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Barriers to circular economy adoption among adults in the eastern province of Saudi Arabia

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Abstract: The circular economy (CE) presents a viable strategy for mitigating food waste and extending the lifespan of food products. This study aims to assess the reliability and validity of utilizing ten questions as a tool for measuring barriers to CE adoption and to provide recommendations for policymakers to alleviate these barriers. A sample of 384 Saudi adults, aged 18 and older, from the Eastern Province was chosen to complete the questionnaire. The collected data was then examined using descriptive statistics, Cronbach's Alpha, and Exploratory Factor Analysis (EFA). Cronbach's Alpha indicates that the questions measuring barriers to CE adoption have good internal consistency. The EFA results also reveal that there is only one component that explains about 63.42% of the total variance in the questions measuring barriers to CE adoption. Therefore, it is important to create and carry out educational and awareness campaigns that focus on practical ways to incorporate CE principles into everyday life. Consequently, the study promotes the need to overcome the barriers hindering CE, accompanied by accepting the questions measuring barriers to CE adoption as a reliable and valid tool for assessing the implementation of CE in Saudi Arabia.

Keywords: *Barriers, Circular economy (CE), Cronbach's alpha, Exploratory factor analysis (EFA), Food waste, Saudi Arabia.*

1. Introduction

Recently, the economics of recycling have become an important part of achieving sustainability. The principal factors contributing to unsustainability were resource scarcity and the inefficient management of both resources and processes. Consequently, the implementation of a circular economy (CE) presented a potentially effective solution to the challenges inherent in the conventional linear economic model [1]. As a result, the circular economy (CE) showed potential as a means of launching a road toward sustainable development [2]. To achieve sustainability, resources must be used efficiently, with a focus on reuse, repair, recycling, and material regeneration within closed-loop systems Sangoremi et al. [3]. Lawal [4] argued that circular economy strategies yield positive environmental outcomes, including waste reduction, decreased greenhouse gas emissions, and the conservation of natural resources. Furthermore, industrialized nations are increasingly adopting the circular economy concept, which fosters sustainable production, the efficient utilization of resources, the development of a novel economic model, and the creation of high-skill employment opportunities [5-7]. According to Biswas et al. [8], there are five criteria related to the adoption of circular economy concepts: sustainability, resource management, product lifespan, collaboration and partnerships, and technology-innovation.

The circular economic model has gained traction in various sectors, especially in developed countries. Although its benefits for the environment, economy, and society are widely acknowledged, the circular economy's practical application still faces constraints. This limited uptake is largely due to several factors, such as significant initial capital demands, difficulties in obtaining financial support, and

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the immature state of markets for recycled materials [5]. Policy and regulatory deficiencies present considerable impediments. These encompass subsidies that incentivize linear economic paradigms, excessively stringent standards, and a lack of adequate backing for circular design principles and producer responsibility initiatives. Moreover, technological and infrastructural limitations, including the scarcity of validated large-scale projects, deficient reverse logistics systems, and the restricted accessibility of sophisticated recycling technologies, compound these challenges. Organizational and cultural resistance, characterized by businesses and institutions' reluctance to embrace risk, their adherence to linear business models, and their resistance to altering established practices, also impede progress [9]. Therefore, the global shift toward a circular economy is hindered by a lack of understanding and awareness. These stem from a widespread lack of comprehensive understanding regarding circular principles, associated metrics, and the long-term benefits, as observed in numerous businesses, policymakers, and consumers [10].

In the food sector, the adoption of the circular economy is of paramount importance, as it fosters food sustainability and maximizes the utility of food resources. Despite over 700 million individuals globally continuing to experience hunger, food loss and waste accounted for one-third of all food production in 2022, totaling 1.05 billion tons. This situation exacerbates resource scarcity, contributes to greenhouse gas emissions (8–10% of the total), and impedes access to adequate nutrition [11]. Therefore, applying circular economy principles, such as waste valorization and redistribution, offers a practical way to improve consumption patterns and strengthen the resilience of food systems [12-14]. Furthermore, United Nations Environmental Programme [15] supported the implementation of "zero waste" systems in cities, prioritizing prevention, source separation, reuse, recycling, and composting over landfilling and incineration.

