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ARIMA-Based Forecasting of Livestock and Poultry: Annual Volume of Animals Slaughtered/Dressed by Animal Type and Provinces

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Abstract
Livestock and poultry are essential for human survival and development, as they convert low-quality feed into high-quality protein and nutrients that support human diets. With the global population growing and the demand for animal-based food increasing, especially in developing countries, it is important to use livestock to improve food system efficiency and promote sustainability. In the Philippines, the livestock industry is a key part of agriculture, contributing about 18.23% of the gross output value, with hogs and chickens being the most consumed animals. Northern Mindanao is one of the leading regions in livestock production, particularly in meat production. Although there is data on meat production trends and regional differences,
there is a lack of detailed forecasting for livestock and poultry production by province and animal type. This study aims to fill this gap by using time series analysis and forecasting methods, specifically the autoregressive integrated moving average (ARIMA) model, to analyze the annual volume of livestock and poultry slaughtered or dressed by animal type and province in the Philippines. The research provides valuable predictions on production trends, helping stakeholders make better decisions, improve production planning, find growth opportunities, and address challenges in the livestock and poultry sector. The results of this study will support informed decision making, ensure a stable supply chain, and aid the ongoing development of the country's livestock industry.

Keywords: ARIMA, K-means, Forecasting, Trend Analysis

Introduction

Livestock and poultry are essential for human survival and development. They can transform low-quality feed into high-quality protein and essential minerals with high bioavailability, making them easily incorporable into human diets (Zhao et al., 2023). As the global population grows and the demand for animal-derived food rises, particularly in developing countries, it becomes essential to leverage livestock to improve food system efficiency and promote a circular food system (Dou, 2021). Understanding the diverse roles that livestock play in developing and developed countries is crucial for assessing their impact on livelihoods, economic growth, and the environment (Herrero et al., 2021).

The Food and Agriculture Organization (FAO) estimates that livestock contributes 40% of the global agricultural output's value, with 1.3 billion people relying on it for their livelihoods and food security (Brown et al., 2021). In the Philippines, the livestock industry plays a crucial role in the country's agricultural sector, accounting for approximately 18.23% of the gross output value in agriculture. It also serves as a significant source of livelihood for many rural residents, highlighting its importance to the national economy (Ortega et al., 2021). Livestock, poultry, and dairy industries, largely dominated by the private sector,are major contributors to the nation's economy, together representing one-third of the agriculture sector's total output (Philippine Institute for Development and Studies, 2023). Among all animals raised for human consumption, hogs and chickens are the most widely consumed, making up the largest share of livestock and poultry production in the country (Balita, 2024). According to Jose Apollo Pacamalan, the Regional Executive Director of the Department of Agriculture DA)-10, northern Mindanao is ranked as one of the top five regions in the Philippines for livestock production of major commodities (Philippine Information Agency, 2024).

The Philippine Statistics Authority (PSA) provides a comprehensive overview of meat production in the Philippines, particularly in Northern Mindanao, by sorting the data by animal type and location. It shows trends in production, differences between regions, and how each province contributes to the overall supply of livestock and poultry. However, while significant research exists on specific production issues and challenges, there is a lack of comprehensive analyses focused on forecasting trends across provinces and animal types. Such insights are crucial for optimizing production planning and ensuring a stable supply chain.

To address this gap, the objective of this study is to utilize time series analysis and forecasting techniques, specifically the autoregressive integrated moving average (ARIMA) model, to examine the annual volume of livestock and poultry slaughtered or dressed by animal type and province in the Philippines. This research aims to provide a predictive understanding of production trends, enabling stakeholders to identify growth opportunities and address vulnerabilities within the sector

