4% indicated that they recycle their foodstuffs occasionally. Conversely, 27.6% indicated that they utilize applications and platforms related to the circular economy, while 51.8% stated that they use such applications and platforms “sometimes.” Mobile apps that help people recycle directly support the concepts of a circular economy by making it easier to sort, collect, and recover materials for reuse. On the other hand, 97.7% of the people who took part in this research disagreed that an unwillingness to keep leftover food is a main reason for food waste. An unwillingness to keep leftover food is a major reason why people waste food. This is often because they think keeping leftovers is too hard, they dislike the taste, or they do not store it properly. This plainly goes against the principles of a circular economy by sending resources that may be reused to landfills instead of being reused. This lowers their economic worth and raises emissions.

Table 2. Descriptive statistics of the socioeconomic characteristics and the consumer behaviors and attitudes toward the CE in the Eastern Province of Saudi Arabia.

Participant Characteristics	Categories	Value
Sex	Male	230 (59.9%)
	Female	154 (40.1%)
Age	18–25	34 (8.9%)
	25–35	133 (34.6%)
	35–45	150 (39.1%)
	45–55	53 (13.8%)
	55–65	14 (3.6%)
Family size		5.4 ± 1.5
Individual monthly income	≤2000	58 (15.1%)
	>2000–4000 SR	115 (29.9%)
	>4000–6000 SR	123 (32%)
	>6000–8000 SR	52 (13.5%)
	>8000–10,000 SR	22 (5.7%)
	>10,000 SR	14 (3.6%)
Occupation	Employee	229 (59.6%)
	Other occupational status	155 (40.4%)
Marital status	Married	271 (70.6%)
	Otherwise	113 (29.4%)
Recycling of foodstuffs	No	28 (7.3%)
	Sometimes	182 (47.4%)
	Yes	174 (45.3%)
Use of applications and platforms for the CE	No	79 (20.6%)
	Sometimes	199 (51.8%)
	Yes	106 (27.6%)
Belief that unwillingness to keep leftover food is a cause of food waste	No (disagree)	375 (97.7%)
	Yes (agree)	9 (2.3%)
Boredom as a motivator for purchasing food	No	369 (96.1%)
	Yes	15 (3.9%)
Average rationalization motivations utilizing the CE system		1.68 ± 0.78

Note: sample size (n) = 384 individuals, mean ± standard deviation.

Approximately 96.1% of the participants indicated that boredom was not a motivator for purchasing food. Consumer motivations for purchasing food, including convenience, cost, quality, and health, strongly correlate with circular economy principles by affecting

waste production, resource cycles, and sustainable sourcing. Consequently, when experiencing boredom, consumers pursue immediate sensory pleasure (e.g., consuming packaged snacks), circumventing intended purchases and augmenting leftovers by 15–25% as a result of overconsumption [39]. The average rationalization motivations for utilizing the CE system were determined based on five criteria evaluated through a five-point Likert scale (strongly disagree, disagree, neutral, agree, strongly agree). The variables were employed to evaluate the motivational direction of individuals in rationalizing food consumption through the CE system, and they included reducing expenditures to navigate challenging economic circumstances such as debt, pre-planning meals, avoiding impulsive purchases to mitigate excess food quantities, lessening environmental damage by minimizing food waste, and effectively utilizing resources while ensuring their sustainability. The average value of rationalization reasons for utilizing the CE method was 1.6, signifying a “disagree” response, which reflects a low level of agreement or endorsement of these motives by the respondents. This indicates that individuals predominantly do not justify their conduct using CE reasons.

3.2. Food-Related Circularity Adoption Level

The circular economy classification seeks to analyze how individuals justify their food consumption to address food waste. This also categorizes individual behavior about food-related circular activities. Table 3 presents the classification of adult customers based on their food-related circularity adoption in the Eastern Province of Saudi Arabia. The results indicate that 3.1% of individuals exhibit a low level of food-related circularity, whereas 34.4% have a middle level of food-related circularity. Approximately 62.5% of the participants exhibited a high level of consumer engagement. Thus, the high prevalence of food-related circularity adoption observed in this study reflects the study sample only and may not be generalizable to the broader population. Notably, the combination of relatively low motivation for rationalizing the CE system and a very high rate of food-related circularity adoption (62.5%) suggests that adoption may be driven more by external or practical factors than by motivational support. The coexistence of low rationalization motivation and high reported adoption indicates that CE-related behavior may be shaped by factors beyond self-reported motivation, such as contextual conditions, institutional support, habitual practices, or reporting effects. However, the cross-sectional design of the present study does not allow these possibilities to be tested directly. The authors of [40] contend that the CE categories facilitate the identification of how consumers rationalize food consumption to mitigate waste by dividing actions into linear versus circular stages, hence elucidating shifts in thinking from disposal to value retention. A study conducted in Vietnam by the authors of [37] categorized the levels of circular economy (CE) adoption into four tiers: “no intention to adopt CE,” “intention to adopt CE but uncertain about the timeline,” “currently in the process of adopting CE,” and “CE has already been adopted.” A study conducted in Menoufia Governorate by the authors of [29] revealed that 80.6% of families exhibited low to moderate levels of consumption reduction through the circular economy.

Table 3. Categorization of adult consumers according to the extent of food-related circularity adoption in the Eastern Province of Saudi Arabia.

Food-Related Circularity Level	Circular Level Classification	Frequency
Low level	Less than 50% (less than 60 degrees)	12 (3.1)
Middle level	50–70% (from 60 degrees to less than 72 degrees)	132 (34.4)
High level	Greater than 70% (greater than 72 degrees)	240 (62.5)

Note: sample size (n) = 384 individuals; the numbers between the brackets are the percentages.

