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PROJECTED TRENDS IN FRESH OR CHILLED RABBIT AND HARE MEAT PRODUCTION IN ROMANIA AND THE EUROPEAN UNION THROUGH 2035

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Abstract

Romania and the European Union (EU) have encountered significant declines in recent decades, driven by changing consumer tastes, economic limitations, and changed attitudes towards rabbit meat. This study aims to forecast production trends in Romania and the EU until 2035 by utilizing historical data from FAOSTAT, employing exponential smoothing methods, and assessing model accuracy through statistical error metrics such as Mean Absolute Scaled Error (MASE), Symmetric Mean Absolute Percentage Error (SMAPE), Mean Absolute Error (MAE), and Root Mean Square Error (RMSE). The findings reveal an ongoing decline in production, with Romania anticipated to sustain near-zero levels, while the EU is forecasted to encounter additional output losses. The study indicates that economic challenges, evolving dietary preferences, and heightened competition from other protein sources are factors contributing to the sector's collapse. Opportunities for revival are there through the development of value-added goods, enhanced marketing strategies, sustainable agricultural techniques, and advancements in genetics and nutrition. The findings highlight the need for regulatory interventions and industry adjustments to conform to changing market demands and guarantee the long-term sustainability of rabbit and hare meat production in Romania and the EU.

Key words**:** *rabbit, hare, forecasting, Romania, European Union, sustainability*

INTRODUCTION

In Romania and across the European Union, the production of rabbit and hare meat is shaped by various factors, including consumer preferences, production techniques and health considerations. The production of rabbit meat has experienced variations in demand and supply, affected by economic conditions and evolving dietary preferences. In Romania, like various regions in Europe, rabbit meat is acknowledged for its nutritional value, characterised by low fat content and high protein levels, rendering it a desirable option for health-conscious consumers [36, 4]. Historically, rabbit production in Romania has been defined by small-scale farms and backyard operations, which play a crucial role in local meat supplies. The industrialisation of rabbit farming is progressively developing, as larger farms implement more intensive production techniques to satisfy increasing demand [25]. The EU rabbit meat industry is primarily characterised by intra-EU trade, with Italy as a significant contributor, virtually achieving self-sufficiency in rabbit

production [35]. This tendency is seen in Romania, where domestic production is progressively augmented by imports to meet consumer demand. The quality of rabbit meat is influenced by multiple factors, such as the animal's food, pre-slaughter environment, and processing techniques. Research indicates that the incorporation of feed additives, including synbiotics and botanical extracts, could improve meat quality by enhancing growth rates and carcass characteristics [18, 17, 23]. The incorporation of fresh alfalfa in rabbit diets has been associated with enhanced meat quality, influencing both the chemical composition and sensory characteristics of the meat [9]. Additionally, the pH levels of rabbit meat, which might impact softness and shelf life, are influenced by dietary choices and processing methods [30, 21]. Chilled rabbit meat is more susceptible to microbial contamination, presenting difficulties for preservation and storage. Studies demonstrate that natural antioxidants, including plant extracts, can reduce lipid oxidation and extend the shelf life of refrigerated rabbit meat [18, 6]. The addition of these compounds boosts the meat's nutritional profile and sensory attributes, increasing its attractiveness to customers [1, 11]. This is essential in a market where consumer preferences are increasingly preferring healthier, minimally processed meat products. Rabbit meat consumption in Romania has been shaped by socio-economic factors, including economic downturns and the growing perception of rabbits as companion animals rather than livestock [35]. This transition has resulted in a decrease in rabbit meat consumption, compelling producers to investigate innovative marketing tactics to rekindle interest in rabbit meat products. The development of processed rabbit meat products, including sausages and ready-to-eat meals, has emerged as a viable strategy in response to customer desire for convenience and diversity [4, 25]. Hare meat, although less frequently consumed than rabbit meat, has potential for production and marketing in Romania. The nutritional analysis of hare meat reveals it as a superior protein source, abundant in polyunsaturated fatty acids, consistent with contemporary dietary preferences for lean meats [13]. The production of hare meat is frequently constrained by hunting rules and seasonal availability, impacting supply consistency. Health issues associated with meat eating, particularly the possibility of zoonotic illnesses, have impacted consumer perceptions of rabbit and hare meat [29]. The future of rabbit and hare meat production in Romania and the EU will likely hinge on producers' capacity to adapt to evolving customer expectations, elevate meat quality through refined production procedures, and address health and safety issues. The incorporation of sustainable practices in rabbit farming, including organic methods and ethical animal treatment, is essential for appealing to a health-conscious consumer demographic [4].