In Saudi Arabia, roughly 4 million tons of waste are discarded annually, a figure representing a 33% waste rate. This highlights the potential economic value, estimated at SR40 billion, that could be redirected to help the nation achieve its sustainability objectives, particularly as households increasingly require access to better quality food. Saudi Arabia has initiated numerous measures to mitigate food loss and waste through the National Program to Reduce Food Loss and Waste (Li Tadum), a national initiative designed to safeguard natural resources. This program endeavors to diminish food loss and waste by adhering to contemporary international standards and practices. Launched in 2018 by the Saudi Grains Organization, an entity under the Ministry of Environment, Water, and Agriculture, the program established regulations targeting food loss and waste reduction across a broad spectrum of food products, encompassing wheat, rice, dates, vegetables, fruits, and both red and white meat [16]. Conversely, unsustainable food practices in Saudi Arabia are intensified by overconsumption, the over-preparation of food for social events, and the disposal of food approaching its expiration date [17-19]. The integration of circular economy principles within Saudi Arabia's food sector offers a substantial opportunity to reduce food waste, improve nutritional practices, and promote food sustainability. Conversely, the practical application of a circular economy model encounters various obstacles rooted in consumer conduct. Therefore, this research seeks to evaluate the barriers impeding the implementation of the circular economy (CE) model, utilizing a questionnaire comprising ten questions. The study also aims to assess the reliability and validity of utilizing barriers to the adoption of circular economy (CE) questions as a measurement tool for CE implementations and to provide recommendations for policymakers to alleviate these barriers. The study aligns with the objectives of Saudi Vision 2030, identifying the barriers to sustainable food consumption and helping policymakers to enhance food security.

2. Research Methodology

2.1. Sampling Size

The sample was taken from the Eastern Province between September and August 2025. The Eastern Province is located on the Arabian Gulf coast in eastern Saudi Arabia. It is well-known for its diverse population, which includes both urban and rural residents. The Eastern Province is a very

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important part of the Kingdom of Saudi Arabia. It has many different industries, such as agriculture, commerce, and industry. It is also characterized by a consumer culture influenced by indigenous traditions and globalization. This makes it intriguing in the context of examining consumer behavior regarding food waste and the development of a circular economy. The climatic environment, both dry and humid, influences the development of distinct consumer behaviors. The sample was randomly selected from a total population of approximately 2,949,854 individuals [20] using the Stephen Thompson equation to ensure a comprehensive and representative sample from the designated population [21]. The Stephen Thompson equation can be written like this:

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

Whereas:
N: the size of the study community
Z: the normative degree corresponding to the level of significance is 0.95 and is equal to 1.96
d: the error ratio is equal to 0.05
p: the ratio of availability of the property and neutral is 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 study sample initially comprised 384 individuals; however, to ensure data accuracy and reliability while minimizing incomplete data, the authors opted to augment the sample size.

2.2. Data Collection

The primary data of this study was a survey utilizing a structured questionnaire to ascertain the barriers preventing individuals in the Eastern Province from embracing a circular economy to enhance food consumption efficiency. The 10-question survey was meant to find out what makes it hard for people in the Eastern Province to switch to a circular economy. The self-report questionnaire used a five-point Likert scale (strongly disagree, disagree, neutral, agree, and strongly agree). Table 1 shows the barriers that hinder the practical application of the circular economy (CE) model and provides quick references. Before the questionnaire was sent out, a group of experts and professionals reviewed it to ensure it was well-designed and aligned with the study's goals. This method guarantees that the questionnaire accurately assesses its intended parameters. The questionnaire has specific requirements to ensure that the respondents are appropriate for the study. The requirements specify that Saudi citizens must be at least 18 years old and reside in the Eastern Province. Pilot research was conducted by administering the questionnaire to 25 individuals who met the eligibility criteria. Their feedback was used to identify issues participants faced when completing the questionnaire. Based on this feedback, modifications were made after reviewing the comments. The main data was collected by distributing the questionnaire electronically through social media. Additionally, the study incorporated secondary data from relevant external sources.

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Table 1.
Barriers to Circular Economy (CE) Adoption and Quick References.

