Enhancing feed optimization in Kenya’s poultry subsector: Commodity pricing dynamics and forecasting

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Abstract: The poultry subsector has the potential to transform Kenya’s economic and social welfare. This study seeks to understand pricing dynamics of feed raw material based on available local price data with comparison to historical global data. Historical data of at least two years on the prices of various raw materials used in formulating poultry feed as well as climatic, geographical, demographical, and socio-economic data on Kenya and its counties were collected from various repositories. This was supplemented by key informant interviews. The Box-Jenkins Auto Regressive Integrated Moving-Average models predict an increasing trend in maize price at a rate of Kshs. 3.3 per day with a variance of 14.45% over a rolling 90-day cycle. For wheat, there is a decline over the same period of Kshs. 1.2 per day with a variance of -2.90%. The price forecast for finger millet shows a variation of 5.30%, with fluctuation in the trend. Energy prices and exchange rates have no influence on pricing of the three agricultural commodities. There is no confluence between Kenyan pricing movements and global price fluctuations for maize and

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PUBLIC INTEREST STATEMENT

The poultry sector in Kenya is a major contributor to the economy and nutrition of the nation. Currently, this sector is underdeveloped as a consequence of expensive poultry feeds whose nutritional value is poorly understood. This study seeks to understand pricing dynamics of feed raw material based on available local price data with comparison to historical global data. Using a popular forecasting approach based on 2017 and 2018 data, maize prices are predicted to increase at a rate of Ksh. 3.3 per day and wheat to decrease by Ksh. 1.2 per day over a 90-day cycle. Energy prices and exchange rates have no influence on pricing of the key agricultural commodities. There is no relationship between Kenyan pricing movements and global price fluctuations for maize and wheat. This study provides initial but critical insights into the process of improving feed optimization in the Kenyan poultry industry.
wheat. Moving forward, participatory creation of platforms to complement the National Farmers Information Service website is key.

Subjects: Agriculture & Environmental Sciences; Zoology; Economics and Development

Keywords: Agricultural commodity price dynamics; poultry feed; Auto-Regressive Integrated Moving-Average models; poultry subsector; Kenya

1. Introduction

Kenya, similar to many developing countries, is largely a country whose economic backbone is Agriculture. Agricultural output has steadily grown since the 1960s to date. Maize production, for instance, increased from 35.4 million bags in 2017 to 44.6 million bags in 2018 (Kenya National Bureau of Statistics [KNBS], 2019). In 2018, the value of livestock products and marketed livestock increased by 8.3% to Kshs. 146.8 billion (or about $ US 1.4 billion). Also, there was a marked improvement in the production of wheat. There has been a steady increase in value of marketed production of chicken and eggs from Kshs 6.0 billion in 2015, Kshs 8.8 billion in 2016, Kshs 10.7 billion in 2017 to 12.1 billion in 2018 (Kenya National Bureau of Statistics [KNBS], 2019).

Poultry production is a vital livelihood activity among Kenya’s smallholder farmers who contribute about 80% of total national poultry production (Njuguna et al., 2017). While agriculture contributes 25% of the GDP in Kenya, the poultry subsector encompasses 30% of this contribution (Netherlands Africa Business Council [NABC], 2019). Indigenous chicken in particular is highly valued among consumers for its leanness, tastiness and the notion that it is an organic product (Njuguna et al., 2017). The Kenya Agricultural and Livestock Research Organization (KALRO) in collaboration with the Ministry for Agriculture, Livestock and Fisheries has developed the improved indigenous chicken (KARI-Kienyeji), which is a superior crossbreed of different indigenous chicken ecotypes from various localities in Kenya (Kamau et al., 2018). Nevertheless, the country’s estimated consumption per capita of poultry eggs at 36 eggs and poultry meat at 7.59 kg is still lower than the recommended consumption requirements by the World Health Organization (Kenya Market Trusts, 2019; Netherlands Africa Business Council [NABC], 2019; Njuguna et al., 2017). The poultry subsector has also been negatively impacted by cheap and highly processed chicken particularly in the urban areas that have in recent years witnessed the “supermarket” revolution and the proliferation of fast-food chains (Kimenju et al., 2015; Reardon et al., 2009; Rischke et al., 2015; Timmer, 2009). This situation has led to increased incidence of diseases such as cancer and diabetes as well as obesity.

