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ANALYSIS OF DEMAND FORECASTING FOR TEMPEH PRODUCTS AT INDONESIAN TEMPEH HOUSES USING THE HOLT-WINTERS ADDITIVE METHOD APPROACH

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Abstract: Rumah Tempe Indonesia is an MSME engaged in processing soybeans into tempeh products. The production system used is made to stockThis production system can cause problems, including the amount of production that does not match consumer needs, causing a shortage or excess of products which are very inefficient for the company's business continuity. For this reason, a study was carried out to determine the forecast for the demand for GMO Tempe at Indonesian Tempe Houses for the next 12 periods using the Holt-winters method and to determine the accuracy of the forecast made. The method used in this research is the Holt-winter method with the help of Ms. Excel Where. The final result of the research using Holt-winters has a level of forecasting accuracy90.1515344%, which means it is very good at predicting the demand for tempe in the future. Forecasting results in periods 37 to 48 respectively are 13372PCS, 12367PCS, 14196PCS, 12848PCS, 16655PCS, 15965PCS, 18032PCS, 15107PCS, 15132PCS, 17969PCS, 14267PCS, 21498PCS.
Keywords: Accuracy, Holt-Winters, Forecasting, Demand, GMO Tempe

INTRODUCTION

Rumah Tempe Indonesia is an MSME engaged in processing soybeans into tempeh products. The production system used is make-to-stock, which means that these SMEs make tempeh products which are then directly marketed to consumers. This production system can cause problems, including the amount of production that does not match consumer needs, causing a shortage or excess of products which are very inefficient for the company's business continuity.

Precise predictions are needed so that the production carried out by UMKM Indonesian tempeh houses can meet consumer needs. Forecasting is a technique for estimating a future value by considering past and present data. Many forecasting methods can be used according to the data pattern, such as the smoothing method, the regression method, and the ARIMA method.

Smoothing methods can be done in various ways, one of which is by using exponential smoothing, namely by using the Holt-Winters method. Some studies using the Holt-winters method include Nurhamidah et al. with the title Forecasting Seasonal Time Series Data using The Holt-Winters Exponential Smoothing Method of Additive Models, which aims to forecast the number of passengers at Hasanudin Airport one year ahead from December 2019 - November 2020 [1]. Elisa Fani conducted a study entitled Comparison of the Winter Exponential Smoothing Method and the Event-based Method to determine the best product sales at Company X. Her research aimed to find the best forecasting method by looking at the smallest MAPE value [2]. The Holt Winter method was also used by Eliza Staviana in her research entitled System for Forecasting Drug Stock Needs Using the Holt-winters Method, where this study aimed to predict the need for drug stock at Budi Sehat Hospital [3]. Likewise, the research conducted by Ayu Aryati entitled Forecasting Using the Holt-Winters Exponential Smoothing Method (Case Study: Number of International Tourists Visiting Indonesia) to forecast tourists visiting Indonesia in October and November 2018 [4].

This study aimed to determine the demand forecast for GMO Tempe at Indonesian Tempe Houses for the next 12 periods and to determine the accuracy of the forecasts made.

RESEARCH METHOD

This research is an operational research method. Research methods are made with the intention that research leads to correct results and conclusions according to the objectives of the research that has been made. The research method can be seen in Figure 1.

