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A comparative study of various exponential smoothing models for forecasting coriander price in Indian commodity market

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ABSTRACT

The present study analyzes the price forecasting methodologies of coriander in selected market using its price data over the period from 2008 to 2017. The study compares several exponential smoothing models viz. Single and double exponential smoothing, Holt-Winter trend adjusted -no seasonal model, Holt-Winter triple additive and multiplicative exponential smoothing models to predict price data and compare with the actual value of coriander prices. All the exponential models are fully applicable to time series and applicability of forecasting methods are evaluated by minimizing their root mean square error. Best model selection helps to producer, supplier and customer in making rational decisions. Compared to other methods, Holt Winter trend adjusted model provides a better forecast of coriander prices with suggestive parameters.

Keywords: Exponential smoothing models, commodity price forecasting, price forecasting model, coriander prices, root mean square error.

Introduction

Agriculture sector plays a very significant role for both developed and developing countries. It provides basic raw/ processed material to Agro-industries and constitutes a major employment source of any country. Agriculture commodity prices are influenced by various factors such as demand-supply, weather conditions, government policy and other economic variables etc. These factors have a varying degree of influence over the commodity price. Due to the uncertainty of the influence, food prices forecasting is advantageous for agribusiness industries, policy-maker, farmers and individuals. For farmers, it helps to find out about the quantity and the type of crop to produce. It provides support to policy-makers to formulate various policies about production, procurement & supply of agriculture commodities to different states. Prices have significantly optimized the market production and market strategy. Government policies are formulated towards short, medium and long-term prediction of economic variables such as agriculture products. In agriculture production, time plays a very important factor because the crop is grown in one period and harvested in another. Price forecasting gains important significance as it becomes an important determinant of future profit and loss.

In India, spices are considered as an important ingredient in food. They also have various medicinal and nutritional properties. Among them, Coriander is a spice and an important cash crop of India. India is the largest producer of coriander with a market share of 70%. Coriander (Coriandrum sativum L.) is mainly a Rabi crop produce in Madhya Pradesh, Gujarat, Tamil Nadu, Rajasthan, Utter Pradesh.

Literature Review:

Booranawong et.al. (2018) investigate double exponential smoothing, additive and multiplicative Holt-winter exponential smoothing models to forecast lime, chili and lemongrass prices in Thailand. The optimum initial value and weight factors are used to predict future values models are evaluated using MAPE value. For Thai chili and lemongrass, DES model is appropriate to forecast the future price values and multiplicative Holt-Winter model shows better accuracy in price prediction for lemongrass.

Vijko et.al. (2018) in their study, forecast tourism demand using tourist arrival data collected from Republic statistics office (Belgrade). The exponential smoothing models were applied on monthly data from January 2000 to December 2013 to predict the value till may 2018. The accuracy of the selected model is determined by Bayesian information criterion and found that the Winter multiplicative model is more suitable because of the presence of seasonal effect on observed data.

Siregar et. al. (2017) compared various exponential smoothing technique viz. exponential smoothing (ES), double exponential smoothing (DES), triple exponential smoothing (TES), triple exponential smoothing additive model (TES additive) and triple exponential smoothing multiplicative (TES multiplicative) model. In their study many α, β and γ combinations are chosen to minimize the MAE and RMSE. The performance of the model is analyzed using RMSE (root mean square error).

Hansun (2016) recommended double exponential smoothing technique, also known as Brown exponential smoothing method to forecast Jakarta stock exchange index data. He finds that DES model is better than single exponential technique. In DES the exponential filter process is used twice to predict the future values and the weighted moving average is used to get the initial value. The forecasting results were verified with smaller values of mean absolute percentage error.

Vasanth Kumar et. al. (2015) forecasted maize prices by exponential smoothing model. The secondary price data of maize for 16 years period was taken from APMCs (Agriculture produce marketing committee) of the Davanagere market located in Karnataka. All exponential smoothing (single ES, double ES & triple ES) methods were compared to find the best predicting exponential smoothing methods. The precision of the obtained prediction was determined by R^2, RMSE, MAPE, coefficient of variation and correlation coefficient. The study concludes Double exponential smoothing method is better for price forecasting in Davanagere market in Karnataka.

Eva and Oskar (2012) explained single exponential smoothing (SES) method, applies it to data having stable mean and no trend. In the study, SES used weighted moving average of past data to forecast the future values of electricity production in Slovakia. The exponential smoothing assigns large amplitude weight factors to observations that are recent and then decreasing weights are assigned as observation get older. The accuracy of the model depends on the choice of smoothing constant. The indicator, used to evaluate accuracy, are lower values of mean absolute error (MAE), RMSE (Root mean square error) and mean absolute percentage error (MAPE).