Feed costs contribute considerably to increased variable costs and may have an adverse effect on profitability (Njuguna et al., 2017). As a strategy to transform the Kenyan indigenous chicken industry into a profitable and a regionally and internationally competitive venture, we seek to develop a network for poultry feed actors and products; a platform that will underpin feed optimization to save on costs. To meaningfully carry out feed optimization, it is imperative to have good pricing data of feed raw materials coupled with an understanding of pricing dynamics. There are several approaches that have been utilized for efficient diet optimization. Linear programming models, which aim at obtaining a balanced diet at the least possible cost, have been applied in the Nigerian poultry industry (Oladokun & Johnson, 2012). Alqaisi et al. (2017) extend this model by using a multi-period linear programming (LP) model to formulate broiler diets in an environment where decision-making is made frequently on a daily, weekly or monthly basis. Multi-period LP models have been described as essential to making recommendations on dietary switching between feed commodities in the context of fluctuating feed commodity prices thus enhancing sustainability in feed formulation (Alqaisi et al., 2019). Another relevant model is the Box-Jenkins Auto-Regressive Integrated Moving-Average (ARIMA). ARIMA, which models the dependent variable solely as a function of its past values and disturbances, is widely used in time series forecasting (StatcoCorp, 2013; Zhang, 2003). It is quite a suitable approach to undertake in cases where there are gaps in the data (Amidi, 2014; Ren et al., 2019). The objectives of this
study include: i) Profiling the patterns in the data over time to project cycles; ii) Assessing factors that influence local pricing within certain time scales; and iii) To assess whether Kenyan economy pricing movements coincide with global commodity price fluctuations. We seek to answer questions such as a) the trends and projected price fluctuations of the raw material used to make poultry feed, b) factors that impact local pricing of raw materials for poultry feed, and how local pricing of raw materials in Kenya is affected by global commodity price fluctuations.

2. Methodology

2.1. Study area
Kenya is an East African country categorized as lower middle income. It has a population of approximately 47.8 million (as of 2018) and a GDP of Ksh 8.9 trillion or US $89 billion (Kenya National Bureau of Statistics [KNBS], 2019). Kenya, whose land size is 591,958 km², has varied agro-ecological zones ranging from vast swathes of arid and semi-arid land in the north to the arable highlands in the western, rift and central regions. About 20% of the total land mass is classified as medium to high potential with rest being classified as arid and semi-arid lands. Kenya experiences a bi-modal rainfall pattern, that is, the long rains season which occurs from March to May and the short rains from October to December. Annual rainfall patterns have fluctuated between 791.9 mm and 945.3 mm over the last five years (Kenya National Bureau of Statistics [KNBS], 2019). The higher altitude areas including the central and western highlands receive average annual rainfall of up to 2000 mm. Temperatures are generally mild with annual mean maximum temperatures fluctuating between 27.9 and 29°C and mean minimum temperatures between 17.2 and 17.3°C over the last five years.

Since the promulgation of the new constitution in 2010, Kenya has been under a devolved system of government. Consequently, the country has two levels of government (National and County) and is composed of 47 counties headed by elected governors. Although Kenya is rapidly urbanizing, most of these counties are pre-dominantly rural. Only Nairobi County, the commercial capital and the seat of administration, and Mombasa County can be considered to be fully urbanized.

In terms of labor employment, jobs in the informal sector (excluding small-scale agriculture and pastoralist activities) constitute about 84% of total employment (Kenya National Bureau of Statistics [KNBS], 2019). This translates to about 14.9 million persons earning an average of Ksh 717,000 per annum. The literacy rate in Kenya stands at 78% for those 15 years of age and over (https://www.indexmundi.com/kenya/literacy.html).