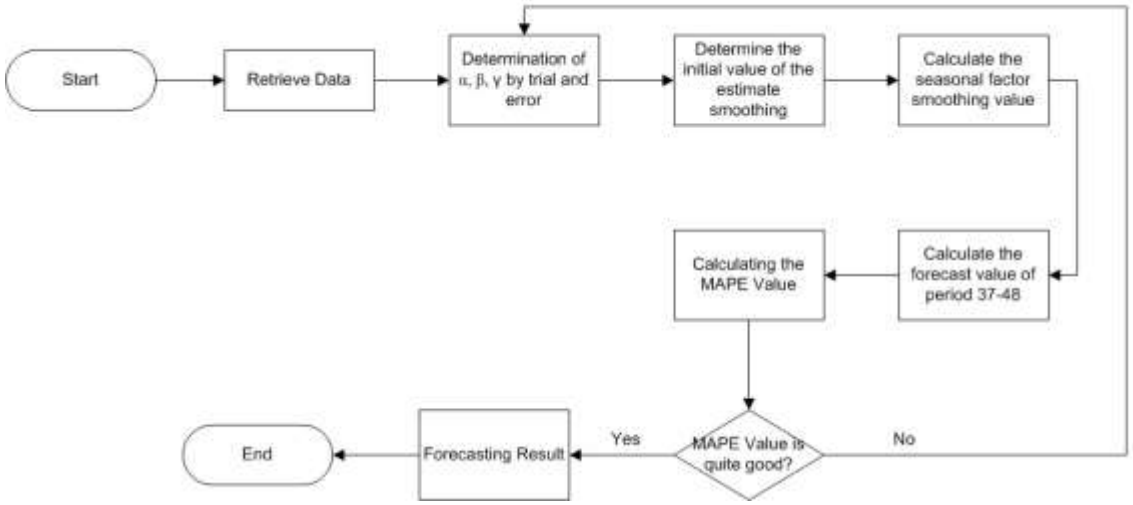

Figure 1. Flowchart for making ZX – 200 5G side frames

Data was collected at UMKM Indonesian Tempe Houses, namely data on consumer demand for our tempeh products and KIM's tempeh. Data was taken for the last 36 or 3 years, from June 2020 to May 2023. They determined the values of α, β, and γ using trial and error until the smallest RMSE value was obtained. Next is to determine the initial value of the smoothing estimate by dividing the first season's value by the average actual value in the first season and for periods two to twelfth. Then calculate the trend value for the first season and then up to period 36. After obtaining the seasonal and trend values, the next step is calculating the forecast value using the formula F14 = (Lt+Tt) x St-M+1 until period 36. Calculate the error value obtained by subtracting the number of requests from the forecast value. The forecasting value from 37 to 48 is obtained using Ft+k = (Lt + k . Tt) St – M+k. Then is to calculate MAPE where the smaller the MAPE value, the better the forecasting. If you have obtained the MAPE value, the forecasting value for 12 periods from 37 to 48 has been completed.

RESULT AND DISCUSSION

The GMO tempe product is produced by UMKM Indonesian Tempe Houses with the production system used by UMKM is made to stock. The number of requests for GMO tempeh products over the last three years, starting from June 2020 – May 2023, can be seen in Table 1.

Table 1. Data on demand for GMO Tempe Products

Period	Total Quantity (Pcs)	Period	Total Quantity (Pcs)	Period	Total Quantity (Pcs)
1	5416	13	6017	25	9256
2	4862	14	5402	26	8310
3	5422	15	6024	27	9266
4	4771	16	5301	28	8155
5	6018	17	6686	29	10284
6	5617	18	6241	30	9601
7	6182	19	6868	31	10565
8	5050	20	7767	32	9735
9	4935	21	7592	33	9255
10	5721	22	15057	34	12352
11	4437	23	6825	35	14797
12	6534	24	10051	36	12784

Based on the product demand table, the demand for GMO tempeh products is predicted for the following 12 periods, from June 2023 to May 2024. The data pattern for demand data can be seen in Figure 2.

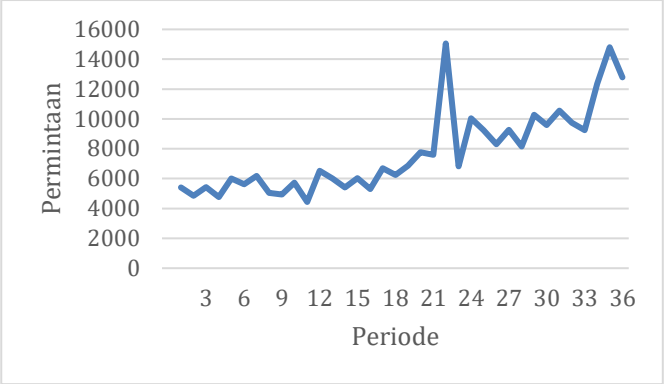

Figure 2. Data Patterns of GMO Tempe Demand for Indonesian Tempe House SMEs

Looking at Figure 2, the data pattern on demand for GMO tempeh products tends to increase and is slightly seasonal. So to find out the forecast can use the Holt-Winters method. The following is a calculation step using the Holt-Winters method.