Theoretical Framework

This study is based on the Box-Jenkins Model Theory (Box, Jenkins, & Bacon, 1967), which is used to analyze time series data for forecasting by utilizing historical data points to predict the outcome of a variable. The model employs the Autoregressive Moving Average (ARMA) and Autoregressive Integrated Moving Average (ARIMA) models to identify the best fit for forecasting based on historical data (Sabroso & Bugarin, 2023). As noted by Robert Nau (2021), the ARIMA model builds on the ARMA model by incorporating an integration component. ARIMA models are designed for non-stationary time series, while ARMA models are used for stationary time series. A stationary time series is one in which statistical parameters, such as the mean and variance, remain constant over time. However, most real-world time

series are non-stationary, and transformations are typically required to stabilize them. Ceylan (2020) applied the ARIMA model to predict the prevalence of COVID-19 in Italy, Spain, and France, demonstrating its effectiveness in forecasting the patterns of infectious disease outbreaks. In addition to its use in health-related fields, ARIMA has also been applied to economic forecasting. For example, Mariati (Putu et al., 2023) used the ARIMA model to predict inflation rates in Denpasar after the COVID-19 pandemic, showing its relevance in financial and economic settings. The model's adaptability and ability to capture various patterns make it a strong choice for economic forecasting, as demonstrated by Beniwal in a comparative analysis of ARIMA and linear regression for predicting stock prices (Putu et al., 2023).

Materials and Methods

Materials

The data used in this study are the statistical data taken from the Philippines in Figures of the Philippine Statistics Authority (PSA) from the year 2019 to 2023. The statistical report covers various areas; however, this study will focus on forecasting the annual volume of animals slaughtered or dressed by animal type and by province. The data were sourced from the PSA, National Meat Inspection Service (NMIS), Department of Agriculture (DA), and other relevant government agencies. The specific data sets used in this study are from the publications Philippines in Figures for the years 2019 to 2023, which reflect the data from 2019 to 2023. These data will be analyzed to identify trends and create forecasts for livestock and poultry production across different provinces.

Methods

The study utilized a univariate time series, which consists of individual observations gathered at regular time intervals. This type of time series can be examined, analyzed, and predicted using time series methods. Moreover, the autocorrelations and partial autocorrelations of the series reveal the direction and strength of the relationship between each data point and its previous values (Vishwas & Patel, 2020). This study used a time-series analysis approach, utilizing the ARIMA (Autoregressive Integrated Moving Average) model as its research framework. The ARIMA model is a widely recognized method for analyzing time-series data, capable of capturing trends, seasonal variations, and irregular fluctuations (Paduloh et al., 2021; Ramos & Ativo, 2023).

Three steps were used to forecast the annual volume of livestock and poultry slaughtered/dressed by animal type and provinces using ARIMA-based forecasting. The first step involved clustering the data using the K-means algorithm, which grouped similar data points together. This helped identify patterns and trends in the livestock and poultry data. In the second step, the study used Gretl software for time-series analysis and model identification. Gretl helped analyze the time series data, check for stationarity, and examine seasonal effects using autocorrelation and partial autocorrelation methods. The third step involved estimating parameters and testing different models to choose the most suitable ARIMA model. Finally, predictive analysis was performed to forecast future trends in livestock and poultry production. The use of the K-means algorithm, Gretl software, and Microsoft Excel provided a strong analytical framework, improving the study's ability to uncover patterns and support informed decision making.

Results and Discussion

In the trend analysis of livestock and poultry production, specifically the annual volume of animals slaughtered/dressed by animal type and province, the GRETL software was used. Tables 1-5 present the

raw data on livestock and poultry slaughtered/dressed, covering the years from 2019 to 2023.

Annual Chicken Processing Volumes by Province	Table 1. Raw Data on Annual Volume of Chickens Slaughtered					
	Year					
	2019	2020	2021	2022	2023	TOTAL
1. Bukidnon	38,118,280.00	38,578,219.00	42,525,408.00	52,610,267.00	52,577,765.00	185,831,720
2. Camiguin	482,029.00	673,770.00	789,456.00	687,444.00	699,101.00	3,331,800.00
3. Lanao del Norte	5,039,471.00	5,249,047.00	5,576,977.00	6,771,520.00	6,405,746.00	29,042,761.00
4. Misamis Occidental	10,652,334.00	9,941,525.00	12,146,821.00	2,308,059.00	12,185,191.00	47,233,930
5. Misamis Oriental	54,556,034.00	49,943,366.00	47,740,136.00	48,973,718.00	48,707,806.00	249,921,060

