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FORECASTING HONEY PRODUCTION IN ROMANIA AND THE EUROPEAN UNION: ANALYSIS OF HISTORICAL TRENDS (1961-2022) AND PROJECTIONS UNTIL 2035

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Abstract

Honey production in Romania and the EU is essential for agriculture, food security, and economic sustainability. Romania, a leading producer, benefits from favourable conditions but faces challenges such as climate change, habitat loss, and market competition. This research analyses historical honey production trends and forecasts production until 2035 using FAOSTAT data and an exponential smoothing (ETS) model. Statistical evaluation confirms a strong predictive accuracy ($R^2 = 0.8918$), projecting Romania's honey production to reach 250,000–300,000 tonnes by 2035. While the outlook is positive, environmental and economic factors may influence actual trends. Sustainable beekeeping, policy support, and market strategies are crucial for ensuring long-term viability. Future research should integrate climate and economic variables to enhance predictive accuracy.

Key words**:** *honey production, forecasting, Romania, European Union, sustainability*

INTRODUCTION

Honey production in Romania and the European Union (EU) is crucial for agriculture and food security, enhancing the economy and promoting ecological balance through pollination. Along with countries like Spain, Hungary, and Germany, Romania is regarded as one of the top producers of honey in the EU. These nations all enjoy climates that are conducive to beekeeping [2, 3, 4]. The country's varied flora and conventional beekeeping methods resulted in numerous honey varieties, each possessing distinct flavours and health advantages, hence improving its marketability domestically and globally [25]. The significance of honey production beyond commercial worth; it is essential for agricultural sustainability. Honeybees are essential pollinators, and their contribution to pollination markedly enhances crop yields and biodiversity [26]. The reduction in bee numbers, attributable to factors such as pesticide application and habitat destruction, jeopardises food security, hence necessitating the preservation of beekeeping methods [11, 27]. The beekeeping sector in Romania bolsters the agricultural economy and serves as a source of income for numerous rural households, therefore aiding rural development and food security [25, 8, 14, 23]. Romania's honey production has experienced variability due to climatic shifts and environmental problems. Research demonstrates that honey produced in Romania typically exhibits high quality, characterised by minimal contaminants, including heavy metals and pesticide residues, in accordance

with EU food safety regulations [6, 10]. The European Union enforces rigorous standards for honey quality, encompassing restrictions on hydroxymethylfurfural (HMF), a key indicator of honey freshness and quality [30]. Adherence to these criteria is essential for preserving customer confidence and guaranteeing the health advantages linked to honey consumption [21, 15]. Consumer behaviour about honey in Romania illustrates a multifaceted terrain. Although Romania is a prominent honey producer, its consumption remains comparatively low relative to other European nations, due to cultural influences and insufficient awareness of its health advantages [22].

Demographic characteristics affecting honey intake encompass education level and age, with increased consumption rates noted among persons with higher levels of education. The health advantages of honey are extensively documented, with numerous research emphasising its antioxidant, antibacterial, and therapeutic properties [9,20]. Honey serves as both a natural sweetener and a potential treatment for several health issues, including respiratory and digestive problems [9]. Moreover, the therapeutic properties of honey, especially in traditional applications, highlight its cultural importance in Romania [24]. The trade dynamics inside the EU further impact honey production in Romania. The nation exports a substantial quantity of its honey, predominantly to other EU member states, so bolstering its economic viability [25]. Nonetheless, competition from imported honey, especially from non-EU nations, presents difficulties for local honey producers. The uniqueness of Romanian honey by branding and quality assurance can alleviate these obstacles and enhance the promotion of local products in the worldwide market [25,16]. Environmental conditions significantly influence honey production. The influence of climate change on floral availability and bee health is an increasing issue for beekeepers in Romania and throughout Europe [26]. Sustainable beekeeping practices, such as organic farming and minimising pesticide application, are crucial for the lasting viability of honey production [11].

Incorporating environmental sustainability into agricultural methods is essential for preserving honey production and ensuring food security.

This study aims to analyze historical honey production trends in Romania and the European Union and develop a predictive model to forecast production levels up to 2035, considering key environmental, economic, and agricultural factors.

MATERIALS AND METHODS

Data collection

The data used in this study was obtained from the FAOSTAT database, covering honey production statistics in Romania and the European Union from the earliest available records up to the year 2022. The dataset included annual production values measured in metric tons.

Data Preprocessing

Missing data points were filled using linear interpolation to maintain trend continuity.

In cases where duplicate records existed, values were aggregated using the average to obtain a single representative value for each year [11].

Forecasting Methodology

The forecasting of honey production up to 2035 was performed using Microsoft Excel, leveraging built-in time series forecasting tools.