2.2. Data collection
Our main interest was to collect data (at least two years of historical data) on the prices of various raw materials used in the formulation of poultry feed (Table 1). In addition, climatic, geographical, demographical, and socio-economic data on Kenya and its counties were collected. Secondary sources were the main means through which data was collected for this study, which was done between 24 June 2019 and 24 July 2019. The approach also integrated a desktop study and key informant interviews. The search engines used for extracting historical data for raw materials for poultry feed included Google Scholar and Scopus. A number of keywords or a combination of them were used for example, “Kenya” AND “Poultry Sector” AND “Poultry Feed”. The other useful electronic repository for our purpose was the National Farmers Information Service (http://www.nafis.go.ke/category/market-info). This site holds historical data collected on a daily basis (but with gaps or missing observations) of market information for agricultural commodities such as a maize, wheat, beans, and others. Reference was also made to sources such as indexmundi (https://www.indexmundi.com/commodities) to extract global price data.

Given the paucity of data obtained from online sources, key informant interviews with owners of feed processing companies and agrovets augmented the data collection process. However, we encountered serious challenges with getting data from the larger feed processing companies. The
main concern for companies was that the information they provided could be used to undercut them in the market. The small and medium enterprises (SME) feed processors were more forthcoming with their data. The main challenge with SMEs was that it was difficult to collect historical data (two or more years) from them. This could be attributed to a lack of high-quality record keeping thus necessitating the use of recall data in some cases. It was also difficult to garner daily, monthly or even quarterly data as they were not actively tracking the prices of raw materials. In contrast, we obtained detailed, historical data from the Ministry of Agriculture, Livestock and Fisheries (MOALF). These data, however, captured only three commodities, that is, maize, wheat and finger millet, used for poultry feed production. The rest of the commodities are mainly for human consumption.

### 2.3. Data analysis

Secondary data collected were entered in excel (Ms Excel 10). It was then subjected to a data integrity analysis where any anomalies and outliers were removed. The data were imported to STATA 13 for subsequent analysis. In line with our objective of profiling, the patterns in the changes of commodity prices and given that there were several gaps in the data (there were days in which prices were not recorded on the local NAFIS site), we chose to use the Box-Jenkins
approach with ARIMA model to carry out time series analysis to project the trend and predict fluctuations. ARIMA models the dependent variable solely as a function of its past values and disturbances (StataCorp, 2013). ARIMA is a widely used model in time series forecasting and is favored because of its statistical properties as well as its model building process entailing the use of past observations of the same model (Zhang, 2003). To fit the ARIMA models, the autoregressive (p), differencing (d) and moving-average (q) parameters were specified on the basis of autocorrelations (correlograms), partial autocorrelations (partial correlograms) and line plots (StataCorp, 2013). Variance over a rolling 90-day cycle was determined to assess fluctuations of forecasted raw material prices. We chose 90 days as it is roughly the cycle of poultry (from day chick to point of sale); hence, the feed would be purchased and used within that time frame.
A deviation of the ARIMA, the ARMAX model, was used to model the dependent variable (price of raw material or commodity) in terms of a linear combination of independent variables (fuel price, exchange rates). Correlation analysis between local and global price fluctuation was estimated using spearman’s correlation.

### 3. Results and discussion

#### 3.1. Trends in prices of maize and its relationship with energy costs and exchange rates

Maize is one of the most ubiquitous ingredients for making poultry feed (Elangovan et al., 2004). In Kenya, about 80% of maize grain is locally sourced. Interestingly, the trend analysis showed a downward trend of dry maize prices over the two years, that is, 2017 and 2018 (Figure 1). However, given the data limitations, it is difficult to infer an overall trend as it is not possible to distinguish long-term trends from cycle trends over two to three years.

We fit an ARIMA model that includes differencing and autoregressive and moving average components, that is, ARIMA (1,1,1). In addition, we predict the trend over a rolling 90-day period. The out-of-sample prediction, from 1 January 2019 to 31 March 2019 shows as increasing trend over the 90-day period (Figure 2).

The calculated slope or rate of change in pricing over the 90-day period is:

\[
\text{Slope or rate of change} = 2354.223 - 2057.054/90 = 3.302 \text{ (in Kshs)}
\]

The variance in price change over the same period is 14.45%. Although the strength of the ARIMA model is in linear modeling, Zhang (2003) argues that in complex real-world situations it is often difficult to determine whether a time series is generated from a linear or non-linear process. It is worth noting that the predicted average price of dry maize as of 31 March 2019 (Kshs. 2354.22) only slightly differs from actual price of Kshs. 2366.67 on the subsequent date (1 April 2019) that appears on the NAFIS website. Thus, there is a difference of only Kshs. 12.45 or Ksh. 9.15 if you factor in the rate of change.