3.3. Factors Affecting the Food-Related Circularity Adoption Level

Table 4 presents the results of the ordered logistic regression model (OLRM). The model fit results indicate that the likelihood ratio χ^2 is 69.48 with 18 degrees of freedom (*df*). This result is highly statistically significant; $p < 0.01$ indicates that, assuming the null hypothesis of all regression coefficients being equal to zero, the probability of observing results at least as extreme as those obtained is less than 1%. This indicates that the independent variables exert a statistically significant influence on the level of the food-related circularity. Numerous pseudo- R^2 statistics have been suggested for the ordered logistic model. McFadden's R^2 is among the most renowned. Pseudo- R^2 varies from 0 to 1; a higher number indicates a stronger link. The value of pseudo- R^2 in this model was 0.118. This indicates an 11.8% enhancement in the anticipated result based on the predictors relative to the null model.

Table 4. Results of food-related circularity levels using ordinal logistic regression model.

Number of Obs = 384 LR χ^2 (18) = 69.48 Prob > χ^2 = 0.000 Pseudo- R^2 (McFadden) = 0.118		Log likelihood = −253.96 Approximate likelihood-ratio test of proportionality of odds across response categories: χ^2 (18) = 4.521 Prob > χ^2 = 0.995						
Variable code	Estimate	Plain-language interpretation	Odds ratio (OR)	SE	Wald χ^2	p value	95% CI	
							Lower Bound	Upper Bound
[food-related circularity level = 1.00]	0.625	Model threshold (cutpoint); not interpretable as a predictor.		1.228	0.259	0.611	−1.782	3.033
[food-related circularity level = 2.00]	4.097	Model threshold (cutpoint); not interpretable as a predictor.		1.269	10.421	0.001	1.610	6.585
FS	0.176	Each additional household member is associated with 19% higher odds of being in a higher food-related circularity adoption category (OR = 1.19, p = 0.015).	1.19	0.072	5.926	0.015	1.03	1.37
[INC = 1.00]	1.350	Compared with the reference income group (INC = 6), respondents in income category 1 had significantly higher odds of being in a higher food-related circularity adoption category (OR = 3.86, p = 0.035).	3.86	0.642	4.422	0.035	1.10	13.59
[INC = 2.00]	1.608	Compared with INC = 6, income category 2 had significantly higher odds of higher food-related circularity adoption (OR = 5.0, p = 0.010).	5.00	0.621	6.714	0.010	1.48	16.86
[INC = 3.00]	1.433	Compared with INC = 6, income category 3 had significantly higher odds of higher food-related circularity adoption (OR = 4.19, p = 0.019).	4.19	0.610	5.517	0.019	1.27	13.86
[INC = 4.00]	1.266	Compared with INC = 6, income category 4 had significantly higher odds of higher food-related circularity adoption (OR = 3.55, p = 0.056).	3.55	0.662	3.655	0.056	0.97	13.00
[INC = 5.00]	0.756	Compared with INC = 6, income category 5 had no significant association with the food-related circularity level (OR = 2.13, p = 0.301).	2.13	0.731	1.070	0.301	0.51	8.93
[INC = 6.00]	0 ^a	Reference category.						
[OCCU = 0.00]	−0.206	No significant association with food-related circularity level (p = 0.374).	0.81	0.232	0.792	0.374	0.52	1.28

Table 4. Cont.

[OCCU = 1.00]	0 ^a	Reference category.						
[MS = 0.00]	−0.411	No significant association with food-related circularity level ($p = 0.100$).	0.66	0.246	2.787	0.100	0.41	1.08
[MS = 1.00]	0 ^a	Reference category.						
[RFS = 1.00]	0.188	No significant association with food-related circularity level ($p = 0.685$).	1.21	0.464	0.165	0.685	0.49	3.00
[RFS = 2.00]	−0.417	Compared with the reference group (RFS = 3), respondents in RFS category 2 had significantly lower odds of being in a higher food-related circularity adoption category ($OR = 0.66$, $p = 0.076$).	0.66	0.235	3.138	0.076	0.42	1.05
[RFS = 3.00]	0 ^a	Reference category.						
[APCE = 1.00]	−1.005	Compared with the reference group (APCE = 3), respondents in APCE category 1 had significantly lower odds of being in a higher food-related circularity adoption category ($OR = 0.37$, $p = 0.003$).	0.37	0.340	8.732	0.003	0.19	0.71
[APCE = 2.00]	−0.352	No significant association with food-related circularity level ($p = 0.210$).	0.70	0.281	1.570	0.210	0.41	1.22
[APCE = 3.00]	0 ^a	Reference category.						
[UWKF = 0.00]	2.137	Respondents who disagreed that “unwillingness to store leftovers” causes food waste had significantly higher odds of being in a higher food-related circularity adoption category than those who agreed ($OR = 8.47$, $p = 0.003$).	8.47	0.727	8.642	0.003	2.04	35.12
[UWKF = 1.00]	0 ^a	Reference category.						
[MBFP = 0.00]	1.583	Respondents who did not shop out of boredom had significantly higher odds of being in a higher food-related circularity adoption category than those who did ($OR = 4.87$, $p = 0.005$).	4.87	0.561	7.958	0.005	1.62	14.63
[MBFP = 1.00]	0 ^a	Reference category.						
ARMCE	−0.293	Higher average rationalization motivations are significantly associated with lower odds of being in a higher food-related circularity adoption category ($OR = 0.75$, $p = 0.058$).	0.75	0.155	3.606	0.058	0.55	1.01

Note: Dependent variable = food-related circularity adoption level (1 = low, 2 = middle, 3 = high). OCCU = Occupation; 0 = other occupational status and 1 = employee. MS = marital status; 0 = unmarried and 1 = married. UWKF = Belief that unwillingness to keep leftover food is a major reason for food waste; 0 = NO and 1 = Yes. MBFP = Boredom as a motivator for purchasing food; 0 = No and 1 = Yes. Superscript a indicates the reference category. Superscript a indicates the reference category. OR = odds ratio; CI = confidence interval; SE = standard error. Odds ratios represent the odds of being in a higher food-related circularity adoption category relative to all lower categories, assuming proportional odds. Plain-language interpretation is placed in the third column.