Table 1 presents the annual volume of chickens slaughtered by province from 2019 to 2023. Bukidnon had the highest total volume of chickens slaughtered, ranging from 38.1 million in 2019 to 52.6 million in 2022, totaling 185.83 million over the five years. Camiguin experienced steady growth in slaughter volumes, increasing from 482,029 in 2019 to 699,101 in 2023, with a total of 3.33 million chickens slaughtered. In Lanao del Norte, slaughter volumes rose from 5 million in 2019 to 6.77 million in 2022, accumulating 29.04 million chickens over the five years. Misamis Occidental had fluctuating slaughter volumes, ranging from 9.9 million in 2020 to 12.19 million in 2023, totaling 47.23 million chickens. Misamis Oriental consistently recorded the highest slaughter volumes, with figures ranging from 47.74 million in 2021 to 54.56 million in 2019, amounting to 249.92 million chickens over the five years. Overall, Misamis Oriental led in total slaughter volume, followed by Bukidnon and Misamis Occidental, while Camiguin had the lowest total chickens.

Annual Chicken Processing Volumes by Province	Table 2. Raw Data on Annual Chicken Dressed Volumes					
	Year					
	2019	2020	2021	2022	2023	TOTAL
1. Bukidnon	62,487	64,133	64,471	76,720	79,350.60	347,162
2. Camiguin	719.36	852.31	924.18	852.85	849	3345.39
3. Lanao del Norte	7,817.38	8,523.22	9,170.63	9,938.07	10,368.47	45,817.77
4. Misamis Occidental	17,165.23	17,155	19,265	19,581	19,457	75,459
5. Misamis Oriental	81,831	80,267.74	69,314	70,052.90	68,378	369,844.20

Table 2 presents the annual volume of chickens dressed by province from 2019 to 2023. Bukidnon had

the lowest dressing volume compared to its slaughter volume, with 347,162 dressed chickens over five years, increasing from 62,487 in 2019 to 79,350.6 in 2023. Camiguin saw a steady rise in dressed chickens, from 719.36 in 2019 to 924.18 in 2021, totaling 3,345.39 dressed chickens over the five years. In Lanao del Norte, dressing volumes grew from 7,817.38 in 2019 to 10,368.47 in 2023, totaling 45,817.77 over five years. Misamis Occidental experienced stable dressing volumes, ranging from 17,165.23 in 2019 to 19,581 in 2023, totaling 75,459 dressed chickens. Finally, Misamis Oriental had the highest dressing total, with 369,844.2 over five years, despite fluctuations in annual volumes, peaking at 81,831 in 2019 and remaining relatively high in subsequent years.

Annual Chicken Processing Volumes by Province	**Table 3. Annual Volume of Chickens Slaughtered and Dressed**					
	Year					
	2019	**2020**	**2021**	**2022**	**2023**	**TOTAL**
1. Bukidnon	38,180,767.46	38,642,351.91	42,589,878.68	52,686,987.41	52,657,115.60	224,757,101
2. Camiguin	482,748.36	674,622.31	790,380.18	688,296.85	849	2,636,896.70
3. Lanao del Norte	5,047,288.38	5,257,570.22	5,586,147.63	6,781,458.07	6,416,114.47	29,088,578.77
4. Misamis Occidental	10,669,499.23	9,958,680.43	12,166,086.37	2,327,640.04	12,204,647.72	47,326,553.79
5. Misamis Oriental	54,637,865	50,023,634	47,809,450	49,043,771	48,776,184.04	250,290,904

Table 3 presents the annual volume of chickens slaughtered and dressed by province from 2019 to 2023. Bukidnon experienced consistent growth, processing a total of 224,757,101 chickens over the five years, with the volume reaching 52,657,115.60 in 2023. Camiguin, on the other hand, had modest processing volumes, totaling 2,636,896.70 chickens, with a slight increase in 2023 to 849, though the overall numbers remained low. Lanao del Norte showed steady increases, culminating in a total of 29,088,578.77 chickens processed by 2023. Misamis Occidental's processing volumes fluctuated significantly, but the total for 2023 amounted to 12,204,647.72 chickens, contributing to an overall total of 47,326,553.79. Lastly, Misamis Oriental had the highest processing volumes, totaling 250,290,904 chickens, with minor variations over the years. Overall, the data highlights growth trends in most provinces, with some fluctuations in Misamis Occidental and Camiguin.