### Table 2. Estimated results of the ARIMA model for maize prices

|                      | Coefficient | Standard error | P > z  | 95% Confidence Interval |
|----------------------|-------------|----------------|--------|-------------------------|
| Maize price (Kshs.)  |             |                |        |                         |
| Maize_price_cons     | 3202.628    | 1075.781       | 0.003  | 1094.136                |
| ARMA                 |             |                |        |                         |
| AR                   |             |                |        |                         |
| L1.                  | 0.997       | 0.005          | 0.000  | 0.986                   |
| MA                   |             |                |        |                         |
| L1.                  | -0.649      | 0.056          | 0.000  | -0.759                  |
| Sigma                | 139.593     | 3.892          | 0.000  | 131.966                 |
| Wald Chi² (2)        | 35,727.29   | 180            |        |                         |
| Prob > Chi²          | 0.000       |                |        |                         |
| Observations         | 180         |                |        |                         |
The estimated results of the same model show that Auto Regressive (AR;1) coefficient is 0.997 and the Moving Average (MA;1) is −0.649 and both are highly significant (Table 2). The estimated standard deviation of the white noise disturbance $\epsilon$ is 139.593.

For comparison purposes, we estimated an ARMAX (1, 1, 2) model with maize price as dependent variable and energy price (diesel price) and foreign exchange rates as independent variables. This model (with one-step and dynamic prediction) shows a much higher increasing rate of change in price which is sharply at deviance with the previous ARIMA model as well as actual prices obtained from the NAFIS website (Figure 3).

The dynamic prediction is much less accurate than the one-step prediction because prior forecast errors accumulate over time (StataCorp, 2013). In this case, the calculated slope or rate of change in pricing over the 90-day period is:

$$\text{Slope or rate of change} = \frac{3477.485 - 2124.163}{90} = 15.037 \text{ (in Kshs.)}$$

Therefore, the variance in price change over the same period is 63.71%. The variance of the ARMAX model is much higher than that of the ARIMA model, hence giving more credence to the latter model. The reason why the ARMAX performs poorly may be predicated on the lack of predictive power on the model by the two independent variables (diesel price and exchange rates), which are not statistically significant (Table 3). These results also by extension suggest that there is no relationship between maize prices, on one hand, and diesel prices and the exchange rate on the other, at least for the two years concerned. This is indeed surprising as increase in the prices of agricultural commodities has traditionally been linked with increase in energy prices and vice versa. A possible reason for this disparity, which we did not control for, could be the favorable weather conditions experienced in 2017 and 2018 (Kenya National Bureau of Statistics [KNBS], 2019). This could have played a role mitigating any effects resulting from fluctuations in energy prices or exchange rates. Moreover, since a majority of maize grain is locally sourced or grown diesel prices and exchange rates do not have a substantial effect.
Table 3. Estimated results of an ARMAX model for maize prices in Kenya

| D.Maize price (Kshs.) | Coefficient | Standard error | P > z | 95% Confidence Interval |
|-----------------------|-------------|----------------|-------|-------------------------|
| Maize price           |             |                |       |                         |
| Diesel                |             |                |       |                         |
| D1.                   | 36.974      | 250.511        | 0.883 | -454.019 - 527.967      |
| Exchange rate         |             |                |       |                         |
| D1.                   | 46.269      | 365.794        | 0.899 | -670.673 - 763.212      |
| _cons                 | -8.054      | 4.065          | 0.048 | -16.022 - -0.086        |
| ARMA                  |             |                |       |                         |
| AR                    |             |                |       |                         |
| L1.                   | -0.484      | 0.724          | 0.504 | -1.902 - 0.935          |
| MA                    |             |                |       |                         |
| L1.                   | -0.609      | 0.743          | 0.412 | -2.065 - 0.846          |
| L2.                   | -0.391      | 0.793          | 0.622 | -1.945 - 1.164          |
| /sigma                | 82.243      |                |       |                         |
| Wald Chi² (5)         | 99.61       |                |       |                         |
| Prob > Chi²           | 0.000       |                |       |                         |
| Observations          | 188         |                |       |                         |

