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Analysis of vegetable production trends, growth rates, instability index, and decomposition in Nigeria

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ABSTRACT

The research examined the trends, growth rates, and instability indices related to the output, harvested area, and yield of major vegetables (Carrot and Turnip; (*Daucus carota* and *Brassica rapa*); Chillies and peppers, dry (*Capsicum spp., Pimenta spp.*), Chillies and peppers fresh (*Capsicum spp., Pimenta spp.*) green; Pineapple (*Ananas comosus*), and Tomato (*Solanum lycopersicum*)) in Nigeria. It also analyzed the decomposition of their production. Utilizing secondary data sourced from the Food and Agricultural Organization (FAO) covering the period from 1961 to 2023, the study revealed fluctuating trends in output, harvested area, and yield of vegetables across the specified timeframe. The exponential growth rate, compound growth rates, Cuddy-Della Valle instability index (CDI) and the Coppock Instability Index (COI) for tomato yield from 1961 – 2023 were identified as -1.59%, -1.63%, 15.48, and 52.64 respectively. For pineapple yield within the same period, the estimates were; 0.51%, 0.43%, 3.13 and 40.58 respectively. For carrot and turnips the estimates were; 0.36%, 0.28%, 2.48, and 39.59 respectively. The instability indices of vegetable yields were relatively low, indicating low activities in the sub-sector in Nigeria. A decomposition analysis of the total effect of vegetable outputs showed that the land area effect accounted for 56.10% for carrot and turnips, 75.08% for chillies and pepper dry, 116.15% for chillies and pepper, green, 65.45% for pineapple, 290.56% for tomato, and 46.93% for other vegetables. The findings suggest that the growth of land area and not improve technology is the major driving force of vegetable output in Nigeria. Consequently, it is recommended that various programs be implemented within the sub-sector to stimulate technology adoption among farmers and potentially enhance both outputs and yields.

Nijerya'da sebze üretim eğilimleri, büyüme oranları, istikrarsızlık endeksi ve ayrışma analizi

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ÖZET

Araştırmada, Nijerya'daki başlıca sebzelerin (Havuç ve Şalgam (*Daucus carota* ve *Brassica rapa*); Acı biber kuru biberler (*Capsicum* spp., *Pimenta* spp.), Acı biberler ve taze yeşil biberler (*Capsicum* spp., *Pimenta* spp.), Ananas (*Ananas comosus*) ve Domates (*Solanum lycopersicum*)) çıktı, hasat alanı ve verimiyle ilgili eğilimler, büyüme oranları ve istikrarsızlık endeksleri incelenmiştir. Ayrıca, üretimlerinin ayrıştırılması da analiz edilmiştir. Gıda ve Tarım Örgütü'nden (FAO) 1961-2023 dönemini kapsayan ikincil veriler kullanılarak yapılan çalışma, belirtilen zaman dilimi boyunca sebzelerin çıktı, hasat alanı ve veriminde dalgalanan eğilimleri ortaya koymuştur. 1961-2023 yılları arasında domates verimi için üstel büyüme oranı, bileşik büyüme oranları, Cuddy-Della Valle istikrarsızlık endeksi (CDI) ve Coppock İstikrarsızlık Endeksi (COI) sırasıyla -%1,59, -%1,63, 15,48 ve 52,64 olarak belirlendi. Aynı dönemdeki ananas verimi için tahminler sırasıyla; %0,51, %0,43, 3,13 ve 40,58 olarak bulundu. Havuç ve şalgam için tahminler sırasıyla; %0,36, %0,28, 2,48 ve 39,59 olarak bulundu. Sebze verimlerinin istikrarsızlık endeksleri nispeten düşük olup, Nijerya'daki alt sektörde düşük faaliyetleri göstermektedir. Sebze çıktılarının toplam etkisinin ayrıştırma analizi, arazi alanı etkisinin havuç ve şalgam için %56,10, acı biber ve kuru biber için %75,08, acı biber ve yeşil biber için %116,15, ananas için %65,45, domates için %290,56 ve diğer sebzeler için %46,93 olduğunu gösterdi. Bulgular, Nijerya'daki sebze çıktısının ana itici gücünün teknolojiyi iyileştirmek değil arazi alanı büyümesi olduğunu göstermektedir. Sonuç olarak, çiftçiler arasında teknoloji benimsemesini teşvik etmek ve potansiyel olarak hem çıktıları hem de verimi artırmak için alt sektörde çeşitli programların uygulanması önerilmektedir.

1.Introduction

According to FAO (2025) and Tadesse (2023), vegetable crops are considered essential staple food components worldwide. The aggregate annual production of vegetable crops has shown steady growth over the years (FAO, 2025). In Africa, vegetable crops are widely cultivated by smallholder farmers and hold great importance (Kadzere et al., 2023). However, the continent currently has the lowest vegetable production and consumption per capita (Schreinemachers et al., 2021; Steenhuijsen et al., 2021). Vegetables are increasingly being recognized as crucial for ensuring food and nutrition security. Researchers such as Schreinemachers et al. (2018) and Akpan et al., (2019b) suggest that vegetable cultivation presents a promising economic opportunity for reducing rural poverty and tackling unemployment in developing countries. Additionally, it plays a key role in enabling farm income diversification (Akpan et al., 2023). Studies have shown that vegetable crops offer a cost-effective source of essential vitamins and minerals crucial for human health maintenance. The World Health Organization (WHO) recommends a minimum daily intake of 200g per person for vegetables, totalling approximately 73kg per year, and 400g per day for fruit and vegetables combined, equating to 146kg per person annually (WHO, 2020). Despite the abundance of research highlighting the health benefits of vegetable consumption, many developing countries still fall short of meeting the WHO's minimum intake standards (Akpan and Okon, 2019a).

In Nigeria, vegetable production plays a significant role in the agricultural sector due to its growing domestic demand and its substantial contribution to achieving the Sustainable Development Goal (SDG) of reducing hunger by 2030 (Akpan et al., 2024a). Nigerian cuisine frequently features vegetables as essential ingredients in dishes such as soups and stews, underscoring their cultural significance. The country's diverse climate environment allows for year-round vegetable production, enabling farmers to grow a wide variety of vegetables, including bitter leaf, carrot, turnip, chillies, African Spinach, waterleaf, African basil, pepper, leafy fluted pumpkin, potatoes, onion, corn, squash, tomatoes, onions, cabbage, okra, and other leafy greens. The vegetable sub sector in Nigeria continues to play a vital role in the country's agricultural landscape. The cultivation of vegetables plays a crucial role in ensuring food security and promoting economic growth (Schreinemachers et al., 2018; Sithole et al., 2023). The production of vegetables is a significant component of the agricultural sector, with an annual output of approximately 137.8 million tons in the country (FAO, 2025). Increased vegetable production, as highlighted by Tadesse (2023), Sithole et al. (2023), and Gebru et al. (2019), has led to improvements in food security and has created employment opportunities for both rural and urban populations. Studies by Mukaila et al. (2022), Akpan et al. (2023), and Akinola et al. (2023) have shown that vegetable production serves as a major source of income for small-scale farmers and those with limited resources in developing countries. The vegetable value chain not only generates income but also helps in reducing poverty and unemployment levels.

Recent studies (Schreinemachers et al., 2018; Akpan and Okon, 2019a) have revealed that vegetable consumption in Sub Saharan Africa falls significantly below the World

Health Organization's minimum standard for human consumption (WHO, 2020). Per capita vegetable intake in this region not only lags behind global averages but is also on a downward trend (Ganry, 2009). The annual consumption of fruits and vegetables in Sub Saharan Africa ranges from 27kg to 114 kg per capita, well below the WHO/FAO recommendation. Nigeria, as highlighted by Kamga et al. (2013), leads in vegetable consumption within the region, with a level at 61.31g per capita per day, still below the required nutritional threshold stipulated by the WHO. To address this gap, there is a pressing need to increase vegetable production in alignment with the goals of the WHO's Fruit and Vegetable Initiative. The federal government of Nigeria has taken steps in recent years to boost agricultural output through various programs and institutional support.

Furthermore, there has been a growing recognition of the health benefits of consuming vegetables in the country. This has led to various intervention programs being implemented by individuals, groups, organizations, and communities to enhance vegetable production. Notably, the cultivation of popular leafy vegetables such as water leaf, tomato, chilies pepper, fluted pumpkin, bitterleaf, and Amaranths plays a significant role in the livelihood activities of rural communities. Vegetable cultivation has emerged as a preferred crop enterprise for youth agro-entrepreneurship and development programs in several states in Nigeria due to its short gestation period, high technical efficiency, nutritive value, gross margin, demand, and affordability (Akpan et al., 2018 and Akpan et al., 2022, Edet and Akpan, 2025). The cultivation of vegetables is considered as one of the potent poverty reduction strategies especially among the resource poor rural women in Nıgeria (Akpan et al., 2019b). While the potential for vegetable cultivation in Nigeria is promising, there are challenges that hinder agricultural development in the country. These challenges include policy inconsistency, weak marketing systems, high input costs, and inadequate infrastructure.

In light of the importance of vegetables and their consistently low per capita consumption in many developing countries, numerous researchers have conducted analyses on the production trends of vegetables. In India, studies by Lalenpuii et al. (2024), Vanitha et al. (2021), and Sethi et al. (2024) have shown a substantial growth rate in production, land areas, and yields for various vegetable crops over different time periods. These studies employed the coefficient of variation, Cuddy-Della Valle Index analysis, and Coppock Instability Index, with results indicating a moderate level of instability in the output, land area, and yield of vegetables in India. The examination of the decomposition analysis revealed that the increase in land expansion played a significant role in driving vegetable output in India. In a separate study, Mathobo et al. (2024) from South Africa assessed the growth rate and instability of area, production, yield, consumption, import and export of dry beans from 1970 to 2019. The findings showed a decrease in the average growth rate of land area, production, and export of dry beans by 1.497%, 0.472%, and 0.282% respectively. Other scholars, including Liverpool-Tasie et al. (2023), Schreinemachers et al. (2023), and Faye et al. (2023), have documented discrepancies in the outputs and yields of vegetables across various African countries. In Nigeria, a number of empirical studies have been carried out to analyze

trends, growth rates, instability indices, and decomposition of different arable crops. For instance, Ochoche et al. (2022), Ikuemonisan et al. (2022), Adebayo (2023), and Akpan et al. (2024b, 2025a, 2025b) have all conducted research focusing on these aspects, revealing fluctuating outputs, land areas, and yields over time. The decomposition analyses of these studies have indicated that land area plays a dominant role in total production of these crops. However, there is a notable gap in similar studies concerning vegetable crops in Nigeria, despite their increasing significance.

Given the limited availability of empirical research on historical trends and growth rates of output, land usage, and yields of major vegetable crops in the country, this study is deemed essential due to the significant impact of vegetable crops on the nation's economy. Analyzing the trends, growth rates, and decomposition of vegetable crop production, cultivated/harvested areas, and yield components is crucial for achieving the desired growth in this sub-sector. Consequently, the study was specifically designed to examine the trends, growth rates, instability indices and decomposition structure of selected vegetable crops in Nigeria spanning from 1961 to 2023.

2. Materials and Methods

2.1. Study Area and Data Source

The study was conducted in Nigeria. The country is endowed with abundant agricultural, marine, and forest resources. The richness of natural resources allows for the cultivation of a wide range of agricultural products. More than sixty percent of the population is involved in agricultural activities, including the production of cassava, groundnuts, oil palm, cotton, sugarcane, rubber, cocoa, rice, maize, aquaculture and artisanal fishing, coconut, livestock, yams, various beans and legumes, sorghum, carrots, and a variety of vegetables, among others. The study made use of secondary data sourced from Food and Agricultural Organization (FAO) extended from 1961 to 2023.

2.2. Analytical Techniques

The study calculated growth rates, instability indices and decomposition of vegetables in Nigeria. The details of the calculations are presented below:

2.2.1. Exponential Growth Rate

In measuring the exponential growth rate of vegetable production, harvested area, and yield, the following equation were defined in accordance with Akpan et al., (2025a),

$$log_e(V_o, V_a, V_y) = \alpha_0 + \alpha_1 t + U_t \quad (1)$$

Where, V_o, V_a, V_y are the output of vegetable in ton, harvested area in hectare and yield in ton/ha respectively in a given year. Variable "t" represents the time variable or trend measured in years. The choice of the exponential growth rate was based on the assumption that the vegetable output, harvested area and yield would likely exhibit exponential growth patterns over the years as a result of various intervention policies implemented by the federal government to boost the subsector's productivity. The exponential growth rate (EGR) is as specified in equation 2.

$$EGR_t = (e^{\alpha_1} - 1)\ x\ 100$$
(2)

Where "EGRt" is the measure of exponential growth rate for a specified variable express in a percentage. The OLS technique was used to estimate equation 1 from which the required parameter α_1 $w$as obtained. An exponential growth rate characterizes the rapid increase of a quantity over time, where the rate of change is directly proportional to the quantity itself. This implies that the rate of increase corresponds directly with the current magnitude of the quantity. Consequently, a greater growth rate results in a larger quantity being measured and produces a steeper curve.

2.2.2. Annual Compound Growth Rate

Compound annual growth rate (CGR) measures the annualized growth rate for compounding values over a given time period. The CGR smoothed the effect of volatility of periodic values that can render arithmetic means less meaningful. The rate represents the rate of return that an investment would need to have every year in order to grow from its beginning balance to its ending balance, over a given time interval. The study assumes that, the annual growth in production, harvested area and yield of vegetable subsector were as a result of investment done over the years by stakeholders in the subsector. Hence, a simple business CGR was estimated for the production, harvested area and yield of respective vegetables as thus:

$$\boldsymbol{CGR} = \left(\left(\frac{V_n}{V_f}\right)^{\frac{1}{n}} - 1\right) * \ 100 \qquad (3)$$

Where ''n'' represents the total number of years considered, V_f represent the initial or the first year value and V_n is the last year value of the variable considered. The rate is expressed as a percentage. A higher value of CGR represents a higher annual growth rate and a lower value, a lower annual growth rate.

2.2.3. Coefficient of Variability (COV)

The COV is a prominent index used for assessing variability and instability within a series. It quantifies the relative dispersion of data around the mean value. However, it is important to note that the COV tends to overestimate instability in time series with long-run trends and does not adequately account for the trend component inherent in the data. A higher COV indicates greater variability, while a lower COV suggests less variability.

$$COV = \frac{\text{standard deviation}}{\text{mean}} \qquad (4)$$

2.2.4. Cuddy-Della Valle index (CDI)

The Cuddy Della Valle index removes trend effects from annual series, providing a clear indication of instability direction (Cuddy and Della Valle, 1978). By utilizing the adjusted coefficient of determination, it eliminates the impact of trends on the coefficient of variation (COV), resulting in a superior measure of instability (Wasem,

2001). A low value of this index suggests low instability in the series, whereas a high value indicates the opposite. The formula for calculating this index is as follows:

$$CDI = COV\sqrt{1 - \bar{R}^2} \quad (5)$$

Where COV is the coefficient of variation in percent, and $\bar{R}^2$ denotes the adjusted coefficient of determination obtained from the linear time trend regression on output, harvested area and yield of vegetables in the country. The degrees of instability are classified into three ranges: Low instability (from 0 – 15); medium instability (greater than 15, but less than 30) and high instability (>30).

2.2.5. Coppock Instability Index (COI)

The Coppock (1962) instability index measures instability by utilizing log variance methodology. A greater Coppock instability index indicates heightened instability, while a lower index signifies lower instability. It is given as:

$$\text{Coppock Instability Index (COI)} = \text{Antilog}\left(\sqrt{\text{logV}} - 1\right)\text{x } 100 \quad (6)$$

Where,

$$logV = \frac{1}{N-1}\sum(logX_{t+1} - logX_t - M)^2 \quad (7)$$

$$M = \frac{1}{N-1}\sum(logX_{t+1} - logX_t) \quad (8)$$

Note,

X_t = Time series or variable under consideration (e.g. log of output/area/yield) in period t.

M = Mean value of the first differences of logarithm

N = Total number of observations

V = Value of Variance log obtained by substituting the values of first differences and M in equation 7.

2.2.6. Vegetable Production Decomposition

The instability indices does not consider the proportional impact of harvested area and yields on the respective vegetable crops. The decomposition analysis isolate the effects of yield, harvested area and the interaction effect from the total production. The process is shown as thus:

Total effect = Area effect + Yield effect + Interaction effect

$$D = \frac{A_0\Delta Y * 100}{\Delta P} + \frac{Y_0\Delta A * 100}{\Delta P} + \frac{\Delta Y\Delta A * 100}{\Delta P} \quad (9)$$

Where,

A_0 = Area in the base year

ΔA = Current harvested area minus the base area

Y_0 = Yield in the base year

ΔY= Current yield minus the base yield

ΔP = Current production minus base production

All analyses specified in the study are done for three (3) periods i.e. 1961–1985, 1986–2023 and 1961 – 2023. These periods represent the major policy eras in Nigeria. The vegetable crops considered were; Carrot and Turnip; (*Daucus carota* and *Brassica rapa*); Chillies and peppers, dry (*Capsicum spp., Pimenta spp*.), Chillies and peppers (*Capsicum spp., Pimenta spp*.) green; Pineapple (*Ananas comosus*), Tomato (*Solanum lycopersicum*), and other Vegetables. The choice of the vegetables was based on the availability of data.

3.Results and Discussion

3.1. Trend Analyses

The trends for vegetables' output from 1961 to 2023 in Nigeria is presented in figure 1. The outputs of the specified vegetables displayed a fluctuating pattern, with notable irregular peaks and troughs over the examined period. For instance, carrot and turnip outputs assumed a zero growth from 1961 to 1988. A depression occurred in 1993 and 2011, the rest of the periods assume an average upward trend. A steady upward trends were observed for dry chillies and peppers, green chillies and peppers, pineapple, tomato and other vegetables in most of the periods considered. The fluctuation in vegetable outputs in the country was observed to have an average upward trend during the pre-Structural Adjustment Programme (SAP) period spanning from 1961 to 1985. Most of the conspicuous troughs in the trends occurred during the SAP period of 1986 to 1993 and post-SAP period of 1994 to 2023.

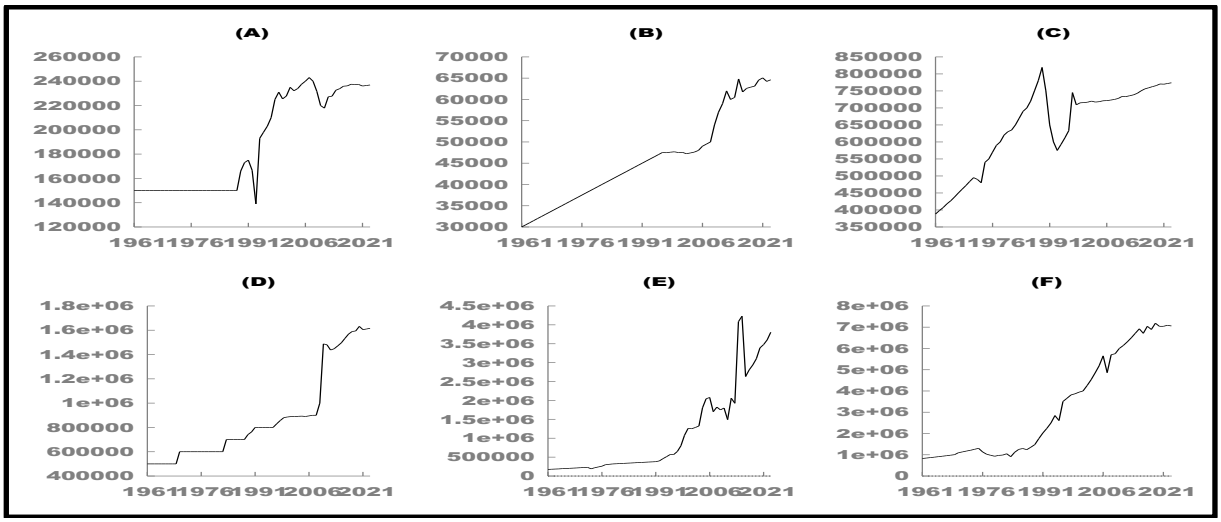

Figure 1. Trend in vegetables production (tons) in Nigeria (1961 – 2023). Where (A) = Carrot and Turnip; (B) = Chillies and peppers, dry; (C) = Chillies and peppers, green; (D) = Pineapple; (E) = Tomato; (F) = other vegetables.

However, the last four years of the time frame considered (from 2020 – 2023) witnessed a consistent upward growth in all vegetable outputs examined. The trends observed in vegetable outputs depict the fact that, the country has injected concerted effort to grow vegetables over the years. The observations found are similar to those reported by Ochoche et al., (2022), Ikuemonisan et al., (2022), Adebayo (2023), Akpan et al., (2024b), Akpan et al., (2025a), and Akpan et al., (2025b) for other arable crops.

Figure 2 illustrates the trends in the harvested land area dedicated to vegetable crops examined in this study. These trends predominantly mirror the output patterns identified throughout several time periods. Notable fluctuations occurred particularly during the SAP and Post SAP phases. The parallels between the trends in harvested area and output for vegetable crops can be linked to various government policies concerning arable crop production that have been enacted over the years. A significant number of these policies aimed to enhance vegetable crop production primarily through land expansion, rather than the adoption of advanced technologies. Consequently, the increases in output observed during most of the analyzed periods are directly attributable to the expansion of cultivable land area.

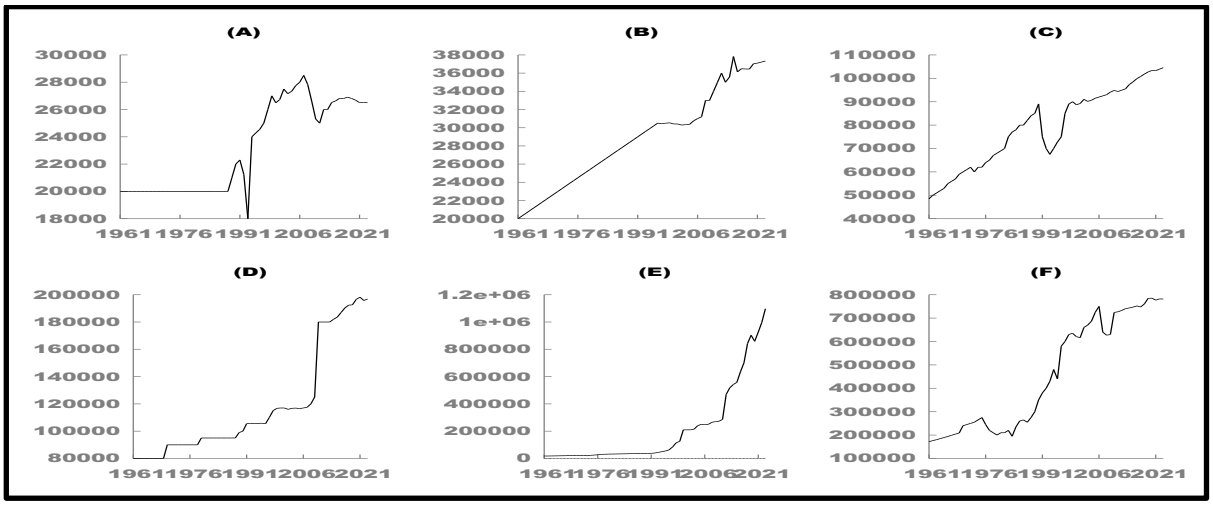

Figure 2. Trend in harvested area (hectare) of vegetables in Nigeria (1961 – 2023). Where (A) = carrot and turnip; (B) = chillies and peppers, dry; (C) = chillies and peppers, green; (D) = pineapple; (E) = tomato; (F) = other vegetables.

The data indicates a consistent increase in the area of land harvested for all vegetable crops studied from 1961 to 2023. This ongoing expansion of agricultural land suggests a persistent issue of low productivity affecting the subsector throughout the years in the country.

Figure 3 illustrates the trends in vegetable crop yields, which have demonstrated variability when compared to trends observed in output and harvested area during the same period. Notably, only carrots, turnips, dry chillies and peppers, pineapples, and other vegetables displayed an average upward trend during the study's timeframe. In contrast, green chillies, peppers, and tomatoes exhibited an average downward trend within the analyzed period.

The fluctuations in yield response among designated vegetable crops over time are considerably influenced by agricultural policies and programs in the country. These policies play a crucial role in aligning with economic demands and capabilities, which ultimately determine the trends in vegetable yields nationally. For instance, in Nigeria, historical agricultural policies have largely overlooked vegetable crop production, directing focus instead toward non-vegetable arable crops such as cassava, yam, and groundnut. Consequently, farmers have tended to prioritize these staple crops over

vegetable production, rendering the adoption of innovations in the vegetable sector particularly difficult, especially prior to the era of the Structural Adjustment Program (SAP).