The seasonality of the data was automatically detected, ensuring that recurring patterns were incorporated into the forecast.

The model accounted for trend, seasonality, and error components in the time series data.

Forecast Model Selection

The forecasting algorithm used exponential smoothing (ETS) with parameters Alpha (level), Beta (trend), and Gamma (seasonality) optimized based on historical data [11].

The forecast was extended until 2035, with a 95% confidence interval to assess prediction uncertainty.

Model Evaluation Metrics

The accuracy of the forecast was evaluated using, Mean Absolute Scaled Error (MASE),

Symmetric Mean Absolute Percentage Error (SMAPE), Mean Absolute Error (MAE), and Root Mean Square Error (RMSE).
These metrics were computed to assess the performance of the forecasting model and ensure reliability in the prediction results.

RESULTS AND DISCUSSIONS

The statistical assessment of the forecasting model for honey production in Romania offers significant insights into the precision and dependability of the predictions. The model employs smoothing parameters, specifically an Alpha value of 0.25, signifying that recent observations have a minor impact on the forecast. The Beta parameter is established at 0.00, indicating the model lacks a substantial long-term trend correction, whilst the Gamma value of 0.25 signifies the identification and integration of seasonal fluctuations with moderate emphasis. The parameter configurations indicate a reliable forecasting method that incorporates both level and seasonality, however, does not explicitly include trend dynamics.
Various error metrics were computed to evaluate the model's performance. The Mean Absolute Scaled Error (MASE) is 1.22, signifying that the forecast error marginally exceeds that of a naïve model, implying a relatively good forecasting method. The Symmetric Mean Absolute Percentage Error (SMAPE) is remarkably low at 0.06 (6%), indicating a high degree of accuracy and minimal divergence from actual data. The Mean Absolute Error (MAE) of 13,035.99 tonnes and the Root Mean Square Error (RMSE) of 17,698.47 tonnes offer additional insight into forecast accuracy, with RMSE highlighting greater variations due to its squared-error calculation. Although these values exhibit some variance, they remain within an acceptable range, so maintaining the trustworthiness of the projected production trends.
The statistical results support the reliability of the forecasting model, indicating that honey production in Romania is projected to exhibit a consistent increase trajectory. The minimal forecast errors and optimal smoothing parameter selections demonstrate that the model effectively captures production trends while accommodating mild seasonal fluctuations. Nevertheless, although the forecast exhibits considerable precision, external variables such as environmental alterations, climatic fluctuations, and economic circumstances may still influence actual production results. Consequently, ongoing surveillance and model modifications may be essential to enhance future forecasts and uphold predictive precision. The projection of honey production in Romania from 2022 to 2035, as depicted in the graph, demonstrates a consistent increase trajectory. The historical data, covering 1961 to 2022, indicates a steady rise in honey output, albeit with periodic volatility. The linear trend equation, $y = 2{,}615.7x + 86{,}262$, indicates that yearly honey output is increasing at an estimated rate of around 2,616 tonnes per year. The coefficient of determination, $R^2 = 0.8918$, indicates a robust connection between time and production, signifying that almost 89% of the variance in honey output can be accounted for by the linear trend.
The projected values shown in Figure 1, indicated by the prolonged dark green line past 2022, imply sustained rise in honey output. The confidence interval, depicted as coloured areas surrounding the projected numbers, offers an estimation of possible fluctuations in production levels. The narrow boundaries signify a high level of confidence in the predictions, hence enhancing the model's reliability. The projection indicates that by 2035, honey production in Romania is anticipated to attain roughly 250,000 to 300,000 tonnes, contingent upon external variables including environmental circumstances, beekeeping methodologies, and market demand.
The data indicates that honey production in Romania is increasing, bolstered by conducive beekeeping circumstances and consistent output trends. Nonetheless, although the projection indicates an optimistic perspective, external factors like as climate change, agricultural methodologies, and policy determinations may still affect actual output trends. Ongoing surveillance and

modifications to predictive models will be essential to enhance future forecasts and accommodate unexpected alterations in the business [5].