3.2. Trends in prices of wheat and its relationship with energy costs and exchange rates

Wheat is another common poultry feed ingredient in Kenya with wheat grain 100% sourced in Kenya (Table 1). Contrary to maize price trends, trend analysis shows a cyclical trend of wheat prices in 2017 and 2018 (Figure 4). This trend is expected as prices of commodities may fluctuate from time to time in the course of the year.

We estimate an ARIMA model with two autoregressive and four moving average components but no differencing, that is, ARIMA (2,0,4). The forecast shows a very brief cyclical period followed by levelling of prices (Figure 5).

The calculated slope or rate of change in pricing over the 90-day period is:

Slope or rate of change = 3657.418–3766.676/90 = −1.214 (in Kshs)

The variance in price change over the same period is −2.90%. This implies a general decrease in the price of wheat grain but with minimal variation over a 90-day period and leveling of the prices at some point. The estimated results of the same model show that AR (2) coefficient is 0.432 and the MA (4) is −0.374 and former is significant (Table 4). The estimated standard deviation of the white noise disturbance ε is 465.689.

Similar to maize, the ARMAX model reveals that the independent regressors, diesel fuel price and exchange rates, are not statistically significant (Table 5). Hence, there is no relationship between wheat prices and energy prices and exchange rates. In the case of exchange rates, this could be attributed to the fact that wheat grain is a 100% sourced in Kenya (Table 1). Globally, fuel prices have been on the decline especially since the US, a major oil consumer, is becoming self-sufficient in oil thus driving down demand. The price of crude oil has reduced considerably since 2014 when a barrel of oil was selling for US$ 96.2, but is now stabilizing at about US$ 66 (The World Bank, 2019). This could be a plausible reason for the reduced influence of fuel prices on agricultural commodities in Kenya.
3.3. Trends in prices of finger millet and its relationship with energy costs and exchange rates

The trend analysis for finger millet prices (2017 and 2018) shows a somewhat decreasing trend with several cycles (Figure 6). It is difficult, however, to adjudge a downward trend given the limitation of data. Millet is more expensive than maize and wheat thus it is not as popular with feed processors.

The ARIMA model estimated has three autoregressive and four moving-average components and is differenced. The one-step prediction closely matches the observed values (Figure 7). Furthermore, it predicts an up-trend of millet prices with peaks and valleys over a 90-day cycle. The calculated slope or rate of change in pricing over the 90-day period is: 

Figure 4. Trend of wheat prices in Kenya, 2017 and 2018.

Figure 5. Graphical output of ARIMA model and predicted wheat prices over a 90-day cycle in Kenya.

ARIMA forecast

[Graph showing ARIMA forecast with observed and predicted values]
Table 4. Estimated results of an ARIMA model for wheat prices in Kenya

|                      | Coefficient | Standard error | P > z | [95% Confidence Interval] |
|----------------------|-------------|----------------|-------|---------------------------|
| Wheat price (Kshs.)  | 3657.418    | 59.116         | 0.000 | 3541.553 - 3773.283       |
| Wheat price_cons     |             |                |       |                           |
| ARMA                 |             |                |       |                           |
| AR                   | 0.432       | 0.206          | 0.036 | 0.028 - 0.837             |
| MA                   | -0.374      | 0.254          | 0.142 | -0.872 - 0.125           |
| /sigma               | 465.689     | 35.521         | 0.000 | 396.069 - 535.309        |
| Wald chi2(2)         | 4.98        |                |       |                           |
| Prob > chi2          | 0.083       |                |       |                           |
| Observations         | 182         |                |       |                           |

Slope or rate of change = 7687.257–7300.451/90 = 4.298 (in Ksh)

The variance in price change over the same period is 5.30%. This implies a general increase in price of millet grain but with minimal variation. More so, it appears the prices start to flatten out at some point.