In this study, the K-means clustering algorithm was used to group similar data based on the annual volume of livestock and poultry slaughtered or dressed by animal type and province. The purpose of using K-means was to find patterns and trends in the data, which allowed for the classification of provinces or animal types with similar production levels. By grouping the data, the study was able to highlight regional differences in livestock and poultry production, offering a better understanding of how production varies across the country. This method improved the analysis by focusing on specific groups, which helped support better decision making in the livestock and poultry industry. Tables below presented Clustering Algorithm to a dataset on the Annual Volume of Chicken Classified by Processing Stage in the Mindanao Philippines. It classifies items as slaughtered or dressed, starting by defining centroids (C1 and C2) for both categories. The algorithm calculates distances from these centroids and assigns each item to either

C1 or C2. After the initial Clustering, new centroids are computed based on the average values within each cluster. Subsequent recalculations of distances result in updated final clustering assignments. Notably, the algorithm iteratively refines the centroids until convergence, offering insights into regional groupings based on resolved and unresolved data in the Philippines.

Table 4. K-means Clustering

Initial Value of Centroids		
	Slaughtered	**Dressed**
c1	185,831,720	347,162
c2	3,331,800	3345.39

Object Distance	**Centroids**					
Group	**Bukidnon**	**Camiguin**	**Lanao del Norte**	**Misamis Occidental**	**Misamis Oriental**	
Slaughtered	0	182500243.9	156789248.6	138598056.3	64089344.01	
Dressed	182500243.9	0	25710996.08	43902189.23	246589532.4	

Object Clustering	1 - if less than | 0 - if greater than					
Group	**Bukidnon**	**Camiguin**	**Lanao del Norte**	**Misamis Occidental**	**Misamis Oriental**	
1	1	0	1	1	1	
2	0	1	0	0	0	

Initial Value of Centroids		
	Slaughtered	**Dressed**
c1	128,007,368	209,571
c2	3,331,800	3345.39

Object Distance	**Centroids**					
Group	**Bukidnon**	**Camiguin**	**Lanao del Norte**	**Misamis Occidental**	**Misamis Oriental**	
Slaughtered	57824515.95	124675738.3	98964742.23	80773549.09	121913797.6	
Dressed	182500243.9	0	25710996.08	43902189.23	246589532.4	

Object Clustering	1 - if less than | 0 - if greater than					
Group	**Bukidnon**	**Camiguin**	**Lanao del Norte**	**Misamis Occidental**	**Misamis Oriental**	

1	1	0	0	0	1
2	0	1	1	1	0

Initial Value of Centroids		
	Slaughtered	**Dressed**
c1	103,072,254	168,326
c2	0	0

Object Centroids Distance						
Group	**Bukidnon**	**Camiguin**	**Lanao del Norte**	**Misamis Occidental**	**Misamis Oriental**	
Slaughtered	82759659.02	99740590.65	74029594.57	55838401.42	146848944.1	
Dressed	185832044.3	3331801.68	29042797.14	47233990.28	249921333.7	

Object Clustering	1 - if less than | 0 - if greater than				
Group	**Bukidnon**	**Camiguin**	**Lanao del Norte**	**Misamis Occidental**	**Misamis Oriental**
1	1	0	0	0	1
2	0	1	1	1	0

Table 4 Illustrate the application of the K-means.

Table 5. Annual Volume of Chicken Classified by Processing Stage			
Annual Chicken Processing Volumes by Province	**Slaughtered**	**Dressed**	**Group**
1. Bukidnon	185,831,720	347,162	**1**
2. Camiguin	3,331,800	3345.39	**2**
3. Lanao del Norte	29,042,761	45,818	**2**
4. Misamis Occidental	47,233,930	75,459	**2**
5. Misamis Oriental	249,921,060	369,844.20	**1**

Table 5 represents the annual chicken processing volumes by province, categorized by processing stages: slaughtered and dressed, with each province assigned a group number. Bukidnon has the highest volume of slaughtered and dressed chicken, placing it in Group 1, indicating its significant contribution to chicken processing. Meanwhile, provinces such as Camiguin, Lanao del Norte, Misamis Occidental, and Misamis Oriental fall into Group 2, highlighting lower volumes in comparison, except for Misamis Oriental, which is included in Group 1 due to its high dressed chicken volume. The data Misamis major Bukidnon and reveals that the are Oriental contributors to chicken processing, while Camiguin, Lanao del smaller Norte, and Misamis Occidental have volumes, in processing capacities among these suggesting a disparity provinces.