The aim of this study is to forecast the production of fresh or chilled rabbit and hare meat in Romania and the European Union up until 2035 using historical data from FAOSTAT, applying exponential smoothing techniques, and evaluating model accuracy through statistical error metrics.

MATERIALS AND METHODS

Data Collection

The data used in this study was obtained from the FAOSTAT database, which offers statistical data regarding agricultural production trade. The dataset comprises production statistics for fresh or chilled rabbit and hare meat in Romania until 2018 and in the European Union (EU) until 2023. It is important to note that some of the EU data consisted of estimations rather than official figures, as reported by FAOSTAT.

Data Processing

Absent values were addressed by linear interpolation, maintaining a continuous time series without artificial distortions. In cases of duplicate values within the dataset, data was consolidated by computing the average of the existing entries to ensure consistency. The seasonality component of the time series was identified automatically to address reoccurring patterns in production trends.

Methodology for Forecasting

The forecasting analysis was performed via Microsoft Excel, employing its built-in statistical and forecasting functions.

The forecast utilised an exponential smoothing model incorporating parameters Alpha (α), Beta (β), and Gamma (γ) to enhance trend and seasonality adjustments.

The subsequent error metrics were calculated to evaluate the model's accuracy and reliability: Mean Absolute Scaled Error (MASE), Symmetrical Symmetric Mean Absolute Percentage Error (SMAPE), Mean Absolute Error (MAE), Root Mean Square Error (RMSE)

Additionally, a 95% confidence level was used to assess the uncertainty of the projected values, outlining a range in which the actual values are are expected to fall.

RESULTS AND DISCUSSIONS

The forecasting model used to produce fresh or chilled rabbit and hare meat in Romania exhibited a strong responsiveness to recent trends, evidenced by an Alpha value of 0.9, which assigns considerable weight to the latest observations.

The Beta value of 0.001 indicates a negligible impact of long-term trends, suggesting that the historical trend is largely steady or only marginally changing over time. The Gamma value, approximately zero (2.22×10^{-16}), suggests that seasonality was either minimal in the dataset or significantly mitigated throughout the forecasting procedure.

The model's accuracy was assessed by various statistical error indicators. A Mean Absolute Scaled Error (MASE) of 0.0609 indicates that the forecasting model outperformed a naive model, hence affirming its robust prediction accuracy.

A Symmetric Mean Absolute Percentage Error (SMAPE) of 15.07% suggests that, on average, the predicted values deviated by approximately 15% from the actual production data, which is generally regarded as an acceptable accuracy level in time series forecasting.

The Mean Absolute Error (MAE) of 33.38 indicates that, on average, the predicted values deviated from actual production figures by about 33.38 metric tonnes, while the Root Mean Square Error (RMSE) of 58.26 underscores infrequent larger inconsistencies, although not excessively high, thereby affirming the model's overall reliability.

The results demonstrate that the employed forecasting method effectively captures short-term variations while preserving overall predictive consistency. The model's minimal error values demonstrate its reliability in predicting trends in fresh or chilled rabbit and hare meat production in Romania, making it a valuable tool for future policy development and market strategy in the sector.

Figure 1 presents the historical and projected production of fresh or chilled rabbit and hare meat in Romania from 1961 to 2035.

The historical data indicates a consistent trend until the late 1980s, followed by a significant surge in production, reaching its peak in the early 1990s. This apex is succeeded by a slow descent, ultimately approaching negligible levels in the 2000s and remaining static in subsequent years.

The projected trend (2018-2035) indicates that production will remain nearly negligible, with no substantial rise anticipated. The linear regression equation ($y = -9.3723x + 647.37$) with $R^2 = 1$ signifies an excellent linear correlation, underscoring the consistent decrease in productivity (Figure 1).

The upper and lower confidence ranges indicate an expanding range of uncertainty as the projection progresses into the future, implying heightened variability and possible discrepancies in output forecasts.