The estimated results of this ARIMA model show that AR (3) coefficient is 0.861 and the MA (4) is 0.423 and both are highly significant (Table 6). The estimated standard deviation of the white noise disturbance \( \epsilon \) is 246.159.

As with the prior commodities, there is no statistically significant relationship between finger millet and fuel price and exchange rates (Table 7). As discussed earlier, this could be as a result of flagging (or stabilization) global crude oil prices waning the influence of energy prices and/or local sourcing of the commodity.

3.4. Comparison of global and local commodity prices
It is essential to understand the confluence of Kenyan pricing trajectories with global commodity price fluctuations. Therefore, we compared local prices (wholesale commodity prices) of maize and wheat grain obtained from MOALF with historical global data accessed from indexmundi prices (wholesale commodity prices). Since the MOALF data were a bit more fragmented with comprehensive data for only two years, we only compared price fluctuations for 2017 and 2018. Given the relatively short time span, we do not expect any serious bias in price results due to variance in exchange rate or inflation.

Clearly, global prices for the two commodities are lower compared with local prices (Table 8). For the most part, there is considerable divergence in fluctuation of global and local prices for both maize and wheat. Only in the case of December 2017/January 2018, June 2018/July 2018, August 2018/September 2018 for maize, and September 2017/October 2017 and January 2018/February 2018 for wheat do the fluctuations follow a similar pattern. A correlation analysis further reinforces the divergence of global and local commodity prices. The Pearson correlation coefficient (r) for global maize price vs. local maize price is −0.246, which is weak and inverse (Table 9). Likewise, the correlation of global and local wheat prices is also weak though it is positive with a coefficient of 0.457. Therefore, there is no confluence between Kenyan pricing movements and global price fluctuations, at least for maize and wheat. This could be attributed to the low share of
maize grain and wheat grain imported into Kenya (Table 1). Nonetheless, a comparison of only two years is definitely limiting thus the results are not entirely conclusive.

4. Conclusions, challenges and recommendations

In this study, we carry out trend analysis and forecasting for the prices of three major commodities used in making poultry feed, that is, maize grain, wheat grain and finger millet. In addition, we analyze factors that may influence commodity prices and compare local pricing and global price fluctuations. Based on 2017 and 2018 data, there is a decreasing trend in prices for maize and finger millet though the trend in the latter is more cyclical. Similar to finger millet, the price trends for wheat are cyclical. The ARIMA models predict, over a rolling 90-day cycle, an increasing trend in maize price at a rate of Kshs. 3.3 per day with a variance of 14.45%. For wheat, there is a decline over the same period of Kshs. 1.2 per day with a variance of −2.90%. The price forecast for finger millet shows a variation of 5.30%, with a peaks and valleys in the trend. However, it is important to note that real-world time series implicitly display both linear and nonlinear patterns (Zhang et al., 2003). Therefore, ARIMA and other linear approaches are limited in the sense that they more robust in forecasting linear time series. Interestingly, energy prices and exchange rates have no influence on pricing of the three agricultural commodities. Also, there is no confluence between Kenyan pricing movements and global price fluctuations for maize and wheat. This is because only a small proportion of these commodities are imported into the Kenyan market.

Although these results shed light on the pricing dynamics of three important raw materials for poultry feed production, the study does not address the pricing dynamics of other raw materials. This is mainly because of a paucity of historical data on prices of premixes, soya cake, cotton cake, sunflower cake and others not covered in the analyses. Key informant interviews confirmed the insinuation that feed processors do not keep very good records necessitating a reliance on recall data. The poultry value chain also currently experiences constraints in information sharing with the larger private companies for several reasons, justified or unjustified, reluctant to share data and information. The MOALF has focused disproportionately on foods consumed by humans to the detriment of livestock feeds thus there is a scarcity of reliable, time-scale national data for raw material used in making poultry and livestock feeds. Moreover, the available data for maize, wheat and finger millet had several gaps. Whereas this data was meant to be collected on a daily basis, there were glaring gaps with as much as 30 days’ worth of data missing in some cases. This informed the selection of the ARIMA model for the analysis as it is widely lauded for its gap filling