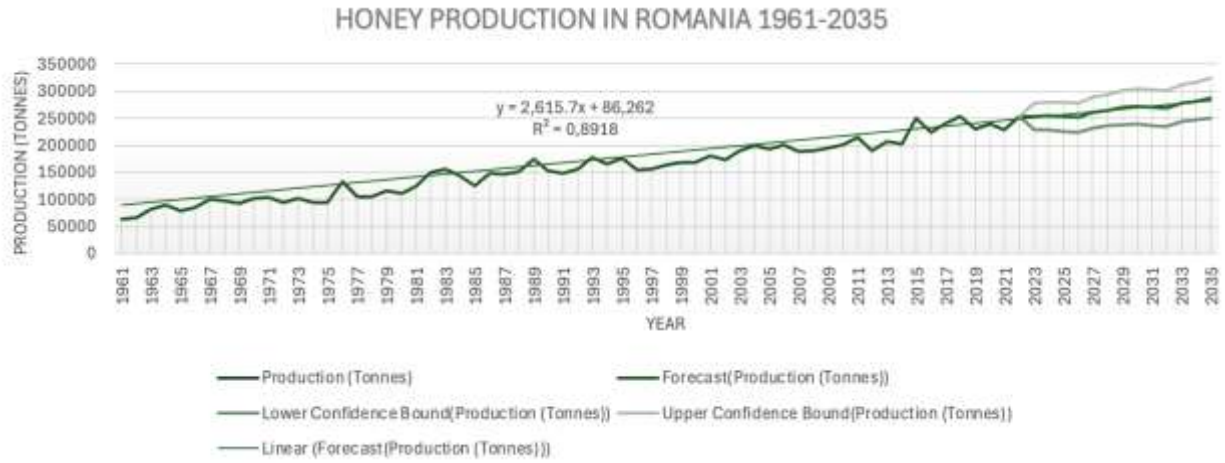

Fig. 1. Honey production forecast in Romania (1961-2035)
Source: FAOSTAT [13].

The statistical analysis of the forecast model for honey production in the European Union offers insights into the model's precision and predictive efficacy. The Alpha parameter, established at 0.25, signifies that current observations exert a moderate impact on the predicted values, indicating that the model incorporates recent trends without overly responding to short-term variations. The Beta parameter, noted as 0.00, indicates that the model lacks a substantial long-term trend correction, suggesting that the forecast relies predominantly on level and seasonal components rather than a defined trend. The Gamma value, set at 0.25, indicates the existence of seasonality in the dataset, attributing modest significance to seasonal fluctuations.

To assess the dependability of the forecast, various error metrics were examined. The Mean Absolute Scaled Error (MASE) is 1.22, showing that the forecast error is somewhat more than that of a naive benchmark model, reflecting a relatively accurate predictive performance. The Symmetric Mean Absolute Percentage Error (SMAPE) is 0.06 (6%), indicating a minimal percentage error and confirming that the model provides very precise forecasts in relation to actual output values. The Mean Absolute Error (MAE) is 13,035.99 tonnes, indicating that, on average, the forecast diverges from actual values by this magnitude. The Root Mean Square Error (RMSE) is 17,698.47 tonnes, indicating the range of mistakes, with more errors receiving more significant weight in the computation. The projection for honey production in the European Union from 2022 to 2035, as illustrated in Figure 2, shows a persistent increase trajectory. The historical data from 1961 to 2022 demonstrates a steady rise in honey output, albeit with occasional variations. The linear regression equation $y = 4,266.9x+1,551.2$ indicates an estimated annual increase in honey production of approximately 4,267 tonnes. The coefficient of determination ($R^2 = 0.918$) suggests a strong correlation between time and production levels, with 91.8% of the variation in honey output explained by the linear trend. This high predictive reliability supports the assumption that production will continue to grow under similar conditions.

The projected values for the period 2022–2035, depicted by the extended dark green line, demonstrate a consistent increase in production, underpinned by a comparatively small 95% confidence range, illustrated by the shaded areas. The projection indicates that by 2035, honey production in the European Union is anticipated to fluctuate between 250,000 and 300,000 tonnes, contingent upon external variables like climatic conditions, apicultural practices, and regulatory policies.

The existence of upper and lower confidence bounds signifies possible fluctuations; nonetheless, the model's robust correlation implies that departures from the anticipated trend are expected to be minimal.

The sustained rise in honey production within the EU corresponds with advancements in beekeeping methodologies, agricultural policies that bolster apiculture, and an escalating consumer appetite for honey and bee-derived items.

The model delivers a dependable prediction of EU honey output, indicating a consistent growth trend with negligible uncertainty. The results underscore the necessity for ongoing investment in sustainable beekeeping techniques, research on pollinator health, and regulatory initiatives to guarantee the long-term stability of honey production. Nonetheless, due to possible external factors, consistent monitoring and modifications to predictive models will be essential to uphold prediction precision and facilitate informed decision-making in the apiculture industry [17,19].

Fig. 2. Honey production forecast in the European Union (1961-2035)
Source: FAOSTAT [13].