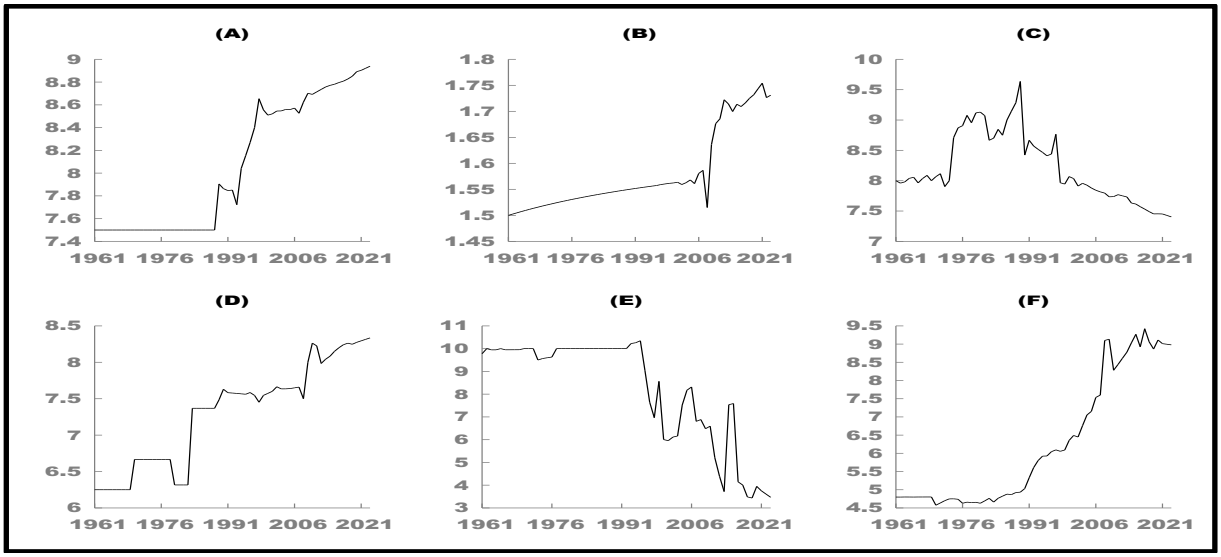

Figure 3. Trend in Yield (ton/ha) of vegetables in Nigeria (1961 – 2023). Where (A) = Carrot and Turnip; (B) = Chillies and peppers, dry; (C) = Chillies and peppers, green; (D) = Pineapple; (E) = Tomato; (F) = Other Vegetables.

In recent years, however, there has been a marked increase in the production and yield of certain vegetable crops within the country. Crops such as carrots, turnips, pineapples, and dry chillies have demonstrated significant improvements in both output and yield over the last five years. This progress can be attributed to multiple initiatives undertaken by the government and stakeholders in the agricultural sector aimed at promoting awareness of the nutritional and economic benefits associated with these crops. Nonetheless, the yields of exotic vegetables, including tomatoes and green chillies, continue to struggle in adapting to local conditions due to insufficient advanced technology to enhance their yields. These yield observations align with the findings of Ikuemonisan et al. (2022), Adebayo (2023), Akpan et al. (2024b), Akpan et al. (2025a), and Akpan et al. (2025b).

3.2. The Compound Growth Rate and Instability Index in Output, Area and Yield

The estimated coefficients of variation (COV), exponential growth rate (EGR), compound growth rate (CGR), Cuddy-Della Valle instability index (CDI), and Coppock instability index (COI) associated with the output, harvested area, and yield of vegetable crops in Nigeria for the periods 1961–1985, 1986–2023, and 1961–2023 are presented in Tables 1, 2, and 3, respectively.

3.2.1. Growth rates and Instability Indices in Output of Vegetable Crops

The analysis estimates that capture the coefficient of variation, exponential growth rate, compound growth rate, and instability index of vegetable output in the specified timeframe are discussed below:

Carrots & turnips: The production levels of carrots and turnips remained stable during the initial period from 1961 to 1985, resulting in a coefficient of variation (COV), exponential growth rate (EGR), and compound growth rate (CGR) of zero percent. In the subsequent period from 1986 to 2023, there was a slight increase in COV and single-digit values for EGR and CGR, accompanied by low instability indices. The overall analysis spanning from 1961 to 2023, showed a minimal coefficient of variation in output (14.73%), as well as low EGR (1.04%) and CGR (0.73%). These findings suggest that there were few significant changes or interventions in the subsector during this time frame that significantly affected carrot and turnips output in the country.

Chillies and peppers, dry and green: The output of both dry and green chilies and peppers demonstrated a consistent trend of positive growth with low instability rates throughout the analyzed period. It was noted that the growth rates and coefficient of variation (COV) were higher during the 1961-1985 period compared to the 1986-2023 period. This suggests that there were fewer significant activities affecting the output of these subsectors during the period of analysis.

Table 1. Growth rates and Instability Indices in vegetable Outputs (ton) in Nigeria.

	Vegetables					
Indicator	Carrots & turnips	Chillies and peppers, dry	Chillies & peppers, green	Pineapple	Tomato	other vegetables
			1961 – 1985 (Pre- SAP Period)			
Mean	150000	36000	530120	576000	251640	1029800
COV (%)	0.000	10.222	18.647	11.516	24.734	13.354
EGR (%)	0.000	1.407	2.551	1.411	3.196	0.877
CGR (%)	0.000	1.355	2.388	1.355	2.788	1.684
CDI	0.000	0.00	2.681	5.220	11.211	12.062
COI	36.792	40.781	44.335	41.257	46.890	41.954
			1986 – 2023 (SAP and Post-SAP Period)			
Mean	213911	52571	721599	1094036	1708209	4672701
COV (%)	14.727	15.049	7.605	32.288	70.135	43.025
EGR (%)	1.181	1.266	0.334	2.670	7.474	4.768
CGR (%)	1.210	1.109	0.190	2.225	6.440	4.567
CDI	8.748	5.063	6.850	12.596	26.428	7.782
COI	43.344	42.618	39.869	50.256	84.532	63.789
			1961 – 2023 (Overall period)			
Mean	188550	45995	645615	888466	1130206	3227106
COV (%)	21.119	22.738	18.649	42.329	103.717	73.637
EGR (%)	1.044	1.222	0.969	2.052	5.694	4.353
CGR (%)	0.728	1.225	1.102	1.879	4.999	3.464
CDI	9.159	5.084	9.380	17.319	51.471	24.043
COI	45.443	46.096	45.218	54.224	104.869	83.006

Source: computed by authors.

Pineapple, tomato and other vegetable: The vegetable crops analyzed exhibited positive Exponential Growth Rate (EGR) and Compound Growth Rate (CGR) over the study period. This indicates that the production of pineapple, tomato, and other vegetables increased during the analysis period. The rate of growth was found to be higher in the pre-Structural Adjustment Program (Pre-SAP) era compared to the SAP and post-SAP periods. The computed Cuddy-Della Valle index (CDI) and Coppock Instability Index (COI) indicated moderate instability for pineapple and other vegetable outputs, while tomato output showed high instability. The coefficient of variation (COV)

was relatively high for the specified vegetable outputs from 1961 to 2023. These results imply that various interventions were implemented to boost the production of these crops during the study period. Similar fluctuations observed in the indices of vegetable output instability have been documented in numerous studies conducted in developing countries, as highlighted by Ochoche et al., (2022), Liverpool-Tasie et al., (2022), Schreinemachers et al., (2022), Adebayo (2023), Akpan et al., (2024b), Akpan et al., (2025a), and Akpan et al., (2025b).

3.2.2. Growth Rates and Instability Indices in Harvested Area (ha) of Vegetable Crops in Nigeria

Similarly, the analysis conducted provides estimates of various statistical quantities that characterize the coefficient of variation, growth rate, and instability index of the harvested area of vegetable crops within the specified timeframe.

Carrots & turnips: The study reveals that key indicators related to the harvested area exhibit a distribution pattern akin to output indicators. Specifically, the coefficient of variation (COV), the exponential growth rate (EGR), and the compound growth rate (CGR) all presented as zero between 1961 and 1985. However, these indicators displayed a positive trend in subsequent periods, signifying a consistent upward trend in the harvested land area of carrots and turnips over the years. It is noteworthy that the instability indices, the CDI and COI remained low across all periods, indicating low instability in the harvest area of carrots and turnips during the specified timeframe.

Table 2. Growth rates and Instability Indices in harvested land area (ha) of vegetable in Nigeria

Indicator	Vegetables					
	Carrots & turnips	Chillies and peppers, dry	Chillies & peppers, green	Pineapple	Tomato	other vegetables
1961 – 1985 (Pre- SAP Period)						
Mean	20000	36000	62460	87800	25364	217795.2
COV (%)	0.000	9.356	14.290	7.181	24.162	13.663
EGR (%)	0.000	1.286	1.919	0.919	3.177	0.969
CGR (%)	0.000	1.238	2.022	0.690	2.696	1.664
CDI	0.000	0.00	2.814	2.708	6.966	12.123
COI	36.792	40.221	42.390	39.565	46.675	42.135
1986 – 2023 (SAP and Post-SAP Period)						
Mean	25218	32337	90076	138797	336218	611317
COV (%)	10.645	10.144	11.314	28.182	95.219	27.553
EGR (%)	0.742	0.873	0.905	2.332	10.796	2.708
CGR (%)	0.743	0.807	0.706	1.936	9.449	2.886
CDI	7.498	2.927	5.663	10.790	36.991	11.250
COI	41.265	40.674	41.428	48.321	117.160	51.683
1961 – 2023 (overall period)						
Mean	23147	28870	79117	118560	212863	455158
COV (%)	14.277	17.957	21.086	33.324	136.707	51.496
EGR (%)	0.679	0.992	1.165	1.540	7.406	2.951
CGR (%)	0.448	10.995	1.226	1.439	6.741	2.431
CDI	7.065	2.545	5.521	15.040	79.422	16.293
COI	42.418	44.175	45.940	49.662	143.692	64.516

Source: computed by authors.

Chillies and peppers, dry and green: The harvested areas of dry and green chillies and peppers showed consistent growth over the specified period, with both EGR and CGR

indicating positive trends. This suggests that the harvested areas of these vegetables increased steadily on average throughout the analysis timeframe. However, the growth rates were notably higher before the implementation of SAP, declining slightly during and after this period. The calculated values for COV, CDI, and COI indicate a low level of variability in the cultivated areas of dry and green chillies and peppers over the course of the analysis. This implies that there were only marginal positive changes in the harvested areas of these vegetables during the specified timeframe.

Pineapple, tomato and other vegetable: The harvested areas of pineapple, tomato, and other vegetables exhibited positive growth rates over the specified time periods. The estimated EGR and CGR values were positive from 1961 to 1985 and showed even higher values from 1986 to 2023. This indicates a consistent increase in the harvested areas of these vegetables throughout the review period. The calculated Cuddy-Della Valle index (CDI) and Coppock Instability Index (COI) indicated moderate instability for pineapple and other vegetable harvested areas, and a high instability rate for tomato harvested areas. The coefficient of variation (COV) for the vegetable harvested areas was relatively high from 1961 to 2023. These findings suggest that various activities or programs were implemented in these crop enterprises during the analysis period, leading to the expansion of their cultivated land areas. Comparable findings have been reported for various crops by Vanitha et al., (2021), Ochoche et al., (2022), Ikuemonisan et al., (2022), Adebayo (2023), Akpan et al., (2024b), Lalenpuii et al., (2024), Akpan et al., (2025a), Akpan et al., (2025b), and Sethi et al., (2024).

3.2.3. Growth Rates and Instability Indices in Yields (ton/ha) of Vegetable Crops

Estimates for growth rates, coefficient of variation, and instability index of vegetable crop yields were also calculated.

Carrots & turnips: The yield remained stable from 1961 to 1985, while there was a slight increase in yield from 1986 to 2023 with low instability indices (COI and CDI). Analysis of aggregate data from 1961 to 2023 showed that the yield of carrots and turnips grew by 0.36% for EGR and 0.28% for CGR.

Throughout the analysis period, COV, CDI, and COI remained relatively low. Compared to Egypt (EGR = 0.83% and CGR = 0.76%), Nigeria had a lower growth rate in carrot and turnip yield, but higher than South Africa (EGR = -0.122% and CGR = -0.13%) (FAO, 2025). These findings suggest that improved technologies are needed for carrot and turnip production in Nigeria to increase production and yield. This would also help position the country in a more competitive and sustainable advantage relative to other African nations.

Chillies and peppers, dry and green: The analysis reveals a consistent positive annual growth in the yield of dry chillies and peppers over the study period. From 1961 to 1985, the estimated values of EGR and CGR stood at 0.12%, and 0.12% respectively, increasing to 0.39% for EGR and 0.30% for CGR from 1986 to 2023. The aggregate data for the entire period (1961-2023) shows a growth rate of 0.23% for both EGR and CGR. However, these growth rates were lower than those observed in other countries such as

Cameroon (EGR = 1.50%; CGR = 1.27%), Egypt (EGR = 0.62%; CGR = 0.57%), Ghana (EGR = 3.39%; CGR = 2.67%), and South Africa (EGR = 1.00%; CGR = 1.17%) within the same period.

Table 3. Growth rates and Instability Indices in yield (ton/ha) of vegetables in Nigeria

	Vegetables					
	Carrots & turnips	Chillies and peppers, dry	Chillies & peppers, green	Pineapple	Tomato	other vegetables
1961 – 1985 (Pre- SAP Period)						
Mean	7.500	1.524	8.440	6.545	9.911	4.731
COV (%)	0.000	0.883	5.536	5.545	1.598	1.579
EGR (%)	0.000	0.119	0.620	0.488	0.018	-0.091
CGR (%)	0.000	0.116	0.359	0.661	0.090	0.020
CDI	0.000	0.0743	3.219	4.230	1.627	1.459
COI	36.792	37.119	38.875	38.824	37.392	37.379
1986 – 2023 (SAP and Post-SAP Period)						
Mean	8.443	1.618	8.059	7.798	7.009	7.270
COV (%)	5.166	4.928	7.033	4.098	34.552	22.057
EGR (%)	0.435	0.389	-0.566	0.330	-2.999	2.003
CGR (%)	0.463	0.299	-0.513	0.284	-2.749	1.634
CDI	2.085	2.313	2.918	1.822	15.474	6.007
COI	38.797	38.629	39.388	38.320	5 53.874	46.230
1961 – 2023 (Overall period)						
Mean	8.069	1.581	8.210	7.301	8.160	6.262
COV (%)	7.115	4.906	6.800	9.628	28.890	28.132
EGR (%)	0.363	0.227	-0.193	0.505	-1.594	1.362
CGR (%)	0.279	0.228	-0.123	0.433	-1.632	1.009
CDI	2.480	2.496	5.881	3.131	15.482	11.339
COI	39.490	38.594	39.341	40.584	52.637	48.032

Source: computed by authors.

On the contrary, the growth rates of green chillies and pepper showed a slight positive trend from 1961 to 1985. However, there was an average annual decrease in both yields during the periods of 1986 to 2023 and for the overall period of 1961 to 2023. This indicates a consistent decline in yields of green chillies and pepper throughout the analysis. For the entire data set from 1961 to 2023, the estimated EGR and CGR were found at -0.19% and -0.12% respectively. In comparison, Egypt saw improvements in yields with an EGR of 0.19% and CGR of 0.41%, while Ghana had even higher increases with an EGR of 2.24% and CGR of 2.15% (FAO, 2025). The COV, CDI, and COI values were relatively low, indicating consistent low instability in yields for these vegetable crops over the selected time periods. The data suggests that in Nigeria, the production of dry and green chillies and peppers relies more on land expansion rather than advancements in technology. This differs from other African countries such as Ghana, Egypt, and South Africa, where significant technological improvements have been implemented in the production of these vegetable crops.

Pineapple, tomato and other vegetables: The analysis of pineapple yield over the specified timeframe showed a consistent positive marginal increase in growth rate. This indicates a gradual improvement or increase in pineapple yields during the period under review. The instability indicators; CDI, COI, and COV were all low, suggesting relatively low instability in yields and minimal fluctuations in the subunit activities. For

the overall data spanning from 1961 to 2023, the pineapple yield growth rates were 0.51% for EGR and 0.43% for CGR. These rates are notably lower compared to other countries such as Cameroon (EGR = 2.36%, CGR = 0.85%), Cote d'Ivoire (EGR = 0.94%, CGR = 1.73%), and Ghana (EGR = 6.69%, CGR = 5.07%) as reported by FAO in 2025. These findings suggest that Nigeria's pineapple production lags behind several other African countries. It also implies that countries like Ghana and Egypt have adopted advanced technologies in their pineapple production process, surpassing Nigeria in terms of efficiency and output. Despite this, Nigeria's annual growth rate in yield exceeded that of South Africa (EGR = -1.60%, CGR = -1.05%) and Congo (EGR = -0.20%, CGR = -0.14%) (FAO, 2025).

During the period from 1961 to 1985, the growth rates of tomato yield exhibited a marginal positive trend. The coefficient of variation (COV) and instability indices (CDI and COI) of tomato yield were low, suggesting minimal fluctuations. However, from 1986 to 2023, there was a decline in tomato yield with an EGR of -2.99% and CGR of -2.75%, along with moderate instability indices. The negative trend persisted in the aggregate data, with estimated EGR and CGR of -1.59% and -1.63% respectively, and moderate instability indices. These findings indicate a declining trend in tomato yield in Nigeria from 1961 to 2023. The findings indicate that the current technology being used for tomato production in Nigeria is not sufficient to sustain production levels in the present or future. The estimated yields are unable to meet domestic demand and do not position the country competitively in Africa. For example, when compared to other African countries from 1961 to 2023, Nigeria's performance lags behind Ghana (EGR: 0.87%, CGR: 0.71%), Cameroon (EGR: 2.24%, CGR: 2.51%), Congo (EGR: -1.00%, CGR: -0.65%), Egypt (EGR: 2.11%, CGR: 1.65%), South Africa (EGR: 2.09%, CGR: 1.45%), and Cote d'Ivoire (EGR: 0.005%, CGR: 0.068%) (FAO, 2025).

The growth rate trend for yield of other vegetable crops exhibited a consistent positive growth from 1961 to 2023. A detailed analysis indicated that the annual growth rate for yields of other vegetable crops was positive at 1.36% for EGR, and 1.01% for CGR. The CDI and COI metrics indicated a low level of instability in the yield of other vegetables. Interestingly, Nigeria demonstrated a superior performance in the productivity of other vegetable crops compared to several African countries during this period. For example, Nigeria's yield growth rate surpassed that of countries such as Cameroun (EGR = 1.01%, CGR = 0.97%), Egypt (EGR = -2.20%, CGR = -1.50%), Congo (EGR = 0.12%, CGR = 0.07%), South Africa (EGR = -0.30%, CGR = -0.33%) and Cote d' Ivoire (EGR = 0.33, CGR = 0.28) according to data from the FAO in 2025. The results correspond with the conclusions drawn in prior studies on various crops by Vanitha et al., (2021), Lalenpuii et al., (2024), Sethi et al., (2024), Faye et al., (2023), Mathobo et al., (2024), Akpan et al., (2024b), Akpan et al., (2025a), and Akpan et al., (2025b).

3.3. Decomposition of Output of Vegetable Crops in Nigeria

The breakdown of vegetable outputs decomposition is detailed in Table 4. The analysis highlights the key components influencing the total effect, including the area effect, yield effect, and interaction effect. It was found that between the years 1961 and

1985, the land area effect played a dominant role in driving variations in the total effect of vegetable outputs. This suggests that the growth in vegetable production during this time frame was primarily driven by the expansion of cultivable land rather than improvements in technology or agricultural practices. Thus, it can be inferred that the government prioritized increasing cultivable land through its various programs without focusing on enhancing vegetable crop yields.

Table 4. Percentage decompositions of area, yield and their interaction effects on vegetable outputs in Nigeria.

	1961 – 1985			
	Yield effect (%)	**Area effect (%)**	**Interaction effect (%)**	**Total effect**
Carrots & turnips	0.00	0.00	0.00	0.00
Chillies and peppers, dry	7.35	90.00	2.65	100.00
Chillies & peppers, green	11.66	80.77	7.57	100.00
Pineapple	44.74	46.87	8.39	100.00
Tomato	2.30	95.53	2.17	100.00
Other vegetables	0.95	98.57	0.48	100.00
	1986 – 2023			
Carrots & turnips	33.13	56.10	10.77	100.00
Chillies and peppers, dry	23.08	68.67	8.25	100.00
Chillies & peppers, green	-236.66	409.25	-72.59	100.00
Pineapple	8.70	81.96	9.34	100.00
Tomato	-6.73	307.84	-201.11	100.00
Other vegetables	19.09	43.71	37.20	100.00
	1961 – 2023			
Carrots & turnips	33.13	56.10	10.77	100.00
Chillies and peppers, dry	13.35	75.08	11.57	100.00
Chillies & peppers, green	-7.49	116.15	-8.66	100.00
Pineapple	14.04	65.46	20.50	100.00
Tomato	-3.13	290.86	-187.73	100.00
Other vegetables	11.69	46.93	41.38	100.00

Source: computed by authors.

During the time frame from 1986 to 2023, the dominance of the land area effect on vegetable production was still evident. The area effect accounted for over 40.00% of the total output in all specified vegetables, offsetting the negative impacts of interaction effects on green chillies and pepper, and tomato enterprises.

An analogous discovery was noted in the combined data spanning from 1961 to 2023, highlighting the significant influence of land area effect on vegetable crop production in Nigeria. The analysis demonstrated that the land area effect accounted for more than 45.00% of the total impact, counteracting any negative effects from interactions, particularly in tomato cultivation. These findings underscore the pivotal role of land area in understanding variations in vegetable production across the country. The finding has a serious implication for a sustainable vegetable production in the country. Giving the rising rural population and associated land pressures, mounting soil degradation and rural poverty in the country; continuous land expansion cannot yield sustainable vegetable production in the long run.

Continuous land expansion would compromise the traditional farrow system, intensify soil infertility and makes it more difficult for smallholder farmers to benefit from yield gains offered by plant genetic improvement. The results corroborate Ochoche

et al., (2022), Ikuemonisan et al., (2022), Adebayo (2023), Akpan et al., (2024b), Akpan et al., (2025a), and Akpan et al., (2025b).

4. Conclusion

The study examined trends, growth rates, and instability index linked to vegetable crops production, harvested area, and yield in Nigeria spanning from 1961 to 2023. A decomposition analysis was conducted to separate the total output effect into area effect, yield effect, and interaction effect. The analysis was segmented into three distinct sub-periods: 1961–1985, 1986–2023, and the complete period from 1961 to 2023. The trend analysis revealed fluctuations in the output, harvested area, and yield of vegetables across all sub-periods and the aggregated period. The calculated exponential growth rate (EGR) and compound growth rate (CGR) for vegetable outputs and harvested areas remained positive throughout the analysis period, indicating an increase in these factors over time. In contrast, the CGR and EGR of green chillies and pepper, and tomato exhibited decreasing trends. Conversely, other specified vegetables such as carrot, turnips, dry chillies, pepper, and pineapple displayed an upward trend in yield. The calculated Cuddy-Della Valle index (CDI) and Coppock Instability Index (COI) for pineapple and other vegetables indicated a moderate level of instability, whereas the tomato enterprise showed high instability. These results suggest that various initiatives were implemented, leading to significant fluctuations in output and harvested areas of these vegetables. However, when considering the yield component, most specified vegetables had low instability levels except for tomatoes, which showed moderate instability.

Decomposition analyses indicate that throughout various time periods from 1961 to 2023, the significant growth in total vegetable crop production in the country was primarily driven by the expansion of land area rather than improvements in yield. This suggests that the observed increases in vegetable crop production are largely attributed to the increase in cultivable land, with yield and other factors playing a minor role. To enhance yield performance and overall output, it is imperative for stakeholders within the vegetable sub-sector to adopt advanced technologies and reduce their dependency on land area expansion. By implementing additional initiatives, the sub-sector can promote increased activity and cultivate a more sustainable approach towards enhancing yield contributions. Also incorporating vegetable production into youth development programs in the country is essential to promoting youth participation in vegetable production. The utilization of hydroponic systems and greenhouses for vegetable production is strongly encouraged, as these technologies can attract more young people to engage in vegetable production. Additionally, enhancing access to high-quality planting materials, financial assistance, and land for vegetable farmers can significantly boost activities within the sub-sector and enhance yields.

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Author Contribution
All authors contrıbuted equally ın the conception and development of the entire research work.

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Optimizing the output of rice farmers in Niger and Nasarawa states, Nigeria

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ABSTRACT

This research study focused on optimizing the output of rice farmers in Niger and Nasarawa States, Nigeria. The study collected primary data from 180 rice farmers utilizing structured questionnaires. The specific objectives of the study were to describe the farm specific and farmers features of rice production, optimize and determine the input factors (farm size, labour, fertilizer, agrochemicals, seeds) affecting output of rice producers, evaluate the socio-economic factors affecting the technical inefficiency of rice producers and determine the technical efficiency scores of rice producers. The analytical tools used to achieve the objectives were stochastic production efficiency frontier model (SPEFM), return to scale (RTS), elasticity of production model (EP) and t-Test of difference between means. The findings revealed that rice production generates profits and demonstrated a substantial financial difference between cost and returns. Production elasticity showed a positive result for all farm inputs including farm size, labour, fertilizers, agrochemicals and seeds and as a result, these inputs boost output levels. A proportional increase in input resources results in more than a proportional increase in output at a return to scale ratio of 1.020 in the rice farming operation. The analysis reveals that farm size with combined seeds and fertilizers stands as the significant and primary production factors for rice but actual production efficiency depends mainly on the education level, farm experience and cooperative standing of the producers. Rice productivity will increase through better access to productive inputs combined with available land improvements and financial assistance. The paper suggests policy solutions which support both efficient resource management and technical training initiatives to enhance farmers' output levels.