Sanjoy (2011) describe exponential smoothing techniques to predict future values. The forecasting accuracy of exponential smoothing technique depends on the choice of the appropriate value of smoothing constant. The minimum values of mean square error and mean absolute error are preferred for optimization of smoothing constant. The Trial and error method is applied to optimize the smoothing constant parameter value.

Objectives:

1. To study and analyze the daily price fluctuation of coriander based on different exponential smoothing methods.

2. To forecast and compare the coriander price based on appropriate exponential smoothing model.

Data Analysis Method

The Daily coriandar price (time-varying data), from 11th August 2008 to 30th April 2018, is used for the study. The forecast function, based on past observations, is most commonly observed by the exponential procedure. The exponential smoothing technique allows the forecasting function to be restructured very easily every time when new observation becomes available.

The exponential smoothing(ES) model is used to forecast time series and is equivalent to the weighted moving average (WMA) method. The Exponential forecasting model is a parametric non-linear forecasting model intended for short-term forecasts. ES model is applied to univariate time series model for discrete data. ES models are based on an assumption of fitting a suitable curve on the historical time series data.

Exponential smoothing technique gives highest weights to more recent observations, then decreasing weights are assigned as observation get older. The data is smoothed using damped coefficient called weighing factor, whose value lies between 0 and 1. To forecast initial value of data point, an average of the first few values of the observation is chosen. ES models are broadly classified as seasonal and non-seasonal exponential smoothing models. Different types of exponential smoothing models are

1. Simple exponential smoothing model
2. Brown's linear (Double) exponential smoothing model
3. Holt's linear (Double) exponential smoothing model
4. Holt-Winters' (Triple) exponential smoothing model
   - Holt-Winter additive model
   - Holt-Winter multiplicative model

Model I: Simple Exponential smoothing model:

The simple exponential smoothing (SES) model is a time series forecasting technique that can be defined using an additive model with no trend and seasonal pattern.

New forecast value at time t+1= old forecast at time t + α (error in the last forecast)

$$F_{t+1}= F_t+\alpha(y_t - F_t)$$

Here, α is the smoothing parameter $0 \leq \alpha \leq 1$. The smoothing constant (α) value is selected based on error minimization approach.

Model II: Brown's linear (Double) exponential smoothing model (Brown,1959)

The double exponential smoothing model is used to model TS data with trend but no seasonality.

Here F' denotes a simple smoothed value and F'' denotes double smoothed value

$$F'_t = \alpha y_t + (1-\alpha)F'_{t-1}$$

$$F_t'' = \alpha s_t' + (1-\alpha)F_{t-1}''$$

$$a_t = F_t' + \left(F_{t_+}' - F_t''\right) = 2F_t' - F_t''$$

a_t denotes the estimated smoothed level at time t

$$b_t = \frac{\alpha}{1-\alpha}(F_t' - F_t'')$$

And b_t shows the estimated trends at the end of time period t, for m-period ahead forecast is

$$F_{t+m} = a_t + mb_t$$

Like SES and DES model needs a starting value to initialize the process. For Brown's linear (Double) exponential smoothing model the estimated starting values are

$$\text{Let } F_t' = F_t'' = y_1$$

$$a_I = y_1, b_t = \frac{(y_2-y_1)+(y_4-y_3)}{2}$$

The initialization value choice can greatly affect the fit value and forecast values. The weight selection depends on the experience method, trial or error method etc. These methods are the simplest ways to determine weights.

Model III: Holt's linear (Double) exponential smoothing method (Holt, 1957)

Holt's method can be implemented on time series data demonstrating a trend. In this technique level & trend components, are smoothed separately using different parameters α and β. Holt's trend corrected double exponential smoothing method uses three equations for level, trend and forecast.

$$L_t = \alpha y_t + (1-\alpha)(L_{t-1} + b_{t-1})$$

$$b_t = \beta(L_t - L_{t-1}) + (1-\beta)b_{t-1}$$

$$F_{t+m} = L_t + b_t m$$

Where L_t= Level of time series at period t

b_t= Trend (slope) estimate of time series at time period t

F_{t+m}= Forecast for m period ahead of t

α and β are smoothing constant for level and trend with their values lying between 0 and 1. The values of α and β combination, that gives lowest absolute percentage error (MAPE), are selected.