The future of honey production in Romania and the European Union (EU) will be shaped by various factors, including environmental sustainability, technological innovations, market dynamics, and customer preferences. Romania's honey sector, a prominent producer within the EU, is at a pivotal point where it must adjust to challenges and opportunities to sustain its competitive advantage and guarantee food security. A primary challenge in honey production is the reduction of bee populations, attributed to reasons such pesticide application, habitat destruction, and climate change [18]. The EU has acknowledged the significance of pollinators in agricultural productivity and has launched various initiatives to save bee populations and encourage sustainable beekeeping methods [18]. In Romania, enhancing the resilience of bee colonies by selective breeding and improved management procedures is crucial for preserving honey production amid these problems [29]. Incorporating ecological knowledge into agricultural operations can improve crop pollination, benefiting both beekeepers and farmers [18]. Technological innovations are anticipated to significantly influence the future of honey production. Advancements in beekeeping apparatus, including automated hive monitoring devices, enable beekeepers to manage their colonies more efficiently and address possible problems proactively [12, 28]. Furthermore, the application of data analytics and artificial intelligence can enhance honey production operations, encompassing hive health monitoring and market trend forecasting [22]. These methods enhance efficiency and promote the sustainability of honey production by reducing resource waste and improving product quality. Market dynamics are evolving, characterised by a rising

consumer demand for premium, organic, and locally derived honey. In Romania, increasing awareness of the health benefits of honey consumption may elevate demand for domestically produced honey [9]. Nevertheless, Romania's present consumption rates are inferior to those of other EU nations, signifying a necessity for focused marketing efforts to establish honey as a dietary staple. Educational initiatives that emphasise the nutritional and medicinal benefits of honey may substantially impact consumer behaviour and enhance market demand [9].

The quality of honey is essential for sustaining competitiveness in the EU market. Romanian honey is known for its varied flower origins, which enhance its distinctive flavours and health advantages [2].

Subsequent investigations are to concentrate on the characterisation of honey varieties utilising advanced analytical methodologies, including high-performance liquid chromatography (HPLC) and mass spectrometry, to guarantee authenticity and quality [7]. Implementing stringent quality assurance processes will be crucial for Romanian honey producers to comply with EU regulations and effectively compete with imported honey, especially from nations with reduced production costs [1]. Moreover, the future of honey production in Romania will probably be shaped by the growing focus on sustainability and environmental conservation. The EU's Green Deal and Farm to Fork Strategy seek to advance sustainable agriculture practices by minimising pesticide usage and augmenting biodiversity [18]. Romanian beekeepers can synchronise their operations with these activities by implementing organic agricultural techniques and participating in habitat restoration projects that benefit pollinator populations [12]. This connection benefits the environment and boosts the marketability of honey products, as customers increasingly want sustainable solutions. Alongside environmental factors, the socio-economic dimensions of honey production must be acknowledged. The beekeeping industry in Romania sustains numerous rural people and enhances local economies [25]. Consequently, assisting small-scale beekeepers via training initiatives and financial resources will be essential for the sector's viability [12]. Collaborative programs linking beekeepers with agricultural producers can bolster the resilience of both sectors, fostering a symbiotic relationship that enhances food security [18]. Honey's contribution to food security is complex; it serves as a healthy food source and is vital for pollination, which is crucial for crop development [22]. As global food systems encounter escalating challenges from climate change and population expansion, the significance of preserving robust bee populations and sustainable honey production methods will intensify [18]. Romanian and EU policymakers must prioritise the safeguarding of pollinators and the advancement of sustainable farming methods to guarantee long-term food security.

CONCLUSIONS

The forecasted honey production trends in Romania and the European Union through 2035 suggest a sustained upward trajectory, indicating consistent growth in the apiculture sector. Statistical analysis and time series forecasting utilising the Exponential Smoothing (ETS) model indicate a consistent increase in honey production, corroborated by historical trends and minor seasonal fluctuations. The model's accuracy, demonstrated by low error values and a high coefficient of determination, indicates that the forecast is dependable, with limited uncertainty over future output levels.

The results indicate that Romania and the European Union will gain from enhanced honey output, propelled by improvements in beekeeping techniques, advantageous agricultural policies, and persistent market demand. Nonetheless, exogenous factors such climate variability, habitat destruction, use of pesticides, and economic variations may influence actual production trends. Although the model offers a strong prediction based on past data, ongoing monitoring and modifications are essential to address unexpected difficulties that may emerge in the future.

To guarantee the continued sustainability of honey production, authorities, academics, and beekeepers must cooperate to mitigate potential hazards, improve bee health, and adopt adaptive strategies in response to environmental and economic fluctuations. Subsequent research ought to concentrate on integrating additional factors, including meteorological and ecological data, into forecasting models to enhance forecasts and bolster resilience against future uncertainty.

The anticipated rise in honey production offers substantial prospects for the beekeeping sector, emphasising the necessity for data-informed decision-making and sustainable apiculture methods. Utilising technical breakthroughs and forceful regulatory measures, the honey producing sector can continue to thrive, aiding both economic development and ecological balance within the European Union.

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