Nijerya'nın Nijer ve Nasarawa eyaletlerindeki pirinç çiftçilerinin üretiminin optimize edilmesi

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ÖZET

Bu araştırma çalışması, Nijerya'nın Nijer ve Nassarawa eyaletlerindeki pirinç çiftçilerinin çıktılarını optimize etmeye odaklanmıştır. Çalışma, yapılandırılmış anketler kullanarak 180 pirinç çiftçisinden birincil veri toplamıştır. Çalışmanın özel hedefleri, pirinç üretiminin çiftliklere özgü ve çiftçilere özgü özelliklerini tanımlamak, pirinç üreticilerinin çıktısını etkileyen girdi faktörlerini (çiftlik büyüklüğü, emek, gübre, tarım kimyasalları, tohumlar) optimize etmek ve belirlemek, pirinç üreticilerinin teknik yetersizliğini etkileyen sosyo-ekonomik faktörleri değerlendirmek ve pirinç üreticilerinin teknik verimlilik puanlarını belirlemekti. Amaçlara ulaşmak için kullanılan analitik araçlar, stokastik üretim verimliliği sınır modeli (SPEFM), ölçeğe göre getiri (RTS), üretim modelinin esnekliği (EP) ve ortalamalar arasındaki farkın t-Testi idi. Bulgular, pirinç üretiminin kar getirdiğini ve maliyet ile getiriler arasında önemli bir finansal fark olduğunu ortaya koydu. Üretim esnekliği, çiftlik büyüklüğü, emek, gübre, tarım kimyasalları ve tohumlar dahil olmak üzere tüm çiftlik girdileri için pozitif bir sonuç gösterdi ve sonuç olarak bu girdiler çıktı seviyelerini artırdı. Pirinç çiftçiliği işletmesinde girdi kaynaklarındaki orantılı bir artış, 1,020'lik ölçek getirisi oranında çıktıda orantılıdan daha fazla bir artışla sonuçlanmaktadır. Analiz, kombine tohum ve gübrelerle çiftlik boyutunun pirinç için önemli ve birincil üretim faktörleri olduğunu ancak gerçek üretim verimliliğinin esas olarak eğitim düzeyine, çiftlik deneyimine ve üreticilerin kooperatif statüsüne bağlı olduğunu ortaya koymaktadır. Pirinç verimliliği, mevcut arazi iyileştirmeleri ve mali yardımla birleştirilmiş üretken girdilere daha iyi erişim yoluyla artacaktır. Makale, çiftçilerin çıktı seviyelerini artırmak için hem verimli kaynak yönetimini hem de teknik eğitim girişimlerini destekleyen politika çözümleri önermektedir.

1.Introduction

Rice (*Oryza sativa L.*) is a fundamental food in Nigeria. Its production massively supports national food security, while creating jobs and facilitating economic advancement (FAO, 2022). Rice is one of the dominant staple foods in Nigeria and the nationwide demand has surged because of fast population expansion and changing dietary choices and the effects of urban development (Mohammed et al. 2019). Despite its position as a leading rice producer across Africa local supply has failed to meet consumption needs, so the nation imports rice extensively at high prices (Abbas et al., 2018). Enhancing rice production in domestic operations has become essential for Niger and Nasarawa and other major producing states. These states maintain beneficial rice cultivation environments yet their agricultural efficiency remains low along with unacceptable yield (Merem et al., 2017).

The Nigerian government keeps advancing programs such as the Anchor Borrowers' Program (ABP) together with the Presidential Fertilizer Initiative (PFI) as well as import restrictions to enhance rice production (CBN, 2021). Rice production has received minor improvements from government initiatives but numerous farmers maintain ineffective resource use and poor output combined with performance barriers (Okodua, 2017). These interventions succeed according to the extent farmers can enhance their input optimization and increase productivity efficiency. The main obstacle for rice farmers involves suboptimal utilization of farm size, labor force and fertilizers, agrochemicals and seeds. The effective use of farming inputs by farmers directly affects both their output production levels and their profitability. Rice farmers who operate small agricultural farms in Nigeria struggle to access contemporary agricultural tools and quality agricultural products, while lacking sufficient funds which decreases their ability to effectively employ existing resources (Obianefo et al., 2023). To determine the elasticity of production and return to scale, it is essential to evaluate how each input influences rice output. By enhancing how farmers manage their resources they achieve better yield levels and financial success (Izekor & Alufohai, 2014). The technical inefficiencies of rice production stem from numerous socio-economic factors including the education level, experience in farming, availability of credits, quality of extension services and market connections (Adejoh et al., 2018). High technical efficiency enables farmers to generate more production from their current input resources than farmers with lower efficiency levels. Few studies have investigated the relationship between socio-economic factors and technical inefficiency in Niger and Nassarawa States. It is essential to detect inefficiencies in rice farming along with their root causes in order to create specific intervention methods that will both enhance farmer output and boost the rice sector's productivity.

Rice farmers in Nigeria face numerous difficulties, which restrict their ability to maximize production. Nigerian rice producers face challenging circumstances marked by expensive operation costs along with minimal investment returns combined with unsatisfactory technical efficiency that restrains their output and financial returns (FAO, 2022). Research on rice output maximization in these specific states of Nigeria exists as a critical knowledge gap. The research has a crucial deficit due to the absence

of thorough assessment for key production input elasticity. Numerous research studies have studied individual input effects such as fertilizers and agrochemicals yet they fail to provide a complete analysis of farm size, labor, fertilizers, agrochemicals and seed interactions on rice output (Bello et al., 2021). Researchers have not established empirical evidence about how efficient rice farmers currently operate in Nigeria. Policymakers together with stakeholders face challenges when developing efficient rice production strategies because they lack full understanding of key influencing factors. These states lack comprehensive research which explores the relationship between socio-economic factors and technical inefficiency of their rice farming sector. Research on how socio-economic determinants including agricultural credit accessibility and agricultural education levels alongside extension service availability affect the resource efficiency of farmers needs further exploration despite other studies' lack of discussion on this subject (Ukwuaba et al., 2020). The improvement of knowledge about technical efficiency deficits enables better policy development which enhances productivity and livelihoods of rice farmers.

1.1 Research Questions

This research proffer answers to the under-listed research questions:

(i) What is the farm-specific and farmers' features of rice producers?
(ii) What are the optimum and determinant factors (farm size, labour, fertilizers, agrochemicals, seeds) affecting output of rice producers?
(iii) What are the socio-economic factors affecting the technical inefficiency of rice production?
(iv) What are the technical efficiency scores of rice producers?

1.2 Objectives of the Study

The main aim of the investigation focused on optimizing the output of rice farmers in Niger and Nasarawa States, Nigeria. The specific objectives were:

(i) describe the farm specific and socio-economic' features of rice producers,
(ii) optimize and determine the input factors (farm size, labour, fertilizers, agrochemicals, seeds) affecting output of rice producers,
(iii) evaluate the socio-economic factors affecting the technical inefficiency of rice producers,
(iv) determine the technical efficiency scores of rice producers.

1.3 Hypotheses of the Study

This study was guided by the following null-hypotheses:

(i) Rice production is not profitable
(ii) The coefficient of elasticity of production for each input is not greater than zero
(iii) The return to scale is not greater than zero.
(iv) There are no significant input factors (farm size, labour, fertilizers, agrochemicals, seeds)
affecting output of rice producers
(v) There are no significant socio-economic factors affecting technical inefficiency of rice production.

2. Materials and Methods

This study was carried out in Niger and Nasarawa States, Nigeria. The study selected the two states because they are predominantly known for rice farming in the Northern region, Nigeria. The two states were chosen due to their favorable climate for the crop and better irrigation systems to support all year farming. A multi-stage sampling approach was utilized. A multi-stage sampling approach was utilized because of a variety of reasons, such as time efficiency, cost reduction, flexibility, and increase reliability. In the first stage, two states were purposively selected being known predominantly for rice farming in the Northern region. In the second stage, three local government areas were randomly selected in each state. In the third stage, three villages for each local government area were randomly selected making a total of eighteen villages. In the fourth stage, a simple random sampling approach was used, approximately ten rice producers were selected from each village making a total of 180 rice producers. The sample frame of rice producers approximately 327 respondents. The total sample number consists of 90 rice producers selected each from the two states, respectively. Primary data of cross-sectional sources were used based on a well-planned questionnaire that was subjected to reliability and validity test. The questionnaire was validated by the team of professional experts and appropriate reliability test was carried out. The questionnaire was pre-tested on selected rice growers to evaluate the appropriateness of the design, clarity, and relevance of the questions. The appropriate corrections were made on the pre-tested questionnaire in order to capture the relevant information required to achieve the objectives of the study, questions that proved vague or ambiguous, attracted additional corrections on the questionnaire to ensure its appropriateness, and reliability. The result of the pre-test was collated and subjected to reliability test using Pearson product moment correlation analysis. The correlation coefficient of 0.91 (91%) shows that there was a strong degree of correlation between the variables tested. The Cronbach's alpha coefficient for the variables was 0.828 (82.8%), suggesting that the factors included in the research instrument had relatively high internal consistency and highly reliable for the analysis. This sample number was estimated based on the established formula of Yamane (1967) as follows:

$$n = \frac{N}{1+N(e^2)} = \frac{327}{1+327(0.05)^2} = 180 \ldots\ldots\ldots\ldots\ldots \quad (1)$$

Where,

n = The Sample Number

N = The Complete Number of Rice Growers

e = 5%

The data obtained were analyzed using descriptive statistics, and stochastic production frontier model.

2.1 The SPEFM (Stochastic Production Efficiency Frontier Model)

According to Alabi et al. (2022), the SPEFM is stated thus:

$$Y_i = f(X_i, \beta_i)e^{v_i - u_i} \quad (2)$$

$$Ln\ Y_i = Ln\ \beta_0 + \sum_{j=1}^{5} \beta_i\ LnX_i + (v_i - u_i) \quad (3)$$

$$TE_i = \frac{Y_i}{Y_i^*} \quad (4)$$

$$TE_{ij} = \frac{F(X_i,\beta)\exp(v_i - u_i)}{F(X_{i,}\beta)\exp(v_i)} \quad (5)$$

$$TE_{ij} = \exp(-u_{ij}) \quad (6)$$

where,

Y_i = Output of Rice (Kg)

Y_i^* = Unobserved Frontier Output of Rice (Kg)

X_i = Inputs

β_i = Vectors of Estimated Parameters

V_i = Random Errors

U_i= Error Term as a result of TIE (Technical Inefficiency)

X_1 = Farm Sizes (ha)

X_2 = Labour (Mandays)

X_3 = Fertilizers (Kg)

X_4 = Agrochemicals (Litre)

X_5 = Seeds (Kg)

$$U_i = \alpha_0 + \alpha_1 Z_1 + \alpha_2 Z_2 + \alpha_3 Z_3 + \alpha_4 Z_4 + \alpha_5 Z_5 \quad (7)$$

where,

Z_1 = Age (Years)

Z_2 = Experience (Years)

Z_3 = Education (Years)

Z_4 = Household Size (Number)

Z_5 = Cooperative Organization (Years)

α_0 = Constant Term

$\alpha_1 - \alpha_5$ = Estimated Parameters

U_i= Error Term due to TIE

2.2 Return to Scale (RTS) and Elasticity of Production (EP) Model

Elasticity of production (EP) is a measure of a farm success in yielding maximum output from a given set of factors. The (E_P) and (RTS) was estimated following the study of Alabi et al. (2022) as:-

$$E_{P_{x_i}} = \frac{\partial Y}{\partial X_i} \cdot \frac{\overline{X}}{\overline{Y}}, i = 1, 2 \ldots k \quad (8)$$

$$\sum_{i=1}^{K} E_{P_{x_i}} = RTS \quad (9)$$

Where;

$\overline{X}$ = Mean of Inputs (Units)

$\overline{Y}$ = Mean of Output (Units)

$E_{P_{x_i}}$ = Elasticity of Production of Input x_i

$\sum_{i=1}^{K} E_{P_{x_i}}$ = Return to Scale i.e Sum of Elasticity of Production

2.3 The t-Test of Difference Between Means

This is stated thus:

$$t = \frac{\overline{X}_1 - \overline{X}_2}{\sqrt{\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}}} \quad (10)$$

Where,

$\overline{X}_1$= Mean of Values in Group 1

$\overline{X}_2$= Mean of Values in Group 2

s_1^2, s_2^2 = Standard Deviation in Group 1 and Group 2

$n_1 n_2$= Number of Observation in Group 1 and Group 2

3.Results and Discussion

3.1 The Continuous Variables of Farm-Specific and Farmers Features of Rice Producers

Table 1 below shows the continuous variables farm-specific and socio-economic features of rice producers. The average age of the rice farmers approximately 46 years, having a standard deviation (SD) of 7.23. This suggested that most of the farmers were middle aged. The result is in consonance with the findings of Kadiri et al. (2014) who indicated that middle age farmers were the most prominent in rice farming in Nigeria as a result of their physical strength and experience. This is in line with studies of Oluleye et al. (2022) and Oluleye et al. (2024) who obtained an average age of 45 and 39 years among farmers in Nasarawa and Kaduna States, Nigeria, respectively. The average farming experience of the rice farming was 11 years, having a standard deviation (SD) of 4.98. This suggested that most farmers had some level of experience on rice production. This outcome is in consonance with the findings of Bala et al. (2020) who noted that farmers having longer experience are likely to adopt new farming techniques to improve and optimize production. The studies of Oluleye et al. (2022) and Oluleye et al. (2024) noted that the average farming experiences were 10 and 7 years among farmers in Nasarawa and Kaduna States, Nigeria, respectively. The average size of the farm was 1.27 hectares, with a standard deviation (SD) of 0.64. This implies that most of the rice farmers cultivated on a small-scale farm land. This finding is in the line with the results of FAO (2020) who reported that majority of Nigeria rice output is produced by small-scale farmers. Productivity of rice production is low because these small farms may limit economies of scale and mechanization. The average level of education of the rice farmers was 12 years, having a standard deviation (SD) of 2.97. The study indicated that the farmers have completed secondary school education. This study is in line with the findings of Esiobu (2020) who noted that the level of education attained by the farmer is sufficient for them to access and

interpret agricultural information and adopt new practices to optimize their production. The average household size of the farmers approximately 9 persons, having a standard deviation (SD) of 2.07. This suggest that a large household size and family labour will be grossly utilize as the means of labour to reduce cost but by implication, household consumption pressure will increase thereby affecting savings and reinvestment in farming (Edeoghon, 2017). The average rice yield was estimated at 2 tons per hectare, indicating that production may be below optimal. This could be as a result of some constraints such as limited access to input, climate change as stated in a similar study by Kamai et al. (2020).

Table 1. The Continuous Variables of Farm-Specific and Socio-Economic Features of Rice Producers

Variables	Unit of Measurement	$\bar{X}_i$	SD
Age	Years	46	7.23
Farming Experience	Years	11	4.98
Farm Size	Hectares	1.27	0.64
Education	Years	12	2.97
Household Size	Number	9	2.07
Output	Kilograms per Hectare	2	0.70

Source: Field Survey (2024)

3.2 The Descriptive Analysis of Categorical Variables of Farmers Characteristics among Rice Producers

Table 2 shows the categorical variables of rice farmers characteristics in Niger and Nasarawa States, Nigeria. The results demonstrate that male respondents represent the largest group accounting for 81.66% among all respondents, while the female participants constitute 18.34% of the total respondent. A previous study by Mwalyagile et al. (2024) validates how Nigerian rice farming shows male domination because men both own land and need to perform physically demanding work. Although women participate at lower rates, they are still crucial for processing after harvest and marketing activities.

Among the respondents, 88.33% are married individuals followed by 11.67% who are single. Married farmers gain additional labor support from their household members which enables them to carry out their ongoing farm work (Tijani et al., 2010). A large proportion of 70.56% within the sample population belongs to cooperatives but 29.44% of the respondents do not have cooperative membership. The rice farmers that actively belong cooperative societies benefit from it because it improves their ability to obtain financial support and vital agricultural materials in addition to operational support (Lin et al., 2022). The combined power of cooperative membership enables participants to gain better income and crop yields through group negotiation and exchange of agricultural information.

Table 2. The Categorical Variables of Rice Farmers Features

Farmers Characteristics	Frequency	Percentages
Sex		
(a) Male	147	81.66
(b) Female	33	18.34
Marital Status		
(a) Married	159	88.33
(b) Single	21	11.67
Members of Cooperatives		
(a) Yes	127	70.56
(b) No	53	29.44
Total	**180**	**100.00**

Source: Field Survey (2024).

3.3 The Factors Influencing the Output and Technical Inefficiency of Rice Producers

Table 3 below shows the maximum likelihood estimates using stochastic production frontier. The result shows a positive correlation between farm size and rice output since the coefficient value is 0.2460 and the statistical significance level reaches below 0.01. The results support previous findings which showed that expanding farm sizes leads to increased productivity through advantages of scale (Omotilewa et al., 2021). Labor input deficiencies do not drive changes in rice output levels because the labor variable (0.2309, $p>0.05$) has no statistically significant effect on rice production results. The findings suggested that there was a broad use of manual labor techniques because the output was low compared to mechanized techniques. The study also revealed that productivity will increase when farmers use more fertilizer according to statistical analysis with a value of 0.2035 at $p<0.05$. The study findings confirm previous research by Eze et al. (2020) that shows adequate fertilizer application as a key factor in promoting rice yield improvement. The lack of significance in agrochemical variables (0.1539, $p>0.05$) indicates these inputs do not substantially affect output since improper applications alongside resistance problems may be evident. The coefficient value of high-quality seeds was 0.1857 at $p<0.05$, suggested that it has a significant impact of rice output. In a report by FAO (2020), it was indicated that implementing better seed varieties leads to raised productivity within climate-smart agricultural systems which is supported by this study. The measured return to scale value of 1.020 revealed that rice farmers in the research location operate with increasing returns to scale thereby generating more than output expansion from proportionately raising all input resources. The socio-economic factors (experience and education) decrease technical inefficiency of rice production at 1% alpha level. The institutional factor (cooperative) decrease technical inefficiency of rice production at 1% alpha level. This implies that a one-unit increase in experience and education of rice farmers, while keeping all other predictors constant will give rise to 0.2207 and 0.2581 units increase in technical efficiency of rice producers. Similarly, a one-unit increase in cooperative membership, while keeping all other predictors fixed will give rise to 0.2751-unit decrease in technical inefficiency of rice production.

In the diagnostic statistics section, the coefficient of variance ratio(γ) also termed gamma was estimated at 0.8001, this connotes that 80.01% variations of rice output from frontier (potential) output was as a result of technical inefficiency, while the balance 19.99% of rice output deviation from the potential level was due to random noises such as frost, unexpected rainfall, and other natural disaster outside the control of rice growers. Therefore, reducing the extent of the effect of variance or gamma ratio will enhance the rice output and greatly improve the productivity of the producers. The coefficient of total variance (σ^2) also termed sigma square was evaluated at 3.3465, which is statistically different from zero at 1% alpha level. This hypothesized that perfect goodness of data conform with the Cobb-Douglas stochastic frontier model and the assumptions of the composite error term was correctly specified. The LLF (Log-Likelihood function) was estimated at -821.46. The finding is supported with

outcomes of Asfaw (2021) who reported the estimated Sigma-squared of 0.57, and gamma value of 0.89 among tomato producers in Ethiopia.

Table 3. Maximum Likelihood Estimates Using Stochastic Production Frontier

Variables	Coef	Std. Er.	*P*-value
Farm Size	0.2460***	0.0630	0.000
Labour	0.2309	0.2178	0.931
Fertilizer	0.2035**	0.0791	0.042
Agrochemicals	0.1539	0.1509	0.789
Seed	0.1857**	0.0709	0.047
Constant	2.5729***	0.6126	0.000
RTS	**1.020**		
Inefficiency Model			
Age	-0.2915	0.2674	0.945
Experience	-0.2207***	0.0515	0.000
Education	-0.2581***	0.0591	0.001
Household Size	-0.2072	0.1954	0.972
Cooperatives	-0.2751***	0.0562	0.000
Diagnostic Statistics			
δ^2	3.3465***		
Gamma	0.8001		
Log-Likelihood Function	-821.46		

Source: Field Survey (2024)

3.4 Technical Efficiency Scores of Rice Producers

The Table 4 below shows the technical efficiency (TE) scores evaluation of the rice farmers' efficiency levels. The calculated mean technical efficiency scores reveal farmers work with 71.67% efficient utilization of resources. Better resource utilization and management strategies would allow farmers to boost their rice production by 28.33%. This is similar to the findings of Linn & Meanhout (2019). The evaluation shows that almost half of the farmers (49%) maintain efficiency ratings above 0.81 which indicates high efficiency and another thirty-one percent (31%) demonstrates moderate efficiency from 0.61 to 0.80. The necessity for specialized interventions to enhance production efficiency exists since 5.56% of farmers perform under a 0.20 efficiency level. This results clearly indicates that government should implement policies, giving priority to three areas: quality input distribution and educational programs combined with farmer cooperatives to boost operational effectiveness. Farmer production processes receive additional support when agricultural extension services operate through investments.

Table 4. Technical Efficiency Scores of Rice Producers.

Technical Efficiency Scores	**Frequency**	**Percentage**
0.0 – 0.20	10	05.56
0.21 – 0.40	16	08.89
0.41 – 0.60	35	19.44
0.61 – 0.80	31	17.22
0.81 – 1.00	8	48.89
Minimum	0.0158	
Maximum	0.9810	
Mean TE	0.7167	

Source: Field Survey (2024)

3.5 The Return to Scale (RTS) and Elasticity of Production (EP) among Rice Producers

Table 5 below shows the Elasticity of Production (EP) of factor inputs and Return to Scale (RTS). Rice farmers in the study area show increasing returns to scale because their elasticities sum up to 1.020. Every proportional increase in all inputs results in more than proportional increase of output. Farm size had the highest elasticity value of

0.2460 at a significant level of 0.01, suggesting the most impact by any other input. This indicates that land expansion proves to be a significant factor that increases production levels. The finding of this study indicated that labor (0.2309, p>0.05) and fertilizer (0.2035, p<0.05) increase rice output yet proper staff management and precise fertilizer application remain crucial (Eze et al., 2020). The elasticity value for agrochemicals (0.1539, p>0.05) is low because improper application methods and below-optimal pesticide usage might restrict yield increase.

Table 5. Elasticity of Production (EP) of Factor Inputs and RTS (Return to Scale)

Elasticity(ε_p)	Farm Size	Labour	Fertilizer	Agrochemicals	Seed	RTS= ($\sum\varepsilon_p$)
Estimates	0.2460	0.2309	0.2035	0.1539	0.1857	1.020

Source: Field Survey (2024)

3.6 The t-Test of Differences between Cost and Returns

Table 6 below shows the outcome of t-test difference between costs and returns. The results indicate that: the average cost per farmer equals ₦692,780.93. The research also shows farmers earn an average of ₦1,417,954.41 in revenue (returns) per person. The standard deviation of cost equals ₦313,992.66. The standard deviation of returns equals ₦899,787.75. The t-test statistics computed a t-value of 16.60 which exceeds the critical 1.96 value from the t-table at a 5% significance level thus proving the two variables differ significantly. Evidence from the study indicates that rice farmers achieve profitable earnings because their revenue exceeds their production costs by a substantial margin. Nwahia (2020) reached identical findings to the study which reveals rice farming profits when farmers use their resources wisely. The profitability data urges governments to implement policies which improve both input access and cost reduction efficiency and effective financial management measures to maximize profits in rice farming operations.

Table 6. t-Test of Difference Between Costs and Returns

Variable	Estimates (Number)
Costs (Naira)	692,780.93
Returns (Naira)	1,417,954.41
Standard Deviation Cost	313,992.66
Standard Deviation Returns	899,787.75
t-Calculated	16.60
t-Table	1.96

Source: Field Survey (2024)

4. Conclusion

This investigation focused on optimizing the output of rice farmers in Niger and Nasarawa States, Nigeria. A multi-stage sampling approach was utilized to select 200 rice growers. The following conclusions were made based on study hypotheses:

Rice production is not profitable

The hypothesis that rice production is not profitable is rejected. The findings from t-test analysis established a statistically important distinction between expenses and income of rice cultivation. The values from rice farming revenue exceed all production expenses effectively demonstrating economic feasibility in the study area.

The coefficient of elasticity of production for each input is not greater than zero

The hypothesis that the coefficient of elasticity of production for each input is not greater than zero is rejected. The result revealed that all production variables including farm size and the use of labor and fertilizers and agrochemicals and seeds produce positive effects on rice farming yield.

The return to scale is not greater than zero.

The hypothesis that the return of scale is not greater than zero is rejected. The calculated return to scale of 1.020 indicates farmers in the rice cultivation zone function beneath increase returns to scale because they achieve more than output growth from equal input proportion increases.

There are no significant input factors (farm size, labour, fertilizers, agrochemicals, seeds) affecting output of rice producers

The hypothesis that there are no significant input factors (farm size, labour, fertilizers, agrochemicals, seeds) affecting output of rice producers is rejected. The study analysis found that farm size and labor and fertilizers and seeds function as fundamental factors in shaping rice output production where farm size demonstrates maximum elasticity rate. Increased land distribution together with ample input resources have the power to greatly improve rice yield levels.

There are no significant socio-economic factors affecting technical inefficiency of rice production.

The hypothesis that there are no significant socio-economic factors affecting technical inefficiency of production is rejected. The results give concrete evidence that factors including education level and farming experience as well as cooperative associations strongly affect rice farmer.