Trend Analysis

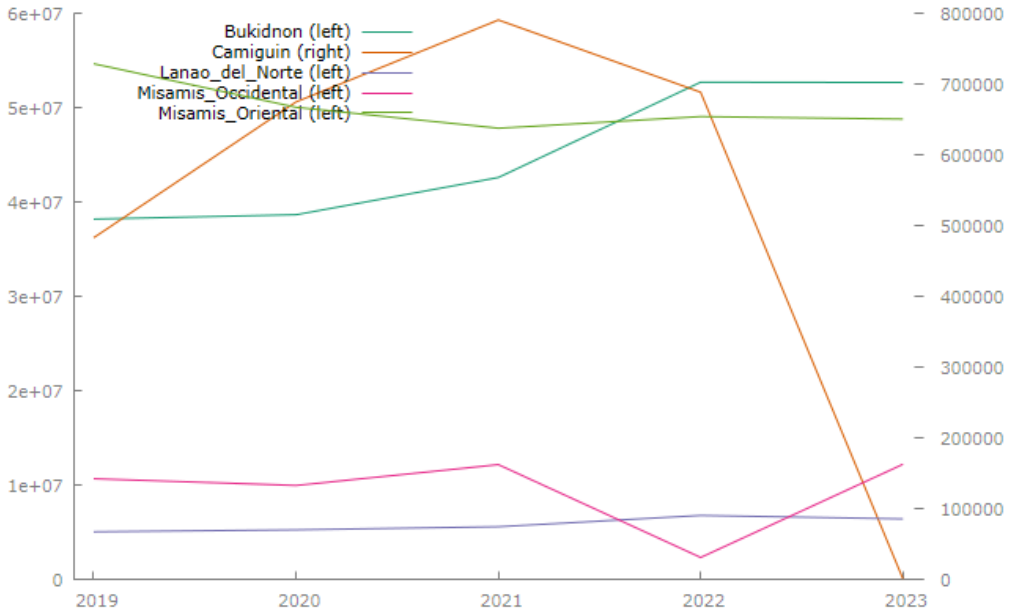

Figure 1. Forecasted Annual Chicken Processing Volumes by Province during the forecasted years.

Figure 1 presents the forecasted annual chicken processing volumes by province in the Philippines for the years 2019 to 2023, generated using the Gretl software. The figure provides a detailed illustration of the projected trends in chicken processing volumes, highlighting variations across different provinces over the five-year period. This forecast offers insights into how each province contributes to the overall chicken processing industry, showcasing potential growth or decline in processing activities.

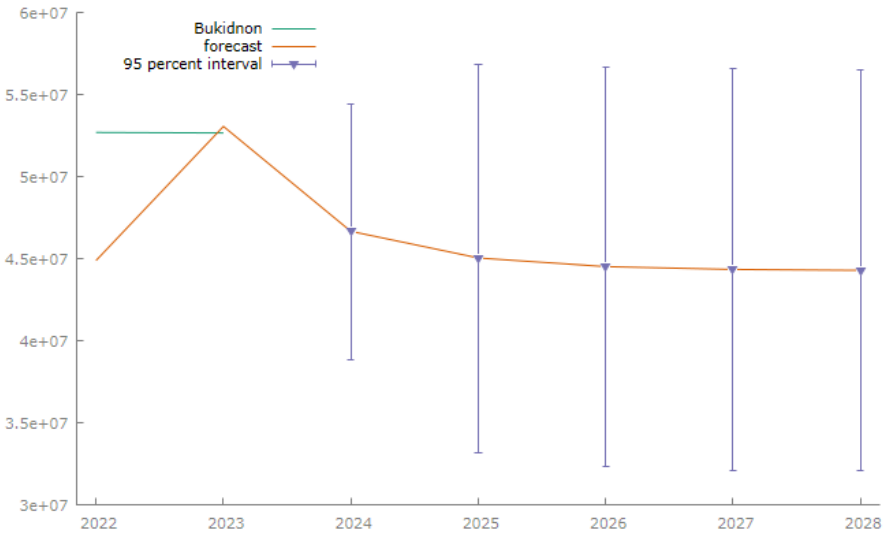

Figure 2. Forecasted Annual Chicken Processing Volumes in Bukidnon

Figure 2 displays the forecasted annual chicken processing volumes in Bukidnon for the years 2022 to 2028, highlighting trends and fluctuations over this period. The data reveals a noticeable increase in processing volumes in the year 2024, indicating a period of growth. However, following this rise, the data