| Table 5. Estimated results of an ARMAX model for wheat prices in Kenya |
|-----------------------------|-----------------|-----------------|-----------------|-----------------|
| Wheat price (Kshs.) | Coefficient | Standard error | P > z | [95% Confidence Interval] |
| Wheat price | | | | |
| Diesel | −16.820 | 31.460 | 0.593 | −78.482 | 44.841 |
| Exchange rate | −303.255 | 200.893 | 0.131 | −696.998 | 90.487 |
| -cons | 36,374.86 | 22,608.53 | 0.108 | −7937.04 | 80,686.76 |
| ARMA | | | | |
| AR | 0.312 | 0.251 | 0.213 | −0.179 | 0.804 |
| MA | | | | |
| L4. | −0.100 | 0.230 | 0.000 | −1.451 | −0.549 |
| /sigma | 317.938 | | | |
| Wald Chi² | 317.938 | | | |
| Prob > Chi² | 0.0001 | | | |
| Observations | 72 | | | |
properties. Despite such properties, it has its own limitations as earlier mentioned. Going forward, the combination of ARIMA with a nonlinear model such as artificial neural networks (ANN) would enhance forecasting (Bobu and Reddy, 2014).

Nevertheless, it is imperative that the MOALF is sensitized on the importance of collecting livestock/poultry-related data at sufficient frequency (daily, monthly or even quarterly) to facilitate the creation and archiving of more comprehensive datasets. Hence, there are several steps to be undertaken to improve feed optimization in the Kenyan poultry industry and this study provides initial but critical insights to this process. Enhanced commodity price forecasting leading to effective feed optimization will enable farmers to produce high quality, organic chicken at optimal costs. Given that the poultry

Figure 6. Trend of finger millet prices in Kenya, 2017 and 2018.

Figure 7. Graphical output of ARIMA model and predicted finger millet prices over a 90-day cycle in Kenya.
Table 6. Estimated results of an ARIMA model for finger millet prices in Kenya

| Coefficient | Standard error | P > z | [95% Confidence Interval] |
|-------------|----------------|-------|--------------------------|
| Millet price (Kshs.) | | | |
| Millet price_cons | 7693.814 | 136.3474 | 0.000 | 7426.578 | 7961.05 |
| ARMA | | | |
| AR | | | |
| L3. | 0.861 | 0.029 | 0.000 | 0.804 | 0.917 |
| MA | | | |
| L4. | 0.423 | 0.095 | 0.000 | 0.236 | 0.610 |
| /sigma | 246.159 | 10.320 | 0.000 | 225.932 | 266.386 |
| Wald chi²(2) | 919.43 | | | |
| Prob > chi² | 0.000 | | | |
| Observations | 184 | | | |

Table 7. Estimated results of an ARMAX model for finger millet prices in Kenya

| Coefficient | Standard error | P > z | [95% Confidence Interval] |
|-------------|----------------|-------|--------------------------|
| Millet price (Kshs.) | | | |
| Millet price_cons | 126.133 | 90.693 | 0.164 | −51.621 | 303.887 |
| Exchange rate | −451.422 | 419.008 | 0.281 | −1272.663 | 369.819 |
| -cons | 43,114.84 | 50,544.88 | 0.394 | −55,951.31 | 142,181 |
| ARMA | | | |
| AR | | | |
| L3. | 0.921 | 0.038 | 0.000 | 0.847 | 0.995 |
| MA | | | |
| L4. | 0.495 | 0.184 | 0.007 | 0.134 | 0.857 |
| /sigma | 188.024 | 17.540 | 0.000 | 153.646 | 222.4027 |
| Wald Chi² (4) | 674.51 | | | |
| Prob > Chi² | 0.000 | | | |
| Observations | 73 | | | |

Table 8. Comparison of Kenyan and global prices for maize and wheat grain

| Maize | Wheat |
|-------|-------|
| MOALF | Indexmundi | MOALF |

| Month-Year | Price ($US) | Change | Price ($US) | Change | Price ($US) | Change |
|------------|-------------|--------|-------------|--------|-------------|--------|
| Jan-17     | 28.88       |        | 14.40       | 4.95%  | 33.31       | 13.79  | 8.03% |
| Feb-17     | 14.66       | 1.79%  |             |        |             |        |      |

(Continued)
sector, in particular, contributes substantially to the GDP of the nation this cannot be overstated. However, the MOALF may not have adequate resources to collect such data on its own. This calls for greater collaboration with other players in the poultry value chain including private companies. Therefore, steps should be taken to consultatively create platforms that can complement the NAFIS website to improve knowledge sharing and information access in the poultry subsector of Kenya.