Author Contribution

Design of the Article-AOO,EFA, KHK, SGF, EAO, OAO, APA, OOD, YCA, Administration of Questionnaire- AOO,EFA, KHK, SGF, EAO, OAO, APA, OOD, YCA, Coding and Analysis-AOO,EFA, KHK, SGF, EAO, OAO, APA, OOD, YCA, Report Writting and Corrections-AOO,EFA, KHK, SGF, EAO, OAO, APA, OOD, YCA, Final Report- AOO,EFA, KHK, SGF, EAO, OAO, APA, OOD, YCA

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DergiPark veritabanında gastronomi ve gıda alanında sıfır atık temalı makalelerin bibliyometrik incelemesi

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ÖZET

Bu çalışmada, gastronomi ve gıda alanında sıfır atık kavramı üzerine DergiPark veri tabanında yayımlanmış makale çalışmalarının, bibliyometrik analiz yöntemi ile kapsamlı bir şekilde incelenmesi amaçlanmıştır. Araştırma için 2019-2025 yıllarını kapsayan son 7 yılda yayımlanmış makale çalışmaları kullanılmıştır. Gastronomi, gıda ve sıfır atık kavramları üzerine gelişmiş arama yapılıp çıkan 1386 makale üzerinden 1373 tanesi değerlendirmeye alınmıştır. Araştırma kapsamında belirlenen 1373 makale çalışması, Microsoft Excel ve EkşiVeri uygulamaları üzerinden analiz edilerek sonuçlar şekil olarak bulgularda sunulmuştur. Elde edilen bulgular, sıfır atık uygulamalarının gastronomi ve gıda sektöründe giderek artan bir öneme sahip olduğunu göstermektedir. Çalışmaların sayısında belirgin bir artış gözlenmiş, özellikle 2021 ve 2023 yıllarında en yüksek seviyelere ulaştığı görülmüştür. En sık kullanılan anahtar kelimeler, "gıda", "gastronomi", "atık", "sürdürülebilirlik" ve "güvenlik" olmuştur. Ayrıca, gıda israfını önleme, atıkların geri dönüştürülmesi ve sürdürülebilir restoran uygulamaları gibi konuların akademik ilgi gördüğü belirlenmiştir. Bu araştırma sonuçları ile konu üzerinde gelecekte yapılacak çalışmaların hangi kriterler doğrultusunda hazırlanması gerektiğini göstererek, araştırma yapacak yazarlara kaynak sunulmuştur. Sıfır atık kavramının gastronomi ve gıda alanındaki önemi vurgulanarak, konunun daha detaylı ele alınması sağlanmıştır.

Bibliometric analysis of articles on zero waste in the field of gastronomy and food in the dergipark database

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ABSTRACT

This study aims to conduct a comprehensive bibliometric analysis of zero waste-themed articles published in the field of gastronomy and food within the DergiPark database. The research covers the last seven years (2019–2025) and includes a refined selection of 1373 articles from an initial set of 1386 results, obtained through advanced keyword searches using terms such as "gastronomy," "food," and "zero waste." The data were analyzed using Microsoft Excel and the EkşiVeri application, and findings were presented in graphical form. The results indicate a growing academic interest in zero waste practices within the gastronomy and food sectors, with a significant increase in publication volume, particularly in 2021 and 2023. The most frequently used keywords include "food," "gastronomy," "waste," "sustainability," and "safety." Topics such as food waste reduction, recycling practices, and sustainable restaurant operations have attracted considerable scholarly attention. The study highlights key criteria for future research and offers valuable insights for researchers by emphasizing the increasing importance of the zero waste concept in the gastronomy and food fields.

1. Giriş

Dünyadaki nüfusa bağlı olarak gelişen tüketim sürekli artış göstermektedir. Bunun beraberinde getirdiği atık kavramı ise birçok ülkenin ortak sorunu haline gelmiş, küresel bir problem niteliği taşımaktadır. Atık, israfların yol açtığı çevresel etkiler, doğal kaynakların tükenmesi ve dolaysıyla sera gazı emisyonlarının artışına kadar oldukça geniş bir alanda sorun teşkil etmektedir. Dünya genelinde her yıl tonlarca ürünlerin israf edilmesi, çevresel zararlar ve ekonomik kayıplara neden olmaktadır (Altuntop ve ark., 2014). Atık kavramı üzerinde dünyada birçok çalışma yapılmaktadır. Devletler bu durumla ilgili yaptırımlar ve çeşitli politikalar izlemektedir. Türkiye'de de atık sorunu büyük bir sorun teşkil etmekte olduğu için bu durumla ilgili birçok çalışma gerçekleştirilmiştir. 2017 yılında Çevre ve Şehircilik Bakanlığı tarafından Sıfır Atık projesi başlatılmış olup, projenin başlatıldığı "*2017 yılından 2024 yılı sonuna kadar 32,5 milyon ton kağıt-karton, 9,1 milyon ton plastik, 3,1 milyon ton cam, 6,4 milyon ton metal ve 23,4 milyon ton organik ve diğer geri kazanılabilir atıklar olmak üzere toplamda yaklaşık 74,5 milyon ton geri kazanılabilir atık, kurumdan lisans almış işletmelerce işlenerek ekonomiye kazandırıldığı*" bildirilmiştir (Çevre, Şehircilik ve İklim Değişikliği Bakanlığı, 2025; Selçuk, 2022). Sıfır atık projesi; israfı azaltmak, kaynakların verimli kullanılmasını sağlamak, oluşan atıkların azaltılması ve yeniden kullanılması için oluşturulmaktadır. Bir ürünün atık olarak nitelendirilebilmesi için o ürünün artık kullanılmayacak durumda olması gerekmektedir (Çevre ve Şehircilik Bakanlığı, 2012).

Sıfır atık, sürdürülebilirlik kavramının özellikle çevresel boyutuna önemli katkılar sağlamaktadır (Dal ve Akçay, 2021). Sıfır atık yaklaşımı sayesinde, atıkların çevreye zarar verme oranları düşüş sağlamaktadır. Aynı zamanda doğal kaynakların korunması ve ekonomik kazanç sağlanması, kazandırdığı avantajlar arasında sayılmaktadır. Bununla birlikte, sıfır atık uygulamaları ile karbon ayak izinin azaltılması, biyolojik çeşitliliğin korunması ve enerji tasarrufu gibi sürdürülebilirlik hedeflerine doğrudan katkı sağlanmaktadır (Özdil ve Çırak, 2024). Sürdürülebilirlik ve sıfır atık arasındaki ilişki, özellikle gıda atıkları gibi organik atıkların yönetimi konusunda belirginleşmektedir. Sıfır atık uygulamaları, bu atıkların kompostlama yoluyla toprağa kazandırılmasını sağlayarak hem çevresel hem de ekonomik faydalar oluşturmaktadır (Yavaş ve Pehlivan, 2023). Sıfır atık, sürdürülebilirliğin uygulanabilir şekli olarak değerlendirilmektedir. Atıkların geri dönüşüm ve yeniden kullanım şeklinde değerlendirilmesi ile doğal kaynakların etkin kullanımını desteklemekte, çevresel zararlar ile israfın önlenmesine ve böylece sürdürülebilirliğe büyük ölçüde avantajlar sağlamaktadır (Apak ve Gürbüz, 2022).

Gastronomi, insanlık tarihi boyunca gelişim göstermiş, birçok disiplini içinde barındıran; yemek kültürü, yemek bilimi ve sanatla beraber nitelendirilmiş bir bilim dalı olarak tanımlanmaktadır (Öney, 2016). Gastronomi kavramı, etimolojik olarak ele alındığında, Yunancada mide "gastros" ve yasa "nomos" kelimelerin birleşmesiyle türetilmiştir. Gastronomi kavramı tarihsel açıdan incelendiğinde ise MÖ 4. yüzyılda, Archestratus tarafından yazılan "Gastronomia" adlı kitapta gastronomi teriminin kullanıldığı, dönemin yemek kültürü ve beslenme alışkanlıklarıyla ilgili bilgi verilmiş olduğu bilinmektedir (Şat ve ark., 2024). Gastronomi, gıdaların hazırlanmasından

başlayarak, pişirilmesi, sunumu ve tüketilmesine kadar olan süreci kapsamaktadır. Gastronomi, aynı zamanda gıdaların kimyasal yapısını ve pişirme tekniklerini inceleyen bilimsel bir yaklaşımı içermektedir. Bu doğrultuda gastronomi fizik, kimya, biyoloji ve tarih gibi çeşitli disiplinlerle de etkileşim halinde bulunarak gıdaların farklı açıdan özelliklerinin anlaşılmasına katkı sağlamaktadır (Sarıışık ve Arbay, 2015).

Gastronomi, günümüzde beslenme bilimi, kültürel miras, turizm, sürdürülebilirlik ve çevresel duyarlılık gibi pek çok farklı boyutları bünyesinde barındırmaktadır ve sürekli gelişim göstermektedir (Macit ve Kıran, 2022). Gastronomi sektöründe özellikle doğal kaynaklar aşırı kullanılmaktadır. Bu kaynakların kullanımına bağlı olarak oluşan atıklar, çevresel sorunları beraberinde getirmektedir.

Sıfır atık yaklaşımı, gastronomi alanını da oldukça ilgilendirmektedir. Gastronomi alanı; besinlerin hazırlanması, sunulması ve tüketilmesine kadar gerçekleşen süreçleri içinde bulundurmanın yanı sıra gastronominin çevresel, kültürel ve ekonomik boyutlarını da doğrudan etkilemektedir (Gül ve Yaman, 2021). Sıfır atık kavramının ön plana çıkması ile gastronomi sektöründe atıkların yönetimi, kaynakların verimli kullanımını ve gıda israfının önlenmesini içeren uygulamalar sürdürülebilirlik bağlamında önemlilik arz etmektedir (Bilgili, 2021).

Bu çalışmada, birbiriyle ilişkili olan gastronomi ve sıfır atık konusu ele alınıp, literatürde yer alan ilgili çalışmaların sistematik değerlendirilmesi için bibliyometrik analiz ve doküman analizi yöntemleri uygulanarak konunun derinlemesine incelenmesi ve gelecek çalışmalara bakış açısı kazandırmak amaçlanmıştır.

2. Kavramsal Çerçeve

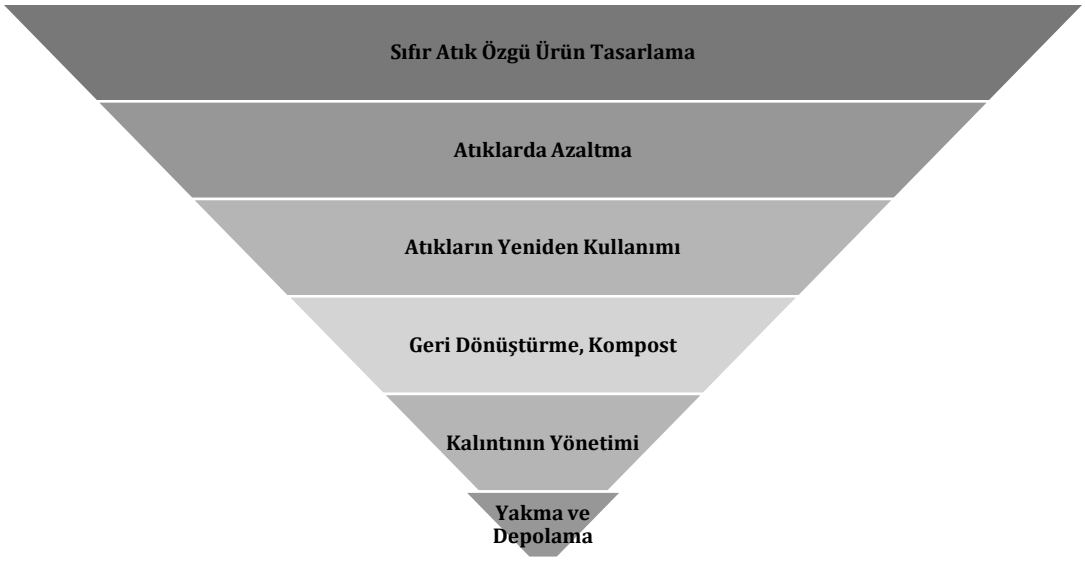
2.1. Sıfır Atık Kavramı

Sıfır atık kavramına yakın düşüncelerden ilk olarak 1800'lü yıllarda bahsedilmiştir ancak sıfır atık kavramını ilk kez kullanan ve "Zero Waste Systems" kuruluşunu kuran kişi 1973 yılında Paul Palmer'dir. Sıfır atık kavramının kullanılmasına rağmen oluşan atıkların zamanla daha da artması nedenli, atık problemleri küresel bir sorun haline gelmiş bulunmaktadır. Atık problemlerine çözüm yolu bulunması için çalışmalar yürütülmüş ve sonucunda Uluslararası Sıfır Atık İttifakı (ZWIA), "Sıfır Atık Gündemi" oluşturulmuştur. (Bilgili, 2021).

Atıklar, türlerine göre sınıflandırılmaktadır. Sınıflandırılmalarına göre de bertaraf etme yöntemleri uygulanmaktadır. Bu yöntemler yakma ve depolama şeklinde gerçekleşmektedir (Salihoğlu ve ark., 2018). Depolama yöntemlerinden bir diğeri olan çöp depolama sahalarında suların dışarı çıkması ve oluşan anaerobik ayrıştırmalar sonucu metan gazını açığa çıkmaktadır. Metan gazını toplayabilen tesislerde elektrik üretilmektedir bu noktada avantaj sağlamaktadır ancak uygulanan bu yöntemler genel olarak ekosisteme zarar vermekte, küresel ısınma ve iklim değişikliği gibi olumsuz durumlara neden olmaktadır (Bayram, 2016).

Bertaraf uygulamalarının vermiş olduğu zararları azaltmak için geliştirilen sıfır atık uygulamalarından biri kompostlama yöntemidir. Kompostlama yöntemi hayvansal ve bitkisel atıklar ile kentsel atıkların bir kısmını kapsayacak şekilde oluşan atıkların, mikroorganizmalar tarafından parçalanması ve ayrıştırılması işlemi olarak tanımlanmaktadır (Ekinci ve ark. 2021). Topraklardan çıkan ürünlerin atık şeklinde geri

dönüşüme girmesi ve bunun kompostlama yöntemiyle gübreye dönüştürüp tekrar toprağa karışması çevre için oldukça önemli bir uygulama niteliği taşımaktadır. Aynı zamanda sera gazı ve emülsiyonlarını azaltması neticesinde ekosistemi korumaktadır. Bunun yanında yakma ve depolama uygulamalarının azaltılması ve atıkların yeniden kullanılması, kompostlama yönteminin her alanda kullanılmaya başlanması büyük önem taşımaktadır. Böylece çevre dostu, sürdürülebilirlik ve ekonomi bağlamda faydalar sağlamaktadır (Akay ve Yılmaz, 2023). Sıfır atık hiyerarşi modeli Şekil 1'de verilmiştir. Basamaklar, en çok tercih edilmesi gerekenlerden başlayarak, en az tercih edilmesi gereken uygulamalara doğru ilerlemektedir (Bilgili, 2021).



Şekil 1. Sıfır Atık Hiyerarşisinin Gösterimi.
Kaynak: Bilgili, 2021'den türetilmiştir.

Gıda atıkları, küresel bir problem niteliği taşımaktadır. Bu doğrultuda geliştirilen atık sorunu üzerine ise çeşitli kamu kurumları, özel sektör ve kuruluşlar, ilgili çözüm yöntemlerine yönelik çalışmalar gerçekleştirmektedir. Atıkların geri kazanımı ve toplumsal bilincin artırılması amacıyla yürütülen çalışmalar, gelecekte daha sürdürülebilir bir yaşam tarzı oluşması oldukça önemli bir konu olarak görülmektedir (Ademoğlu, 2021).

2.2. Dünya'da ve Türkiye'de Sıfır Atık Yönetim Sistemi

Sıfır atık yönetim sistemi; küresel boyutta bir problem haline gelmiş, çevre sorunlarının etkilerini azaltmayı hedeflemiştir. Sıfır atık yönetim sistemi kısaca oluşan atıkların azaltılması için uygulanan geri dönüşüm yöntemlerini ve atıkların yeniden kullanım süreçlerini kapsamaktadır. Aynı zamanda çevreye verilen zararları minimuma indirmek hedeflenmiş, kapsamlı bir sistem şeklinde yürütülmektedir (Bilgili, 2021).

Dünya genelinde sıfır atık yönetim sistemlerine 1900'lü yıllarda başlanmış 2000'li yıllardan itibaren birçok ülkede benimsenmiş şekilde yürütülmektedir. Aynı zamanda sıfır atık sistemi çeşitli uluslararası girişimlerle desteklenmektedir. Buna örnek olarak; 2003 yılında Uluslararası Sıfır Atık İttifakı'nın (ZWIA), sıfır atık uygulamalarını yaygınlaştırmak amaçlı kurulmuş olması ve bu kapsamda "Sıfır Atık Gündemi" oluşturulması verilebilmektedir. Yeni Zelanda, sıfır atık zirvelerine ev sahipliği yaparak bu kavramın küresel ölçekte tanıtılmasına öncülük etmiş ve bu konuyu oldukça

önemsemiştir (Gül ve Yaman, 2021). 2018 yılında ZWIA tarafından yapılan açıklamalar sonucunda sıfır atık kavramı yeniden gündeme gelmiş ve yeni tanımlamalar yapılmıştır (ZWIA, 2018). Eklenen tanım ile doğal kaynaklara veya ürünlere, doğaya zarar verecek hiçbir bertaraf yönteminin uygulanmaması, geri dönüştürme işlemleri ile korunması şeklinde tanımlama yapılmıştır (Bilgili, 2021).

Avrupa Birliği ülkeleri, atık yönetim sistemiyle ilgili politikalarını sıfır atıkla oluşturdukları hedeflere göre yeniden şekillendirmiştir. AB Döngüsel Ekonomi Eylem Planı, sıfır atık sisteminin bir parçası olarak, atıkların önlenmesi ve geri dönüşüm oranlarının artırılmasını öncelikli hedefler doğrultusunda belirtmiş bulunmaktadır. Bu bağlamda, plastik kullanımının azaltılması ve kompost edilebilir malzemelerin teşvik edilmesi gibi uygulamaların yaygınlaştırılması amaçlanmaktadır (Mısır ve Arıkan, 2022).

Türkiye'de sıfır atık yönetim sistemi, Çevre ve Şehircilik Bakanlığı tarafından 2017 yılında başlatılmış olup "Sıfır Atık Projesi" ile resmi bir politika haline getirilmiş bulunmaktadır. Projenin temel amacı, atıkların kaynağında ayrıştırılması ve geri dönüşüm oranlarının artırılmasını sağlamaktır. Bu proje ile geri dönüşüm oranlarının artışı, plastik kullanımının azaltılması ve organik atıkların kompostlama yöntemiyle kullanılması gibi yapılan uygulamalar sürdürülebilir kalkınma hedeflerine önemli katkılar sunmaktadır (Selçuk, 2022). Özellikle hastaneler, okullar, kamu kurumları ve toplu kullanım alanlarında yani endüstriyel atıkların yaygın olduğu alanlarda sıfır atık projeleri yayılım göstermektedir (Gül ve Yaman, 2021). Türkiye, Sıfır Atık Yönetmeliği ile atık oluşumunun önlenmesi, atıkların kaynağında ayrıştırılması, yeniden kullanımı ve geri dönüşüm süreçlerinin etkin bir şekilde yürütülmesini amaçlamaktadır. Bunun için Atık Getirme Merkezleri Yönetmeliği gibi diğer düzenlemeler de sıfır atık politikalarını desteklemektedir. Bu yönetmelik, atıkların ayrıştırılarak geri dönüşüm tesislerine ulaştırılmasını kolaylaştırmak için yerel yönetimlerin altyapı kurmasını ve atık toplama merkezlerinin yaygınlaştırılmasını zorunlu hale getirmektedir (Çevre ve Şehircilik Bakanlığı, 2022). Türkiye, sıfır atık politikaları ile uluslararası çevre koruma hedeflerine önemli ölçüde katkı sağlamaktadır. Paris İklim Anlaşması ve Birleşmiş Milletler Sürdürülebilir Kalkınma Hedefleri kapsamında, özellikle olan Sorumlu Üretim ve Tüketim doğrultusunda gerçekleşen sıfır atık uygulamaları, stratejik olarak büyük önem taşımaktadır. Ayrıca, Avrupa Birliği'nin Döngüsel Ekonomi Eylem Planı ile uyumlu çalışmalar yürütülmektedir (Akay, 2020). Yerel yönetimler de sıfır atık kapsamında geliştirilen politikaların uygulanması açısından oldukça önemli görevler üstlenmektedir. Belediyelerin, atık yönetim sistemlerinin şehirlerde ve ilçelerde uygulanması için halkın bilinçlendirilmesi, geri dönüşüm altyapısının güçlendirilmesi ve mevzuatlara uygun denetimler gerçekleştirmesi gibi etkin görevleri bulunmaktadır (Resmi Gazete, 2025).

2.3. Gastronomi Alanında Sıfır Atık Kavramının Önemi

Gastronomi alanında; üretim, tüketim ve tedarik aşamalarında oldukça fazla kaynak kullanımı ve buna bağlı olarak atık oluşumu gerçekleşmektedir. Sıfır atık bu bağlamda gastronomi sektöründe çevresel ve sürdürülebilirlik açısından büyük avantajlar sağlamaktadır. Sıfır atık uygulamaları özellikle mutfak atıklarının kompost yöntemi uygulanarak değerlendirilmesi ve dönüştürülebilir malzemeleri kullanımına teşvik edilmesi gibi uygulamalarla somutlaştırılabilmektedir (Şen ve ark., 2019).

Gastronomi sektörü, gıda üretiminden tüketimine kadar geniş bir süreci kapsaması nedeniyle yüksek oranda gıda israfına yol açmaktadır. Bu israf hem ekonomik kayıplara neden olmakta hem de doğal çevreyi olumsuz etkilemektedir. Dünya genelinde her yıl yaklaşık 1,3 milyar ton gıda israf edilmektedir (FAO, 2019). Türkiye'de ise yılda yaklaşık 26 milyon ton gıda israf edilmekte olup, bu durum hem ülke ekonomisi hem de çevre açısından ciddi sorunlar doğurmaktadır (Direk ve ark., 2022). Gıda israfı, yalnızca israf edilen ürünlerin maliyetinde oluşan zararla sınırlı kalmayıp aynı zamanda üretim ve tedarik süreçlerinde harcanan enerji, emek ve doğal kaynakların da boşa gitmesine neden olmaktadır (Alıntaş, 2021). Özellikle gastronomi işletmelerinde, menü planlama, porsiyon kontrolü ve tedarik zinciri yönetimindeki eksiklikler, israf miktarlarını artıran önemli faktörler olarak gösterilmektedir. Bu durum, işletmelerin maliyetlerini artırmakta ve karlılık oranlarını olumsuz etkilemektedir (Tekiner ve ark., 2021). Gıda israfının ekonomik etkileri, yalnızca işletmelerle sınırlı kalmayıp, ulusal düzeyde büyük ölçüde etkilere neden olmaktadır. İsraf edilen gıdaların üretimi, tarım sektörü ve ürün pazarındaki maliyetlerin artmasına neden olmaktadır (Yıldırım ve ark., 2022). Bununla birlikte, gıda israfı sera gazı emisyonlarının artmasına da neden olmaktadır. İsraf edilen gıdaların çöp toplama alanlarında ayrıştırılması neticesinde ortaya çıkan metan gazı, küresel ısınma üzerinde karbon dioksitten çok daha güçlü bir etkisi olmaktadır. Bu durum, iklim değişikliğini hızlandırarak, biyolojik çeşitlilik üzerinde olumsuz etkiler yaratmaktadır (Ademoğlu, 2021).

Gastronomide sıfır atık uygulamaları, işletmelerin ekonomik ve çevresel performanslarını artırmasını sağlayan, yenilikçi bir yaklaşım olması bakımından oldukça önemli bir kavram olarak nitelendirilmektedir. Atık yönetiminde sıfır atık yaklaşımını benimseyen işletmeler, mali tasarruf, marka imajının güçlendirilmesi ve çevre dostu üretim süreçlerinin oluşturulması gibi pek çok faydalar elde etmektedir (Boz, 2024). Sıfır atık uygulamaları sayesinde, işletmelerde tasarruf sağlanarak işletme giderlerinde önemli düşüşler görülebilmektedir. Porsiyon kontrolü ve menü planlamasının optimize edilmesiyle de gıda israfı azaltılarak satın alma maliyetlerinde düşüş sağlanmaktadır. Ayrıca yerel ve mevsimsel ürünlerin tercih edilmesi, sıfır atık uygulamalarında önemli bir rol oynamaktadır. Bu şekilde lojistik süreçlerdeki enerji tüketimi azaltılır ve yerel üreticiler desteklenerek toplumsal fayda sağlanabilmektedir. Ayrıca, sürdürülebilir menü tasarımları, müşterilerin çevreye duyarlı tercihler yapmalarını teşvik edilerek satışları artırabilmektedir (Şen ve Demir, 2019).

3. İlgili Çalışmalar

Bu araştırmada, gastronomi ve gıda alanında sıfır atık kavramını ele alan makaleler incelenmiştir. Elde edilen bulgulara göre, konu üzerine yayımlanmış çalışmalar, yıllar içinde artış göstermiş bulunmaktadır. Sıfır atık yaklaşımına yönelik artan ilgi doğrultusunda, gastronomi sektörü ve gıda alanında gerçekleştirilen uygulamalar incelendiğinde olumlu sonuçlar sağlandığı görülmektedir. Sıfır atık politikalarını uygulayan gıda işletmeleri üzerine yapılan araştırmalar sonucunda gıda israflarında azalmaların gerçekleştiği ve işletmelere ekonomik ve sürdürülebilirlik açısından avantaj sağladıkları vurgulanmıştır. Bu bağlamda sıfır atıkla ilgili uygulanan politikaların etkili olduğu sonuçlarına ulaşılmıştır. Bununla birlikte gıdalar için de sıfır atık kavramı ile gıda

ürünlerinin geliştirilmesi ya da atıkların başka formlarda kullanılması üzerine yapılmış çalışmalara yer verildiğine ulaşılmaktadır. Öte yandan sıfır atık, sağlıklı beslenme ve temiz gıda gibi akımlarla da doğrudan ilişkili olduğu için özellikle COVİD-19 sürecinde oldukça ilgi görmüştür. Çalışmaların yıllara göre dağılımlarında 2019 sonrası artışın etkilerinden biri olarak görülebilmektedir (Ertaş Sabancı ve Onur, 2024). Temiz gıda ve sağlıklı beslenme etkileri sayesinde de tarladan sofraya tercileri başlayarak yereli koruma ve destekleme gibi çevresel bilinç ve yerel ekonomiye katkılar sağlanmıştır.