Holt model is appropriate for non-stationary data and is used to make short-term forecast. There are two models of Holt Winter exponential smoothing model. Viz. Holt-Winter additive seasonal (HWAS) model and Holt-Winter multiplicative seasonal (HWMS) exponential smoothing model.

Model IV: Holt-Winters' (Triple) exponential smoothing model (Winter,1960)

Holt and winter extended the Holt's model to capture seasonality in time series data. In triple exponential smoothing model high frequency signals are removed from TS data occurred over repeated intervals of time

$$L_t = \alpha \frac{y_t}{s_{t-12}} + (1-\alpha)(L_{t-1} + b_{t-1})$$

$$b_t = \beta(L_t - L_{t-1}) + (1-\beta)b_{t-1}$$

$$s_t = \gamma \frac{y_t}{L_t} + (1-\gamma)s_{t-1}$$

$$F_{t+m} = (L_t + b_t m)s_{t-s+m}$$

Here L_t=Level of time series at time period t

b_t= Trend (slope) estimate of the time series t

s_t= Seasonal component at time t

Where s= length of seasonality

F_{t+m}= Forecast of m period ahead of t

α, β and γ are smoothing constant. The combination of α, β and γ , which gives minimum mean absolute percentile error (MAPE), are selected.

Model IV (a): Additive Holt-Winter method –

Exponential smoothing TS data can be defined as an additive model with increasing or decreasing trend and with constant (additive) seasonal variations.

$$y_t = (\beta_0 + \beta_1 t) + SN_t + IR_t$$

$$\text{Level } L_t = \alpha\,(y_t - Sn_{t-L}) - (1-\alpha)(L_{T-1} + b_{T-1})$$

$$\text{Growth rate (Trend) } b_t = \beta(L_t - L_{t-1}) + (1-\beta)b_{t-1}$$

$$\text{Seasonal factor } Sn_t = \delta\left(\frac{y_t}{L_t}\right) + (1-\delta)Sn_{t-L}$$

Where $(\beta_0 + \beta_1 t)$ = Level L_t

SN_t= Seasonal Pattern

IR_t = Irregular component

Model IV (b): Multiplicative Holt-Winter method – This method is used for time series with increasing (multiplicative) seasonal variations.

$$y_t = (\beta_0 + \beta_1 t) \text{ x } SN_t x IR_t$$

$$\text{Level } L_t = \alpha\frac{y_t}{Sn_{t-l}} - (1-\alpha)(L_{T-1} + b_{T-1})$$

$$\text{Growth rate (Trend) } b_t = \beta(L_t - L_{t-1}) + (1-\beta)b_{t-1}$$

$$\text{Seasonal factor } Sn_t = \delta\left(\frac{y_t}{L_t}\right) + (1-\delta)Sn_{t-L}$$

L= number of seasons in a year (L=4 for quarterly data and L=12 for monthly data)

Where α, β and δ are smoothing parameters, where $0 \leq \alpha, \beta$ and $\delta \leq 1$

To initiate the forecast process, we need the initial values of the level, trend and seasonality. For initialization of seasonality parameter one complete seasonal cycle values $y_1, y_2, \ldots, y_s$ are needed. For level and trend parameter, the initial values are calculated using the following equation

$$L_s = \frac{1}{s}\sum_{i=1}^{s} y_i$$

$$b_5 = \frac{1}{s}\left[\frac{y_{s+1}-y_1}{s} + \frac{y_{s+2}-y_2}{s} + \cdots + \frac{y_{2s}-y_s}{s}\right]$$

Where $s_i = y_i - L_s,\ i = 1,2,\ldots,s$

The effectiveness of a forecasting model requires evaluation of various exponential smoothing methods and to identify the one that provides the minimum errors.

Data analysis:

The time series forecasting techniques are applied to make prediction about future values. For this raw data is divided into two categories; training and test datasets. Training dataset is used to build the desired model and a small part of this training dataset is chosen as validation set. All the competing models are analyzed for out of sample data observations. Smoothing coefficients are updated and compared the forecasted values with actual observations (out of sample). The performance measures used to estimate the forecasting adequacy of different models are sum of square error and mean absolute percentage error. The forecast horizon is calculated for chosen exponential smoothing model.

Result and Discussion

Time plot of coriander closing price data, from 11th August 2008 to 31st December 2017, is used to study the price pattern and is shown in fig 1.