The cutpoints were evaluated for their utility in estimating the food-related circularity level. The estimated values of 0.625 and 4.097 indicate the predicted values for the observed Y:

$$Y_i = 1 \text{ if } Y_i^* \text{ is } \leq 0.625.$$

$$Y_i = 2 \text{ if } 0.625 \leq Y_i^* \leq 4.097.$$

$$Y_i = 3 \text{ if } Y^*_i \geq 4.097.$$

Table 4 shows the socioeconomic factors, consumer behaviors, and attitudes toward the food-related circularity that affect its adoption in the Eastern Province of Saudi Arabia. The results show that larger family size is associated with a higher likelihood of reaching a higher food-related circularity adoption level. As the number of individuals in a respondent's household increases, so do their odds of being in a higher adoption category. Specifically, each additional household member was associated with 19% higher odds of being in a higher food-related circularity category ($OR = 1.19$, 95% CI [1.03, 1.37], $p = 0.015$). This effect is statistically significant, and the confidence interval is relatively narrow, indicating a precise and reliable positive association. The authors of [41] found that, in larger households, the cost often outweighs the desire for environmentally friendly goods, making it harder for green shopping patterns to become widespread.

Compared with the highest income category (>10,000 SR), lower income categories tended to show higher odds of being in a higher food-related circularity adoption category, although the precision of these estimates varied. Respondents earning ≤ 2000 SR per month had 3.86 times higher odds of higher adoption (95% CI [1.10, 13.59], $p = 0.035$). Those earning >2000–4000 SR had 5.00 times higher odds (95% CI [1.48, 16.86], $p = 0.010$), and those earning >4000–6000 SR had 4.19 times higher odds (95% CI [1.27, 13.86], $p = 0.019$). For respondents earning >6000–8000 SR, the point estimate indicated 3.55 times higher odds, but the 95% CI included the null (95% CI [0.97, 13.00], $p = 0.056$). Individuals earning >8000–10,000 SR also showed elevated odds, but this association was not statistically significant ($OR = 2.13$, 95% CI [0.51, 8.93], $p = 0.301$). Although lower income categories tended to show higher odds of being in a higher adoption category, the confidence intervals were wide, indicating substantial uncertainty about the magnitude of these associations. For the >6000–8000 SR category, the 95% CI included the null, and for the >8000–10,000 SR category there was no statistically significant association. Monthly income showed a statistically significant but non-monotonic association with food-related circularity adoption level. Relative to the reference category (>10,000 SR), all lower-income groups had higher odds of being in a higher adoption category, with the highest odds observed in the >2000–4000 SR group. However, the pattern was not linear: odds ratios declined in some of the higher-income categories rather than increasing steadily with income. This suggests that food-related circularity adoption is not determined by income alone. Other factors—such as individual spending patterns, price sensitivity, consumption habits, and awareness of circular practices—may help explain the variation across income groups. One possible explanation is that middle-income individuals may be more cost-conscious and therefore more likely to engage in resource-saving and waste-reduction behaviors, whereas higher-income households may face fewer budget constraints and rely less on such practices. Nevertheless, the association between income and food-related circularity adoption warrants cautious interpretation. Although all income categories below 10,000 SR exhibited higher odds of stronger adoption relative to the highest-income group, the pattern was non-monotonic and accompanied by wide confidence intervals, indicating considerable uncertainty around individual category estimates. Moreover, the model's limited explanatory power (pseudo- $R^2 = 0.118$) suggests that income accounts for only a modest share of the variation in circularity behaviors, with many other unobserved factors likely at play. While the observed pattern is consistent with resource-saving motivations among lower- and middle-income individuals, alternative explanations—including unmeasured confounders and sample-composition effects—cannot be excluded. Accordingly, these findings should be viewed as suggestive of a potential income gradient rather than as precise or generalizable effect estimates. Recent research by the authors of [41] demonstrated that lower-income households often struggle to adopt sustainable purchasing patterns due to

the occasionally high costs of commodities such as organic food and fruit. Moreover, the authors of [37] provided significant evidence of the positive impact of circular economy adoption on the household income in the Red River Delta, Vietnam. The authors of [29] conducted a study that demonstrated a positive and significant impact of monthly income on the rationalization of consumption via the circular economy in Menoufia Governorate.

Compared with employed respondents, participants with other occupational statuses had approximately 19% lower odds of belonging to a higher food-related circularity-adoption category; however, the association was not statistically significant ($OR = 0.81$, 95% CI [0.52, 1.28], $p = 0.374$). The confidence interval was wide and included the null, indicating that the data do not provide precise or statistically reliable evidence of an association with adoption level. The study conducted by [41] indicated that individuals' occupations were significantly associated with their preferences for eco-friendly and green products. On the other hand, a study conducted by [29] in Menoufia Governorate found that the occupations of male-headed households were significantly associated with the use of circular economy practices to promote more rational consumption. In contrast, the occupation of female-headed households was negatively associated with the use of these practices for more rational consumption.