Bu araştırma kapsamında 2019-2025 yıllarını kapsayacak biçimde alanyazın taraması yapılmıştır. Yapılan sınırlamalar doğrultusunda DergiPark veri tabanı üzerinden toplam 1386 makaleye ulaşılmış 1373 tanesi değerlendirmeye alınmıştır. Yıllar açısından en fazla çalışma 2023 yılında (268) yapılmıştır. 2021 yılında (258), 2024 yılında (253), 2022 yılında (227), 2020 yılında (186), 2019 yılında (148) ve son olarak 2025 yılında (33) çalışma yapıldığı tespit edilmiştir. Araştırma makaleleri alanyazın kısmının %77'lik kısmını oluşturmaktadır. Derleme makaleleri ise %23'lük oranı kapsamaktadır. Dillere göre dağılımında ise alanyazının %83'lük kısmını Türkçe çalışmalar kapsamaktadır. %17'lik kısım İngilizce çalışmalara aittir. Çalışmalar arasında yalnızca bir adet Rusça kaynak bulunmaktadır. Gastronomi konusu da gıda bilimleri çalışmaları içerisinde yer almıştır. Alanyazın incelenmesinde, son yıllardaki çalışmaların restoranlar, oteller ve üniversiteler bazında gerçekleştiği gözlemlenmiştir. Bu alanda yapılan çalışmaların büyük bir bölü mü gıda atıkları konusunda bilgi düzeyi ölçümü ve atık dönüşümü için alternatif yolların geliştirilmesi üzerinedir. Gıda atıkları üzerine yapılan çalışmalar genel olarak tüketici kabulü konusu üzerine yapılmıştır. İlgili çalışmaların özet olarak incelenmesi amacıyla "sıfır atık veya gastronomi veya gıda" kelimeleri ile tarama yapılarak ulusal (Dergipark platformu veri tabanı) veri tabanında yer alan alanyazından çalışma örnekleri ve içerikleri verilmiştir. Gastronomide sıfır atık yaklaşımına yönelik ulusal ve uluslararası alanyazın örnekleri Tablo 1'de verilmiştir.

Tablo 1. Gastronomide sıfır atık yaklaşımı üzerine yapılmış bazı makalelerin incelenmesi

Çalışma adı	Yöntem	Bulgular	Kaynak
Ulusal alanyazın			
Restoranlarda Gıda Atık Yönetimi	İstanbul'daki 29 restoran üzerinde, gıda atık süreçleri ile yarı yapılandırılmış görüşmeler yapılarak nitel analiz ile incelenmiştir.	Atıkların çoğunluğunun servis aşamasında oluştuğu, sebzelerin en yaygın atık türü olduğu belirtilmiş. Atıkların ve yemek atıklarının biyodizel için toplanmaktadır. Bu konu üzerine farkındalık artırılması önerilmiştir.	Çirişoğlu ve Akoğlu (2021)
Eğitim Mutfaklarında Gıda Atıkları Yönetimi	Eğitim mutfaklarında iki hafta boyunca atıkların türleri ve miktarları gözlemlenip analiz edilmiştir.	En fazla atıkların üretim sırasında oluştuğu belirtilmiştir. Gıda israfını önlemek için sektörel eğitimlerin artırılması gerektiği önerilmiştir.	Toker ve Atabey (2023)
Kent Restoranlarında Sıfır Atık Yaklaşımı	Kentsel restoranlarda literatür taraması ve saha gözlemi.	Yeşil restoran uygulamaları ve sıfır atık menülerin müşteri memnuniyetini artırdığı tespit edilmiştir.	Haksevenler ve Kavak (2020)
Gıda Atıklarının Endüstriyel Değerlendirilmesi	Literatür derlemesi ile küresel gıda atıklarının değerlendirme yöntemleri analiz edilmiştir.	Gıda atıkları kompost gibi yöntemlerle biyogazlara dönüştürülebilmektedir. Kaynakta ayrıştırmanın kritik bir yönetim aracı olduğu belirtilmiştir.	Okumuş (2023)
Beş Yıldızlı Otellerde Sıfır Atık Yaklaşımı	Antalya'daki otellerde mutfak şefleriyle nicel yöntemlerden anket yöntemiyle veri toplanmıştır.	Sıfır atık uygulamalarının maliyetleri düşürdüğü, ancak daha fazla eğitime ihtiyaç olduğu belirtilmiştir.	Kılınç Şahin ve Bekar (2018)
Mutfakta Sıfır Atık	Literatür taraması ve uygulamalı	Meyve-sebze atıklarının sirke ve turşu	Kutlu ve

Yaklaşımıyla Sirke ve Turşu Üretimi	üretim teknikleriyle inceleme yapılmıştır.	üretiminde kullanılması hem ekonomik kazanç hem de atıkların değerlendirilmesine katkı sağladığı belirtilmiştir.	Yakupoğlu (2024)
Zincir Restoranlarda Sürdürülebilirlik Uygulamaları	Betimsel analiz; uluslararası sürdürülebilir restoran politikaları incelendi.	Zincir restoranların sürdürülebilir mutfak uygulamalarıyla hem ekonomik hem de çevresel fayda sağladığı belirtilmiştir.	Taş ve Olum (2020)
Üniversitelerde Atık Yönetimi	Üniversite kampüslerinde sıfır atık uygulamalarını değerlendiren saha çalışması yapılmıştır.	Sıfır atık bilincinin artırılması için kapsamlı eğitim programlarının geliştirilmesi gerektiği vurgulanmıştır	Ömürbek ve ark, (2019)
Yükseköğretim Öğrencilerinin Gıda İsrafı Konusundaki Bilgi, Görüş ve Davranışları	Anket yöntemiyle üniversite öğrencilerinden nicel veriler toplanmış ve istatistiksel analiz yapılmıştır.	Öğrencilerin büyük bir kısmı gıda israfının önemli bir sorun olduğunu kabul etmekte, ancak günlük tüketimlerinde bilinçsiz alışkanlıklar sergiledikleri tespit edilmiştir. Eğitim programları önerilmiştir.	Aksoy ve Şallı (2023)
Sürdürülebilir Gastronomi ve Atık Yönetimi	Betimsel tarama yöntemiyle Türkiye'deki gastronomi programlarında sürdürülebilirlik içerikli dersler incelenmiştir.	Üniversitelerde sıfır atık ve sürdürülebilirlik temalı derslerin giderek arttığı tespit edildi. Eğitimlerde atık azaltımı ve sürdürülebilir mutfak uygulamalarına vurgu yapılmıştır.	Boz (2024)
Uluslararası alanyazın			
Edible Coating from Breadfruit Starch and Chitosan for Food Packaging	Ekmek nişastası ve kitosan kullanılarak çözücü buharlaştırma yöntemiyle yenilebilir film üretilmiştir. Farklı oranlarda karışımlar test edilip sebzelerin (havuç, biber, tatlı patates) üzerine uygulanmıştır.	%70 nişasta, %30 kitosan içeren film; gıda yüzeyinde etkisi ele alınmıştır. Bu çalışma, sıfır atık yaklaşımıyla gıda atıklarının gastronomide ambalaj olarak değerlendirilmesini ele almıştır.	Sulistyowati ve ark, (2024)
Extraction of Anthocyanin Pigments from the Peel of Dragon Fruit for Food Coloring	Ejder meyvesi kabukları (meyve işleme atığı) asidik etanol ile ekstrakte edilmiştir. Renk yoğunluğu, pH stabilitesi ve termal dayanımı ölçülmüştür.	Ejder meyvesi kabukları, doğal antosiyanin kaynağı olarak kullanılabilir; sağlıklı ve sürdürülebilir bir doğal gıda boyası olarak kullanılmaktadır. Atıkların gastronomide doğal renklendiriciye dönüştürülmesini sağlayarak sıfır atığa katkı sunmaktadır.	Muyassaroh ve ark, (2024)
Preparation and Physicochemical Characterization of Bioplastics from Vegetables Waste/PVA and Coating with Polyeugenol	Sebze atıkları (moringa, su ıspanağı, ıspanak) kurutulup öğütülerek PVA ile karıştırılmıştır. Elde edilen biyoplastikler polieugenol ile kaplanmıştır. Termal, kimyasal ve yüzey analizleri yapılmıştır (FTIR, XRD, SEM).	Polieugenol kaplamasıyla biyoplastiklerin dayanımı ve antimikrobiyal özellikleri artırılmıştır. Çalışma, sebze atıklarını sürdürülebilir gastronomik ambalaj materyaline dönüştürerek hem sıfır atık hem de çevreci ürün sunmaktadır.	Abdul Rahim (2024)
Extraction and Characterization of Pectin from Lemon Waste for Commercial Applications	Limon kabukları (meyve suyu endüstrisi atığı) sıcak asidik ekstraksiyon ile pektin eldesi için işlenmiştir. Elde edilen pektin FTIR ve jel oluşumu testleri ile analiz edilmiştir.	Elde edilen pektin; reçel, marmelat gibi gastronomik ürünlerde kullanılabilecek kalitede olduğu sonuçlarına ulaşılmaktadır.	Beyech Hundie ve Abdissa (2024)
The Properties of Waste Cooking Oil Soap with Avocado Waste Extract as Filler	Mutfaklardan toplanan atık kızartma yağı kullanılarak sabun üretilmiştir. Sabuna avokado kabuğu ve çekirdeğinden elde edilen özler eklenerek formülasyonlar oluşturulmuştur.	Sabunların köpürme ve nemlendirme kapasitesi artmıştır. Atık yağ ve meyve atıkları, temizlik ürününe dönüştürülerek gıda ve kozmetik sektörüne sıfır atık katkısı sunulmaktadır	Irawan ve ark, (2024)
The Impact of Technology on Food Waste: Smart Packaging	Akıllı ambalaj örnekleri (gaz göstergeleri, RFID, QR kodları, sensörler) analiz edilmiştir. Raf ömrü takibi ve tüketici bilinci etkileri incelenmiştir.	Akıllı ambalajlar sayesinde tüketici, ürünün tazeliği hakkında bilgi sahibi olmaktadır ve israf üzerinde olumlu etkisi bulunmaktadır.	Doughmi ve ark., (2024)
Waste Minimization in Food Services: The Role of Technology and Innovation	Teknoloji ve inovasyonun gıda hizmetlerinde atık azaltmaya etkisini inceleyen bir çalışma olarak hazırlanmıştır.	Dijital çözümler, akıllı paketleme ve izleme sistemlerinin gıda atıklarını azaltmada etkili olduğu bulunmaktadır.	Çolak (2023)

Spanish Consumers' Commitment towards Sustainable Food Consumption	İspanya'da 324 tüketiciyle anket yapılmıştır. Çevreye duyarlı tüketiciler, geri dönüşüm ve atık azaltma gibi sürdürülebilir uygulamalara yönelmektedir.	Tüketicilerin %63'ü sürdürülebilir gıda ürünlerini tercih etmeye eğilimli olduğu sonuçlarına ulaşılmıştır.	Lami ve ark., (2021)
Zero Waste Strategies and Turkey's Zero Waste Project	Türkiye'nin ulusal sıfır atık politikası incelenmiştir, AB ve diğer ülkelerle karşılaştırılmıştır. Belediyeler, sanayi ve gastronomi uygulamaları analiz edilmiştir.	Sıfır atık projesi ile gastronomi sektörü de dahil olmak üzere pek çok alanda atık azaltımı sağlanmakta, çevresel farkındalık artırılmaktadır.	Tan (2021)

Gastronomi ve sıfır atık yaklaşımına ilişkin bibliyometrik ayrıntılı bir inceleme ya da gastronomi ile ilişkisini bu konu kapsamında konu alan bibliyometrik bir çalışmaya rastlanamamıştır. Bunların yanı sıra sıfır atık kavramı gastronomi trendleri arasında popüler bir akım yakalamaya başlamıştır. Bu konu hakkında çeşitli araştırmalar yapılmaya başlanmışken, alanyazının bibliyometrik özelliklerinin incelendiği bu çalışmada, makalelerin yıllara göre dağılımı, yayın türlerine göre dağılımı, makalelerin dillere göre dağılımı, en çok makale yayımlayan dergilerin tespit edilmesi gibi ve bu alanyazının nasıl ilerlediğini göstermek adına mevcut ve yeni araştırmacılara, mutfak uygulama alanında çalışan profesyonellere ve bilinçli tüketicilere yol göstermesi ve kaliteli yayınlara kolay erişimleri anlamında katkı sağlaması beklenmektedir.

4. Materyal ve Metot

Bu çalışmada, gastronomi ve gıda alanlarında yer alan sıfır atık yaklaşımının kapsamlı olarak incelenmesi amaçlanmıştır. Bununla birlikte, ilgili konu üzerinde çalışma yapacak olan araştırmacılara güncel veri sunarak kaynak oluşturulması, çalışmanın hedefleri arasında yer almaktadır. Araştırmada, DergiPark veri tabanında yer alan makale çalışmaları üzerinden, doküman analiz yöntemi ve bibliyometrik analiz yöntemleri uygulanmıştır. Mevcut araştırmada bibliyometrik analiz yöntemi sayesinde veriler sayısal değerlere çevrilerek istatistiksel sonuçların elde edilmesiyle akademik çalışmalar arasındaki bağlantılar ortaya koyulmuştur (Ülger ve Ülger, 2022). Veri tabanı olarak DergiPark platformu, hakemli akademik dergileri içermesi, kapsamlı bir veri tabanı özelliği sunması nedenli tercih edilmiştir (ULAKBİM, 2025).

26.03.2024 tarihinde DergiPark veri tabanı üzerinden "sıfır atık veya gastronomi veya gıda" anahtar kelimeleri ile gelişmiş arama yapılmıştır. Akademik çalışmaların yayımlanma tarihi 2019-2025 yılları olarak belirlenip son 7 yılın verileri üzerinden araştırma gerçekleştirilmiştir. Araştırmada kullanılacak yayın türleri, araştırma makalesi ve derleme makalesi olacak şekilde sınırlandırılıp, araştırma kapsamında 1386 adet makaleye ulaşılmıştır. Elde edilen makalelerin içerik kontrolleri sağlandıktan sonra farklı alanlar üzerinde yapılmış çalışmalar veri setinden çıkarılarak, 1373 adet makale üzerinden çalışma gerçekleştirilmiştir. Çalışmada betimsel bibliyometrik analiz yöntemi uygulanmıştır. Veriler, kategorilere ayrılarak belirli başlıklar altında incelenmiştir (Güler ve Keskin, 2020).

Araştırmada analiz için Microsoft Excel uygulaması kullanılmıştır. Microsoft Excel, verilerin dağılımını belirlemek, sayısal çıktılara ulaşmak ve sıralama oluşturmak için kullanılmaktadır (Suvacı, 2016). Bu doğrultuda, araştırma kapsamında belirlenen 1373

makale, Microsoft Excel tablosu üzerinde düzenlenmiş, her makale için verilerin analizleri sağlanmıştır. Analiz sonucunda araştırmadaki ana temalar; gıda, atık, gastronomi, turizm, güvenlik, sürdürülebilirlik ve tüketim olarak belirlenmiştir. Veriler arasındaki kavramsal ilişkileri analiz edebilmek ve bibliyometrik ağ analizlerini görselleştirmek amacıyla EkşiVeri uygulaması kullanılmıştır. EkşiVeri uygulaması, Microsof Excel dosyaları üzerinden aktarılan verileri kullanarak, veri madenciliği temelli analizler gerçekleştirebilen bir uygulamadır. Bununla birlikte EkşiVeri uygulaması ile anahtar kelimeler üzerinden kelime bulutları, ağ analizleri ve korelasyon temelli kelime ilişkileri ile tematik sınıflandırmalar yapabilmektedir (Atabay, 2024).

Araştırmanın DergiPark veri tabanı üzerinden gerçekleştirilmesi ve 2019-2025 yıllarını kapsayan makaleler üzerinden çalışmaların oluşturulması, araştırmanın sınırlılıklarını belirlemiştir. Çalışmada farklı veri tabanlarına yer verilerek, ulusal ve uluslararası çalışmalar ile araştırmanın kapsamı genişletilebilir. Bununla birlikte yıl sınırlaması artırılarak daha uzun vadede konuya ilişkin gelişmeler akademik olarak sunulabilecektir.

Aşağıda yer alan Şekil 2'de bu araştırma kapsamında ele alınan araştırma soruları verilmiştir.

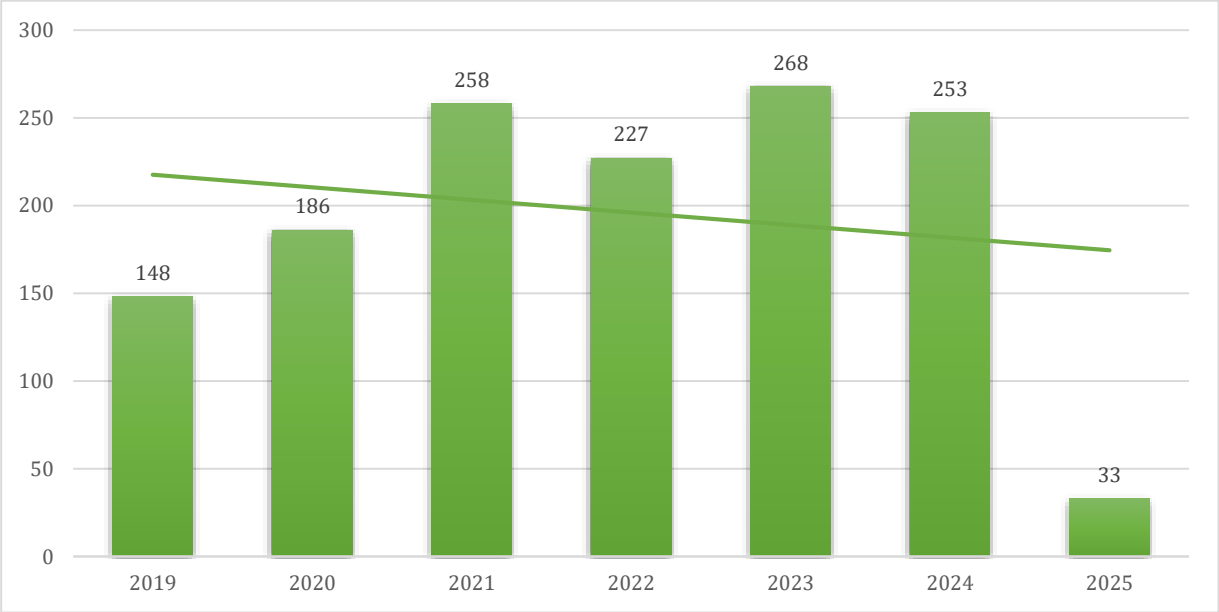
Şekil 2. Araştırma soruları

5. Bulgular ve Tartışma

Bu araştırmada, gastronomi ve gıda alanlarının sıfır atık yaklaşımı ile olan ilişkisi üzerinde DergiPark veri tabanında yer alan 2019-2025 yılları arasında yayımlanmış 1373 makale bibliyometrik analiz yöntemiyle incelenmiştir. Elde edilen veriler Microsoft Excel ve EkşiVeri uygulamalarıyla analiz edilmiştir. Elde edilen analizler doğrultusunda sıfır atık yaklaşımının gastronomi ve gıda bilimleri alanında giderek artan bir akademik ilginin olduğuna ulaşılmaktadır.

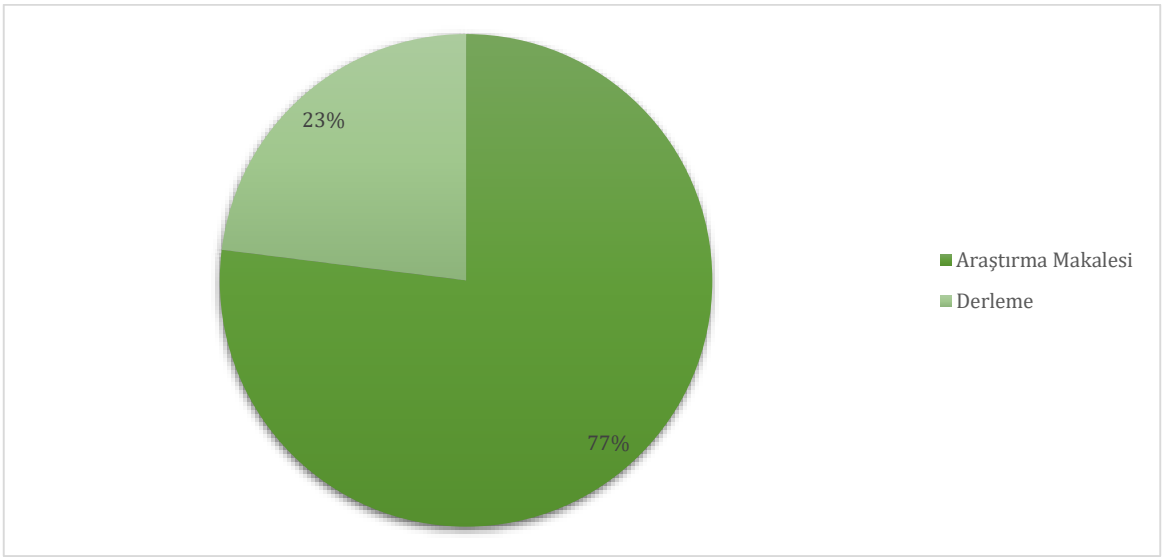
Makalelerin yıllara göre dağılımı incelendiğinde, 2019 yılında 148 olan yayın sayısının 2021 yılında 258'e, 2023 yılında ise 268'e yükseldiği görülmektedir. Şekil 3'te, DergiPark veri tabanından elde edilen verilerin yıllara göre dağılımları verilmiştir. Bu artış, sürdürülebilirlik, gıda güvenliği ve çevre bilinci konularının kamu politikaları ve toplum genelinde daha çok gündeme gelmesiyle ilişkilendirilebilmektedir (Strateji ve

Bütçe Başkanlığı, 2020). Ayrıca, COVID-19 pandemisinin etkisiyle birlikte gıdaya erişim, hijyen ve tedarik zinciri güvenliği gibi konuların ön plana çıkması, özellikle 2021 sonrası yıllarda bu alandaki akademik üretimin artışında etkili olmuştur (Tan, 2021).

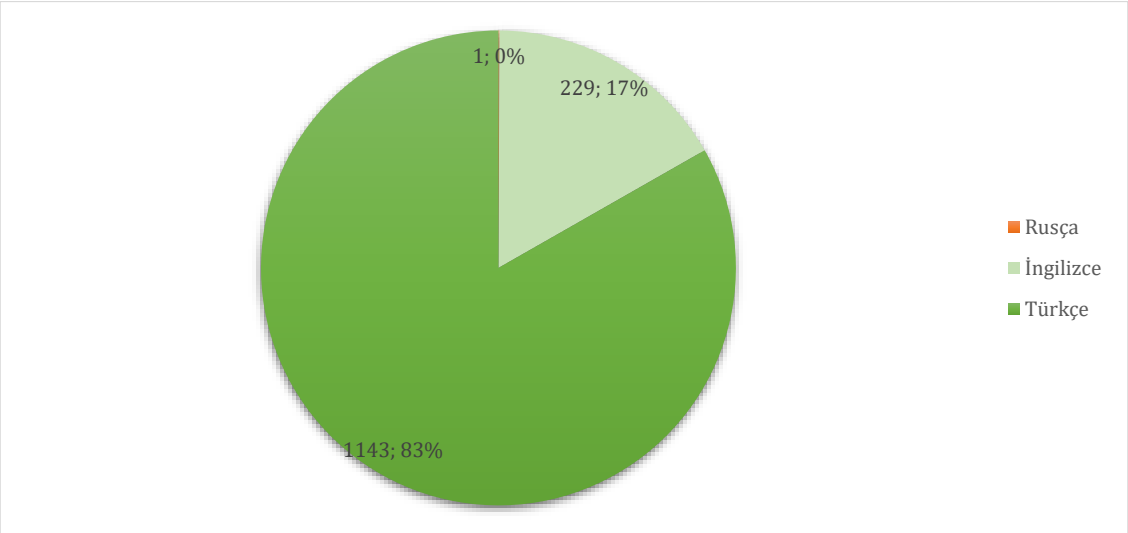


Şekil 3. Makalelerin yıllara göre dağılımları

Çalışmaların yayın türlerine göre dağılımı incelendiğinde, makale çalışmalarının %77'si araştırma makalesinden (1057), %23'ü derleme makalesinden (316) oluşmaktadır (Şekil 4). Bu durum, sıfır atık konusunun sektör alanlarında uygulanabilir olduğunu ve araştırma alanlarının geniş olduğunu göstermektedir (Ülger ve Ülger, 2022). Makale çalışmalarının yayımlandıkları dillerin dağılımlarına göre; çalışmaların %83'ü Türkçe (1143), %17'si İngilizce (229), %0' Rusça (1) olarak yayımlanmıştır (Şekil 5).