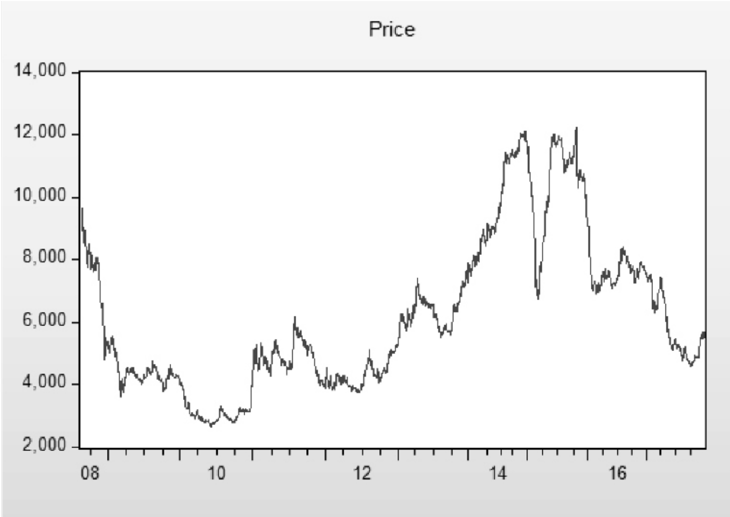

Fig 1. *Coriander price trend over time*

The pattern of variations are observed in coriander price and find that coriander prices oscillated between 5172 to 5644, reflect non-linear characteristics of price series.

To calculate the instability in price, the coefficient of variation (CV) is given as

$$CV = \frac{2459.282}{6159.559} X\ 100 \quad = 39.97$$

The price of coriander shows high variability in the market. Exponential Smoothing models are fitted for the price series using Eviews software. The initiation and data identification processes are carried out using the exponential smoothing models. The calculated value of the smoothing parameters (α & β) with the smaller RMSE is chosen for the future forecast and are shown in table 1. Holt – trend adjusted exponential smoothing model is identified with minimum RMSE among the different applied exponential smoothing models viz. SES, DES, HW- trend adjusted, HWAS and HWMS, for coriander price. The accuracy of the Exponential technique also depends on the choice of appropriate value of smoothing constants to minimize the error in forecasting.

Table 1. *Calculated parameter value for applied econometric models*

Exponential smoothing models	Smoothing Parameter value	Estimated RMSE
Simple Exponential smoothing	$\alpha = 0.9$	146.80
Double Exponential Smoothing	$\alpha = 0.5$	149.41
Holt-Winter trend adjusted	$\alpha = 1.0$; $\beta = 0.06$	100.11
Holt-Winter Additive model	$\alpha = 1.0$; $\beta = 0.06$	100.22
Holt-Winter Multiplicative model	$\alpha = 1.0$; $\beta = 0.06$; $\gamma = 0$	100.14

Source; Author's calculation

Eviews software is used to process the daily data in the forecasting process. With the parameters $\alpha = 1.0$ and $\beta = 0.06$, the result of forecasting using the Holt-Winter-Trend adjusted (No seasonal method) for the period 8^{th} august 2008 to 31^{st} December 2017, the RMSE value is 100.1130.

The result indicates that the double exponential trend adjusted exponential smoothing method is appropriate because the observation data have trend components. The value of α parameter equal to 1 indicate that level respond strongly to every new innovation and small value of β = 0.06 shows that trend (slope) hardly change over time. Forecast for the data (1^{st} January 2018 to 30^{th} April'2018) containing trend component should be solved by using the method of Holt winter trend adjusted exponential smoothing.

Level $L_t = 1.0y_t + (1 - 1.0)(L_t + b_{t-1})$

Trend $b_t = 0.06(L_t - L_{t-1}) + (1 - 0.06)b_{t-1}$

Forecast $F_{t+m} = L_t + b_t m$

The Forecast obtained for Jan 2018 to April 2018 of coriander price using Holt-Winter trend adjusted smoothing model are provided in the table:

Table 2. Coriander forecast price v/s actual price data using Holt trend adjusted method

