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Dates Loss and Its Impact on Food Security and the Environment in the Kingdom of Saudi Arabia

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ABSTRACT

Worldwide, the numeral of people distresses from hunger or severe food insecurity. This condition is giving attention and considering the massive amount of food discarded globally through Sustainable Development Goals (SDGs). Hence, the study projected to exam dates loss (ton) and its impacts on food security and environment in Saudi, using dates losses, dates production (ton) and CO_2 emissions as variables of the study. Annual data was collected for period extended from 2010 to 2023 from FAO statistics and examined by applying ARDL analysis tests and Vector Error Correction Model. The outcomes of the co-integration test revealed that there is a long-run association among dates loss and dates production. Reference to short run relationship, no significant short-run effects from lagged of dates production on dates loss. In addition, the study indicated that dates losses at farm gate lead to reduced food availability along supply chains which resulting in a decrease in the volume of food existing for human consumption leading to affect adversely on food security. Furthermore, the results appeared that there absent of long run relationship between dates losses quantities and CO_2 emissions, concluding that dates losses have no effect on environment (CO_2 emission). This result may be due to reuse or recycle of dates quantities losses as feed to animal inside the farm. To achieve national food security and sustainable agriculture goals some recommendations were drawn from results: minimize or lessen date losses at the producer level through stablishing reliable nationwide practices for date palm harvesting and post-harvest handling.

Keywords: Food security, agriculture sustainability, CO_2 emissions, Saudi.

INTRODUCTION

Date palm (Phoenix dactylifera) is considered as the oldest (among other) fruit crops cultured by humans for agricultural purposes. Dates, the edible fruits of the date palm, belong to the Arecaceae family, part of a taxonomically diverse group comprising more than 2,500 species and nearly 200 genera. They are a staple food in many regions of the world, contributing significant nutritional, medicinal, and economic benefits [1]. Dates have long been known for their extensive benefits in food and industrial sectors [2,3,4]. Historical evidence suggests that humans have recognized their importance for thousands of years, and their presence in the diet has been linked to multiple beneficial effects on human physiology [2,5,6]. Date palm fruit is a good source of high nutritious value food that can be easily stored for a long time [7,8]. Date palm fruits are known for their rich composition of essential nutrients and considered a nearly complete food, containing high levels of carbohydrates, dietary fiber, and fats. Furthermore, dates have a high resistance to oxidation, enhancing their functional and nutritional value [2,5,9] and diabetes-reducing properties [2,10,11]. All of these shows that dates fruits are very important for a healthy diet and they contribute to the improvement of human health.

Dates loss refers to the quantitative and qualitative decline in dates fruits at various stages of the value chain, from harvest, post-harvest, storage, processing, transportation, retail, and consumption. This includes: physical loss (such as spoilage, pest infestation and mechanical damage), nutritional loss (such as deterioration in sugar or vitamin content), and economic loss (such as lower prices due to poor quality or oversupply). Reasons for dates loss include: poor harvesting techniques (such as early harvesting or mechanical damage during picking), inadequate storage (such as high humidity, improper temperature control), pest and fungal infestation, lack of infrastructure (cold storage, transportation systems), inefficient processing and packaging, and market and distribution inefficiencies (abundance, poor market access).

Globally, date palms are cultivated on an area of more than one million hectares, with a yearly production of more than nine million tons [12,13]. Dates palm product signifies a main constituent of agricultural production in Saudi Arabia, serving as a main driver of crop production in the country owed to its adaptability to arid environments and its economic and cultural importance [12,14]. In Saudi Arabia, they cover an area of approximately 136,992 hectares, with an annual production of 1,539,756 tons [12,15]. In Saudi Arabia, palm trees account for 33.2% of the total harvested crop area and 27.4% of the total primary crop production in terms of quantity [12,15]. Furthermore, palm trees contribute approximately 75% of the country's total fruit production [12,16]. Saudi Arabia's involvement to international dates production improved from approximately 13.17% in 2010 to approximately 17.01% in 2023 [17]. This demonstrates the rising rank of Saudi dates in improving worldwide food security. It also occupies a noticeable economic position, representing an important cause of revenue in the agrarian sector. Saudi includes dates to achieve food security through incorporate strategies in the National Agricultural Strategy 2030. The palm and its products contribute approximately 12% of the Kingdom's total agricultural income, valued to approximately 26% of the non-oil GDP [17]. Food losses are an absolute global concern. owing to their impact on social, environmental and economic reducing economic resources essential for food production (land, water, land, human resources, energy and capital). This leads to a decline in the revenues of related sectors and worsens food security especially in resource-limited nations and suffer from environmental damage [18,19]. Saudi Arabia's Vision 2030 emphases on domestic planned objectives, including economic development and economic expansion [20,21]. The author [20,21] linked agricultural development with realizing food security and environmental steadiness. Several plans have been put in place, containing developing production and marketing ability in the agricultural sector [21,22]. It's worth noting that the Kingdom has achieved self-reliance in milk and dates through focused agrarian production. Self-sufficiency rates in fruit, fish, and vegetable production have also reached 60%, 59%, and 80%, respectively [20,23].

LITERATURE REVIEW

The authors identified the causes of food losses and waste, which arise from the agricultural production to final consumption [24]. The causes of food loss and waste are multiple, ranging from insufficient infrastructure, biological, microbial, chemical, biochemical, mechanical, physical, physiological, technological, logistical, psychological and behavioral causes.

Research by [25] demarcated post-harvest loss as the reduction of food along the resource chain resulting in a reduced amount of food for human consumption, whereas waste denotes to the loss at the retail and last consumption. Research by [26] summarized the reasons of food loss and waste are as précised: Lack or poor quality criteria, excess food supply, absence of appropriate storage abilities and lack of packaging materials.

El-Habbab et al., (2017) [27] directed on date harvesting and post-harvest handling to discover the reasons of losses, where they indicated that the chief reasons of great post-harvest losses were mechanical damage, fermentation, insect and bird infestation.

Bhatti; Sundram (2024) [28] evaluated date losses when harvesting three varieties of palm groves in Madinah (Safawi, Anbara, Ajweh), al-Ahsa Oasis (Khalas, Shishi and Ruzeize) and in Al-Qaseem (Sukkary, Khudry and Segae). The study found that the main reasons of waste were experience to harvesting, and ripped dates and small dates size, pest plagues and non-pathological infections. The average dates damage was 12.6%, the greatest dates loss degree in the main dates-producing areas of Saudi Arabia. Eleven commercially available dates varieties were collected from Al-Ahsa dates market, produced in the main producing areas: Al-Ahsa, Riyadh, Al-Qassim, and Medina.