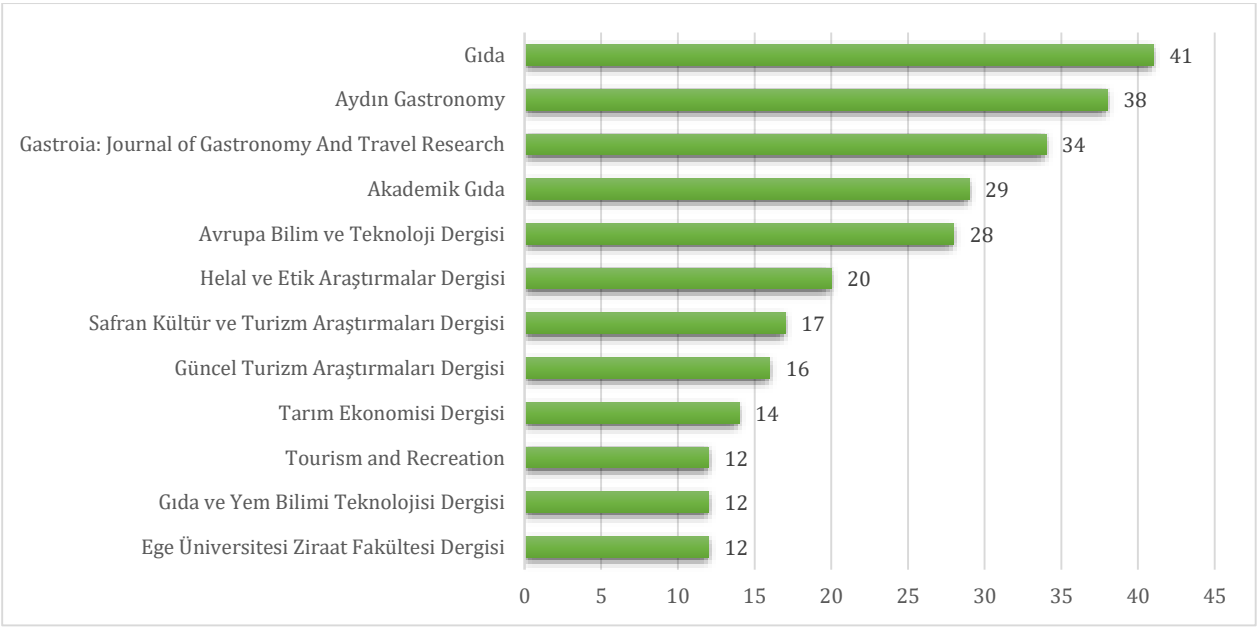


Şekil 4. Makalelerin yayın türlerine göre dağılımları.



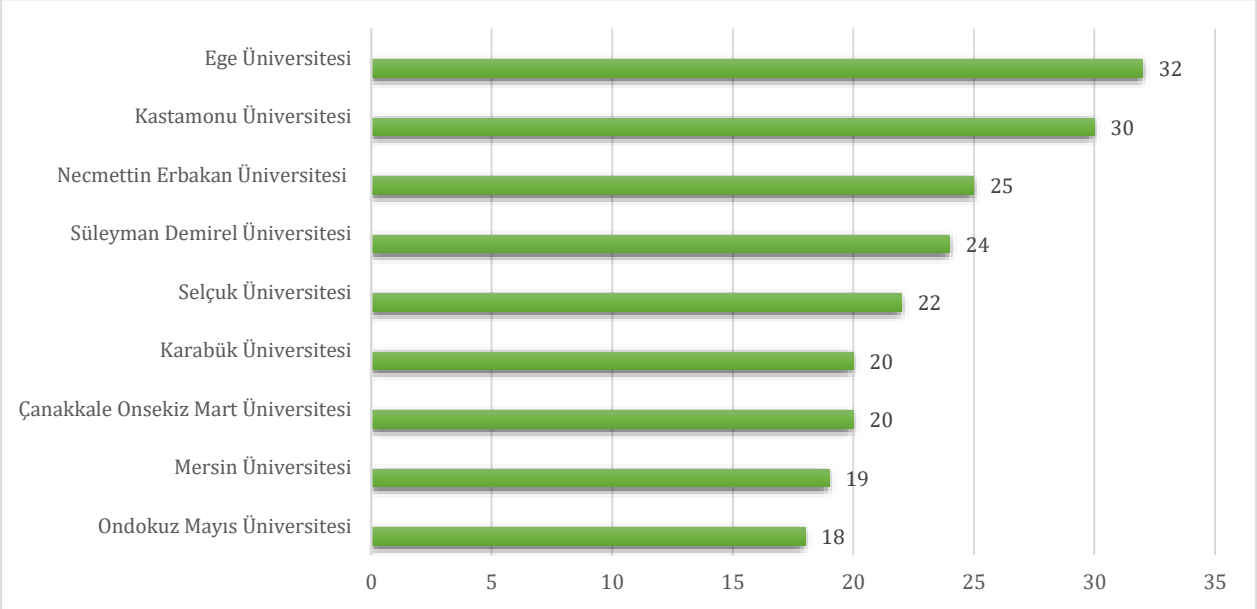
Şekil 5. Makalelerin yayımlandıkları dillere göre dağılımları

Şekil 6'da gastronomi, gıda ve sıfır atık kavramlarıyla ilgili en çok makale yayınlayan ilk 10 dergi yer almaktadır. İlk sırada Gıda (41) dergisi bulunmaktadır. Ardından sırasıyla, Aydın Gastronomy (38), Gastroia: Journal of Gastronomy And Travel Research (34), Akademik Gıda (29), Avrupa Bilim ve Teknoloji Dergisi (28) gibi dergilerde çalışma yapılmıştır. Çalışmada yer alan 1373 makale, toplam 578 farklı dergide yayımlanmıştır. Bu dergilerin gastronomi, gıda teknolojisi ve turizm alanlarında yoğunlaşması, disiplinler arası bir yaklaşımla sıfır atık temalarının işlendiğini ortaya koymaktadır.



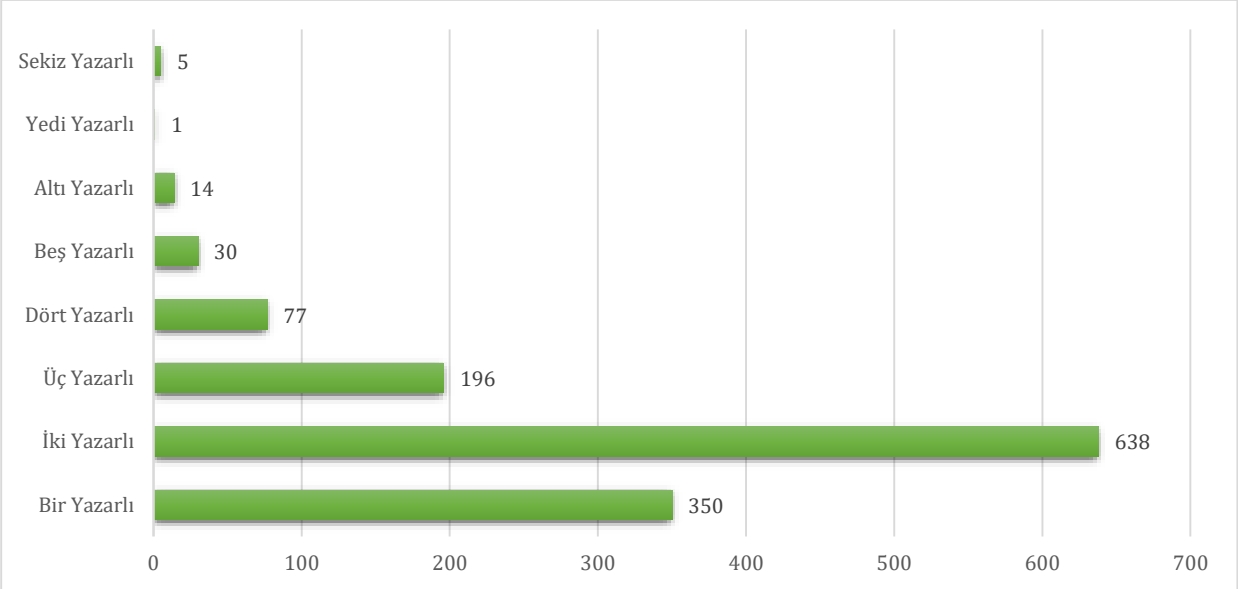
Şekil 6. Makalelerin yayımlandıkları dergilerin dağılımları.

Şekil 7'de yayımlanmış makale çalışmalarına katkı sağlayan ilk 10 kurum verilmiştir. Buna göre Ege Üniversitesi (32) ilk sırada yer almaktadır. Ardından Kastamonu Üniversitesi (30) ikinci sırada yer almakta ve Ege Üniversitesi'ne oldukça yakın bir değer göstermektedir. Araştırmada yer alan 1373 makaleye toplam 185 kurum katkı sağlamıştır. Bu da Türkiye genelindeki üniversitelerde sıfır atık temalı akademik araştırmaların yaygınlaştığını göstermektedir.



Şekil 7. Makale çalışmalarına katkı sağlayan kurumların dağılımları

Yazar sayılarına göre yapılan analizde, en çok çalışmaların yapıldığı yazar sıralamasına göre ilk sırada iki yazarlı çalışmalar (638) yer almaktadır (Şekil 8). Ardından tek yazarlı (350) ve üç yazarlı (196) makaleler sırayla gelmektedir. Yedi ve sekiz yazarlı çalışmaların da yer aldığı makalelerin bulunması, iş birliğine dayalı araştırmaların gerçekleştirildiğini göstermektedir. Şekil 8'de makale çalışmalarının yazar sayıları verilmiştir. Buna göre en çok iki yazarlı (638), bir yazarlı (350) ve üç yazarlı (196) şeklinde çalışmalar oluşturulmuştur.

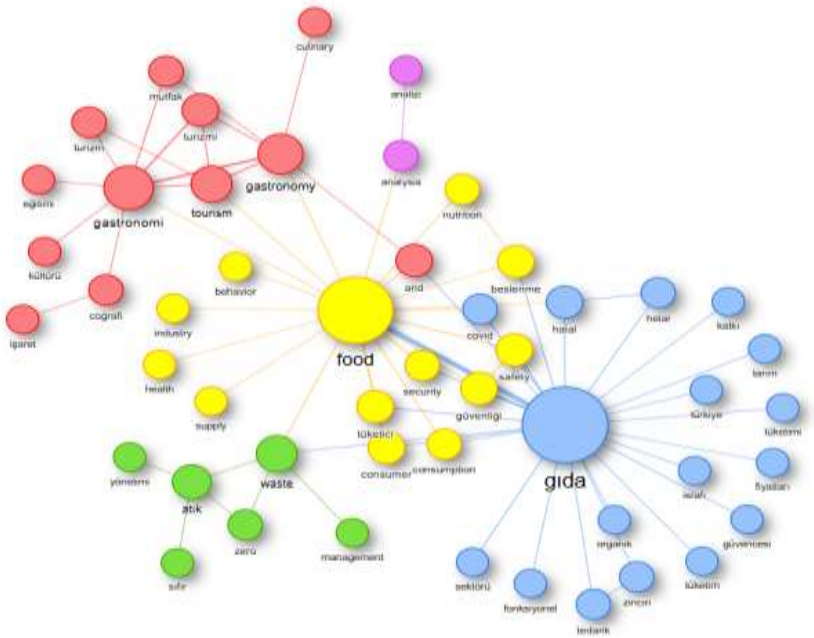


Şekil 8. Makale çalışmalarının yazar sayılarına göre dağılımları

Şekil 9'da anahtar kelime bulutu verilmiştir. Buna göre en çok tekrar eden anahtar kelime olarak gıda (944) ilk sırada yer almaktadır. Ardından sırasıyla food (816), gastronomi (431), gastronomy (298), güvenliği (155), waste (109), tourism (144), covid (106), safety (94), atık (87), sürdürülebilir (55) şeklinde anahtar kelimeler kullanılmıştır.

Şekil 9. Anahtar kelime bulutu

Şekil 10'da anahtar kelime ağ analizi verilmiştir Buna göre grafiğin merkezinde gıda ve gastronomi kelimeleri yer almıştır. Grafikte, gıda güvenliği, sürdürülebilirlik, turizm, tüketici davranışları ve pazar analizi gibi önemli temaların gıda ve gastronomi ile ilişkisi görülmektedir. Ayrıca, "güvenlik", "atık", "turizm" ve "tüketici" gibi kelimelerin de grafikte önemli bir yer tutması, bu alanlar arasındaki ilişkinin ortaya koyulmasını sağlamıştır. Anahtar kelime ağ analizinde en sık kullanılan kavramlar arasında "gıda" (944), "gastronomi" (431), "sürdürülebilirlik" (55), "atık" (87) ve "güvenlik" (155) yer almaktadır. Anahtar kelime bulutu ve ağ analizinde, "gıda" ve "gastronomi" kavramlarının merkezde yer aldığı; "turizm", "tüketici davranışları", "atık yönetimi" ve "gıda güvenliği" gibi temalarla güçlü bağlantılar kurduğu görülmektedir. Bu bulgular, gastronomi ve gıda alanlarının sıfır atıkla çok yönlü bir etkileşim içinde olduğunu, tüketim ve üretim süreçlerinin bu yaklaşımla yeniden değerlendirildiğini ortaya koymaktadır.



Şekil 10. Anahtar kelime ağ analizi

Elde edilen bulgular değerlendirildiğinde; gastronomi ve gıda alanlarının sıfır atık yaklaşımıyla akademik anlamda güçlü bir bağ kurduğunu ve bu bağın çevresel, ekonomik ve toplumsal sürdürülebilirlik çerçevesinde derinleştiğini göstermektedir. Multidisipliner özellik taşıyan bu araştırma alanı, gelecekte daha geniş veri tabanları ve uluslararası yayınlarla daha kapsamlı çalışmalarla desteklenmelidir.

Çalışmada yer alan ulusal ve uluslararası alanyazın örneklerine göre sıfır atık uygulamalarının gastronomi ve gıda sektörüne olan katkısının giderek arttığı ortaya koyulmuştur. Şahin ve Bekar (2018), yaptıkları makale çalışmasında, beş yıldızlı otellerde sıfır atık uygulamalarının ekonomik etkilerini sunmuştur. Otel şefleriyle yapılan anketler doğrultusunda, sıfır atık uygulamalarının, maliyetleri düşürdüğü ancak mutfak personellerine konuyla ilgili daha fazla eğitimin verilmesi gerektiği belirtilmiştir. Bu çalışma, "sürdürülebilirlik", "mutfak" ve "gıda" gibi anahtar kelimelerle örtüşmektedir ve ekonomik kazanımlar vurgusu, bibliyometrik analiz bulgularıyla paralellik göstermektedir.

Tan (2021), Türkiye'nin sıfır atık projesi Avrupa ve diğer ülkelerle karşılaştırılarak analiz edilmiştir. Gastronomi sektörünün de uygulama kapsamında olduğu vurgulanmıştır. Alanyazında yer almış bu çalışma bulgular kısmında yer alan ağ analizinde "sıfır atık" ve "atık yönetimi" gibi temalar ile uyumlu olduğu sonuçlarına ulaşılmıştır.

Alanyazın çalışmasında yer alan konu alanlarından biri teknoloji ve sıfır atık üzerine yapılan çalışmalardır. Buna göre, Okumuş (2023), gıda atıklarının endüstriyel dönüşüm potansiyeli üzerine çalışma yapmış ve biyogaz üretimi gibi yöntemlerin yaygınlaştırılması gerektiğini ifade etmiştir. Çolak (2023), tarafından yapılan bir başka çalışmada ise gıda sektöründe teknolojik çözümlerin (akıllı ambalaj sistemleri, QR kodlar gibi) gıda israfını önleme üzerinde etkili olduğunu sonuçlarında belirtmiştir. Bu da bulgular kısmında yer alan, "teknoloji", "izleme", "gıda güvenliği" anahtar kelimeleriyle örtüşmektedir.

Çalışmada yer alan gıda atıklarından yeni ürün elde edilmesi üzerine alanyazın çalışmalarına bakıldığında, Kutlu ve Yakupoğlu (2024), meyve-sebze atıklarından sirke ve turşu üretimi üzerine uygulamalı çalışma yapmıştır. Benzer şekilde, Muyassaroh ve arkadaşları (2024), ejder meyvesi kabuklarından doğal antosiyanin üretimi gerçekleştirerek gıda boyası elde etmiş ve bu katkı maddesinin sürdürülebilir gastronomide kullanılabileceğini savunmuştur. Bu bulgular da "doğal katkı", "atıkların değerlendirilmesi" ve "gastronomide yenilik" başlıkları ile örtüşmektedir. Sulistyowati ve arkadaşları (2024), ekmek ağacı nişastası ve kitosan ile üretilen yenilebilir filmleri gıda ambalajı olarak test etmiş ve bu filmlerin sıfır atık stratejileri olarak belirtmiştir. Abdul Rahim (2024), tarafından yürütülen çalışmada ise sebze atıklarının biyoplastik üretiminde kullanılması sayesinde ambalaj dayanımı artırılmış ve sıfır atık ilkesi doğrultusunda çevre dostu ürün geliştirilmiştir. Bulgular kısmında yer alan en çok tekrar eden kelimeler olan "ambalaj", "atık yönetimi" ve "çevre" anahtar kelimeleri ile örtüştüğü sonuçlarına ulaşılmıştır.

Gastronomi sektörü, tüketici tercihlerinin sürekli değişmesi, teknoloji alanında gelişen yenilikler ve sürdürülebilirlik kapsamına bağlı olarak yenilikçi uygulamalar

nedenli devamlı değişim göstermektedir. Bu yenilikçi uygulamalar hem çevresel zararlı etkileri azaltmayı hem de işletmelerin ekonomik ve uygulamalı performanslarını artırmayı hedeflemektedir. Özellikle sıfır atık yaklaşımı, gastronomide yenilikçi çözümlerin temelini oluşturmakta ve sürdürülebilir gastronomi anlayışını desteklemektedir (Cankül, 2019). Mutfaklarda uygulanması adına birçok proje üretilmektedir. Bunlardan biri Turuncu Bayrak Projesidir. Bu proje, gıda israfını azaltmak ve sürdürülebilirliği teşvik etmek amacıyla geliştirilmiştir. Yiyecek-içecek üretiminden başlayarak tüketim aşamasına kadar her türlü hizmeti içinde barındırmaktadır (Turuncu Bayrak, 2018). Aynı zamanda turuncu bayrak kazanan işletmeler çevre dostu bir imaj kazandıkları için müşteriler tarafından da tercih edilmektedir. Bunlara ek olarak doğa açısından karbon ayak izini azaltırken, yerel üreticileri destekleyerek toplumsal ve ekonomik fayda sağlamaktadır. Bu tarz yapılan uygulamalar hem doğal bir deneyim sunmakta hem de kaynakların verimli kullanılmasını mümkün kılmaktadır (Çetinoğlu ve Ünlüönen, 2020).

Gastronomi işletmelerinin, plastik kullanımını azaltmak ve çevre dostu bir marka algısı oluşturmak için geri dönüştürülebilir ambalaj malzemeleri kullanımını tercih etmeleri gerekmektedir. Özellikle geri dönüştürülebilen ambalajlar ve yeniden kullanılabilir servis malzemeleri, çevreye olumlu katkılar sağlamaktadır. Akıllı mutfak sistemleri, enerji ve su tüketimini dengelerken gıda atıklarını azaltmak için veriye dayalı analizler sunmaktadır. Bunun yanı sıra, dijital sipariş sistemleri ve QR kod tabanlı menüler, tüketicilere daha hızlı ve kolay bir hizmet sunmayı mümkün kılmaktadır. Bu tür yenilikçi mutfak çözümleri, işletmelerin çevreye duyarlılığını artırırken, sürdürülebilirlik hedeflerini desteklemektedir (Aydın ve Çakır, 2022).

6. Sonuçlar

Bu araştırma, 2019–2025 yılları arasında DergiPark veri tabanında yayımlanan 1373 akademik makalenin bibliyometrik analizi yoluyla, sıfır atık yaklaşımının gastronomi ve gıda bilimleri literatüründe nasıl konumlandığını çok boyutlu biçimde ortaya koymuştur. Elde edilen bulgular, sıfır atık temalı çalışmaların incelenen dönemde istikrarlı bir artış gösterdiğini ve özellikle 2021 ile 2023 yıllarında önemli oranda arttığını göstermektedir. Bu artışın; Covid-19 pandemisi sonrası gıda güvenliği, hijyen, kaynak yönetimi ve sürdürülebilirlik gibi kavramların kamu kurumlarında ve akademik çevrelerde öncelik kazanmasıyla doğrudan ilişkili olduğuna ulaşılmıştır. Analiz kapsamında incelenen 1373 makalenin 578 farklı dergide yayımlanmış olması, konunun çok disiplinli yapısını ve literatürdeki geniş alanlarını ortaya koymaktadır. Yayınlar içerisinde en fazla katkı sağlayan dergilerin “Gıda”, “Aydın Gastronomy” ve “Gastroia: Journal of Gastronomy and Travel Research” olması, gıda ve gastronomi alanlarının sıfır atık konulu çalışmalarda önemli rol üstlendiğini göstermektedir. Ayrıca, araştırmaların büyük çoğunluğunu araştırma makalelerinin (1057) oluşturması, bu alandaki akademik üretimin teorik çalışmaların ötesine geçerek sektöre ve uygulamaya yönelik olduğunu göstermektedir.

Kurumsal katkılar açısından “Ege Üniversitesi”, “Kastamonu Üniversitesi” ve “Necmettin Erbakan Üniversitesi” sırasıyla en fazla yayına sahip yükseköğretim

kurumları olarak öne çıkmakta, bu durum söz konusu üniversitelerde sürdürülebilirlik ve çevre temelli araştırmaların oldukça önem verildiğini düşündürmektedir. Yazar sayısı bakımından iki yazarlı ve tek yazarlı yayınların ağırlıkta olduğu sonuçlarına ulaşılmıştır. Bununla birlikte anahtar kelime analizinde en sık karşılaşılan kavramların "gıda", "gastronomi", "sürdürülebilirlik", "atık" ve "güvenlik" olması; sıfır atık yaklaşımının çevresel bir sorun özelliği taşımasının yanında halk sağlığı, gıda güvenliği ve toplumsal sorumluluk açısından değerlendirilen bir konu olduğunu göstermektedir. Bu çalışma doğrultusunda, sıfır atık temelli sürdürülebilirlik politikalarının gıda tedarik zinciri ile akademik alanda da yer almaya başladığı görülmektedir. Bu çalışma sonuçlarına göre, sıfır atık yaklaşımını güçlendirmek için;

- ✓ Tüketiciler için bilinçli tüketim ile israfı önleme, organik atıkları kompost yolu ile değerlendirme, yerel üreticileri destekleyerek sürdürülebilir tarıma destek olma ve karbon ayak izini düşürmede etkin rol oynama ve sıfır atık ilkelerini destekleyen kuruluşlara, işletmeleri ve mutfakları tercih etme gibi konularda dikkatli olması önerilmektedir.
- ✓ Sanayiciler için üretim süreçlerinde döngüsel ekonomi modelini tercih ederek atık azaltma yoluna gitmesi, tedarik zincirini kontrol etmesi ve fazla gıda atıklarını değerlendirmesi, geri dönüştürülebilir ve çevre dostu ambalajları tercih etmesi, kalan artık maddelerden yan ürünler ve doğal gıda katkıları üretmesi önerilebilir.
- ✓ Akademik alan için sıfır atık eğitim programların arttırılması, genç kuşakların bilinçlendirilmesi, sıfır atık politikalarına uygun endüstri ile iş birliği içinde projelere yönelinmesi, sosyal etkiye yönelik tüketici çalışmaları, artık ürünlerden doğal gıda katkı maddeleri geliştirme ve daha kapsamlı bibliyometrik analizler önerilmektedir.
- ✓ Şefler için gastronomide tüm malzemeleri değerlendirme, kalan malzemelerin sap, çekirdek ve kabuklarını sos, çorba vb. amaçlar için kullanma, atıksız menüler tasarlayarak malzemeleri verimli kullanma, mevsimsel ve yerel ürünler ile çalışma, akıllı stok yönetimi, tabaklarda porsiyon kontrolü ve tüketiciyi tanıma, kompost sistemlerini işletmede kurma, kalana ürünleri başka tariflerde alternatif olarak değerlendirme, sıfır atık prensibini benimseyen etik üreticiler ile çalışma, atıksız mutfak eğitimleri ve workshoplar düzenleme, sebze kabuğundan atıştırmalık gibi yenilikçi reçeteler ile ürün portföyünü geliştirme tavsiye edilmektedir.

Bu bağlamda, sıfır atık yaklaşımların akademik alanda çalışan kişiler, üreticiler, sanayiciler, şefler, gıda mühendisleri, otel yöneticileri, işletme sahipleri, kurum ve kuruluşlar tarafından benimsenmesi büyük önem taşımaktadır. Sıfır atık yaklaşımının yaygınlaşması, atıkların azalmasının yanı sıra toplumun çevresel etik değerlerinin de gelişmesine yardımcı olmaktadır. Çalışma sonucunda, gelecekte gastronomi ve gıda sektörlerinde gerçekleştirilecek akademik araştırmaların daha geniş veri tabanlarını kapsayacak şekilde sektörel açıdan ayrıştırılması ve uygulamalı araştırmalarla desteklenmesi önerilmektedir. Bu sayede, sıfır atık politikalarının etkinliği daha somut ve kapsamlı biçimde değerlendirilebilecek; sektörel dönüşüm süreçlerine daha güçlü katkılar sağlanabilecektir.

Yazarların Katkı Oranları

M.Ç.: Kavramsallaştırma, yöntem, veri analizi ve yorumlama, alanyazın taraması, yöntem, yazma – ilk versiyon, yazma – revizyon.

D.D.A.: Kavramsallaştırma, yöntem, veri analizi ve yorumlama, alanyazın taraması, yöntem, veri sorgulama, yazma – hakemli yanıtlar – revizyon – ilk versiyon.

Çıkar Çatışması Beyanı

Çalışmada herhangi bir çıkar çatışması yoktur.