The estimate indicates that rabbit and hare meat production in Romania is improbable to return to prior levels and will likely remain limited or absent soon.

This trend may be ascribed to economic, regulatory, or market-related concerns, necessitating additional examination of the causes underlying the industry's downfall.

The statistical analysis for fresh or chilled rabbit and hare meat production within the European Union offers insights into the model's precision and predictive efficacy.

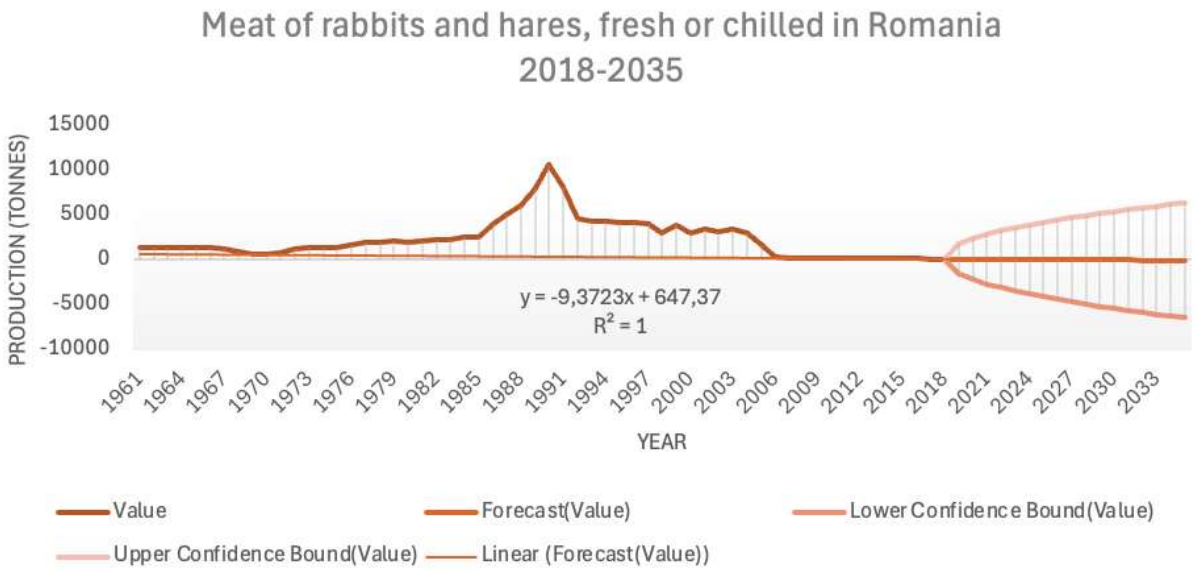

Fig. 1. Meat of rabbits and hares' production forecast in Romania (2018-2035)
Source: FAOSTAT [12].

An Alpha value of 1.00 indicates that the model assigns complete weight to the most recent observations, rendering it highly responsive to current trends while neglecting previous data. A Beta value of 0.10 indicates minimal influence of trend components, suggesting that long-term trends are minimally incorporated into the forecast. A Gamma value of 0.00 indicates that no seasonal fluctuations were identified or incorporated in the model.

The precision of the prediction was evaluated utilising multiple error metrics. A Mean Absolute Scaled Error (MASE) of 0.61 suggests moderate forecasting accuracy, demonstrating that the model performs better than a naive forecast but still has some limitations in capturing variations. Meanwhile, a Symmetric Mean Absolute Percentage Error (SMAPE) of 5% signifies a minimal average percentage deviation between predicted and actual values, indicating a high level of predictive accuracy.

The absolute error metrics—Mean Absolute Error (MAE) of 9,369.92 tonnes and Root Mean Square Error (RMSE) of 13,229.06 tonnes—demonstrate significant variations between expected and actual production levels, suggesting potential volatility or uncertainty in production trends.

The model indicates that, although the forecast accurately reflects recent production trends in the EU, the elevated MAE and RMSE values suggest possible variations and uncertainty in the data. This underscores the necessity for careful interpretation of the projections, especially regarding market dynamics, policy changes and economic impacts on rabbit and hare meat production in the European Union. Figure 2 illustrates the historical and projected production of fresh or chilled rabbit and hare meat within the European Union from 1961 to 2035. The historical data indicates an initial phase of stability, succeeded by a progressive rise in production until the late 1980s, followed by a sudden decrease in the early 1990s. This drop continues at a reduced rate, with production stabilising at diminished levels in the 2000s and subsequently maintaining a somewhat steady trajectory.