Empirical studies have revealed various problems with supply chain efficiency. Several studies have indicated that post-harvest losses in date palms are a significant problem resulting from inefficiency storage systems and infrastructure [29,30]. Other studies found that improving cold storage and transportation facilities could reduce dates post-harvest losses by 30%, creating extra profit 29,31].

Integrating technology into supply chain management enhances product traceability and alleviates the threat of fraud, mutually of which are essential to meeting international export quality standards [29,32,33].

Integrating date palm cultivation technologies has been the emphasis of current experimental research. decision makers in agriculture uses remote sensing and drones to enhance resource use and increase productivity [29,34]. Other study studies on the causes of dates loss from production to consumption [35]. Dates are a nutritious, high-energy food that forms a vital share of the diet in Arab countries. They are consumed processed forms, dried and fresh.

Other writers highlight on the recycling of dates damage during harvesting and unripen as feed to animal. The by-products of date production have always been reused by farmers, and have been considered "an eloquent example of the integrated sustainable use of renewable material resources" [36]. There is an ancient tradition of using dates and date pits as animal feed [36].

Conferring to continuous increasing prices of concentrate feeds globally, dates loss quantities is considered as alternative source for feeding animals. Dates are not suitable for human consumption are considered the wastes as a good alternative feed which are characterized by high carbohydrate as an energy source and cellulose, hemicelluloses and lignin [37]. Nonetheless, its losses during harvesting and marketing are great owing to the existence of insect infestation, pathological diseases and physiological and physical ailments. To reduce and stop such losses, the postharvest technologies and techniques should be recognized for dates handling and processing.

Numerous writers have recognized the influence of environment on agricultural production. Farmers' incomes are negatively affected numerous climate actions like increasing in temperature, droughts, storms...etc. [38-39]. Additional study pointed to evaluate the association between date production and CO_2 in Saudi, exhausting cointegration analytical tools [40]. It discovered the present of long-running connection concerning the variables.

The majority of previous studies concentrated on the relationship between dates production climate but this study selected dates loss. With reference to earlier studies, the significance of this study stems from its intents. The study pointed out to assess dates losses and its impacts on food security and environment (CO_2) in Saudi through measuring the connection and relation between dates loss (ton) and production (ton) in one and, on the other hand dates loss and CO_2 emissions. The study is organized in the following sequences: Introduction, research methods, results and discussion. Finally, conclusions are created.

MATERIAL AND METHODS

Data Description

The study aimed to assess the relationship between dates loss quantities (ton) at producer level, dates production (ton) and CO2 emissions. Also, it aimed to assess the dates losses and its impacts on food security and environment in Saudi. The data were collected and covered the period extended from 2010 to 2023 [41,42] and analyzed using EVIEWS 9 program. Table 1 illustrates the data series:

Table 1: Normalized DCG gains of Google and our fuzzy JEKS algorithm.

Variable	Unit	Sources
Dates losses (L)	Ton	https://www.fao.org/faostat/ar/#data/SCL accessed on 5 March 2025)
Dates production (P)	(ton)	https://www.fao.org/faostat/ar/#data/QCL (accessed on 5 March 2025)
CO2 emissions (CO2)	(Mt CO2e)	https://www.fao.org/faostat/en/#data/GT (accessed on 12 March 2025)

Method of Analysis

Descriptive and Graphical Analysis

Descriptive statistics and graphic analyses are run to exam data cointegration as visible analysis.

Graphical analysis: The general index curves for series were plotted firstly to highlight the opportunity of stability association among the variables in the long run. It is one of the primary analytical techniques for identifying this association, and it also permits to continue using the co-integration test.

Co-integration Test

The conception of co-integration is founded on economic theory concerning the statistical possessions of time series, especially those exhibiting unit roots, and is evaluated through specialized tests designed for such non-stationary data [41]. The theory of co-integration among two or more variables is explained from a statistical viewpoint, signifying the presence of a long-term stability association between these series [43]. Indeed, the equilibrium association between series in the long term may depart faintly from each other, but this deviation from equilibrium is adjusted by strong economic powers that work to return it in the long run .There are various methods are used to test for co-integration, among them is ARDL model.

Cointegration Tests: ARDL Model

Unit Root Test:

Reference to choosing suitable methods for analysis of long-run association, the order of integration requisite to be identified [44], using an Augmented Dickey Fuller (ADF) test [45]. The following equations illustrate this:

$$\Delta X_t = C_{t1} + B_1 X_{t-1} + E_{t1} \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots (1)$$

$$\Delta X_t = C_{t2} + R_t + B_2 X_{t-1} + E_{t2} \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots (2)$$

Where, B_1 and B_2 are ADF coefficients, R is the trend, C is the constant and t is the time selected. Testing H_0: X has a unit root Against H_1*:* X has a stationary. If the t- Statistic of ADF coefficient larger than t- critical values, the series are stationary.

THE ARDL BOUNDS TEST

To assess the long-run relationship among the chains, the ARDL model test was used. Moreover, the test is considered outstanding to other allied tests; Well-organized for minor samples irrespective of the order of the chain I(0) and I(1). The next equations were applied [46]:

$$\Delta X_t = C_1 + \sum_{t-1}^{p} a_1 \ \Delta Y_{t-1} + B_3 X_{t-1} + B_4 Y_{t-1} + e_1 \dots\dots\dots\dots (3)$$

$$\Delta Y_t = C_2 + \sum_{t-1}^{p} a_2 \ \Delta X_{t-1} + B_5 Y_{t-1} + B_6 X_{t-1} + e_2 \dots\dots (4)$$

The ARDL exams the existence of long run linking between the chains. The acceptance of null hypnosis means that absent of long-run relationship. H_0: B_3= B_4=0 (Equation 3) against alternative hypothesis $B_3 \neq B_4 \neq 0$. Similarly, the similar test run for Y variable as independent variable null hypnosis B_5= B_6=0 (Equation 4) against alternative hypothesis $B_5 \neq B_6 \neq 0$. To test the steadiness of the ARDL model, the cumulative sum (CUSUM) method is applied [47]. If the residual observed inside margins of the 5% critical, signifying the coefficients are steady. Equations 3 and 4 have lower and upper bound (two critical F-values) approving the combined order (1(0) and 1(1) of the variables, respectively [46].