Barriers to Circular Economy (CE) Adoption		Quick References
1	The deficiency in understanding the significance of the circular economy arises from the lack of awareness campaigns that illustrate the application of its principles in daily life.	Awareness
2	The lack of social support that promotes sustainable behavior impedes the adoption of environmentally responsible practices.	Social support
3	Owing to insufficient time, individuals often adhere to conventional consumption patterns.	Insufficient time
4	Implementing circular economy practices necessitates extra time for activities including sorting, reusing, and pursuing sustainable alternatives.	Extra time
5	Direct waste disposal is frequently regarded as simpler and more convenient than recycling.	Waste disposal
6	The absence of infrastructure to facilitate circular economy services, including recycling centers and reusable waste collection stations, obstructs effective implementation.	Absence of infrastructure
7	Restricted access to services that enable the implementation of circular economy principles obstructs their effective adoption	Access to services
8	Insufficient innovative technologies or household appliances that adequately address consumer recycling requirements	Innovative technologies
9	The lack of financial incentives deters individuals from embracing sustainable practices.	Financial incentives
10	The lack of legislation requiring the reduction of food waste impedes advancement towards sustainable consumption.	Legislation

2.3. Data Analysis

2.3.1. Internal Consistency of the Questions Measuring Barriers to CE Adoption Using Cronbach's Alpha

The Alpha Cronbach test of internal consistency assesses the degree to which all related questions measure the same underlying construct of impediments to the adoption of CE among Saudi adults in the Eastern Province. This illustrates the context of the questions measuring barriers to CE adoption. The Alpha Cronbach is used to indicate the interconnectedness and dimensionality of the questions measuring barriers to CE adoption. This suggests that responses will be roughly consistent when solicited from the same individuals at different intervals.

Previous studies by DeVellis [22], Tavakol and Dennick [23], Sekaran and Bougie [24], and Shrestha [25] demonstrated that a Cronbach's alpha between 0.70 and 0.95 indicates satisfactory internal consistency among items. Consequently, the questionnaire is reliable and suitable for achieving the study's objectives.

2.3.2. Exploratory Factor Analysis (EFA)

Exploratory factor analysis (EFA) is a statistical method commonly used to evaluate the construct validity of self-report instruments [26]. Therefore, EFA was used to identify barriers to implementing circular economy (CE) practices, based on information from a self-reported questionnaire. Gorsuch [27] and Pett et al. [28] suggested that a sample size of about 384 participants is sufficient for EFA.

We calculated the mean and standard deviation for each question and used a factor analysis correlation matrix to see how the variables were related to each other. Before extracting factors, we used Kaiser's Meyer-Olkin (KMO) Measure of Sampling Adequacy (MSA) and Bartlett's Test of Sphericity to determine if the data were suitable for Exploratory Factor Analysis (EFA) [25, 26]. A KMO value of 0.50 or higher indicates that the sampling adequacy (MSA) is appropriate. Additionally, Bartlett's test was used to check the identity matrix. A P-value below 0.05 indicates that the assumption of sphericity is met. Principal component analysis (PCA), a common method for factor extraction, is mainly used to reduce the number of factors.

The SCREE test and Kaiser's criterion are two common methods for deciding how many factors to extract [25]. The cumulative variance (%) can serve as an extraction method, representing the share of overall variance in barriers to circular economy (CE) adoption illuminated by the extracted elements.

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Ultimately, Promax is used as a rotation method to create associated factors and find a more accurate and significant solution [29].