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Use of medicinal and aromatic plants in poultry nutrition

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ABSTRACT

Due to the ban on antibiotics as feed additives in the European Union in 2006 and the adverse health effects of synthetic products, medicinal and aromatic plants, as well as the herbal extracts and essential oils derived from them, have gained importance in poultry farming as natural products. In recent years, the production of certain aromatic plants has begun, and market volume has increased, particularly in developed countries, due to the rising use in humans, animals, and plants. These plants exhibit numerous effects such as antioxidant, antifungal, antiviral, anti-inflammatory, antimicrobial, and digestive system stimulation. These effects are mediated through secondary metabolites. Consequently, herbal extracts and essential oils obtained from medicinal and aromatic plants (phytobiotics) have become attractive in poultry nutrition. This review aims to present current information on the importance, physical and chemical properties, modes of action, purposes of use, and significance of using herbal extracts and essential oils derived from medicinal and aromatic plants in poultry nutrition.

Tıbbi ve aromatik bitkilerin kanatlı beslemede kullanımı

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ÖZET

Antibiyotiklerin 2006 yılında Avrupa Birliğinde yem katkı maddesi olarak yasaklanmasından ve sentetik ürünlerin sağlığa olumsuz etkilerinin olmasından dolayı tıbbi ve aromatik bitkiler ve bunlardan elde edilen bitkisel ekstraktlar ve esansiyel yağlar doğal ürünler olarak kanatlı yetiştiriciliğinde önem kazanmıştır. Son yıllarda özellikle gelişmiş ülkelerde insan, hayvan ve bitkilerdeki kullanımın artması sonucu bazı aromatik bitkilerin üretimi yapılmaya başlanmış ve pazar hacmi artmıştır. Bu bitkilerin antioksidan, antifungal, antiviral, antiinflamatuar, antimikrobiyal ve sindirim sistemini uyarıcı gibi pek çok etkisi bulunmaktadır. Bu etkilerini sekonder metabolitler ile oluştururlar. Bu etkilerinden dolayı tıbbi ve aromatik bitkilerden (fitobiyotikler) elde edilen bitkisel ekstraktlar ve esansiyel yağlar kanatlı beslenmesinde çekici hale gelmişlerdir. Bu derlemede tıbbi ve aromatik bitkilerden elde edilen bitkisel ekstraktlar ve esansiyel yağların önemi, fiziksel ve kimyasal özellikleri, etki şekilleri, kullanım amaçları ve kanatlı beslemede kullanımının önemi hakkında güncel bilgilerin sunulmasını amaçlanmıştır.

1. Introduction

Plants have been fundamental elements of life throughout human history and have formed the basis of modern medicine (Yeşilbağ, 2007; Arslan et al., 2021). Due to the residues left by antibiotics in milk and meat products, which lead to antibiotic resistance and pose health threats, the use of antibiotics as feed additives (FAs) in animal nutrition was banned in Sweden in 1986, in Denmark and Switzerland in 1998, and in the European Union and Turkey in 2006 (Güven, 2021; Urban et al., 2024). However, the ban on antibiotics has led to the intensification of bacterial infections and a decrease in

poultry productivity during this period (Abd El-Hack et al., 2017; Abd El-Hack et al., 2022; Rahman et al., 2022). Following these bans, considering the harmful effects of synthetic substances, the use of alternative natural FAs, such as medicinal and aromatic plants (MAPs) containing phytochemical compounds, also known as phytobiotics (phytogenic feed additives, PFAs), has become promising (Gürsoy, 2021; Rafeeq et al., 2023; Alem, 2024).

Medicinal and aromatic plants which are phytochemical plants, producing various metabolites to sustain their lives and protect themselves, have been used in human medicine since ancient times, and exhibit pharmacological effects (Yeşilbağ, 2007; Rafeeq et al., 2023). When referring to medicinal and aromatic plants, the plant itself, its extracts, and essential oils come to mind (Okey, 2023; Alem, 2024). These plants stand out with their aromatic activities. Since the active ingredient ratios of extracts obtained from aromatic plants are variable, the direct use of plants is generally not preferred (Aydın, 2023). The various physical and chemical properties of plants are derived from active substances (secondary metabolites) that are not necessary for the normal growth, development, or reproduction of plants but are beneficial (Irchhaiya et al., 2015). In the last twenty years, phytobiotics have shown a wide range of effects, including antioxidant, anti-inflammatory, antimicrobial, antiviral, antilipidemic, antimycotic, and metabolic regulatory properties, in addition to their aromatic effects (Kikusato, 2021; Rafeeq et al., 2022; Öztürk Aydın & Cengiz, 2023). Additionally, they are widely used in poultry production to stimulate the immune system and prevent and control various bacterial, viral, and protozoal diseases (Greene et al., 2021; El-Shall et al., 2022). This review aims to present current information on the use of MAPs, which are important and increasingly used as feed additives, in poultry nutrition.

2. Importance of Medicinal and Aromatic Plants

Plants synthesize secondary metabolites to protect against pathogens such as viruses, bacteria, and fungi. These substances protect the plant's DNA and photosynthetic apparatus from oxidative damage caused by ultraviolet radiation (Kikusato, 2021). Medicinal and aromatic plants are widely used due to their anti-inflammatory, antioxidant, and antimicrobial effects. In fact, these plants have long been used in disease control (Tundis et al., 2017). Using these plants aim to improve the feed conversion ratio (FCR) in poultry nutrition (Spernakova et al., 2007). Plants such as cumin, mint, rosemary, thyme, and cinnamon have been used in poultry nutrition for their antioxidant, anti-inflammatory, antiseptic, antimicrobial, and digestive stimulant effects (Önenç & Turgud, 2019). While many medicinal and aromatic plants are collected from nature, some plants, such as thyme, are also cultivated (Aslan and Karakuş, 2019). Türkiye is rich in medicinal and aromatic plants due to its climate, plant diversity, and geographical location. There are over 12,000 plant species in Türkiye, 3,600 of which are endemic (Anonim, 2019). Plants commonly found and produced in Türkiye, such as sage, linden, licorice, and cumin, are known for their antioxidant, anti-inflammatory, and antimicrobial properties (Şahin-Nadeem et al., 2013). Additionally, these plants are used in various sectors for different purposes (Erten et al., 2023).

3. Properties and Effect Types of Medicinal and Aromatic Plants

Plants experience stress and produce secondary metabolites when the optimal tolerance level of at least one environmental factor, such as temperature, salinity, drought, or high light, is exceeded (Yang et al., 2018; Isah, 2019). These metabolites are found in the roots, leaves, fruits, or seeds of medicinal and aromatic plants (MAPs). Secondary metabolites include essential oils, flavonoids, alkaloids, saponins, tannins, and resins. These metabolites are known as beneficial organic compounds that are not essential for the organism's normal development or reproduction but are advantageous (Irchhaiya et al., 2015). They provide the taste and aroma of plants and also possess bioactive properties. Most MAPs, rich in secondary metabolites, exhibit high antioxidant activity. Plants containing flavonoids demonstrate higher antioxidant activity (Mohammed et al., 2018; Yakoub et al., 2018). Commercially, they are also becoming increasingly important. For example, flavonoids in licorice root are reported to have 100 times more antioxidant effect than vitamin E (Erten et al., 2023).

In addition to their antifungal, antimicrobial, antiviral, antioxidant, and antilipidemic effects, medicinal and aromatic plants (MAPs) are reported to have properties that stimulate the digestive system, strengthen the immune system, and enhance performance and vitality. The composition and effects of herbal extracts obtained from phytobiotics vary depending on the part of the plant used, harvest time, geological origin, processing method, and storage conditions, as well as the species and age of the animals (Adıyaman & Ayhan, 2010; Gürsoy, 2021; Dilbato Dinbiso et al., 2022; Rafeeq et al., 2023).

3.1. Properties and Effect Types of Herbal Extracts

Herbal extracts have been traditionally used for centuries in the treatment of various diseases (Güven, 2021). These extracts contain nutrients in their chemical structures, such as small amounts of fatty acids, proteins, essential amino acids, peptides, oligosaccharides, vitamins, and trace minerals (Aydın, 2023). These extracts improve the sensory properties of feed, enhance animal performance, and increase the quality of products obtained from these animals. They have antimicrobial, antioxidant, anti-stress, and growth-promoting effects (Çetin, 2012; Öztürk Aydın & Cengiz, 2023). Table 1 presents the parts used, active ingredients, and effect of types of some extracts used in poultry nutrition (Tipu et al., 2006; Adıyaman & Ayhan, 2010; Aydın, 2023).

Several theories have been proposed to explain the antibacterial effects of herbal extracts. According to these theories, the active substances in the extracts interact with electron transport, ion gradients, protein translocation, phosphorylation, and enzyme-dependent reactions in the bacterial cell membrane, exhibiting antibacterial activity (Yanar & Aktaş, 2021). Some herbal extracts (thyme, cinnamon, rosemary, garlic) have been reported to have positive effects on performance parameters by inhibiting the growth of microorganisms such as *Salmonella sp.*, *Escherichia coli* (*E. coli*), and *Clostridium sp.* (Öztürk Aydın & Cengiz, 2023).

The diversity of active metabolites in plant species also alters the effects of herbal extracts on the digestive system. Many herbal extracts stimulate saliva secretion, while

some (ginger, turmeric, mint, anise, and cumin) increase the synthesis and release of bile acids in the liver. Additionally, herbal extracts have been reported to stimulate pancreatic enzymes (such as amylases and lipases) and increase the activities of digestive enzymes in the stomach mucosa (Adıyaman & Ayhan, 2010). Herbal extracts play an important role in maintaining the pH balance necessary for the maximum activity of digestive enzymes in the digestive system (Aydın, 2023).

Table 1. Used parts, active ingredients and effect types of some aromatic plants

Aromatic plant	Part used	Active ingredient	Mode of action
Sage	Leaf	Eucalyptol	Digestive stimulant, antiseptic, flatulence
Rosemary	Leaf	Cineole	Digestive stimulant, antiseptic, antioxidant
Bay	Leaf	Eucalyptol	Appetite stimulant, digestive stimulant, antiseptic
Clove	Flower	Eugenol	Appetite stimulant, digestive stimulant, antiseptic
Cumin	Seed	Cuminaldehyde	Digestive stimulant, carminative
Thyme	Whole plant	Thymol, carvacrol	Digestive stimulant, antiseptic, antioxidant
Mint	Leaf	Menthol	Appetite stimulant, digestive stimulant, antiseptic
Garlic	Bulb	Allicin	Digestive stimulant, antiseptic
Cinnamon	Bark	Cinnamaldehyde	Appetite stimulant, digestive stimulant, antiseptic
Ginger	Rhizoma	Zingerone	Digestive stimulant

3.2. Properties and Effects of Essential Oils

Essential (volatile) oils are compounds obtained from medicinal and aromatic plants, typically found in liquid form, which can crystallize at room temperature and are volatile with strong odors. Essential oils have a highly dense and complex structure. They are mostly colorless or light yellow, and the characteristic scent of many plants originates from these oils (Yeşilbağ, 2007; Güven, 2021; Okey, 2023). These oils are obtained from the flowers, buds, leaves, branches, wood, fruits, and roots of plants through distillation and extraction methods. They possess antiseptic, antioxidant, digestive stimulant, antimicrobial, enzymatic, anti-rheumatic, diuretic, anti-inflammatory, and disinfectant properties. The primary effects attributed to essential oils include the increased release of digestive enzymes and the reduced availability of nutrients for pathogenic gut bacteria (Okey, 2023). It is reported that approximately one-third of the 300 plant families in nature contain essential oils (Yeşilbağ, 2007; Güven, 2021). The antimicrobial mechanisms or properties of essential oils are not fully determined, but it is suggested that they increase the lipid solubility of the bacterial cell membrane surface, leading to the rupture and disintegration of the bacterial outer membrane (Dorman & Deans, 2000; Kırkpınar et al., 2011). Some volatile oils, such as terpenoids and phenylpropanoids, are reported to have strong antimicrobial effects against *Clostridium perfringens* and *E. coli* by penetrating bacterial cells using their lipolytic and chemical properties (Okey, 2023).

4. Purposes of Use and Effects of Medicinal and Aromatic Plants

In high-income countries, the use of medicinal and aromatic plants (MAPs) in humans has increased again, bringing their use in the form of natural herbal medicines to the forefront. MAPs have become industrial products in fields such as phytotherapy, medical and veterinary applications, aromatherapy, nutraceuticals, cosmeceuticals, and animal welfare. These innovative applications, which add value, have enabled the use of MAPs in functional foods, livestock, and agriculture (plant protection). Additionally, considering that more than half of the existing medical drugs are derived from plants,

even though the pharmaceutical industry focuses on developing new drugs, natural products will continue to be an important source for new compounds (Arslan et al., 2021).

MAPs contain secondary metabolites such as tannins, saponins, flavonoids, and essential oils, and therefore have found wide usage in sectors such as cosmetics, perfumes, food, and medicine, in addition to adding flavor, aroma, and color to foods since ancient times (Arslan et al., 2021; Alem, 2024). In poultry farming, herbal extracts and essential oils are used to prevent physiological stress in organs and cells due to various stress factors such as stocking density and heat stress (Okey, 2023; Öztürk Aydın & Cengiz, 2023). Moreover, in recent years, they have been widely used in poultry nutrition to enhance flavor, increase efficiency, prevent lipid oxidation, stimulate digestive secretions, improve nutrient digestibility and absorption, promote gastrointestinal microorganisms, strengthen the immune system, and for their antibacterial, coccidiostatic, anthelmintic, antiviral, anti-inflammatory, antioxidant effects, and growth-promoting potential (Aydın, 2023; Alem, 2024).

4.1. Effects of Antibacterial, Antiparasitic and Antifungal

Many researchers have reported that plant extracts or essential oils have strong antimicrobial effects and can be used as alternatives to antibiotics both as feed additives (FAs) and for therapeutic purposes in studies conducted with various animal species (Dorman & Deans, 2000; Çimrin & Demirel, 2016). Many medicinal and aromatic plants (MAPs) contain flavonoid additives with antimicrobial effects, such as baicalein, limonene, cinnamaldehyde, carvacrol, or eugenol, and are effective against microorganisms such as *Salmonella* sp., *E. coli*, *Streptococcus* sp., and *Staphylococcus* sp., as well as having antifungal properties against *Candida albicans* (Alem, 2024). Basmacıoğlu-Malayoğlu et al. (2011) reported in their study that essential oils obtained from cumin, bay leaf, clove, rosemary, anise, and thyme have antimicrobial effects on *Staphylococcus aureus*, *Salmonella typhimurium*, and *E. coli*. Aloe vera has been reported to be a plant with antibacterial and antiprotozoal properties, particularly aiding in the control of coccidiosis in poultry, and contains flavonoids and genes with anti-edema effects in acute irritation (Misra et al., 2018). Another study reported that aloe vera herbal products help combat bacteria and viruses and increase antibody titers against Newcastle disease and coccidiosis in broilers (Akram et al., 2019). Babacan et al. (2012) reported that in the first protocol, disc diffusion method included antibiograms discs with different concentrations of oregano extract were used. Zone diameters were measured in 1/10 oregano concentrations to be 15, 19 and 16 mm for *Salmonella gallinarum, Salmonella enteritidis* and *Salmonella typhimurium*, respectively. This study declared that in the second protocol oregano extract with different concentrations (20 and 30 µl/ml) were added into medium content and bacterial growth were evaluated. Colony counts for S. tyhphimurium and S. enteriditis were 952; 536 and 1600; 440 in 20 and 30 µl/ml concentrations of oregano extract, respectively. Babacan et al. (2012) reported that oregano extract had antibacterial effect on *Salmonella* serotypes according to their results.

4.2. Antioxidant Effects

Antioxidants are substances that delay and prevent lipid oxidation, and when added to food, they reduce spoilage, prevent the formation of unsafe oxidation products, and preserve nutritional quality (Alem, 2024). They also play a role in preventing oxidative stress in both animals and plants (Sordillo, 2013; Zahrazadeh et al., 2018; Öner, 2023). A study (Huang et al., 2021) reported that natural extracts exhibit antioxidant effects by increasing the expression of antioxidant proteins heme oxygenase-1, superoxide dismutase (SOD), and catalase.

4.3. Effects of Anti-inflammatory and Immune-Stimulant

The composition of nutrients can directly affect the immune responses of chicks. The systemic immune system is strongly regulated by gut-associated lymphoid tissue (Rafeeq et al., 2023). Essential oils can strengthen the immune system and positively affect animals by regulating the duodenal mucosa. Natural plants that regulate the immune system can be used as alternatives to standard chemotherapy for disorders such as immunodeficiency (Güven, 2021). Phenols, terpenoids, and flavonoids are the main anti-inflammatory secondary metabolites. Extracts of red pepper, cinnamon, black pepper, ginger, clove, nutmeg, turmeric, mint, and cumin were reported to have anti-inflammatory properties (Jalal et al., 2019). Plants such as echinacea, licorice, garlic, and cat's claw contain chemical substances that stimulate the immune system. These plants can increase the number of lymphocytes and macrophages, stimulate phagocytosis, and promote interferon production (Güven, 2021).

4.4. Effects on Growth Performance

Flavors can make feeds more attractive. It is reported that feed intake is encouraged not only by the taste of the feed but also by its smell, texture, color, and the balance of the compound feed content (Alem, 2024). A study on broilers (Kumar et al., 2014) found that black pepper improved the feed conversion ratio (FCR). Capsaicin has been found to increase the amount of pancreatic and intestinal enzymes in non-ruminant animals by increasing saliva secretion (producing amylase) (Costa et al., 2013). It has been reported that increasing amounts of garlic powder supplementation in compound feed increased the FCR in laying hens (Asrat et al., 2018).

In broilers, growth promotion, live weight gain (LWG), and FCR can be achieved through improved feed intake (FI) and feed utilization, inhibition of bacterial pathogens, and modulation of gut microflora that improves gut health. Moreover, improvements in nutrient digestion and absorption through enhanced gut functions, direct and indirect anabolic activity in target tissues, and activation of endocrine and antioxidative defense systems may be other principles of growth promotion by phytobiotics. However, the mechanisms underlying the effects of phytobiotics are not fully explained (Rafeeq et al., 2023).

The gut is an organ responsible for performing vital functions, including digestion and host defense. Any disruption in gut function can affect nutrient digestion, which can negatively impact the health and growth performance of chickens (Mishra & Jha, 2019; Abdul Basit et al., 2020). Intestinal crypts are thought to be the basis for the

differentiation of epithelial cells of intestinal villi. Additionally, the depth of the crypts is directly related to the rotation of epithelial cells. Deeper crypts reflect increased cell turnover and require more energy to maintain normal gut function in broilers (Abdul Basit et al., 2020). Current research results show that phytobiotics have beneficial effects on intestinal crypts, making them shallower, which indicates a healthy gut. The presence of shallow crypts means reduced cell turnover and, consequently, reduced energy use, which can instead be used for the growth processes of broilers (Abdul Basit et al., 2020). Increased height of intestinal villi and decreased depth of intestinal crypts enhanced the absorption capacity of the small intestine. Longer intestinal villi prevent faster passage of food and increase nutrient intake, leading to increased poultry productivity and FCR (Ortatatlı et al., 2005; Tavangar et al., 2021). Studies have shown that the use of ginger and green tea in the compound feed of chickens increases the size of villi, leading to increased surface area for nutrient absorption and cell division in various parts of the intestine, and reduced risk of pathogenic microbiota (Gadang et al., 2008; Gilani et al., 2021).

5. Use in Poultry Nutrition

In the last few decades, medicinal and aromatic plants (MAPs) have been widely used in poultry compound feeds in many countries (Yeşilbağ, 2007). The use of herbal extracts and essential oils in poultry helps animals cope with stress factors such as stocking density and heat stress, increases the number of beneficial microorganisms in the digestive tract, and improves feed conversion ratio (FCR) (Gürsoy, 2021; Aydın, 2023; Okey, 2023). Additionally, it is reported that the phenolic compounds in herbal extracts enhance oxidative stability and prevent the adverse effects of stress (Aydın, 2023).

Since the immune systems of chicks hatched from eggs are not fully developed, proper nutrition in the early stages is extremely important. Therefore, it has been reported that adding herbal extracts and essential oils to poultry rations during the early development stage is more beneficial (Kahraman, 2009). This can promote feed intake (FI), improve live weight (LW), live weight gain (LWG), and FCR, and activate digestive enzymes (Gürsoy, 2021). Additionally, this can lead to improvements in carcass quality and a reduction in mortality rates (Yeşilbağ, 2007). There are numerous studies on the use of MAPs in poultry.

In a study by Şahin et al. (2012), echinacea (1 and 5 g/kg) was added to quail feeds. They reported that these additions had no effect on LW, LWG, FI, FCR, and carcass yield. In a study on Japanese quails exposed to cold stress (İflazoğlu et al., 2015), the effects of saponin-enriched soapwort extract added to the ration on performance, some carcass characteristics, blood parameters, and mortality rate were examined. No differences were found between the groups in terms of performance, carcass characteristics, mortality rate, low-density lipoprotein (LDL), total cholesterol, alanine aminotransferase (ALT), and aspartate aminotransferase (AST) levels.

In a study on quails using juniper oil as a natural antioxidant (Yeşilbağ, 2018), the effects of this oil on growth performance were investigated. It was reported that live weight gain and carcass weight increased, and juniper oil could be considered a natural

antioxidant to improve performance. In a study by Saraç (2019), it was reported that thyme (*Origanum onites*) essential oil (0, 100, 200, and 400 ppm) did not affect performance parameters, serum biochemical and antioxidant values, and carcass yield in broiler compound feeds. In a study by Jobe et al. (2019) to determine the effects of different stocking densities (5, 10, 20 m^2/animal) and different ratios of senna extract (0, 50, 200, 500 mg/kg) on performance and oxidative stress in chickens, it was reported that FI was lower in the group with high stocking density. In the group with 500 mg/kg senna extract, growth performance decreased, and oxidative stress was reduced.

In a study by Daş et al. (2020), the effects of adding mint oil (0%, 0.1%, 0.2%, and 0.3%) to quail compound feeds on meat quality, fattening performance, carcass composition, and oxidative stress parameters were investigated. It was reported that performance parameters (LW, LWG, FI, FCR), carcass composition, and meat quality parameters (carcass color-pH) were not affected, and there were no differences between the groups ($P>0.05$). In a study by Reda et al. (2021) on quails, the effects of licorice (Glycyrrhiza glabra) (0, 250, 500, 750, and 1000 mg/kg) on performance parameters (LW, LWG, FI, FCR), oxidative status, immunity, and lipid profile were examined. It was found that performance values were best in the groups with 750 and 1000 mg/kg licorice. Additionally, the group with 750 mg/kg licorice had higher total protein and globulin levels, while LDH, total cholesterol, triglyceride, and LDL values were lower. Compared to the control group, serum malondialdehyde (MDA) levels decreased, while superoxide dismutase (SOD), tricarboxylic acid (TAC), immunoglobulin G, and M increased.

6. Conclusion

Projections for poultry meat and egg consumption indicate that demand will continue to increase daily. The conscious consumer is interested in purchasing the highest quality products. Production conditions, including feed quality, naturalness, and welfare levels, are expressed as important criteria for this consumer group. Consequently, the use of medicinal and aromatic plants and the extracts and essential oils derived from them will become an increasingly widespread trend in societies, and animal nutrition will also take its necessary share from this change. After the ban on the use of antibiotics as feed additives in animals, it will be inevitable to permanently add essential oils and plant extracts to poultry compound feeds as natural and health-enhancing additives. Today, the popularity of medicinal and aromatic plants is also increasing due to their antimicrobial, antioxidant, growth-promoting, immunostimulant, flavoring, and preservative effects. It is also inevitable that these plants will provide new perspectives in the nutrition of both humans and animals due to their positive effects on poultry health and their many functional properties. However, there are still some gaps in the mechanisms related to the beneficial effects of herbal extract or essential oil supplements in poultry farming and in determining effective doses. Therefore, future studies should investigate all the mechanisms of action of effective extracts and oils obtained from medicinal and aromatic plants in poultry and develop these products.

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Author Contribution

Y.I.: Writing the article and literature research.
T.T.: Literature research and writing the article.
O.B.: Literature research and writing the article
The authors declare that they have made equal contributions to the study on the above-mentioned topics.

Conflict of Interest Declaration Information

There is no conflict of interest.

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DÜZCE ÜNİVERSİTESİ
Review
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A systematic review on phytogenic feed supplements on the nutritive effects, physiological responses and reproductive parameters in rabbits

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ABSTRACT

The tropics, particularly Nigeria, have been plagued by reduced meat production, antibiotic resistance, lipid peroxidation of meat and meat products, and subpar animal performance. The health and agricultural sectors have been severely impacted by the food crisis, the risk of farmers and animal producers not adhering to antibiotic withdrawal periods, and the high temperatures experienced in the tropics. Over time, antibiotic resistance causes cancer in the end users. On the other hand, meat degradation or spoiling has been linked to lipid peroxidation, which is brought on by high temperatures that create oxidative stress conditions. This paper looks at the basic issues that rabbit farmers face as well as the beneficial solutions that may be implemented through the administration of essential oils and phytogenic feed supplements, as well as the effects these treatments have on various physiological, reproductive, and nutritional parameters. The study used a qualitative analysis approach and drew on secondary sources, including internet publications, textbooks, and journals. Phytogenic supplementation has been found to promptly enhance consumer health and increase animal output by improving production indices and providing a suitable remedy to the challenges associated with antibiotic resistance and lipid peroxidation brought on by climate change.