Error Correction Model (ECM) Test

The ECM test is used to appraise the speediness parameter of the short-run link between the series. In addition, it is used when there is the long-run association among the series [48]. The following are ECM equations:

$$\Delta X_t = \Delta B_7 X_{t-1} + \sum_{t-1}^{p} B_8\ \Delta Y_{t-1} + B_9\, U_{t-1} + V \ldots\ldots\ldots\ldots (5)$$

$$\Delta Y_t = \Delta B_{10} Y_{t-1} + \sum_{t-1}^{p} B_{11}\ \Delta X_{t-1} + B_{12} U_{t-1} + V \ldots\ldots\ldots (6)$$

Where, B_9 and B_{12} denote the quickness of alteration and must be significant and negative to precise model instability. ECM feasibility was tested by residual diagnostics tests as follows: *Residual Normality test:* if the Probability of Jarque- Bera statistic higher than 0.05, then residual is normally scattered. *Heteroskedasticity Test:* Breusch-Pagan-Godfrey: In the exam the null hypothesis: homoscedasticity and alternative hypothesis: heteroskedasticity. Acceptance of null hypothesis occur when P- value is higher than 0.05 signifying that residual is homoscedasticity. The results of ECM viability acquire green light to execute the predicting examination. Additionally, impulse responses check used to identify the response in series when one series subjected to a shock [49].

RESULTS AND DISCUSSION

The study designed to test the dynamics of short- and long-term between dates loss (ton) at producer level, dates production (ton) and CO_2 emissions. Also, it aimed to assess the effects of dates losses on food security and environment in Saudi.

Descriptive Statistics and Graphic Results

Table 2 shows descriptive statistics figures of the variables. Reference to normality test, the Jarque-Bera probabilities figures are greater than 0.05 levels for dates loss (ton) at producer level and production (ton), except CO_2 emission, meaning that some variables appeared normal distribution. Accordingly, all variables were transformed to logarithm form. Table 2. Descriptive statistics results

Table 2: Descriptive statistics results.

	LOS	P	CO_2
Mean	1257.14	12430.26	2898.14
Median	1200.00	11886.01	2893.00
Jarque-Bera	0.60	0.55	6.04
Probability	0.74	0.76	0.05
Kurtosis	2.00	2.08	4.91
Skewness	-0.10	-0.16	-1.30
Observations	14	14	14

Source: data was collected and analyzed. LOS= dates loss; P= production of dates.

Before conducting co-integration test, visual test is performed. It tells how the variables moving together during study period. Figure 1 shows that there may be a long-term association among dates loss (ton) and dates production (ton) while CO_2 emission doesn't keep the same pattern. This result leads further to conduct co-integration analysis.

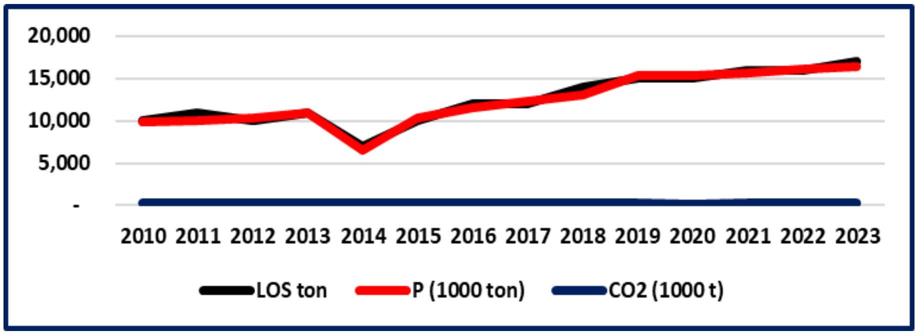

Figure 1: Graphical performance of the variables. LOS= dates loss; P= production of dates.
Source: Drawn by author.

Co-integration Test Analysis Results

The Outcomes of Unit Root Tests

The stationarity of e dates loss, dates production and CO_2 were assessed utilizing Augmented Dickey Fuller (ADF) test. Table 3 displays that the chains continued steady next realizing the first difference 1(1), accordingly, the means of the ADF test statistics were significant at the 1% level.

Table 3: The results of unit root test.

Time series	Intercept	Intercept and trend	Stationarity	Intercept	Intercept and trend	Stationarity
	at level			at first difference		
LOS	-0.63	-2.40	Non-stationary	-4.67*	-4.74**	Stationary
P	-1.26	-2.92	Non-stationary	-4.97*	-4.78**	Stationary
CO2	-2.86	-3.27	Non-stationary	-4.43*	-4.18**	Stationary

Source: Author analyzed data. * and ** at 1% and 5% are level of significance, respectively. LOS and is defined in Table 1.

Results of ARDL Tests (Dates Loss and Dates Production)

Table 4 shows the results of ARDL tests. The results of model suitability residual diagnostics test appeared that the residual is normal distribution, didn't show Heteroskedasticity and serial correlation. In addition, A CUSUM test reflected the steadiness of the model (Figures 2).

Table 4: The results of ARDL model results.

ARDL model (1,1)			
Independent V.	**Coefficient**	**t-Statistic**	**Prob.**
LLOS(-1)	-0.54	-2.04	0.072
LP	0.91	16.77	0.000
LP(-1)	0.58	2.36	0.043
C	-3.07	-4.90	0.001
R-squared 0.985 ; Adj. R-squared 0.980; F- statistics 201.88 Prob.= 0.00; Durbin-Watson stat: 1.74; Serial Correlation LM Test: Breusch-Godfrey 0.14 Prob.=0.71; Jarque-Bera test 0.47 Prob.=0.79 and Breusch-Pagan- Godfrey Heteroskedasticity Test 0.44 Prob.=0.73			

Source: Author analyzed data. LOS and P is defined in Table 1, L means logarithm

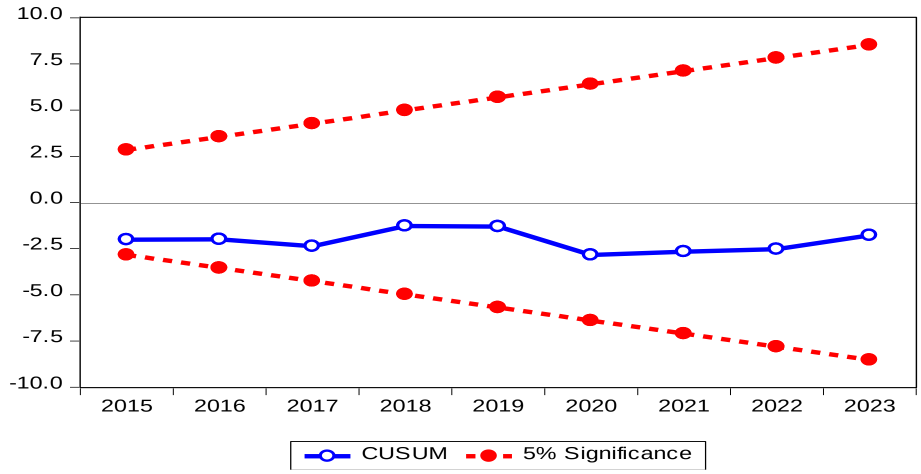

Figure 2: Stability diagnostic (LLOS as dependent variable).