3. Results and Discussion

Table 2 reveals the responses of the participants towards the barriers to the adoption of the circular economy (CE) in the Eastern Province. Saudi adults in the Eastern Province self-reported their barriers to the implementation of CE utilizing a five-point Likert scale. The findings depict that 76.8% of participants "strongly disagree" that the deficiency in understanding the significance of the circular economy arises from the lack of awareness campaigns that illustrate the application of its principles in daily life. On the other hand, about 1.3% "strongly agreed" that the deficiency in understanding the significance of the circular economy arises from the lack of awareness campaigns that illustrate the application of its principles in daily life. About 39.3% of those who took part "disagreed" with the statement that the lack of social support that promotes sustainable behavior impedes the adoption of environmentally responsible practices. Conversely, 7.3% of respondents reported "agree" that the lack of social support that promotes sustainable behavior impedes the adoption of environmentally responsible practices. Likewise, 9.6% of respondents reported that they "agree" with the idea that, owing to insufficient time, individuals often adhere to conventional consumption patterns. About 8.9% of the participants reported that they "agree" that implementing circular economy practices necessitates extra time for activities, including sorting, reusing, and pursuing sustainable alternatives. Around 63.5% of the participants said they "strongly disagree" with the idea that direct waste disposal is frequently regarded as simpler and more convenient than recycling. On the other hand, 1.8% said they "strongly agree" that direct waste disposal is frequently regarded as simpler and more convenient than recycling. On the other hand, 28.4% of participants reported "disagreed" with the statement that the absence of infrastructure to facilitate circular economy services, including recycling centers and reusable waste collection stations, obstructs effective implementation. About 6.8% said they "agree" that the absence of infrastructure to facilitate circular economy services, including recycling centers and reusable waste collection stations, obstructs effective implementation. On the other hand, about 16.9% of those who took part said they "disagree" with the statement that restricted access to services that enable the implementation of circular economy principles obstructs their effective adoption. Around 6.5% "agreed" with the statement that insufficient innovative technologies or household appliances that adequately address consumer recycling requirements are a barrier. Alternatively, almost 63.3% of the participants said they "strongly disagree" that the lack of financial incentives deters individuals from embracing sustainable practices. About 22.9% of the participants said they "disagree" with the idea that the lack of legislation requiring the reduction of food waste impedes progress toward sustainable consumption. Only 5.5% "agreed" that the lack of legislation requiring the reduction of food waste impedes progress toward sustainable consumption. The results indicate that individuals in the Eastern Province of Saudi Arabia possess markedly divergent perspectives regarding the barriers affecting the adoption and implementation of the circular economy model. The evidence suggests that their methods for reducing food waste and optimizing food consumption likely differ significantly, reflecting diverse cultural practices, economic circumstances, and levels of awareness regarding sustainability in the region. Consequently, their behavior directly influences food consumption and sustainability.

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Table 2.
Participants' Responses Towards the Barriers to the Adoption of CE in the Eastern Province, 2025.

Quick references	Participants' Responses				
	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
Awareness	295(76.8%)	48 (12.5%)	19(4.9%)	17(4.4%)	5(1.3%)
Social support	150(39.1%)	151(39.3%)	45(11.7%)	28(7.3%)	10(2.6%)
Insufficient time	232(60.4%)	35(9.1%)	75(19.5%)	37(9.6%)	5(1.3%)
Extra time	185(48.2%)	103(26.8%)	50(13%)	34(8.9%)	12(3.1%)
Waste disposal	244(63.5%)	66(17.2%)	39(10.2%)	28(7.3%)	7(1.8%)
Absence of infrastructure	196(51%)	109(28.4%)	46(12%)	26(6.8%)	7(1.8%)
Access to services	244(63.5%)	65(16.9%)	43(11.2%)	27(7%)	5(1.3%)
Innovative technologies	204(53.1%)	99(25.8%)	48(12.5%)	25(6.5%)	8(2.1%)
Financial incentives	243(63.3%)	65(16.9%)	45(11.7%)	23(6.0%)	8(2.1%)
Legislation	221(57.6%)	88(22.9)	45(11.7%)	21(5.5%)	9(2.3%)

3.1. Results of the Internal Consistency of the Questions Measuring Barriers to CE Adoption:

Cronbach's alpha coefficient was used to assess the reliability of questions measuring barriers to CE adoption in the Eastern Province of Saudi Arabia. Table 3 presents the internal consistency for quick reference of barriers to CE adoption using Cronbach's Alpha. The finding indicates a coefficient of around 0.935, which is considered acceptable as it is within the acceptable range of 0.7 to 0.9 [23, 25, 30]. This result underscores that the questions measuring barriers to CE adoption are legitimate and that no questions necessitate removal. The results confirm the usefulness of these questions in identifying barriers to using circular economy (CE) practices in Saudi Arabia's Eastern Province.

Table 3.
Results of Internal Consistency for the Quick References of the Barriers to CE Adoption Using Cronbach's Alpha.

Quick references	Cronbach's Alpha if item deleted	Cronbach's Alpha coefficient
Awareness	0.932	0.935
Social support	0.929	
Insufficient time	0.928	
Extra time	0.932	
Waste disposal	0.930	
Absence of infrastructure	0.928	
Access to services	0.926	
Innovative technologies	0.927	
Financial incentives	0.928	
Legislation	0.926	

3.2. The Results of the Exploratory Factor Analysis (EFA)

The self-report survey was analyzed using exploratory factor analysis (EFA). The EFA conducted various evaluations, such as matrix assessment, determinant assessment, KMO Measure of Sampling Adequacy (MSA), identification matrix assessment through the sphericity test, and principal component analysis (PCA), to validate the framework supporting the barriers to CE adoption. The EFA of the questions measuring barriers to circular economy (CE) adoption produced a determinant value of 0.001, which is within the acceptable range of 0 to 1. This finding suggests that the concise references pertaining to the barriers to CE adoption are appropriate for EFA. Furthermore, Bartlett's test for sphericity produced a statistically significant result, as evidenced by a P-value less than 0.01. Consequently, this result suggests that the correlation matrix deviates from an identity matrix, thereby justifying the application of EFA.