The projection from 2023 to 2035 predicts a sustained decrease in productivity, as evidenced by the descending trend line ($y = -9{,}437.8x + 706{,}432$). An R^2 value of 1 indicates that the linear model fits the historical data very well, corroborating the anticipation of a consistent decreasing trend. The upper and lower confidence intervals expand as the projection continues, signifying heightened uncertainty in the long-term prognosis.

The data indicates that rabbit and hare meat production in the EU is anticipated to further

drop in the forthcoming years, with no indications of recovery based on past trends. This drop may be attributed to multiple sources, such as changes in customer tastes, legislative changes, economic impacts, or structural modifications within the rabbit meat sector. The expanding confidence intervals underscore the necessity for ongoing surveillance, as external variables may affect the true course of production.

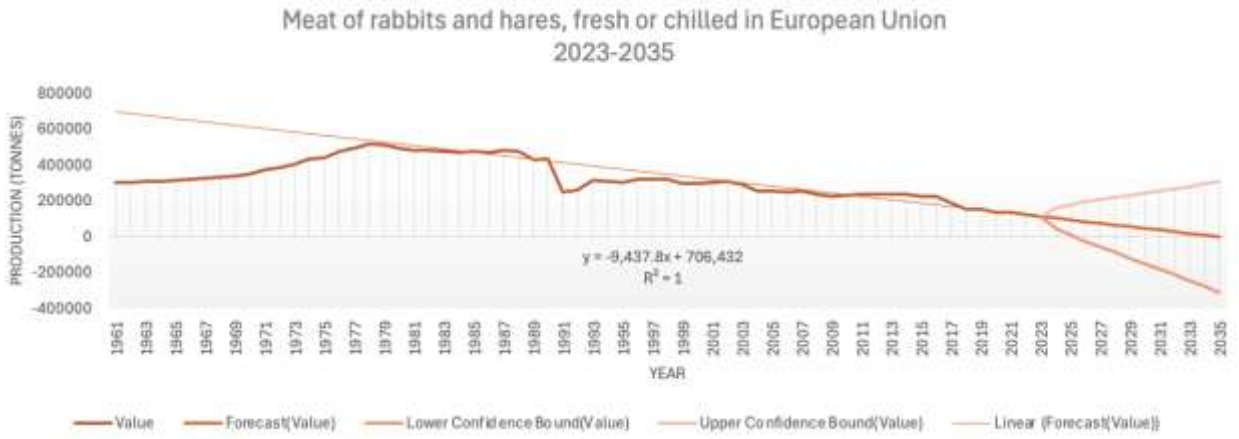

Fig. 2. Fresh or chilled rabbit and hare meat production forecast in the European Union (2023-2035)
Source: FAOSTAT [12].

In recent years, the production of fresh or chilled rabbit and hare meat in Romania and the European Union (EU) has significantly decreased. This trend can be attributed to a mix of causes, including evolving consumer tastes, economic challenges, and health concerns. Understanding these dynamics is essential for stakeholders in the meat production sector to adapt and innovate in response to the changing market environment. The decline in rabbit and hare meat production is primarily attributed to changing customer preferences for alternative protein sources. As customers increasingly prioritise health, there is a rising trend in the consumption of lean meats, such as chicken and fish, which are frequently regarded as healthier alternatives than rabbit meat. Research demonstrates that although rabbit meat is acknowledged for its nutritional benefits, such as low fat and high protein levels, it frequently remains eclipsed by more prevalent meats that possess greater market visibility and consumer recognition [26, 31]. The shift in consumer behaviour has resulted in a decrease in demand for rabbit meat, thereby impacting production levels. Economic issues significantly contribute to the reduction of rabbit and hare meat production.