Source: Author analyzed data.

The bound tests results appeared in the ARDL model (Table 5). the bound examined F-test for the coefficients of LLOS (one lag period and dependents variable). F- statistics are 11.70 for the model which is greater than critical F-statistic (5.58) at 1% upper bound, indicating that there is a long run relationship among dates loss and dates production during the study period.

Table 5: The results of ARDL: Bounds Test.

Dependent	**Function**	**F- statistic**
LLOS	LLOS = f (LP)	11.70
Upper Bound	Lower Bound	Significance
5.58	4.94	1%
4.16	3.62	5%
3.51	3.02	10%

Source: Author analyzed data.

Long Run Endorsement

The results of FMOLS and DOLS models are used to enhance and strengthens of the ARDL estimations (Table 6). The Table showed that the results of the two models (FMOLS and DOLS) contest the ARDL valuation, indicating the present of Long-run relationship among dates loss and dates production. Numerous earlier studies run FMOLS and DOLS to strengthen the results of ARDL model [50,51].

Table 6: Results of robustness Test: FMOLS and DOLS Models (LLOS (-1) dependent variable)

FMOLS Model		**DOLS Model**
Independent V.	Coefficient	Coefficient
LP	0.93 (0.000)	0.98 (0.000)
C	-3.32(0.00)	12.19(0.000)
R-squared	0.99	0.99
Adj. R-squared	0.98	0.98

Source: Author analyzed data. Figures between ( ) are Probability.

Table documented that the outcomes of FMOLS and DOLS match the ARDL assessment. Long-run relationship was noticed between dates loss and production.

Table 7: Long run evidence results.

Dependent- independent	ARDL	FMOLS	DOLS
LLOS – LP	11.70*	0.93*	0.98*

Source: Tables 5 and 6. *Significance level at 1%; LOS and P is defined in Table 1, L means logarithm; ARDL – autoregressive distributed lag; FMOLS – fully modified ordinary least squares; DOLS – dynamic ordinary least squares; L-Logarithm.

Results of ECM

To strength the findings of ARDL model test long run link between the variables under study, ECM was directed. From Table 8, lag 1 was selected to implement VECM. The adjustment coefficient for dates losses (LLOS) (as a dependent variable) showed a negative sign (-0.048) and was statistically insignificant (critical value t = -0.22) (Table 9), which means that the model was unable to adjust to the imbalance in the past time. The results suggested that the model may requisite extra than a year to accurate for prior time unsteadiness. Reference to short run relationship, no significant short-run effects from lagged of dates production (LP) on dates loss (LLOS). To confirm the adequacy of the VECM, serial correlation of LM residuals and heteroscedasticity tests of residuals were verified. LM- statistics (lag 1) equal 1.08 using Prob.= 0.90, demonstrating the nonexistence of serial correlation. The Chi-sq. equal 23.51 using Prob.= 0.66 doesn't indicate heteroskedasticity. The normality Tests: Chi-sq 2.82 with Prob.0.59, indicating normal distribution of residual. The outcomes of the model fit directed to the acceptance of the null hypothesis, no residuals serial correlation and heteroscedasticity. The normal distribution exam indicates a normal distribution of the data.

Table 8: Lag selection results.

Lag	LogL	LR	FPE	AIC	SC	HQ
0	23.2	NA	0.000132	-3.3	-3.2	-3.3
1	31.2	12.4*	7.23e-05*	-3.9*	-3.6*	-3.9*

Source: Author analyzed data. * specifies lag order chosen by the criterion. Where, SC: Schwarz information criterion, FPE: Final prediction error, HQ: Hannan-Quinn information criterion, AIC: Akaike information criterion and LR: sequential modified LR test statistic (each test at 5% level).

Table 9: Results of ECM: LLOS (dependent variable)

Short run results		
Error Correction	**Coefficient**	***t*-value statistic**
CointEq1	-0.05	-0.22
D(LLOS(-1))	-2.25	-1.35
D(LP(-1))	1.86	1.12
C	0.05	0.88
ECM residual serial correlation LM tests: Lags 1 LM-Stat= 1.08 Prob.= 0.90		
Jarque-Bera test: 2.82 Prob. =0.59		
VEC Residual Heteroskedasticity Tests: Chi-sq 23.51 Prob. = 0.66		

Source: Author analyzed data.

Furthermore, an impulse exam was conducted to identify the main series that significantly influences other chain over the long run (Figure 3). The Figure of impulse response showed that production revealed positive reaction in the long run to dates loss, signifying that it may be reflected as the leading series.