Unmarried respondents had lower odds of belonging to a higher food-related circularity adoption category than married respondents; however, this difference was not statistically significant ($OR = 0.66$, 95% CI [0.41, 1.08], $p = 0.100$). The confidence interval was wide and included the null, indicating that the data do not provide precise or statistically reliable evidence of an association with adoption level. Thus, while the point estimate suggests that married individuals may be more likely to report higher food-related circularity levels, this association should be interpreted cautiously due to the lack of statistical significance. The authors of [41] found that marital status affects green shopping behavior. Married individuals are more likely to buy eco-friendly products than single individuals, possibly because they care more about the long-term health of their homes and the environment. The authors of [35] argued that married persons demonstrate a heightened awareness of corporate social responsibility practices.

Individuals who reported not recycling foodstuffs had higher odds of being in a higher food-related circularity adoption category than those who reported recycling; however, this association was not statistically significant ($OR = 1.21$, 95% CI [0.49, 3.00], $p = 0.685$). Thus, there is no reliable evidence that non-recyclers differ from recyclers in their likelihood of higher food-related circularity adoption. Participants who sometimes recycled their food leftovers had lower odds of being in a higher adoption category than the reference group (those who always recycle), but this difference was also not statistically significant ($OR = 0.66$, 95% CI [0.42, 1.05], $p = 0.076$). Although the point estimate suggests that occasional recyclers may have approximately 34% lower odds of higher adoption than consistent recyclers, the confidence intervals were wide and included the null, indicating that the data do not provide precise or statistically reliable evidence of an association with adoption level.

The results indicate that respondents who did not use CE-related applications or platforms had significantly lower odds of being in a higher food-related circularity adoption category compared with regular users ($OR = 0.37$, 95% CI [0.19, 0.71], $p = 0.003$), indicating a robust inverse association. Although the confidence interval is wide in relative terms, it lies clearly below 1, supporting a statistically reliable negative association. In other words, non-users were more likely to belong to a lower food-related circularity adoption category. Similarly, respondents who reported that they sometimes using these digital tools had lower odds of being in a higher adoption category than regular users ($OR = 0.70$, 95% CI [0.41, 1.22], $p = 0.210$); however, this difference was not statistically significant. The

confidence interval includes the null, indicating that the data do not provide precise or statistically reliable evidence of an association for occasional users. Overall, more frequent use of CE-related digital tools was associated with higher levels of food-related circularity adoption, suggesting a positive, dose-response-like relationship between digital tool usage and engagement in circular economy practices. The authors of the study conducted in [37] determined that technology is an essential tool for achieving a circular economy, whereas insufficient technology represents a barrier preventing households from adopting the circular economy.

Participants who disagreed that an unwillingness to store leftover food contributes to food waste had 8.47 times higher odds of belonging to a higher food-related circularity adoption category than those who agreed (95% CI [2.04, 35.12], $p = 0.003$), indicating a strong positive association between perceptions of leftover-food storage and reported food-related circularity adoption. Although the effect was clearly positive and substantial, the very wide confidence interval indicates considerable uncertainty about the exact magnitude of this association. This finding should be interpreted cautiously, as the survey instrument did not directly measure respondents' alternative causal beliefs about food waste (e.g., over-purchasing, poor planning, or aesthetic standards). One possible interpretation is that individuals with higher circularity adoption may attribute food waste primarily to factors other than leftover storage, but this explanation remains speculative. Alternative explanations include response bias, such as socially desirable responding on both belief and behavior items. Although this result may appear counterintuitive, the item captures respondents' attribution of food waste to a specific factor rather than their actual willingness or ability to store leftovers. Thus, disagreement should not be interpreted as suggesting that reluctance to store leftovers is compatible with stronger food-related circularity adoption. Instead, respondents with higher food-related circularity levels may perceive food waste as being driven predominantly by broader upstream practices—such as over-purchasing, inadequate meal planning, preparing excessive quantities of food, or a poor understanding of food-date labels—and view leftover storage as only one of several contributing factors.

Similarly, respondents who did not report boredom as a motivation for food shopping had significantly higher odds of being in a higher food-related circularity adoption category than those who considered boredom a motivation for food purchasing ($OR = 4.87$, 95% CI [1.62, 14.63], $p = 0.005$), indicating a strong positive association with food-related circularity adoption. Thus, not shopping because of boredom was positively associated with higher reported food-related circularity adoption. However, the confidence interval was wide, indicating that the true odds ratio could range from moderately large to very large and that the precise magnitude of this association is imprecisely estimated. Given the cross-sectional design and the conceptual proximity between consumption motivations and CE-related practices, these estimates indicate statistically significant associations between consumption-related orientations and reported food-related circularity adoption. However, the measured attitudes and behaviors may conceptually overlap with food-related circularity adoption and may jointly reflect a broader underlying orientation toward sustainable consumption and environmental responsibility.