	PRICEHWTSM	PRICE		PRICEHWTSM	PRICE
1/01/2018	5557.267	5511.15	3/01/2018	5411.732	5402.80
1/02/2018	5521.051	5573.70	3/05/2018	5401.496	5441.95
1/03/2018	5586.759	5555.15	3/06/2018	5443.073	5392.60
1/04/2018	5566.313	5521.45	3/07/2018	5390.695	5411.30
1/05/2018	5529.922	5472.30	3/08/2018	5410.631	5395.10
1/08/2018	5477.315	5500.00	3/09/2018	5393.500	5403.65
1/09/2018	5506.376	5507.15	3/12/2018	5402.658	5418.75
1/10/2018	5513.572	5644.00	3/13/2018	5418.724	5446.55
1/11/2018	5658.247	5632.85	3/14/2018	5448.193	5422.00
1/12/2018	5645.573	5606.25	3/15/2018	5422.072	5357.60
1/15/2018	5616.614	5568.75	3/16/2018	5353.804	5468.75
1/16/2018	5576.243	5507.15	3/19/2018	5471.850	5334.15
1/17/2018	5510.498	5462.70	3/20/2018	5328.989	5334.85
1/18/2018	5463.180	5429.95	3/21/2018	5330.041	5326.25
1/19/2018	5428.437	5394.95	3/22/2018	5321.213	5284.10
1/23/2018	5391.428	5500.00	3/23/2018	5276.837	5277.80
1/24/2018	5502.991	5475.50	3/26/2018	5270.595	5311.70
1/25/2018	5476.842	5571.75	3/27/2018	5306.961	5277.80
1/29/2018	5578.786	5517.90	3/28/2018	5271.311	5344.35
1/30/2018	5521.283	5485.45	4/02/2018	5342.243	5463.85
1/31/2018	5486.683	5536.10	4/03/2018	5469.038	5501.80
2/01/2018	5540.298	5506.95	4/04/2018	5508.953	5518.05
2/02/2018	5509.147	5498.30	4/05/2018	5525.749	5521.90
2/05/2018	5499.847	5419.15	4/06/2018	5529.368	5501.80
2/06/2018	5415.856	5462.50	4/09/2018	5507.614	5403.85
2/07/2018	5462.004	5456.25	4/10/2018	5403.440	5491.65
2/08/2018	5455.409	5413.50	4/11/2018	5496.531	5383.35
2/09/2018	5410.145	5377.40	4/12/2018	5381.442	5391.30
2/12/2018	5372.080	5394.35	4/13/2018	5389.983	5426.85
2/15/2018	5390.366	5344.00	4/17/2018	5427.745	5370.40
2/16/2018	5337.235	5366.95	4/19/2018	5367.855	5322.50
2/19/2018	5361.967	5396.35	4/20/2018	5317.234	5349.05
2/20/2018	5393.430	5356.45	4/23/2018	5345.692	5316.95
2/21/2018	5351.312	5382.50	4/24/2018	5311.868	5268.75
2/22/2018	5379.233	5461.55	4/25/2018	5261.081	5226.30
2/23/2018	5463.221	5442.40	4/26/2018	5216.545	5236.05
2/26/2018	5442.822	5344.20	4/27/2018	5227.465	5230.60
2/27/2018	5338.705	5347.00	4/30/2018	5222.203	5172.00
2/28/2018	5342.003	5412.50			