stabilizes, showing a consistent volume from 2025 onward. This steady trend suggests that after the initial surge, the chicken processing industry in Bukidnon reaches a plateau, maintaining its capacity without significant further growth volumes to stabilize from 2026 to 2028, reflecting consistent production levels Volumes in Lanao del Norte

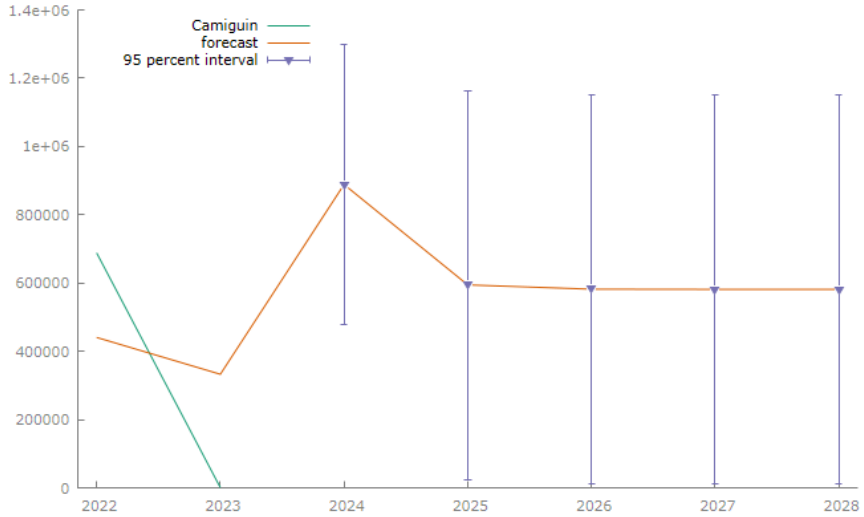

Figure 3. Forecasted Annual Chicken Processing Volumes in Camiguin

Figure 3 displays the forecasted annual chicken processing volumes in Bukidnon for the years 2022 to 2028, highlighting trends and fluctuations over this period. The data reveals a noticeable increase in processing volumes in the year 2024, indicating a period of growth. However, following this rise, the data stabilizes, showing a consistent volume from 2025 onward. This steady trend suggests that after the initial surge, the chicken processing industry in Bukidnon reaches a plateau, maintaining its capacity without significant further growth volumes to stabilize from 2026 to 2028, reflecting consistent production levels Volumes in Lanao del Norte