Table 4 depicts the results of Kaiser –Meyer Olkin (KMO) Measure of Sampling Adequacy (MSA) and Bartlett's Test of Sphericity. The KMO test value in Table 4 is about 0.940, which means that the data were good enough for exploratory factor analysis. This conclusion supports [25, 28] assertion that a KMO score greater than 0.7 indicates adequate data for exploratory factor analysis (EFA).

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Table 4.
The Results of Kaiser –Meyer Olkin (KMO) Measure of Sampling Adequacy (MSA) and Bartlett's Test of Sphericity.

Kaiser-Meyer-Olkin Measure of Sampling Adequacy		0.940
Bartlett's Test of Sphericity	Approx. Chi-Square	2619.195
	df	45
	p-value	0.000

Note: P-value significant at level 1%.

Principal component analysis (PCA) was employed in exploratory factor analysis (EFA) to delineate the diverse components associated with the barriers to adopting circular economy (CE) practices. The PCA results show that there is only one barrier to adopting the circular economy: the deficiency in understanding the significance of the circular economy arises from the lack of awareness campaigns that illustrate the application of its principles in daily life. To obtain the component, several methods were used, such as Kaiser's criteria, the SCREE test, and the cumulative percentage of extracted variance. The eigenvalue for each component was greater than 1, indicating that these components were significant [26]. Kaiser's method was chosen to retain the extraction factors, as it was considered the most accurate way to obtain the desired results. Figure 1 demonstrates the SCREE plot of extracted factors related to barriers to CE adoption. The SCREE test, shown in Figure 1, displays the eigenvalue graph. Therefore, barriers to adopting CE are identified by eigenvalues greater than one. This is confirmed by the extracted factor, which is above the point where the curve flattens, as seen in Figure 1.

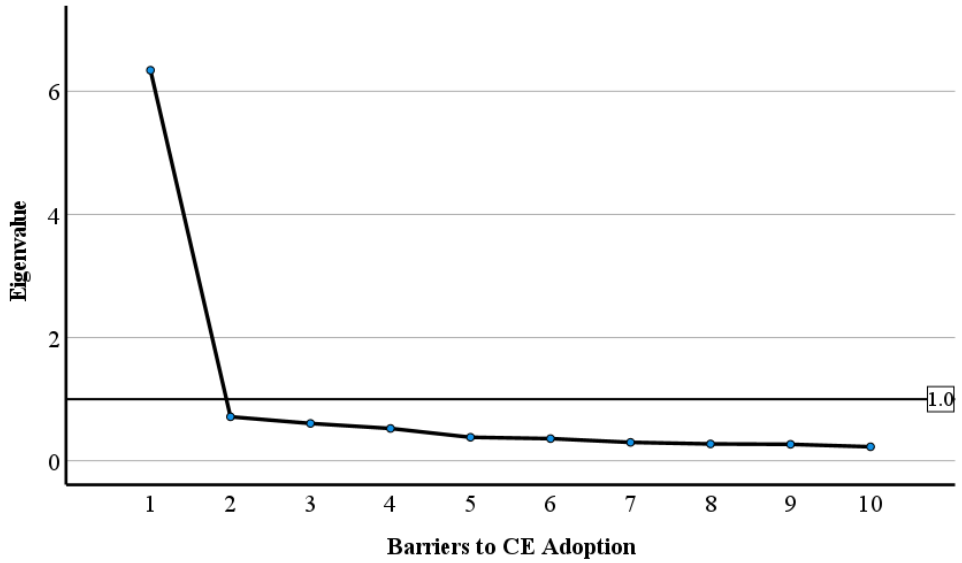

Figure 1.
The SCREE Plot of the Extracted Factor of the Barriers to CE Adoption.