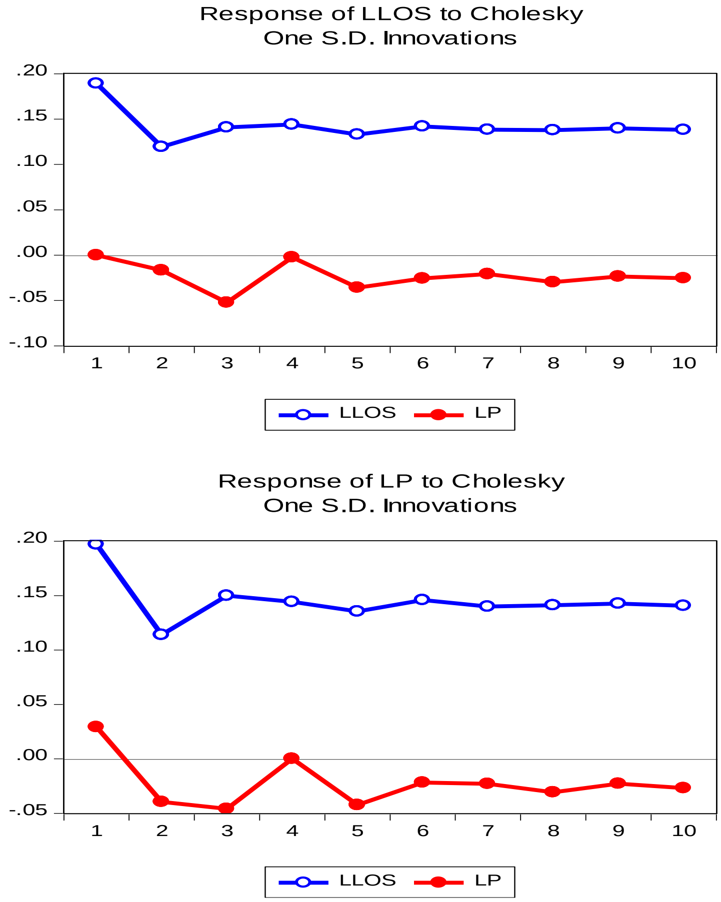

Figure 3: Reaction of LLOS to Cholesky One S.D. Innovations. Source: Author analyzed data.

The Impact of Dates Loss on Food Security

Food security is delineated as “existing when all people, at all times, have physical and economic access to sufficient, safe, and nutritious food that meets their dietary needs and food preferences for an active and healthy life” [52,53]. The delineation comprises the wide theory of food security, which is categorized basing to four pillars linked to availability, stability, utilization, and access [53-56]. Reference to food security pillars, the effect of dates loss on food security can be illustrated as follows: availability: dates loss condensed dates supply for internal consumption and export; accessibility: dates losses increase production costs and final prices, decrease the affordability of low-income consumers and smallholder farmers lose their potential income, impacting their capability to purchase other food items; utilization: wasted or poor-quality dates may be unhealthy for consumption; stability: seasonal excesses followed by insufficiencies due to poor storing disturb the stability of dates availability during the year, this result coincide with previous study (Kitinoja, 2016) [25]. The study indicated that post-harvest losses lead to reduced food availability along supply chains, resulting in a decrease in the quantity of food available for human consumption.

Results of ARDL Tests (Dates Loss and CO2 Emission)

Table 10 shows the outcomes of ARDL tests. To adopt the model result, residual diagnostic tests were performed. Serial Correlation LM Test Breusch-Godfrey, the Jarque-Bera test and Breusch-Pagan- Godfrey Heteroskedasticity test revealed that (Table 10): the data are normal distribution, no Heteroskedasticity and no serial correlation. Moreover, A CUSUM test showed the steadiness of the cumulative sum of the recursive residuals, signifying the power of the model (Figures 4).

Table 10: The results of ARDL model results.

ARDL model (1,1): LLOS (dependent variable)			
Independent V.	**Coefficient**	**t-Statistic**	**Prob.**
LLOS(-1)	0.77	2.63	0.027
LCO_2	0.07	0.20	0.843
LCO_2(-1)	-0.11	-0.37	0.722
C	2.02	0.40	0.701
R-squared 0.53; Adj. R-squared 0.38 - F- statistics 3.40 Prob. 0.07 Durbin-Watson stat: 2.43, Jarque-Bera test 17.71 (0.060); Breusch-Pagan- Godfrey Heteroskedasticity test 0.14 (0.93); Serial Correlation LM Test: Breusch-Godfrey 0.92 (0.37)			

Source: Author analyzed data. Figures between ( ) are Probability.

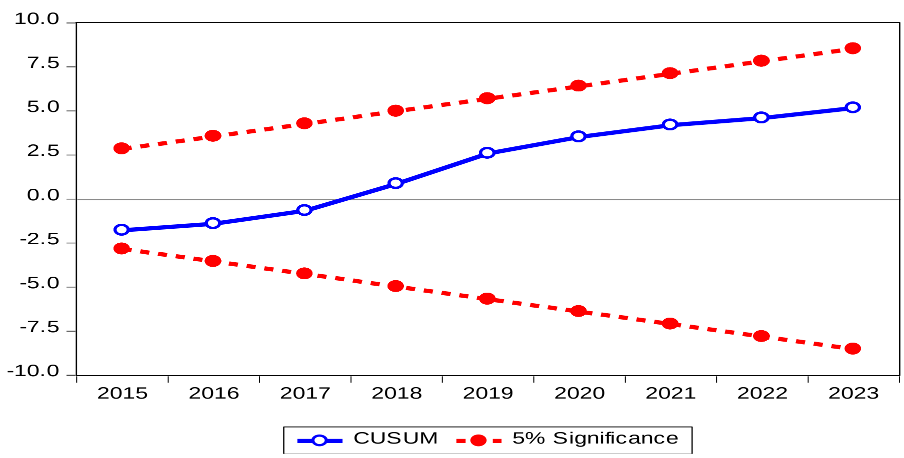

Figure 4: Stability diagnostic (LLOS as dependent variable).
Source: Author calculations based on collected data.

The bound tests results appeared in ARDL model (Table 11). the bound examined F-test for the factors of dates loss. F- statistics are 0.62 for the model which is lower than lower bound of the bounded critical F-statistic (3.02) at 10%, suggesting absent of long-run connotation among of dates loss (LLOS) and CO_2 emission during the study period. The result means no relationship is noticed between dates loss and CO_2 emission. This result may be due to use of dates loss inside the farm to feed animals, concluding that the quantities of dates losses may be treated in sustainable way. This conclusion synchronize with previous studies results [36,37]. The studies disclose that the quantities of dates loss are recycled as animal feed.

Table 11: The results of Bounds Test: ARDL

Dependent	**Function**	**F- statistic**
LLOS	LLOS = f (LCO_2)	0.62
Upper Bound	Lower Bound	Significance
5.58	4.94	1%
4.16	3.62	5%
3.51	3.02	10%

Source: Author analyzed data.

Long Run Confirmation

FMOLS and DOLS models were used to strength of the ARDL estimations (Table 12). The Table showed that the results of FMOLS and DOLS contest the ARDL valuation, significance that Long-run connotation didn't detect concerning dates loss (LLOS) and CO_2 emission.

Table 12: Results of robustness Test: FMOLS and DOLS Models (LLOS (-1) dependent variable)

FMOLS Model		DOLS Model
Independent V.	Coefficient	Coefficient
LCO_2	0.05 (0.88)	0.07 (0.84)
C	0.37 (0.93)	2.02 (0.70)
R-squared	0.49	0.99
Adj. R-squared	0.30	0.98

Source: Author analyzed data. Figures between ( ) are Probability.