Higher average rationalization motivations for using the CE system were associated with lower odds of being in a higher food-related circularity adoption category ($OR = 0.75$, 95% CI [0.55, 1.01], $p = 0.058$), indicating a negative association that was borderline and not statistically significant at the conventional 0.05 level. The confidence interval was wide and included null, indicating that the data do not provide precise or statistically reliable evidence of an association with adoption level. In other words, as respondents' usual reasons for rationalizing CE practices increased, their odds of belonging to a higher food-related circularity category tended to decrease (or, equivalently, their odds of being

in a lower adoption category tended to increase). Specifically, a one-unit increase in average rationalization motivations was associated with an estimated 25% lower odds ($1 - 0.75 = 0.25$) of being in a higher food-related circularity category, but this estimate should be interpreted cautiously given the marginal p -value and the confidence interval that includes no effect. Contrary to initial expectations, higher rationalization motivations were negatively associated with food-related circularity adoption. This negative association was unexpected and may reflect several possibilities. First, it could indicate that respondents who report stronger rationalizations for using the circular-economy system are those who feel a greater need to justify their behavior because their actual adoption is relatively low. Second, it may reflect response bias or social desirability, whereby individuals with lower adoption emphasize motivations to appear consistent with pro-environmental norms. Third, it could be related to scale orientation or item wording; however, all items were coded in the same direction (higher scores indicating stronger agreement), and no reverse coding was applied. Given the cross-sectional design, we cannot determine the direction of causality, and these interpretations remain tentative.

The parallel-lines test assesses the proportional-odds assumption of the ordinal logistic regression model. Specifically, it examines whether the associations between the predictors and the outcome are consistent across the cumulative thresholds of the ordinal dependent variable. Therefore, the chance that the predictor will match the response categories stays the same. The chi-square value was 4.521, and its lack of significance means that the chance of moving up to a higher category stays the same across all of the dependent variables.

Overall, ordinal logistic regression indicated that food-related circularity adoption is most strongly associated with monthly income, the use of CE-related applications and platforms, and attitudes toward food management. In particular, the respondents in all income categories below 10,000 SR had significantly higher odds of reporting stronger food-related circularity adoption than those earning more than 10,000 SR (the reference group), although the odds ratios did not follow a strictly monotonic pattern across income levels. The regular use of CE-related digital tools was also linked to higher food-related circularity adoption, as were the attitudes reflecting deliberate food-management practices; the respondents who did not shop out of boredom and those who disagreed that an unwillingness to store leftovers causes food waste had significantly higher odds of higher food-related circularity adoption. Taken together, these findings suggest that food-related circularity adoption in the Eastern Province is shaped not only by socioeconomic conditions, but also by everyday consumption habits and engagement with digital tools.

4. Conclusions

This cross-sectional survey of 384 adults in the Eastern Province of Saudi Arabia examined food-related circularity adoption. Although many respondents reported high levels of circularity adoption, socioeconomic characteristics, consumer behaviors, and attitudes were significantly associated with variation in food-related circularity practices. The ordinal logistic regression model showed limited explanatory power (McFadden's $R^2 = 0.118$), indicating that the included predictors explain only part of the variation in adoption; thus, findings should be interpreted as associations rather than causal effects. Several explanatory variables, particularly consumption-related attitudes and self-reported behaviors, may conceptually overlap with the circularity outcome and jointly reflect a broader orientation toward sustainable consumption.

Nevertheless, the results suggest actionable pathways to enhance adoption: strengthening rationalization motivations for food-related circularity practices; promoting food-waste recycling through technologies that facilitate individual-level circularity; and improving the availability, accessibility, and awareness of digital platforms as a promising avenue to

support food recycling and resource sharing. CE-related digital platforms could clearly communicate environmental, economic, and social benefits; link household actions to broader sustainability and food-security goals; and provide feedback that reinforces users' perceived impact. Tailored messaging, social-norm cues, and personalized nudges may be especially useful for individuals with weak pro-CE reasoning. At the policy level, campaigns and curricula that normalize CE behaviors, combined with incentives for digital solutions that integrate practical tools (e.g., meal planning, leftover tracking) with behavior-change components, align with Saudi Arabia's Vision 2030 objectives to advance food-related circularity, reduce food waste, and strengthen food security.

However, this study has several limitations. First, the use of convenience sampling and electronic recruitment through social media may have introduced self-selection and coverage bias. Individuals who are more environmentally aware, interested in circular economy (CE) issues, active on social media, or digitally literate may have been more likely to participate. Consequently, the sample may not be representative of the general population of the Eastern Province, and the observed proportion of respondents classified as having high food-related circularity adoption should not be generalized to the wider population. Second, all measures of food waste, recycling, and food-related circularity practices were self-reported and may therefore have been affected by recall and social-desirability biases. Respondents may have overreported socially desirable practices or underreported food-waste-related behaviors. Third, food-related circularity adoption was narrowly operationalized as a set of individual behaviors—specifically, food-waste prevention, leftover management, and the reuse of edible food—rather than as a comprehensive index of CE adoption. Accordingly, the findings should be interpreted as relating to this specific behavioral domain and not to CE adoption more broadly. Fourth, several methodological considerations warrant attention. Although the dependent variable reflects the behavioral scope of the study's index, some explanatory variables—such as food recycling, use of CE applications, rationalization motives, and food-management attitudes—are conceptually proximate to the outcome construct. This overlap, together with the use of self-reported measures collected in a single cross-sectional survey, raises the possibility of common-method bias and shared variance. These issues may have inflated the observed associations and complicated the interpretation of the regression coefficients as independent effects. Fifth, our findings regarding beliefs about food-waste causes and rationalization motivations should be interpreted with caution. The cross-sectional design precludes causal inference, and the survey did not directly measure all relevant causal beliefs or psychological constructs that may underlie these associations. Response bias, reverse causality, and measurement artifacts (e.g., item wording, scale orientation) may contribute to the observed patterns.