Table 8. (Continued)

|       | Maize          | Wheat          |
|-------|----------------|----------------|
|       | Mar-17         | Apr-17         | May-17         | Jun-17         | Jul-17        | Aug-17        | Sep-17        | Oct-17        | Nov-17        | Dec-17        | Jan-18        | Feb-18        | Mar-18        | Apr-18        | May-18        |
|       | 36.85          | 41.72          | 44.60          | 44.98          | 39.50          | 35.97         | 33.21          | 30.40         | 28.90         | 26.40         | 27.55         | 27.59         | 27.86         | 27.89         | 16.12         |
|       | 27.63%         | 13.21%         | 6.90%          | 0.84%          | -12.18%        | -8.94%        | -7.67%         | -8.47%        | 0.00%         | -8.64%        | 4.33%         | 0.17%         | 9.7%          | 0.09%         | 0.97%         |
|       | 14.31          | 14.08          | 14.27          | 14.21          | 14.18          | 13.37         | 13.26          | 13.38         | 13.38         | 13.41         | 14.03         | 14.70         | 15.48         | 15.80         | 16.12         |
|       | -2.39%         | -1.59%         | 1.37%          | -0.42%         | -0.27%         | 5.72%         | 0.81%          | 0.90%         | 0.05%         | -5.72%        | 4.60%         | 4.83%         | 5.29%         | 2.09%         | 1.99%         |
|       | 35.21          | 37.14          | 36.98          | 35.08          | 33.91          | 36.16         | 36.54          | 35.52         | 34.25         | 41.73         | 35.32         | 35.64         | 37.53         | 38.63         | 19.25         |
|       | 5.69%          | 5.50%          | -0.45%         | -5.12%         | 3.34%          | 6.65%         | 1.03%          | 15.81         | 15.14         | 21.83%        | -15.36%       | 9.1%          | 5.30%         | 2.94%         | 11.28%        |
|       | 13.89          | 14.95          | 16.24          | 17.06          | 18.22          | 15.41         | 16.07          | 15.81         | 14.17         | 15.43%        | 16.57         | 17.30         | 17.30         | 17.30         | 19.25         |
|       | -0.48%         | 7.62%          | 8.63%          | 5.09%          | 6.78%          | 4.29%         | 4.29%          | 1.65%         | 2.31%         | 2.45%         | 4.39%         | 0.00%         | 0.00%         | 12.18%        | 11.28%        |

Note: The exchange rate varied from 1 US$ to Kshs. 100.62 to 1 US$ to Kshs. 103.57 during this period

Table 9. Descriptive statistics and correlation analysis for local and global commodity prices

|                  | Mean   | Std. Dev. | Min   | Max   | Pearson correlation coefficient (r) |
|------------------|--------|-----------|-------|-------|------------------------------------|
| Maize price (US $) |        |           |       |       |                                    |
| Local            | 29.63  | 8.00      | 18.68 | 44.98 | -0.246                             |
| Global           | 14.26  | 0.68      | 13.26 | 15.80 |                                    |
| Wheat price (US $) |        |           |       |       |                                    |
| Local            | 36.65  | 2.17      | 33.31 | 41.73 | 0.457                              |
| Global           | 17.35  | 1.98      | 13.79 | 21.30 |                                    |
Acknowledgements
We are grateful to the cooperation received from key informants and SMEs in the poultry sub-sector of Kenya.

Funding
This work was supported by Baib Kenya Limited.

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Disclosure statement
No potential conflict of interest was reported by the authors.

Data availability statement
The data associated with this work can be made available on request.

Citation information
Cite this article as: Enhancing feed optimization in Kenya’s poultry subsector: Commodity pricing dynamics and forecasting, Ivan S. Adolwa, Ray Garcia & Michael Wallis-Brown, Cogent Food & Agriculture (2021), 7:1917743.

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