Table 13 documented that the outcomes of FMOLS and DOLS contest the ARDL valuation. Long-run relationship didn't observe between dates loss (LOS) and CO_2 emission.

Table 13: Long run evidence (Dependent- independent: LLOS – LCO_2)

ARDL	FMOLS	DOLS
0.62	**0.05**	**0.07**

Source: Tables 11 and 12. *Significance level at 1%; LOS – Dates loss; CO_2 –CO_2 emission; ARDL – autoregressive distributed lag; FMOLS – fully modified ordinary least squares; DOLS – dynamic ordinary least squares; L-Logarithm.

CONCLUSION

The study intended to test the dynamics of short- and long-term between dates loss (ton) and dates production (ton) in one hand, on the other hand dates loss and CO2 emissions. Also, it aimed to assess dates losses and its impacts on food security and environment (CO2) in Saudi. Annual data was collected for period extended from 2010 to 2023 from FAO statistics and examined by applying ARDL analysis tests, Vector Error Correction Model (VECM) and regression analysis method. The outcomes of the co-integration test reveal that there is a long-run relationship between dates loss and dates production during the study period. Reference to VECM test results, the adjustment coefficient for dates losses (LLOS) (as a dependent variable) showed a negative sign (-0.048) and was statistically insignificant (critical value t = -0.22), which means that the model was unable to adjust to the imbalance in the past time. The results suggested that the model may requisite extra than a year to accurate for prior time unsteadiness. The results of long run recorded that the dates production (LP) affect negative (coefficient= -0.98) and significant (t-value= -53.79) on dates losses at farm (LLOS), concluding that in the long run increasing in production leads to decrease in dates losses. This means that all causes of dates losses will be conducted in efficiency way. Reference to short run relationship, no significant short-run effects from lagged of dates production (LP) on dates loss (LLOS). In addition, the study indicated that dates losses at farm gate lead to reduced food availability and adversely affect food security. Also, the impact of dates loss and its consequences on food security is illustrated as follows on other pillars of food security: accessibility: dates losses increase production costs and final prices, decrease the affordability of low-income consumers and smallholder farmers lose their potential income, impacting their capability to purchase other food items; utilization: wasted or poor-quality dates may be unhealthy for consumption; stability: seasonal excesses followed by insufficiencies due to poor storing disturb the stability of dates availability during the year. Furthermore, the results appeared that there absent of long run relationship between dates losses quantities and CO2 emissions, concluding that dates losses may be reused inside the farm to feed animal in other words it used in sustainable way. From the results some recommendation was drawn: adopt best harvesting techniques: harvest dates at physiological maturity and train workers on best practices. In addition, the following policy actions are recommended to effectively reduce date losses at the producer level may be through providing farmers with technical knowledge on best post-harvest practices, storage facilities, and setting and spread standardized national protocols for date palm harvesting and post-harvest handling. By implementing these scientific recommendations, date producers can considerably lessen dates losses at producer level. This not only progresses economic returns but also donates to achieving national food security and sustainable agriculture goals.

References

[1]. Al-Karmadi, A., & Okoh, A. I. An overview of date (Phoenix dactylifera) fruits as an important global food resource. *Foods* 2024, *13*(7), 1024. https://doi.org/10.3390/foods13071024

[2]. Sarraf, M., Jemni, M., Kahramanoğlu, I., Artés, F., Shahkoomahally, S., Namsi, A., ... & Rastogi, A. Commercial techniques for preserving date palm (Phoenix dactylifera) fruit quality and safety: A review. *Saudi Journal of Biological Sciences.*2021, *28*(8), 4408-4420. https://doi.org/10.1016/j.sjbs.2021.04.035

[3]. Shaghaghian, S., Niakousari, M., & Javadian, S.Application of ozone postharvest treatment on Kabkab date fruits: effect on mortality rate of Indian meal moth and nutrition components. *Ozone: Science & Engineering*. 2014, 36, 269–275. https://doi.org/10.1080/01919512.2013.872555

[4]. Hussain, M.I., Farooq, M., Syed, Q.A. Nutritional and biological characteristics of the date palm fruit (Phoenix dactylifera L.)–A review. *Food. Bioscience.*2020, *34*, 100509. https://doi.org/10.1016/j.fbio.2019.100509

[5]. Khalid, S., Khalid, N., Khan, R.S., Ahmed, H., Ahmad, A. A review on chemistry and pharmacology of Ajwa date fruit and pit. *Trends in food science & technology*, 2017, *63*, 60–69. https://doi.org/10.1016/j.tifs.2017.02.009

[6]. Mohammed, M., Sallam, A., Alqahtani, N., & Munir, M. The combined effects of precision-controlled temperature and relative humidity on artificial ripening and quality of date fruit. *Foods.* 2021a, *10*(11), 2636. https://doi.org/10.3390/foods10112636

[7]. Arias, E., Hodder, A. J., & Oihabi, A. FAO support to date palm development around the world: 70 years of activity. *Emirates Journal of Food and Agriculture*. 2016, *28*(1), 1. https://doi.org/10.9755/ejfa.2015-10-840

[8]. Biglari, F., AlKarkhi, A.F., Easa, A.M. Antioxidant activity and phenolic content of various date palm (Phoenix dactylifera) fruits from Iran. *Food chemistry*. 2008, *107*, 1636–1641. https://doi.org/10.1016/j.foodchem.2007.10.033

[9]. Mard, S.A., Jalalvand, K., Jafarinejad, M., Balochi, H., Naseri, M.K.G. Evaluation of the antidiabetic and antilipaemic activities of the hydroalcoholic extract of Phoenix dactylifera palm leaves and its fractions in alloxan-induced diabetic rats. *The Malaysian journal of medical sciences: MJMS*. 2010, *17(4), 4–13* . PMID: 22135555. https://pmc.ncbi.nlm.nih.gov/articles/PMC3216186/

[10]. Salehi, B., Ata, A., V Anil Kumar, N., Sharopov, F., Ramírez-Alarcón, K., Ruiz-Ortega, A., Abdulmajid Ayatollahi, S., Valere Tsouh Fokou, P., Kobarfard, F., Amiruddin Zakaria, Z. Antidiabetic potential of medicinal plants and their active components. *Biomolecules*. 2019, *9*, 551. https://doi.org/10.3390/biom9100551