The expenses related to rabbit farming, especially for feed and veterinary services, have increased, rendering it less economically viable for several small-scale producers [28, 24, 14, 15]. In Romania, where several rabbit farms operate on a small scale, economic pressures are especially intense. Producers frequently encounter difficulties in competing with larger agricultural enterprises that capitalise on economies of scale, resulting in industry consolidation and a decline in the number of small farms [24]. The economic pressure is further heightened by the overarching challenges affecting the agricultural industry in Romania, such as restricted access to financing [24]. Health issues associated with meat intake have also led to a decrease in rabbit and hare meat production. Consumer and producer knowledge of zoonotic diseases, such as coccidiosis affecting rabbits, has risen [16]. This has resulted in increased analysis of meat processing methods and a call for elevated food safety regulations. As a result, producers might face supplementary expenses related to complying to health laws, so affecting their profitability and desire to maintain production [24]. The idea of rabbits as companion animals rather than livestock has notably affected consumer attitudes towards rabbit

meat [26]. Consequently, businesses face a diminishing market base, affecting the maintenance of production levels. The marketing and branding of rabbit meat provide obstacles that exacerbate its falling production. In contrast to other meats, rabbit meat exhibits a weak brand presence and is frequently inadequately promoted to customers [5]. The limited availability of processed or semi-processed rabbit products intensifies this problem, as customers increasingly need convenience in their dietary selections [5]. The incorporation of circular economy principles into rabbit husbandry has not been entirely achieved in Romania and the EU. Despite the potential for sustainable methods to improve production efficiency and minimise waste, numerous producers remain either uninformed or unable of efficiently implementing these techniques [32]. The deficiency in knowledge dissemination and innovation within the sector constrains rabbit producers' capacity to adjust to evolving market needs and enhance their economic viability.

The future of fresh or chilled rabbit and hare meat production in Romania and the European Union (EU) is set for transformation, driven by changing customer demands, sustainability efforts, and technical progress. As consumers increasingly emphasise health and environmental sustainability, rabbit meat, recognised for its low fat and high protein content, is garnering interest as a viable alternative to conventional meats such as beef and pork [10, 20]. The transition to more sustainable protein sources is essential, as rabbit production exhibits a markedly lower environmental impact than larger animals, with diminished greenhouse gas emissions per kilogramme of meat produced [22, 7, 33, 8]. Novel methodologies for rabbit meat production are crucial for rejuvenating the sector. Creating innovative, healthier rabbit meat products can appeal to health-conscious consumers and expand the industry [34]. Furthermore, incorporating circular economy ideas into rabbit farming—such as leveraging by-products and optimising feed efficiency—can enhance sustainability and profitability [2, 3]. Consumer desire for transparency and humane treatment of animals is rendering the emphasis on animal welfare and ethical agricultural techniques increasingly significant [27, 19]. Furthermore, progress in genetics and nutrition is anticipated to improve the productivity and health of rabbit populations, increasing their resilience to illnesses and enhancing overall meat quality [20]. Investigating alternate feed sources, such marine macroalgae, may improve the sustainability and nutritional quality of rabbit meat [2].

CONCLUSIONS

This study's findings indicate a notable and ongoing decrease in the production of fresh or chilled rabbit and hare meat in Romania and the European Union. The anticipated trends suggest that Romania's production will stay minimal, whereas the European Union is expected to continue its decline. This decline can be ascribed to multiple factors, including shifting customer preferences, economic constraints, and changing conceptions of rabbits as companion animals instead than livestock. The challenges caused by elevated costs in rabbit farming, escalating regulatory demands, and competition from alternative protein sources have exacerbated the sector's decline.

Notwithstanding these hurdles, prospects persist for the revival of the rabbit and hare meat sector by innovation and adaptability. The creation of value-added and processed rabbit meat products, coupled with enhanced marketing methods, could revitalise consumer interest. The implementation of sustainable agricultural practices and the incorporation of alternative feed sources may improve the economic and environmental sustainability of rabbit farming. Progress in genetics and nutrition, along with heightened focus on ethical and animal welfare standards, may enhance the sector's resilience and potential for recovery.

Considering the present forecasts, governments, industry stakeholders, and producers must cooperate to address the elements leading to reduced production while investigating methods to adapt to changing

customer preferences. A coordinated initiative to modernise production techniques, elevate meat quality, and augment marketability will be crucial in shaping the future direction of rabbit and hare meat production in Romania and the European Union.

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