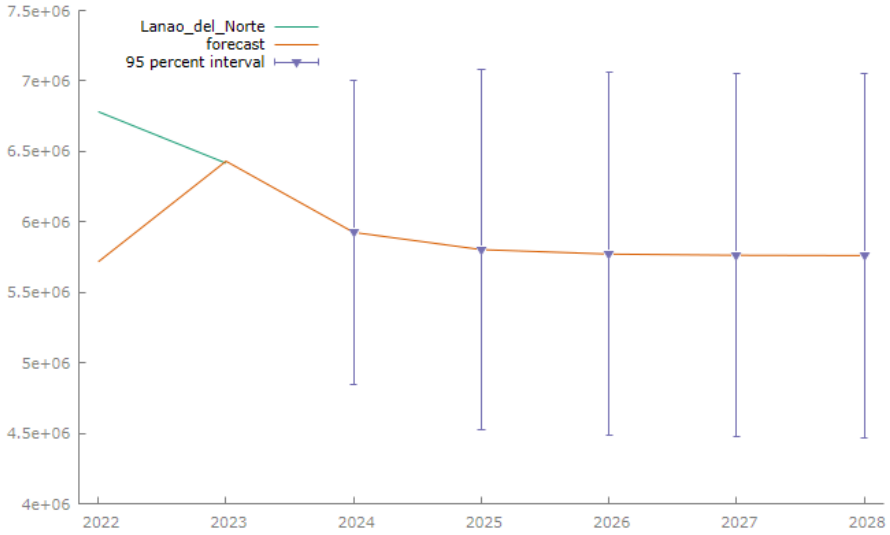

Figure 4. Forecasted Annual Chicken Processing Volumes in Lanao del Norte

Figure 4 illustrates the forecasted annual chicken processing volumes in Lanao del Norte from 2022 to 2028. The data reveals a significant increase in processing volumes in 2024, reflecting potential growth in production capacity or rising demand for poultry products. Following this growth, the volumes stabilize from 2025 onward, indicating a consistent trend in production levels. This stability suggests that the province has achieved a balance between production and market demand, highlighting its steady contribution to the Volumes in Misamis Occidental poultry industry during the forecasted period.

Figure 5. Forecasted Annual Chicken Processing Volumes in Misamis Occidental

Figure illustrates the forecasted annual chicken processing volumes in Misamis Occidental from 2022 to 2028. The data highlights a notable increase in processing volumes in 2024, suggesting a period of growth potentially driven by enhanced production capabilities or increased demand for poultry products. From 2024 onward, the volumes remain steady through 2028, indicating a stabilization in production levels. This consistent trend reflects a balance between production and market demand, showcasing the province's sustained contribution to the poultry industry during the forecasted years in Misamis Occidental

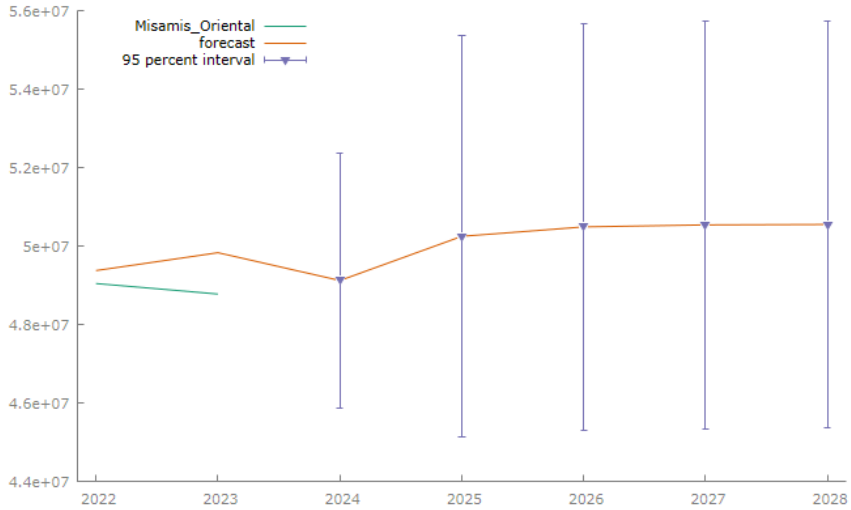

Figure 6. Forecasted Annual Chicken Processing Volumes in Misamis Oriental

Figure 6 illustrated the forecasted annual chicken processing volumes in Misamis Oriental from 2022 to 2028. The data reveals a decrease in processing volumes in 2024. However, from 2025 to 2028, the volumes show a steady increase, suggesting a recovery and subsequent growth in processing capacity. This upward trend reflects a positive outlook for the livestock and poultry sector in Misamis Oriental, indicating that the region will experience growth in processing volumes over the forecasted period.

Conclusion and Recommendation

The trend analysis and forecasting of annual livestock and poultry volumes, especially for animals slaughtered and processed by type and province, offers useful insights into the future of the industry. Using the ARIMA-based forecasting model, we can predict trends in chicken processing volumes across different provinces, which helps stakeholders prepare for changes in production capacity and demand.

The forecasted data shows important trends, such as steady growth in chicken processing volumes in provinces like Bukidnon and Misamis Oriental, while provinces like Camiguin display more unpredictable patterns. This information is valuable for planning, as it allows local authorities and industry stakeholders to adjust their strategies. Provinces with steady growth should focus on expanding processing capacity, while those with fluctuating trends may need to address the factors affecting their production stability.

Future research could build on this by looking at other types of livestock, such as pork and beef, and using similar forecasting methods to understand their trends in different regions. Additionally, exploring other forecasting models could improve prediction accuracy, help refine strategies, and improve overall management of the poultry and livestock industry.

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