[11]. Emam, A. (2025). Climate Change Effects on Dates Productivity in Saudi Arabia: Implications for Food Security. *Sustainability*, *17*(10), 4574. https://doi.org/10.3390/su17104574

[12]. Mohammed M., Sallam A., Munir M., Ali-Dinar H. Effects of deficit irrigation scheduling on water use, gas exchange, yield, and fruit quality of date palm. *Agronomy*. 2021b*, 11*: 2256. https://doi.org/10.3390/agronomy11112256

[13]. Aleid S.M., Al-Khayri J.M., Al-Bahrany A.M. Date palm status and perspective in Saudi Arabia. In: Al-Khayri J.M., Jain S.M., Johnson D.V. (eds.): Date Palm Genetic Resources and Utilization. *Dordrecht, the Netherlands, Springer:* 2015, 49–95. https://link.springer.com/content/pdf/10.1007/978-94-017-9707-8.pdf

[14]. FAO. Crops and Livestock Products. [Dataset]. Food and Agriculture Organization of the United Nations (FAO). 2022. Available at https://www.fao.org/faostat/en/#data/QCL (accessed on 5 March 2025)

[15]. Elfeky A., Elfaki J. A review: Date palm irrigation methods and water resources in the Kingdom of Saudi Arabia. *Journal of Engineering Research and Reports.*2019*, 9*: 1–11.

[16]. FAO. Crops and Livestock Products. [Dataset]. *Food and Agriculture Organization of the United Nations (FAO)*. 2023a. Available at https://www.fao.org/faostat/en/#data/QCL (accessed on 15 March 2025)

[17]. Alhamdan, A., Alamri, Y., Aljuhaim, F., Kotb, A., Aljohani, E., Alaagib, S., & Elamshity, M. Economic Analysis of the Impact of Waste on the Production and Consumption of Dates in Saudi Arabia. *Sustainability.* 2024*, 16*(21), 9588. https://doi.org/10.3390/su16219588

[18]. General Authority for Food Security. 2022. Available online: https://www.my.gov.sa/wps/portal/snp/pages/data-and-reports (accessed on 22 December 2024).

[19]. Emam, A. and Elmsaad, E. Do Non-Agricultural Sectors Affect Food Security in Saudi Arabia? *Sustainability.* 2025, *17*(10), 4625; https://doi.org/10.3390/su17104625

[20]. KSA Vision 2030. Strategic Objectives and Vision Realization Programs, Saudi Vision 2030. 2019. Available online: https://www.my.gov.sa/wps/portal/snp/content/saudivision/?lang=en (accessed on 10 May 2025).

[21]. Ministry of Environment, Water, and Agriculture. Annual Report of the Ministry of Agriculture. 2021. Available online: https://www.mewa.gov.sa/ar/InformationCenter/DocsCenter/YearlyReport/YearlyReports/%d8%a7%d9%84%d8%aa%d9%82%d8%b1%d9%8a%d8%b1%20%d8%a7%d9%84%d8%b3%d9%86%d9%88%d9%8a%20%d9%84%d9%84%d9%88%d8%b2%d8%a7%d8%b1%d8%a9%20%d9%84%d8%b9%d8%a7%d9%85%202021%d9%85.pdf (accessed on 11 May 2025).

[22]. FAO. Crops and Livestock Products. [Dataset]. Food and Agriculture Organization of the Nations (FAO). 2014. Available online: https://www.fao.org/faostat/en/#data/QCL (accessed on 2 January 2025).

[23]. Badran, A., Murad, S., Baydoun, E., & Daghir, N. Water, energy & food sustainability in the middle east. *Springer, Cham*. 2017. https://doi.org/10.1007/978-3-319-48920-9

[24]. Gustavsson, J., Cederberg, C., Sonesson, U., Van Otterdijk, R., & Meybeck, A. Global food losses and food waste. 2011, May). https://www.madr.ro/docs/ind-alimentara/risipa_alimentara/presentation_food_waste.pdf

[25]. Kitinoja, L. "Innovative Approaches to Food Loss and Waste Issues," *Frontier Issues Brief submitted to the Brookings Institution's Ending Rural Hunger project.*2016. https://www.endingruralhunger.org/

[26]. Kader, A. and Hussein, A. Harvesting and post-harvest handling of dates. *ICARDA, Aleppo, Syria. (iv).* 2009*, 15* pp.

[27]. El-Habbab, M. S., Al-Mulhim, F., Al-Eid, S., Abo El-Saad, M., Aljassas, F., Sallam, A., & Ghazzawy, H. Assessment of post-harvest loss and waste for date palms in the Kingdom of Saudi Arabia. *International Journal of Environmental and Agriculture Research.* 2017*, 3*(6), 1-11.

[28]. Bhatti, M. A., & Sundram, V. P. K. Dates Palm Cultivation and Sustainable Supply Chain Practices in Saudi Arabia. *AgBioForum.* 2024*, 26*(1), 32-48. https://agbioforum.org/menuscript/index.php/agb/article/view/312/194

[29]. Rajakal, J. P., Ng, F. Y., Zulkifli, A., How, B. S., Sunarso, J., Ng, D. K. S., & Andiappan, V. Analysis of current state, gaps, and opportunities for technologies in the Malaysian oil palm estates and palm oil mills towards net-zero emissions. *Heliyon.* 2024*,10*(10), e30768. https://doi.org/10.1016/j.heliyon.2024.e30768

[30]. Hiloidhari, M., Sharno, M. A., Baruah, D. C., & Bezbaruah, A. N. (2023). Green and sustainable biomass supply chain for environmental, social and economic benefits. *Biomass and Bioenergy.* 2023*, 175*, 106893. https://doi.org/10.1016/j.biombioe.2023.106893Junaidi,

[31]. Soomro, A. H., Marri, A., & Shaikh, N. Date palm (Phoenix dactylifera): A review of economic potential, industrial valorization, nutritional and health significance. Neglected Plant Foods of South Asia: Exploring and valorizing nature to feed hunger, 2023, 319-350. Springer. https://doi.org/10.1007/978-3-031-37077-9_13

[32]. Gharye Mirzaei, M., Gholami, S., & Rahmani, D. A mathematical model for the optimization of agricultural supply chain under uncertain environmental and financial conditions: the case study of fresh date fruit. *Environment, Development and Sustainability*. 2023, 1-34. https://doi.org/10.1007/s10668-023-03503-7

[33]. Cruz, P. L., Martín-Gamboa, M., Hnich, K. B., Dufour, J., & Iribarren, D. Effect of improvement actions on the life-cycle environmental and economic performance of synthetic biofuels from date palm waste in Tunisia. *Sustainable Energy & Fuels.* 2023*, 7(*12), 2873-2882. https://doi.org/10.1039/D3SE00188

[34]. Kader, A. and Hussein, A. Harvesting and post-harvest handling of dates. *ICARDA, Aleppo, Syria. (iv).* 2009*, 15* pp.