Table 5 depicts the factor loadings of the quick references to the barriers to CE adoption and the cumulative percentage of variance of the extracted factor. The cumulative percentage of variation, as shown in Table 5, indicates that a single identified factor accounts for about 63.42% of the total variance related to the ten barriers to CE adoption. Pett et al. [28] asserted that a cumulative percentage of variance ranging from 50% to 90% is sufficient for the identification of factors for extraction. Rabia and Lu [31] delineated 64 elements affecting CE adoption, classifying them into three interrelated domains: organizational, political, and procedural, and technological aspects. On the other hand, Trần et al. [32] discovered that individuals' environmental perspectives and their intentions significantly influence their willingness to engage in the circular economy within Vietnam. Tapia et al. [33] further posited that more challenging territorial elements, such as accessibility and technological infrastructure, facilitate

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the implementation of the circular economy, whereas less tangible factors, including knowledge, awareness, governance, and environmental conditions, accelerate circular transformations. Luthra et al. [34] contributed to the theory of planned and operational behavior by examining the influence of personal factors on the adoption of circular economy (CE) practices through exploratory factor analysis (EFA) among small and medium-sized enterprises (SMEs). Furthermore, it investigated the behavioral determinants that impact CE adoption within these enterprises. Recent research employed exploratory and confirmatory factor analyses to identify four primary categories of strategies aimed at promoting the principles of the circular economy among built environment firms within the Ghanaian construction industry. These categories include systems and technical-related strategies, market orientation and operational strategies, knowledge dissemination and awareness-related strategies, and environmental and regulatory strategies [35].

Table 5.
Factors loading of the quick references of the barriers to CE adoption and cumulative percent of variance of extracted factor.

Quick references	Factors loading of the quick references for the barriers to CE Adoption	Cumulative Percent of Variance of Extracted Factor
Awareness	0.722	63.42%
Social support	0.795	
Insufficient time	0.807	
Extra time	0.747	
Waste disposal	0.776	
Absence of infrastructure	0.814	
Access to services	0.837	
Innovative technologies	0.823	
Financial incentives	0.797	
Legislation	0.838	

Note: Extraction Method: Principal Component Analysis (PCA)

4. Conclusions

The results indicate that the barriers to implementing the circular economy framework provide a useful way to measure how well the circular economy is being used in Saudi Arabia's Eastern Province. Consequently, they may function as a viable tool for recognizing and alleviating the barriers to the implementation of the circular economy (CE). Additionally, the findings from Alpha Cronbach's and exploratory factor analysis (EFA) demonstrate that the questions measuring barriers to circular economy (CE) adoption serve as a reliable and relevant tool for evaluating its implementation. The main problem is that people don't understand the circular economy well enough. The limited availability of educational and awareness initiatives demonstrating practical applications of circular economy principles in daily life constitutes a significant barrier. To address this deficiency, the establishment and implementation of nationwide educational and awareness campaigns are essential, with a specific emphasis on practical strategies for integrating circular economy concepts into routine activities. Achieving this goal requires collaboration between governments, schools, and businesses. Research suggests that educational programs, from elementary to higher education, should include the principles of a circular economy. This should be combined with hands-on learning experiences that demonstrate sustainable practices in real-world situations. Moreover, these findings are congruent with Saudi Arabia's Vision 2030, which aims to leverage the circular economy to effectively and expeditiously mitigate food waste, thereby bolstering food security.

This research proposes that further studies explore the barriers to linking circular economy frameworks with investigations of food waste and consumer behavior, aiming to provide a more reliable understanding of consumption habits and related food waste issues in the Kingdom of Saudi Arabia. Moreover, employing various methodologies to assess barriers to the implementation of a circular economy and factors affecting its adoption would aid policymakers in accurately gauging the extent of food waste, thus enabling informed decisions to enhance food security and sustainability.

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Institutional Review Board Statement:

The King Faisal University Ethics Committee approved this study (No: KFU-REC-2025-APR – ETHICS3242). The research was executed in compliance with local laws and institutional regulations. The participants granted their written informed consent to engage in this study. Informed written consent was acquired from the individual(s) for the publication of any potentially identifiable images or data contained in this article.

Transparency:

The authors confirm that the manuscript is an honest, accurate, and transparent account of the study; that no vital features of the study have been omitted; and that any discrepancies from the study as planned have been explained. This study followed all ethical practices during writing.

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