Source : Author's calculation

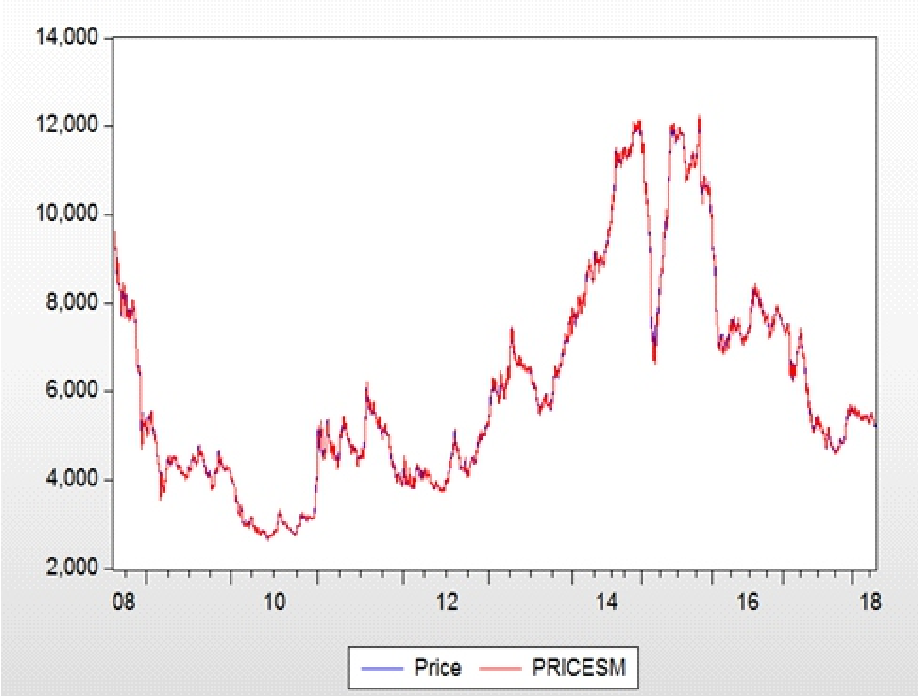

Fig 2. Graph of actual price v/s calculated forecast price data

The graphical presentation (fig. 2) of price (shown by blue line) and forecasted price value (shown by red line) express that both the series co-move together very closely. It shows that the actual value is close to forecasted value. So, this cointegration is expected in future estimated values and actual values also.

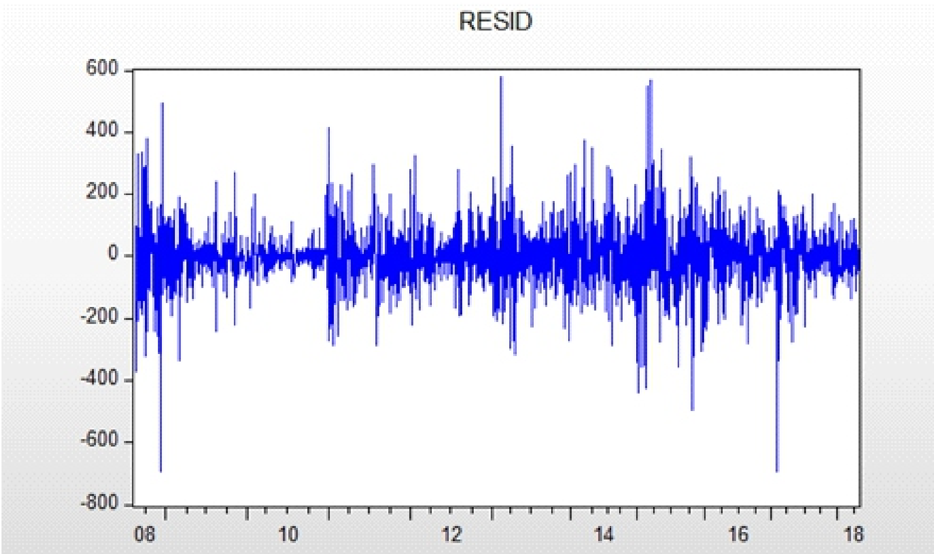

Fig 3: Plot of residual value(error)with time for Holt winter trend adjusted model

The adequacy of Holt Winter trend adjusted model is assessed by its residual data value. This leads to diagnostics regarding the suitability of the applied model. Smaller magnitude of residual error indicates that the applied model has adequately captured the data information. Above figure 3 shows that the mean of the residuals are zero and uncorrelated. Hence, Holt-Winter trend adjusted model is appropriate for making coriander price forecasting.

Conclusion:

In the present study forecasting model based on exponential smoothing model was developed for the price of coriander, daily data from 11th Aug'2008 to 31st Dec'2017 to forecast the price for 1st Jan'18 to 30th April'18. Based on the evaluation of forecasting results of exponential smoothing methods, the best model to forecast coriander price is Holt-Winter trend adjusted. The accuracy of the method depends on the choice of appropriate value of smoothing constant. The trial and error method is used to find the value of smoothing parameter α , β and γ.The value is selected in such a way that minimize the RMSE of the model. The outcome of the study are - single exponential forecasting model ($\alpha = 0.9$) with RMSE = 146.80 , MAPE= 2.44, for Brown's double exponential smoothing ($\alpha = 0.5$) with RMSE= 149.41 ,MAPE= 0.83 , Holt two parameter ($\alpha = 1.0$; β= 0.06), with RMSE=100.11 , MAPE = 0.8 Holt Winter three parameter additive model ($\alpha = 1.0$; β= 0.06; γ= 0) RMSE= 100.22 , MAPE= 0.81 ,and Holt- Winter three parameter multiplicative model ($\alpha = 1.0$; β= 0.06; γ= 0) with RMSE= 100.14,MAPE= 0.812

The proposed algorithm is measured by root mean square error (RMSE) and mean absolute percentage error (MAPE) to assess the performance of forecasting model. Compared to other methods, Holt two parameter trend model provide better forecast of coriander prices with suggestive parameters. The forecasting accuracy technique such as RMSE is select to get the most appropriate forecast for four months ahead forecast.

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