Therefore, future research should address several priorities. First, where feasible, researchers should employ probability-based sampling and triangulate survey responses with objective or behavioral measures—such as food-waste diaries, household waste audits, purchase records, and structured observations—to reduce sampling and self-reporting biases. In particular, nationally representative probability-based samples are needed to generate generalizable estimates of circular economy (CE) adoption and examine heterogeneity across regions and demographic groups in the Kingdom of Saudi Arabia. Second, longitudinal or panel designs would enable researchers to track changes in circularity-related behaviors over time, establish the temporal ordering of predictors and outcomes, and assess the stability and potential causal dynamics of observed associations. Experimental studies should examine whether interventions designed to strengthen rationalization motives result in sustained increases in food-related circularity adoption. Such work would help clarify the direction and mechanisms of the relationships identified in this study. Third,

future studies should develop and apply psychometrically validated consumer scales measuring CE-related behaviors and attitudes, including assessments of reliability, construct validity, and measurement invariance across demographic groups and cultural contexts. Researchers should also incorporate additional psychological, cultural, institutional, and contextual variables to enhance explanatory power. Psychometric validation, structural equation modeling, longitudinal designs, and experimental approaches could help distinguish latent attitudes from observable behavioral manifestations and clarify potential causal pathways.

Fourth, multidimensional CE indices should be developed to encompass diverse waste streams and circular strategies, thereby providing a more comprehensive assessment of consumer-level CE adoption beyond food-waste prevention, leftover management, and the reuse of edible food. Fifth, future research should refine the measurement of rationalization motives by distinguishing among economic, environmental, and social considerations and examining which types of motives are most effective across different population segments and cultural contexts. Sixth, focused studies should investigate high-priority food categories identified by the Saudi National Program to Reduce Food Loss and Waste, including dates, rice, wheat, fruits, vegetables, and red and white meat. Such research should examine how consumers purchase, prepare, store, and handle these foods to identify context-specific points at which waste is generated, including over-portioning, inadequate refrigeration, and misinterpretation of expiration labels. This evidence could inform targeted CE interventions—such as composting, upcycling, and food donation—tailored to consumption patterns in Saudi Arabia.

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Abbreviations

The following abbreviations are used in this manuscript:

CE	Circular economy
OLRM	Ordinal logistic regression model
MLE	Maximum likelihood estimation

Appendix A

Table A1. Results of internal consistency for the items used to construct the food-related circularity level using Cronbach's Alpha.

Recycling Food Items	Items Used to Construct the Food-Related Circularity Level	Cronbach's Alpha if Item Deleted	Cronbach's Alpha Coefficient
Bread	Discarding it in the trash.	0.935	0.931
	Converting stale bread into breadcrumbs.	0.930	
	Creating croutons for salads or soups or preparing nutritious snacks.	0.929	
	Producing an assortment of confections.	0.928	
	Preparing bread soup or thareed, which consists of bread pieces.	0.929	
	Utilizing it to absorb the odor of scorched rice.	0.928	
	Utilizing it to preserve the freshness of some food items, such as placing it in sugar containers.	0.929	
	Utilizing it to feed the birds.	0.929	
Dates	Discarding them in the trash.	0.934	
	Utilizing them as fodder for livestock.	0.929	
	Refrigerating them to prolong their shelf life for later use.	0.930	
	Distributing them as gifts to family and neighbors.	0.929	
	Distributing them to non-profit societies.	0.929	
	Producing an assortment of confections or winter recipes.	0.929	
Cooked Rice	Discarding it in the trash.	0.934	
	Creating additional recipes.	0.928	
	Saving it to consume the next day.	0.929	
	Utilizing it to feed the birds.	0.928	
	Drying it for decorative purposes and writing on boards.	0.929	
Cooked Pasta	Discarding it in the trash.	0.933	
	Utilizing it in preparing salads.	0.928	
	Preparing a baked pasta pie.	0.929	
	Placing it in airtight containers after drizzling oil to use it the next day.	0.928	
Stewed vegetables	Discarding them in the trash.	0.933	
	Utilizing them for other recipes, such as pizza.	0.927	
	Utilizing them in soups or stews.	0.927	
	Mixing with tomatoes to create sauces.	0.926	
	Storing them in the refrigerator for the following day.	0.927	
Stewed meat	Discarding it in the trash.	0.933	
	Preparing a meat pie in the oven.	0.926	
	Utilizing it to prepare soup.	0.926	
	Refreezing meat remnants.	0.926	
	Utilizing it to feed the cats.	0.927	
Fruits	Discarding them in the trash.	0.933	
	Utilizing them to prepare both cold and hot beverages.	0.927	
	Freezing for future culinary preparations.	0.928	
	Preserving in a dried state for year-round consumption.	0.927	
	Producing several varieties of jam.	0.927	
	Utilizing the seeds to cultivate fruit plants to satisfy the family requirements.	0.927	
	Utilizing leftover fruit as fertilizer for houseplants.	0.926	

Table A2. Multicollinearity diagnostics for predictors included in the ordinal logistic regression model of food-related circularity adoption.