[35]. Heuzé, V., G. Tran, Delagrade, R. & Bastianelli, D. Date Palm Fruits. Feedipedia, a Program by INRA, CIRAD, AFZ and FAO. Accessed 14 Sept. 2025 (2016). http://www.feedipedia.org/node/688[09/12/2016

[36]. FM, S. The Effect of Using Discarded And By-Product of Dates Palm In Ruminant's Performance. *Int. J. of Aquatic Science*. 2021, 12(2), 5221-5228. https://www.journal-aquaticscience.com/article_140011.html

[37]. Habib-ur-Rahman, M.; Ahmad, A.; Raza, A.; Hasnain, M.U.; Alharby, H.F.; Alzahrani, Y.M.; Bamagoos, A.A.; Hakeem, K.R.; Ahmad, S.; Nasim, W.; et al. Impact of climate change on agricultural production; Issues, challenges, and opportunities in Asia. *Front. Plant Sci*. 2022, 13, 925548. https://doi.org/10.3389/fpls.2022.925548

[38]. Yuan, X.; Li, S.; Chen, J.; Yu, H.; Yang, T.; Wang, C.; Huang, S.; Chen, H.; Ao, X. Impacts of global climate change on agricultural production: A comprehensive review. *Agronomy* 2024, 14, 1360. https://doi.org/10.3390/agronomy14071360

[39]. Emam, A. Present and Future: Does agriculture affect economic growth and environment in the Kingdom of Saudi Arabia? *J. Agric. Econ. Czech Acad. Agric. Sci.* 2022, 68, 361–370. https://doi.org/10.17221/58/2022-AGRICECON

[40]. FAOb. Crops and Livestock Products. [Dataset]. Food and Agriculture Organization of the Nations (FAO). 2023. Available online: https://www.fao.org/faostat/en/#data/QCL (accessed on 2 January 2025).

[41]. FAOc. Food Balances (2010-). [Dataset]. 2023. Available online: https://www.fao.org/faostat/ar/#data/FBS (accessed on 15 March 2025).

[42]. Emam, A. Climate Change Effect on Dates Productivity in Saudi Arabia: Implications for Food Security. *Sustainability.* 2025, *17*(10), https://doi.org/10.3390/su17104574

[43]. Emam, A. A. The Impacts of Covid-19: An Econometric Analysis of Crude Oil Prices and Rice Prices in the World. *Journal of Agriculture Sciences.* 2020, *35*(2), 137-143. https://doi.org/10.47059/alinteri/V35I2/AJAS20085

[44]. Dickey, D. A., & Fuller, W. A. Distribution of the estimators for autoregressive time series with a unit root. *Journal of the American statistical association*. 1979, 74(366a), 427-431.https://doi.org/10.1080/01621459.1979.10482531

[45]. Pesaran, M. Hashem, Yongcheol Shin, and Richard J. Smith. Bounds testing approaches to the analysis of level relationships. *Journal of applied econometrics*. 2001, *16*(3), 289-326. http://dx.doi.org/10.1002/jae.616

[46]. Pesaran, M. H., & Pesaran, B. (1997): Working with Microfit 4.0: Interactive econometric analysis. Oxford: Oxford University Press. https://cir.nii.ac.jp/crid/1130282270030044416

[47]. Venujayakanth, B., A. Swaminathan Dudhat, B. Swaminathan, and N. J. Ardeshana. Price integration analysis of major groundnut domestic markets in India. *Economic Affairs.* 2017, *62*(2), 233-241. https://doi.org/10.5958/0976-4666.2017.00005.5

[48]. Lütkepohl Helmut. (2010): Impulse response function. In: Durlauf S.N., Blume L.E. (eds) Macroeconometrics and Time Series Analysis. The New Palgrave Economics Collection. Palgrave Macmillan, London. https://doi.org/10.1057/9780230280830_16

[49]. Zhai, X., Geng, Z., & Zhang, X. Two-stage dynamic test of the determinants of the long-run decline of China's monetary velocity. *Chinese Economy.* 2013, *46*(3), 23-40. https://doi.org/10.2753/CES1097-1475460302

[50]. Emam A. A. Present and Future: Does agriculture affect economic Growth and environment in the Kingdom of Saudi Arabia? *Journal of Agricultural economics- CZECH ACADEMY OF AGRICULTURAL SCIENCES*. 2022, Vol. (68), no. 0:361–370. https://doi.org/10.17221/58/2022-AGRICECON

[51]. Doğan, N. The impact of agriculture on CO2 emissions in China. Panoeconomicus. 2019, 66(2), 257–271. https://doi.org/10.2298/PAN160504030D

[52]. Alhamdan, A., Alamri, Y., Aljuhaim, F., Kotb, A., Aljohani, E., Alaagib, S., & Elamshity, M. (2024). Economic Analysis of the Impact of Waste on the Production and Consumption of Dates in Saudi Arabia. Sustainability, 16(21), 9588. https://doi.org/10.3390/su16219588

[53]. Van Meijl, H., Shutes, L., Valin, H., Stehfest, E., van Dijk, M., Kuiper, M., ... & Havlik, P. Modelling alternative futures of global food security: Insights from FOODSECURE. *Global Food Security.* 2020*, 25*, 100358. https://doi.org/10.1016/j.gfs.2020.100358

[54]. FAO. The State of Food and Agriculture. 1996. Available online: http://www.fao.org/3/w1358e/w1358e00.htm (accessed on 22 January 2025).

[55]. Guiné, R. D. P. F., Pato, M. L. D. J., Costa, C. A. D., Costa, D. D. V. T. A. D., Silva, P. B. C. D., & Martinho, V. J. P. D. Food Security and Sustainability: Discussing the Four Pillars to Encompass Other Dimensions. *Foods.* 2021*, 10*(11), 2732. https://doi.org/10.3390/foods10112732

[56]. Béné, C. Resilience of local food systems and links to food security–A review of some important concepts in the context of COVID-19 and other shocks. *Food security.* 2020, *12(*4), 805-822. https://link.springer.com/article/10.1007/s12571-020-01