Tavşanlarda fitojenik yem takviyelerinin besleyici etkileri, fizyolojik tepkileri ve üreme parametreleri üzerine sistematik bir inceleme

MAKALE BİLGİSİ

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ÖZET

Tropikal bölgeler, özellikle Nijerya, azalan et üretimi, antibiyotik direnci, et ve et ürünlerinde lipid peroksidasyonu ve düşük hayvan performansı gibi sorunlarla karşı karşıyadır. Gıda krizi, çiftçilerin ve hayvan üreticilerinin antibiyotik çekilme sürelerine uymama riski ve tropik bölgelerdeki yüksek sıcaklıklar, sağlık ve tarım sektörlerini ciddi şekilde etkilemektedir. Zamanla, antibiyotik direnci nihai tüketicilerde kansere yol açabilir. Öte yandan, yüksek sıcaklıkların oksidatif stres koşulları yaratması nedeniyle ortaya çıkan lipid peroksidasyonu, etin bozulmasıyla ilişkilendirilmiştir. Bu makale, tavşan yetiştiricilerinin karşılaştığı temel sorunları ve bu sorunlara esansiyel yağlar ile fitojenik yem takviyeleri yoluyla uygulanabilecek faydalı çözümleri ele almakta ve bu uygulamaların çeşitli fizyolojik, üreme ve beslenme parametreleri üzerindeki etkilerini incelemektedir. Çalışma, nitel analiz yaklaşımı kullanılarak gerçekleştirilmiş olup, internet yayınları, ders kitapları ve akademik dergiler gibi ikincil kaynaklardan yararlanılmıştır. Fitojenik takviyelerin, üretim parametrelerini iyileştirerek hayvan verimliliğini artırdığı, antibiyotik direnci ve iklim değişikliğinin neden olduğu lipid peroksidasyonuna karşı etkili bir çözüm sunduğu ve böylece tüketici sağlığını hızla iyileştirdiği bulunmuştur.

1. Introduction

The demand for animal protein is steadily increasing as a result of the world's population expansion, rising incomes, and shifting consumer tastes (Anaso 2023a; FAO, 2009). The severe meat shortage in Nigeria brought on by farmer-herder conflicts, the

global pandemic, and unfavorable economic policies has forced livestock farmers to enhance the use of feed resources, the health of their animals, and the amount of meat that they produce (Emmanuel and Alhassan, 2025; Anaso et al., 2024b; Anaso et al., 2021). The cultivation of extremely productive monogastrates with brief production cycles, such as rabbits, can helps fill this gap (Anaso et al., 2024b). Because of their high fertility and quick growth rates, rabbits are a great source of animal-based meat and protein (Anaso, 2024; Dalle and Zotte, 2002). High-quality rabbit meat is distinguished by its low calorie content, sufficient animal protein, and polyunsaturated fatty acids (El-gogary et al., 2018). One of the main climatic factors that always affects rabbit farming and productivity is the tropical climate, which is characterized by high temperatures. Rabbits have a restricted ability to adapt to hot temperatures since they rely heavily on respiratory evaporation to regulate their body temperature (Mailafia et al., 2010). Oxidative stress causes lipid peroxidation, a significant issue in rabbit production that degrades the final product (meat) (El-gogary et al., 2018). Furthermore, because it produces malondialdehyde and other harmful chemicals, lipid oxidation has a negative effect on the quality of meat (Anaso, 2023b). According to reports, the latter has a detrimental effect on people's health (Koné et al., 2016; Cardinali et al., 2015). Other than antibiotics and ionophores, feed additives have recently been employed to improve rabbit productivity and reproductive performance as well as feed utilization (Ismail et al., 2019; Tufarelli et al., 2017; Dhama et al., 2015;). To increase feed efficiency and animal health, feed additives have been used in ruminant diets (Kholif et al., 2017, 2020; Morsy et al., 2018) and more recently in monogastric diets for horses (Elghandour et al., 2016; Elghandour et al., 2014) and rabbits (Abo Hafsa et al., 2016; Gado et al., 2016; Cervantes Valencia et al., 2015). In animal feed, feed additives like essential oils (EOs), spices, and herbs have been effectively used to reduce Pseudomonas species, Enterobacteriaceae, and total mesophilic aerobes (Tufarelli et al., 2017; Koné et al., 2016; Soultos et al., 2009). The threat of antibiotic-resistant bacteria and the recent prohibition of antibiotic growth promoters by several nations have forced the search for alternatives to increase animal productivity while reducing negative effects on human consumers. The use of phytogenics as alternative feed additives in animal nutrition has been the subject of much research as a result of this ban. Essential oils and other phytogenic materials are widely utilized in the food and feed industries and are usually thought to be safe. As a phytogenic feed ingredient, EOs' effects on livestock's intestinal health, antioxidant status, and antibacterial activity are thought to be crucial for biological processes (Ahmed & Abdallah, 2020). According to Miguel (2010), essential oils, also known as volatile oils, are mostly aromatic, oily liquids that are extracted through distillation from various plant components, including flowers, buds, seeds, leaves, twigs, bark, wood, fruits, and roots. These extracts are steam-volatile or, more accurately, organic solvents that have been employed for ages in a variety of cultures around the world. They are mostly recognized for their flavorful and fragrant qualities, as well as their ability to preserve food (Anaso, 2023b). Terpenes, alcohols, acetones, phenols, acids, aldehydes, and esters are among the many distinct chemicals that are typically included in EOs (Negi, 2012). These compounds can defend against attacks by

bacteria, fungi, or insects. Numerous beneficial impacts on feed utilization, animal health, and rabbit live performance have been documented by studies on EOs (Celia et al., 2016).

According to Anaso (2023a) and Anaso (2023b), using essential oils and phytogenics as supplements or administrations can help Nigeria address the issues of antibiotic resistance and lipid peroxidation, which causes meat to spoil. Essential oils and phytogenic supplements can be used in conjunction with antibiotics to provide improved results and reduce the risk of noncompliance with withdrawal periods (Anaso, 2023a). The administration of essential oils and phytogenics as supplements to livestock diets has been shown to increase productivity without compromising health in numerous empirical studies (Ceraulo et al., 2022; Ilyas & Sapuan, 2020).

2. Literature Review

The following are the factors of essential oil supplementation to be considered:

I. Effect of phytogenic supplements and essential oil on voluntary feed intake, digestibility and body weight gain
II. Effect of phytogenic supplements and essential oil on apparent digestibility and nutrient utilization
III. Effect of phytogenic supplements and essential oil on Blood profile and oxidative stress indices
IV. Effect of phytogenic supplements and essential oils on semen characteristics
V. Effect of phytogenic supplements and essential oils on body thermoregulatory parameters
VI. Effect of phytogenic supplements and essential oil on carcass characteristics and meat quality
VII. Effect of phytogenic supplements and essential oils on caecal microbial and fermentation profile

2.1. Effects of Phytogenic Supplements on Voluntary Feed Intake, Digestibility and Body Weight Gain

Anaso et al. (2025b) in an experiment using forty-five clinically healthy weaned male Dutch rabbits of about five weeks of age were used in a 12-week experiment. The rabbits were randomly divided into three treatment groups, with fifteen rabbits per group, and balanced for their body weight such that rabbits in each group had similar average initial body weight (BW) of 262.89 ± 22.36 g in a completely randomised design. Treatment 1 was a basal control diet without *Piliostigma thonningii* essential oil (PEO) supplementation (T1). In treatments 2 and 3, the basal control diet was supplemented with 2 ml PEO/kg diet (T2) and 4 ml PEO/kg diet (T3), respectively. Anaso et al. (2025b) reported that supplementation with PEO significantly improved feed and nutrient intake in rabbits. In their study, which examined the effects of PEO on nutrient intake, serum biochemical parameters, and immune/oxidative stress responses, a progressive increase was observed across treatment groups in the intake of dry matter (DM: 28.32–40.80 g/day), crude protein (CP: 4.68–6.74 g/day), ether extract (EE: 0.64–0.92 g/day), crude fibre (3.77–5.42 g/day), neutral detergent fibre (NDF: 9.07–13.08 g/day), acid detergent

fibre (ADF: 5.30–7.63 g/day), ash (2.67–3.85 g/day), organic matter (OM: 25.64–36.95 g/day), and nitrogen-free extract (NFE: 16.56–23.85 g/day). These parameters showed statistically significant differences ($P < 0.05$), with the highest values recorded in the T3 group and the lowest in the T1 group. The authors attributed these improvements to the organoleptic properties of PEO, which is a monoterpene hydrocarbon containing bioactive compounds such as β-myrcene and limonene. These compounds are believed to enhance feed palatability, particularly at higher inclusion levels, thereby promoting increased feed consumption in the T3 group.

According to El-Nomeary et al. (2020), a number of essential oils, including juniper, cinnamon, and garlic, were added to the basic diet as feed additives at a rate of 0.5 milliliters per kilogram of rabbits' food. This supplementation did not negatively impact the rabbit's overall performance, however it positively impacted on its growth and digestion indicated by improved the feed conversion ratio (FCR) in experimental rabbits. About 72 post weaned male New Zealand White rabbits were used in the experiment. The results highlighted garlic essential oil increased the total body weight gain and average daily weight gain by approximately 12.4% compared to the control group.

Similarly, Ahmed et al. (2019) found that rabbits administered dietary supplements of phytogenics and Eos' such thyme oil (THY) and betaine (BET) had considerably higher digestible energy and dry matter digestibility.

Ahmed et al. (2019) conducted an eight-week experiment with 72 growing New Zealand white (NZW) male rabbits divided into 9 experimental groups. While the other groups were given the same basal diet supplemented with 1500 mg BET (T2), 750 mg BET (T3), 1000 mg THY (T4), 500 mg THY (T5), 1500 mg BET and 1000 mg THY (T6), 1500 mg BET and 500 mg THY (T7), 750 mg BET and 1000 mg THY (T8), and 750 mg BET and 500 mg THY (T9), the control group was given a basal diet without supplementation (T1). The findings also demonstrated that rabbits fed T2, T3, T4, T6, and T9 diets had significantly higher digestible energy and feed dry matter digestibility. Unlike El-Nomeary et al. (2020), they found that rabbits fed the T4, T5, T7, T8, and T9 diets had significantly lower levels of ammonia nitrogen and total volatile fatty acids in their cecum content when compared to those fed the control diet (T1). It was determined that to increase the feed utilization, growth performance parameters, and overall health of NZW rabbits, dietary supplementation with 1500 mg of betaine or 1000 mg of thyme oil/kg diet, or a combination of the two, at the same levels, is advised.

By examining the effects of supplemental dietary extra virgin olive oil (EVOO), gallic acid (GA), or lemongrass essential oil (LGEO) on growth performance and nutrient digestibility, Al-Sagheer et al. (2017) came to the conclusion that adding these oils to a growing rabbit's diet could be an effective way to mitigate the negative effects of heat stress load on performance, nutrient digestibility, and nutrient digestibility. According to Ahmed et al. (2018), adding up to 100 mg of thyme essential oil (EO) to a rabbit's

ration together with 1.50 g of olive oil can be a useful feed addition for young or growing rabbits to enhance their performance in hot and stressful environments.

2.2. Effects of Phytogenic Supplements on Apparent Digestibility and Nutrient Utilization

The bioactive substances in EOs have not yet described their mode of action (MOA) well. However, the MOA of EOs on the digestion of nutrients has been explained by several different mechanisms. According to several writers, using EOs might increase the activity of digestive enzymes including trypsin and amylase (Jang et al., 2004). Other authors have suggested that EOs can also increase the production and secretion of bile acids (Platel and Srinivasan, 2004). Dry matter (DM) digestion was unaffected by the addition of varying experimental amounts of EOs to the laying hen's diet, according to Ding et al. (2017).

In comparison to the control group, Anaso et al. (2025d) found that rabbits supplemented with PEO (T2 and T3) had similar and higher ($P < 0.05$) digestibility in terms of dry matter digestibility (60.10 – 70.98%), crude protein digestibility (68.72 – 76.50%), crude fiber digestibility (34.69 – 46.03%), NDF digestibility (38.09 – 54.26%), and organic matter digestibility (58.35 – 66.39%). Compared to T1 and T2, which exhibited comparable digestibility ($P> 0.05$), T3's ether extract digestibility (53.92 – 73.26%) was higher ($P < 0.05$). T3 had the highest ADF digestibility (29.22–45.37%), whereas T1 had the lowest ($P < 0.05$). However, T1 and T2 and T2 and T3 were equal ($P > 0.05$). PEO supplementation was found to improve growth performance, feed utilization efficiency, nutrient digestibility, and the caecal fermentation characteristics of rabbits.

According to Radwan Nadia et al. (2008), the digestibility of organic matter (OM) was unaffected by the addition of 0.5% to 1.0% of essential oils (EOs) from thyme, oregano, rosemary, or curcuma to the diet of laying hens. According to Yu et al. (2018), laying hens' ability to digest OM was enhanced by the addition of varying amounts of anise oil (200, 400, and 600 mg/kg). However, other studies have found that adding EOs to laying hens boosted their crude protein (CP) digestibility (Ding et al., 2017 and Yu et al., 2018). However, no effect was discovered in another study (Radwan et al., 2008). In contrast to the control, Arslan et al. (2022) found that the addition of EOs at 100 or 200 mg/kg improved the digestion of dry matter, organic matter, and crude protein.

2.3. Effects of Phytogenic Supplements on Blood Profile and Oxidative Stress Indices

The hematological parameters of the rabbits fed a diet supplemented with PEO are shown by Anaso et al. (2024c). According to the research, across treatment groups, Packed call volume (PCV) ranged from 38.00 to 49.95%, Hemoglobin (Hb) from 13.13 to 18.50 g/dL, Red blood cell volume (RBC) from 11.87 to 17.52 $x10^6$/L, White blood cell volume (WBC) from 5.60 to 8.77 $x10^9$/L, Mean corpuscular hemoglobin concentration (MCHC) from 29.80 to 35.91%, and neutrophil from 22.45 to 32.78% for T3 > T2 > T1 ($P < 0.05$). T1 had lower values ($P < 0.05$) than T2 and T3, which had similar values ($P >$

0.05). The Mean corpuscular volume (MCV), Mean corpuscular hemoglobin (MCH), lymphocytes, monocytes, and platelets were 58.02, 64.02, and 65.12 fl; 17.46, 22.45, and 23.67 pg, 49.80, 70.40, and 73.07%; 1.28, 2.40, and 2.72% and 340.16, 530.74, and 580.11 x10^3/uL for T1, T2, and T3, respectively. Eosinophil levels in T3 were greater ($P < 0.05$) than in T1 and T2, which were comparable ($P > 0.05$), and ranged from 1.36 to 2.22%. The neutrophil/lymphocyte ratio (0.41 - 0.45) was similar ($P > 0.05$) between T1 and T2, as well as between T2 and T3; however, it was greater ($P < 0.05$) in T3 than in T1. Likewise, the serum biochemical characteristics of rabbits given PEO are displayed by Anaso et al. (2025). With T1 having the lower value ($P < 0.05$) than T2 and T3, which had similar ($P > 0.05$) values, the trends for serum total protein (4.12 – 7.61 g/dL), serum albumin (2.40 – 4.77 g/dL), globulin (1.72 – 2.84 g/dL), glucose (104.05 – 148.58 mg/dL), and high-density lipoprotein (19.07 – 26.11 mg/dL) were similar. Serum cholesterol was lower in T2 and T3 ($P < 0.05$) than in T1, with a range of 24.18 mg/dL in T3 to 52.50 mg/dL in T1. Compared to T2 and T3, which were not substantially impacted ($P > 0.05$), T1 had increased levels of low-density lipoprotein (42.37 – 71.91 mg/dL), triglycerides (64.74 – 120.70 mg/dL), AST (35.16 – 60.16 u/L), ALT (46.17 – 61.29 u/L), and ALP (6.44 – 11.27 u/L) ($P < 0.05$). Total bilirubin and direct bilirubin were 4.43, 4.73, and 4.88 µmol/L for T2, T3, and T1, and 0.66, 0.73, and 0.78 µmol/L for T3, T1, and T2, respectively. In contrast, the mean values for uric acid, creatinine, and albumin:globulin ratio were 3.43, 3.47, and 3.64 mg/dL, 2.14, 2.25, and 2.30 mg/dL, and 0.96, 1.13, and 1.22 g/dL for T1, T2, and T3, respectively. There was no difference between the treatments ($P> 0.05$). According to Anaso et al. (2025), supplementing the rabbits with *P. thonningii* essential oil improved their immunological response, oxidative status, and serum blood profile.

According to Elghalid et al. (2020), administering lower (LA) and higher (HA) doses of a recently created blend of herbal plants and spices enhanced with unique extracts and essential oils reduced blood cholesterol, triglycerides, and low-density lipoproteins. In contrast, the LA treatment raised total antioxidant capacity and high-density lipoproteins while lowering malondialdehyde in comparison to the control treatment. Three groups of thirty rabbits each were randomly assigned to a basal diet without additives (Control rabbits) or supplemented with 0.5 mL (LA) or 1 mL (HA) of the additives mixture per litre of drinking water. The experiment was carried out using precisely 90 weaned unsexed V-Line rabbits, weighing 668.7±8.2g and aged 30±1days. The effectiveness of rosemary essential oil (REO) as a feed addition on the growth and blood components of growing NZW rabbits was also described by El-Gogary et al. (2018). Four groups of specifically thirty-six NZW were created: three treated groups and one control group. Groups 2, 3, and 4 received feeds supplemented with 0.25, 0.50, and 0.75 g/kg REO, respectively, whereas the control was given the basal diet. Therefore, it was determined that REO at 0.5 g/kg of diet has a positive effect on rabbits' antioxidant state and immunity. A total of seventy NZW male rabbits at approximately five weeks of age with similar or equal body weight were randomly assigned into seven treatment groups (10 rabbits in each group), and Bassiony et al. (2015) similarly reported a significant improvement in some blood hematology WBC, RBC, Hb, and

lymphocytes when compared to the control. As a control, group one was given the basic diet without any supplements. Groups two, three, and four were given the basic diet plus 50, 100, and 200 mg of cinnamon aldehyde per kilogram of food, respectively. 50, 100, and 200 mg of thyme/kg food were added to the basic diet for groups five, six, and seven, respectively. Similar findings were reached by Abdelnour et al. (2018), who used 140 male New Zealand white rabbits that were growing weaned and found that dietary red pepper oil (RPO) or black pepper oil (BPO) supplementation greatly enhanced rabbit growth, improved immunity parameters, and enhanced antioxidant activity. Seven groups, each consisting of five rabbits and four rooms, were randomly selected from among the rabbits. At 13 weeks of age, the trial came to an end after eight weeks. The following dietary interventions were employed: C: control; RPO 0.5: 0.5 g RPO/kg food and basal diet; RPO1.0: 1.0 g RPO/kg diet; RPO1.5: 1.5 g RPO/kg diet; BPO0.5: 0.5 g BPO/kg diet; BPO1.0: 1.0 g BPO/kg diet; and BPO1.5: 1.5 g BPO/kg diet.

2.4. Effects of Phytogenic Supplements on Semen and Seminal Morphological Characteristics

As demonstrated by the significantly greater seminal characteristics or parameters, such as semen volume, motility, concentration, normal cells and life cell ratio, testis length, weight, volume, and epididymis head weight, Anaso et al. (2023) found that the inclusion of PEO in rabbits' diets was advantageous and did not pose any risks. Comparably, the results of Anaso et al. (2024a) demonstrate that the inclusion of PEO in rabbits' diet was advantageous and did not offer any risks, as evidenced by the significantly improved right and left testis length, weight, and volume.

According to El-Ratel et al. (2021), rabbit bucks randomly assigned to four experimental treatments of exactly ten rabbits each showed improvements in libido, vitality, sperm cell concentration, sperm outputs, intact acrosome and membrane integrity, progressive motility, and fertility when supplemented with extra virgin olive oil (EVOO), betaine (BET), or ginger (GIN). The first treatment served as the control group and was fed the commercial pellet diet (CPD) without any supplements. For three consecutive months throughout the summer (warm) season, the other three treatments were given the same basal CPD augmented with 300 milligrams of EVOO, 1000 mg of BET, and 200 mg of GIN per kilogram of diet.

In line with earlier research, Ahmed and Abdallah (2020) found that, after the conclusion of treatments, thyme essential oil (TEO) improved sperm motility, viability, and ejaculate volume in comparison to the positive control (PC) and negative control (NC) groups. In a study employing approximately 150 male Californian rabbits that were 70 days old and divided into five dietary treatments-a basal diet as a negative control, a basal diet supplemented with an antibiotic as a positive control, and a basal diet supplemented with 60, 120, or 180 mg/kg of TEO-it was found that abnormal sperm was significantly decreased with increasing TEO when compared to PC and NC groups. The duration of the experiment was roughly sixty days.

2.5. Effect of Phytogenic Supplements on Body Thermoregulatory Parameters of Rabbits

According to Anaso and Alagbe (2025), supplementing with *P. thonningii* essential oil improved body thermoregulation by lowering the experimental rabbits' serum mineral profile and temperature.

Extra virgin olive oil, betaine, lemongrass essential oil, gallic acid, vitamin C, and vitamin E supplements were found to have beneficial and mitigating effects on the rearing and growth of rabbits under extreme heat load in terms of decreased body temperatures (Daader et al., 2018). In this trial, rabbits were given either a diet that contained no supplements (the control group) or a supplement that contained either 200 mg of vitamin E, 1000 mg of betaine, 400 mg of lemongrass essential oil, 500 mg of garlic acid, 15 g of extra virgin olive oil, or 500 mg of vitamin C per kilogram of the basal diet.

2.6. Effect of Phytogenic Supplements on Carcass Characteristics and Meat Quality

Benlemlih et al. (2014) conducted a study to examine the effects of antibiotics and dietary supplements of thyme and fennel essential oils on rabbits' caecal microbiota and zootechnical parameters. About 40 white New Zealand rabbits that had just been weaned and were about 35 days old were split up into two groups and given two different dietary treatments: EOFT (a diet that included essential oil of *Feoniculum vulgaris* and *Thymus capitatus*) and OTC (a diet that included oxytetracycline in drinking water). After roughly 25 days of the experiment, the OTC group's mean carcass yield was higher than the EOFT group's. In contrast to the findings of Benlemlih et al. (2014), Denli et al. (2004) found no impact on carcass weight or carcass yield when quail were fed thyme essential oil. In a similar vein, Bassiony et al. (2015) investigated and assessed the impact of varying concentrations of cinnamaldehyde and thymol as essential oil bioactive compounds on growth performance, carcass traits, certain blood and caecum characteristics, and the economic efficiency of growing rabbits. They found that dietary treatments had no discernible effects on the relative weight of the carcass, digestive tract, abdominal fat, and caecum weight and length.

According to Rhouma et al. (2018), who carried out a study to assess the impact of varying thymol concentrations on zootechnical performances, caecal microflora, and the quality of rabbit carcass during the summer, adding thymol to the diet had no discernible effect on carcass yields during this time. Anaso et al. (2024d) found that supplementing the experimental rabbits with *P. thonningii* essential oil improved their carcass characteristics. They found that the ideal supplementation level was 4 ml PEO/kg diet, which was more effective at increasing the dressing percentage without compromising the meat's organoleptic qualities.

2.7. Effect of Phytogenic Supplements on Microbial and Fermentation Profile

Studies are required to assess the efficacy of antibiotics and comprehend the mechanisms underlying bacterial resistance because the current growth of multidrug-resistant bacteria has presented a serious threat to public health in Nigeria and

throughout Africa (Anaso and Alhassan, 2025). In comparison to the control treatment, Elghalid et al. (2020) found that both higher and lower dose mixtures of herbal plants and spices enriched with special extracts and essential oil increased beneficial Lactobacillus spp. bacteria and decreased the concentrations of coliform bacteria and E. coli. They also found that the additives mixture improved feed conversion and daily gain and positively altered the caecal bacteria profile, with the lower dose of the phytogenic additives mixture having better results than the high dose. *P. thonningii* essential oil supplementation enhanced feed utilization, nutrient digestibility, growth performance, and decreased caecal pathogenic bacterial counts, all of which improved the experimental rabbits' health state, according to Anaso et al. (2025b). Similarly, Rhouma et al. (2018) shown that the quantity of *Lactobacilli* and *E. coli* is significantly impacted by the presence of thymol. In fact, the rabbits who received the two thymol dosages had more *Lactobacilli* than the control group. Furthermore, the quantity of *E. coli* in treatment one was decreased by this supplementation. Ninety rabbits (35 days old) were split up into three equal groups for this experiment: T: the thymol-free control group and the two thymol-containing groups (T1 and T2), which were given 200 and 300 g/T of thymol, respectively. From day 35 to day 77, duplicates of six rabbits were fed each of the three diets. However, Benlemlih et al. (2014) found no difference in the caecal counts of E. coli and *C. perfringens* between the OTC (diet with oxytetracycline in drinking water) and EOFT (diet with essential oil of *Feoniculum vulgaris* and *Thymus capitatus*) diets. 40 white New Zealand weaned rabbits (35 days old) were split into two groups and given the dietary treatments EOFT and OTC in this experiment.

3. Conclusion

Important bioactive substances with pharmacological actions and qualities, including antioxidant, antibacterial, and anti-inflammatory qualities, are included in phytogenic feed supplements that enhance rabbit growth performance, carcass features, caecal fermentation, feed and nutrient intake, nutrient digestibility, and feed utilization efficiency. By decreasing the number of harmful bacteria (*E. Coli*, *Coliform*, and *Streptococcus* spp.) and increasing the number of beneficial bacteria (*Lactobacillus* spp.), phytogenic feed supplements improve the caecal microbial profile of rabbits. They also lower rectal temperature while improving the rabbits' blood profile, oxidative status, and immune response. Additionally, supplementing the experimental rabbits' diet with phytogenic feed increases their capacity for reproduction.

4. Recommendations

All levels of government should support universities through agricultural research institutes, faculties of agriculture, and ministries of agriculture so that they can conduct additional research and work with veterinary pharmaceutical companies on simple and inexpensive extraction methods, which will increase production levels. Legislation prohibiting the illegal use of antibiotics should be a top priority for governments at all levels. This is because essential oils and phytogenic feed ingredients can be used to increase animal output.

Conflict of Interest Declaration Information

There is no conflict of interest.

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