Predictors	B	SE	Standardized β	<i>t</i>	<i>p</i>	Tolerance	VIF
FS	0.044	0.017	0.124	2.584	0.01	0.975	1.025
INC	−0.055	0.021	−0.123	−2.547	0.011	0.958	1.044
OCCU	0.049	0.054	0.044	0.912	0.362	0.973	1.027
MS	0.099	0.058	0.081	1.693	0.091	0.967	1.034
RFS	0.025	0.043	0.028	0.582	0.561	0.969	1.033
APCE	0.116	0.039	0.145	2.941	0.003	0.916	1.092
UWKf	−0.531	0.177	−0.146	−2.992	0.003	0.945	1.058
MBFP	−0.415	0.137	−0.146	−3.035	0.003	0.971	1.03
ARMCE	−0.098	0.035	−0.139	−2.775	0.006	0.898	1.113

References

- Geissdoerfer, M.; Savaget, P.; Bocken, N.M.; Hultink, E.J. The Circular Economy—A New Sustainability Paradigm? *J. Clean. Prod.* **2017**, *143*, 757–768. [\[CrossRef\]](#)
- Ruggieri, A.; Braccini, A.M.; Poponi, S.; Mosconi, E.M. A meta-model of inter-organisational cooperation for the transition to a circular economy. *Sustainability* **2026**, *8*, 1153. [\[CrossRef\]](#)
- Kirchherr, J.; Reike, D.; Hekkert, M. Conceptualizing the circular economy: An analysis of 114 definitions. *Resour. Conserv. Recycl.* **2017**, *127*, 221–232. [\[CrossRef\]](#)
- Lieder, M.; Asif, F.M.A.; Rashid, A. Towards Circular Economy implementation: An agent-based simulation approach for business model changes. *Auton. Agents Multi-Agent Syst.* **2017**, *31*, 1377–1402. [\[CrossRef\]](#)
- Machado, M.A.D.; Almeida, S.O.; Bollick, L.C.; Bragagnolo, G. Second-hand fashion market: Consumer role in circular economy. *J. Fash. Mark. Manag.* **2019**, *23*, 382–395. [\[CrossRef\]](#)
- Vidal-Ayuso, F.; Akhmedova, A.; Jaca, C. The circular economy and consumer behaviour: Literature review and research directions. *J. Clean. Prod.* **2023**, *418*, 137824. [\[CrossRef\]](#)
- Alves, W.; Silva, Â.; Rodrigues, H.S. Circular Economy and Consumer's Engagement: An Exploratory Study on Higher Education. *Bus. Syst. Res.* **2022**, *13*, 84–99. [\[CrossRef\]](#)
- Chrispim, M.C.; da Silva, A.R.; Christopoulos, T.P.; Ramos, T.B. Circular economy and consumer action: The role of apps in reducing food waste and shaping consumer behavior. *Sustain. Futur.* **2026**, *11*, 101742. [\[CrossRef\]](#)
- Selvefors, A.; Rexfelt, O.; Renstrom, S.; Stromberg, H. Use to use—A user perspective on product circularity. *J. Clean. Prod.* **2019**, *223*, 1014–1028. [\[CrossRef\]](#)
- Chi, T.; Gerard, J.; Yu, Y.; Wang, Y. A study of US consumers' intention to purchase slow fashion apparel: Understanding the key determinants. *Int. J. Fash. Des. Technol. Educ.* **2021**, *14*, 101–112. [\[CrossRef\]](#)
- Chrispim, M.C.; Mattsson, M.; Ulvenblad, P. The underrepresented key elements of circular economy: A critical review of assessment tools and a guide for action. *Sustain. Prod. Consum.* **2023**, *35*, 539–558. [\[CrossRef\]](#)
- Piao, R.S.; de Vincenzi, T.B.; da Silva, A.L.; de Oliveira, M.C.; Vazquez-Brust, D.; Carvalho, M.M. How is the circular economy embracing social inclusion? *J. Clean. Prod.* **2023**, *411*, 137340. [\[CrossRef\]](#)
- Schroeder, P.; Anggraeni, K.; Weber, U. The Relevance of Circular Economy Practices to the Sustainable Development Goals. *J. Ind. Ecol.* **2019**, *23*, 77–95. [\[CrossRef\]](#)
- do Canto, N.R.; Grunert, K.G.; De Barcellos, M.D. Circular Food Behaviors: A Literature Review. *Sustainability* **2021**, *13*, 1872. [\[CrossRef\]](#)
- Borrello, M.; Caracciolo, F.; Lombardi, A.; Pascucci, S.; Cembalo, L. Consumers' Perspective on Circular Economy Strategy for Reducing Food Waste. *Sustainability* **2017**, *9*, 141. [\[CrossRef\]](#)
- Pfaltzgraff, L.A.; Cooper, E.C.; Budarin, V.; Clark, J.H. Food waste biomass: A resource for high-value chemicals. *Green Chem.* **2013**, *15*, 307–314. [\[CrossRef\]](#)
- Mirabella, N.; Castellani, V.; Sala, S. Current options for the valorization of food manufacturing waste. A Review. *J. Clean. Prod.* **2014**, *65*, 28–41. [\[CrossRef\]](#)
- Cherian, J.; Jacob, J. Green Marketing: A Study of Consumers' Attitude towards Environment Friendly Products. *Asian Soc. Sci.* **2012**, *8*, 117–126. [\[CrossRef\]](#)
- Mylan, J.; Holmes, H.; Paddock, J. Re-Introducing Consumption to the 'Circular Economy': A Sociotechnical Analysis of Domestic Food Provisioning. *Sustainability* **2016**, *8*, 794. [\[CrossRef\]](#)

20. Despoudi, S.; Wu, K.; Nedelkou, E.; Zhu, J. Consumers' Attitudes and Behaviors Toward Circular Food Supply Chain Practices and Sustainable Food Purchase Intention: Evidence from China. *Circ. Econ. Sustain.* **2025**, *5*, 4469–4486. [\[CrossRef\]](#)
21. Baig, M.B.; Gorski, I.; Neff, R.A. Understanding and addressing waste of food in the Kingdom of Saudi Arabia. *Saudi J. Biol. Sci.* **2019**, *26*, 1633–1648. [\[CrossRef\]](#)
22. Baig, M.B.; Alotaibi, B.A.; Alzahrani, K.; Pearson, D.; Alshammari, G.M.; Shah, A.A. Food Waste in Saudi Arabia: Causes, Consequences, and Combating Measures. *Sustainability* **2022**, *14*, 10362. [\[CrossRef\]](#)
23. Abdullah, N.; Al-Wesabi, O.A.; Mohammed, B.A.; Al-Mekhlafi, Z.G.; Alazmi, M.; Alsaffar, M.; Anbar, M.; Sumari, P. Integrated Approach to Achieve a Sustainable Organic Waste Management System in Saudi Arabia. *Foods* **2022**, *11*, 1214. [\[CrossRef\]](#)
24. Alsaud, K.; Assad, F.; Patsavellas, J.; Salonitis, K. A Comparative Analysis of Circular Economy Practices in Saudi Arabia. *Sustainability* **2025**, *17*, 3281. [\[CrossRef\]](#)
25. Sulami, S.; Sulami, M.; Nasr, J.; Sharawi, H. Circular Economy Analysis as a Tool to Enhance Sustainability of Supply Chains in Kingdom Saudi Arabia and a Means to Achieve Saudi Vision 2030. *Mod. Econ.* **2024**, *15*, 566–586. [\[CrossRef\]](#)
26. Thompson, S.K. *Sampling*, 3rd ed.; John Wiley & Sons: Hoboken, NJ, USA, 2012; pp. 59–60.
27. General Authority for Statistics. *Saudi Census Statistics, 2022: Population Statistics (2010–2022)*; General Authority for Statistics: Riyadh, Saudi Arabia, 2022.
28. Abdalla, S.M.; Aljeri, M. Barriers to circular economy adoption among adults in the eastern province of Saudi Arabia. *Edelweiss Appl. Sci. Technol.* **2026**, *10*, 282–291. [\[CrossRef\]](#)
29. Rakaban, N.; El-Habashy, M.; Kasem, A. Rationalizing Household Circular Economy System Consumption as an Entry Point for Resource Sustainability and Demographic Factors from the Head of Household's Perspective with an Extension Program Proposal. *J. Home Econ. Menoufia Univ.* **2024**, *34*, 233–264. [\[CrossRef\]](#)
30. Lipsitz, S.R.; Fitzmaurice, G.M.; Regnbogen, S.E.; Sinha, D.; Ibrahim, J.G.; Gawande, A.A. Bias Correction for the Proportional Odds Logistic Regression Model with Application to a Study of Surgical Complications. *J. R. Stat. Soc. Ser. C Appl. Stat.* **2012**, *62*, 233–250. [\[CrossRef\]](#)
31. Fullerton, A.S. A Conceptual Framework for Ordered Logistic Regression Models. *Sociol. Methods Res.* **2009**, *38*, 306–347. [\[CrossRef\]](#)
32. Long, J.S.; Freese, J. *Regression Models for Categorical Dependent Variables Using Stata*, 3rd ed.; Stata Press: College Station, TX, USA, 2014.
33. Williams, R.A.; Quiroz, C. Ordinal Regression Models. In *SAGE Research Methods Foundations*; Atkinson, P., Delamont, S., Cernat, A., Sakshaug, J.W., Williams, R.A., Eds.; SAGE Publications Ltd.: Thousand Oaks, CA, USA, 2019. [\[CrossRef\]](#)
34. Pansera, M.; Barca, S.; Martinez Alvarez, B.; Leonardi, E.; D'Alisa, G.; Meira, T.; Guilibert, P. Toward a just circular economy: Conceptualizing environmental labor and gender justice in circularity studies. *Sustain. Sci. Pract. Policy* **2024**, *20*, 2338592. [\[CrossRef\]](#)
35. Aldieri, L.; Barra, C.; Falcone, P.M.; Vinci, C.P. Socio-political determinants of circular economy behavior: A cross-sectional analysis across Italy. *Socio-Econ. Plan. Sci.* **2025**, *100*, 102252. [\[CrossRef\]](#)
36. Ismail, Y. Creating a Circular Economy of Household Solid Waste: Sustainability Perspective. *Int. J. Environ. Impacts* **2025**, *8*, 765–772. [\[CrossRef\]](#)
37. Tran, Q.P.; Nguyen, T.K.; Dong, M.C. Understanding Factors of Households' Circular Economy Adoption to Facilitate Sustainable Development in an Emerging Country. *Res. World Agric. Econ.* **2023**, *4*, 79–89. [\[CrossRef\]](#)
38. Keprdová, T.; Míinea, D.; de Götzen, A. Transitioning to a Circular Economy: A Gender-Sensitive Exploration of Circular Consumption in Denmark and Southern Sweden. In *DRS2024*; Gray, C., Ciliotta Chehade, E., Hekkert, P., Forlano, L., Ciuccarelli, P., Lloyd, P., Eds.; Design Research Society: Boston, MA, USA, 2024. [\[CrossRef\]](#)
39. Ostrowska, I. The Role and Motivations of Consumers to Join the Circular Economy [Internet]. In *Business, Management and Economics*; IntechOpen: London, UK, 2025. [\[CrossRef\]](#)
40. Ungerman, O.; Dědková, J. Consumer behavior in the model of the circular economy in the field of handling discarded items. *PLoS ONE* **2024**, *19*, e0300707. [\[CrossRef\]](#) [\[PubMed\]](#) [\[PubMed Central\]](#)
41. Solomon Eghosa, U.; Karabo, S. Household awareness and perceptions of circular economy development in Limpopo Province, South Africa: A pathway to sustainable development. *Clean. Waste Syst.* **2025**, *11*, 100316. [\[CrossRef\]](#)

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