a. Determination of the values of α, β, and γ using trial and error with the condition that these values are 0 to 1 until the smallest RMSE value is obtained. For the values of α, β, γ used in this study, respectively α = 0.580555535, β = 0.171386576, and γ = 0
b. Determination of Seasonal value in period 1 using the formula$S_n = \frac{Y1}{Average(Y1,Y2,\ldots,Y12)}$Likewise, with period 2 to period 12.
   Example of calculation for the seasonal period 1.$S_1 = \frac{5416}{5413,75} = 1{,}000415608$
c. Determination of the level in period 13 using the formula$L_{13} = \frac{Y13}{S1}$example of calculating period 13$L_{13} = \frac{6017}{1{,}000415608} = 6014{,}500323$
d. Determination of the Trend value in the 13th period using the formula for the 13th Period Trend calculation example$T_{13} = \frac{Y_{13}}{S_1} - \frac{Y_{12}}{S_{12}} T_{13} = \frac{6017}{1{,}000415608} - \frac{6534}{1{,}206926807} = 600{,}7503231$
e. Determination of the seasonal factor in period 13 using the formula for calculating the seasonal factor for period 13.$S_t = \gamma \frac{Y_t}{L_t} + (1-\gamma) S_{t-M} S_{13} = 0 \frac{6017}{6014{,}500323} + (1-0) 1{,}000415608 = 1{,}000415608$
f. Determination of the level value in the 14th period using the sample calculation formula$L_t = \alpha \frac{Y_t}{S_{t-M}} + (1-\alpha)(L_{t-1} + T_{t-1}) L_t = 0{,}580555535 \frac{5402}{0{,}898083583} + (1 - 0{,}580555535)(6014{,}500323 + 600{,}7503231) = 6266{,}789424$
g. Determination of the Trend value in the 14th period by using the example calculation formula$T_t = \beta(L_t - L_{t-1}) + (1-\beta) T_{t-1} T_t = 0{,}171386576(6266{,}789424 - 6014{,}500323) + (1 - 0{,}171386576) 1{,}000415608 = 541{,}0287474$
h. Determination of the forecast value in the 14th period using the formula$F_{t+1} = (L_t + T_t) S_{t-M+1}$calculation example$F_{14} = (6014{,}500323 + 600{,}7503231) 0{,}898083583 = 5941{,}048006$
i. Error value determination is obtained from Actual Demand - Forecasting Results.
j. Next, calculate the Forecasting value for periods 37 to 48 using the sample formula for calculating the value of k = 1 to 12.$F_{t+k} = (L_t + k.T_t) S_{t-M+k} F_{37} = (12961{,}65691 + 1.404{,}1561445) 1{,}000415608 = 13371{,}368.$

The calculation results of the Holt-winters method can be seen in Table 2.

Table 3. Forecasting Calculations using the Holt-Winters Method

Period	Request (Pcs)	Levels	Trends	Seasonal	Forecasts	Error
1	5416			1.000416		
2	4862			0.898084		
3	5422			1.001524		
4	4771			0.881275		
5	6018			1.111614		
6	5617			1.037543		

Period	Request (Pcs)	Levels	Trends	Seasonal	Forecasts	Error
7	6182			1.141907		
8	5050			0.93281		
9	4935			0.911568		
10	5721			1.056754		
11	4437			0.81958		
12	6534			1.206927		
13	6017	6014,5	600,7503	1.000416		
14	5402	6266,789	541.0287	0.898084	5941,048	-539,048
15	6024	6347,447	462,1273	1.001524	6818,193	-794,1926
16	5301	6348,368	383,0827	0.881275	6001,104	-700,1042
17	6686	6315,324	311.7643	1.111614	7482,774	-796,7742
18	6241	6271,836	250.8788	1.037543	6875,891	-634,8913
19	6868	6227,668	200.3116	1.141907	7448,335	-580,3351
20	7767	7530,15	389,2088	0.93281	5996,083	1770,917
21	7592	8156,893	429,919	0.911568	7219,032	372,968
22	15057	11873.65	993,2392	1.056754	9074,145	5982,855
23	6825	10231.49	541.5663	0.81958	10545,44	-3720,443
24	10051	9353,426	298.2614	1.206927	13002.29	-2951,286
25	9256	9419,737	258.5081	1.000416	9655,699	-399.6988
26	8310	9431,388	216,2001	0.898084	8691,873	-381.8726
27	9266	9417,87	176.8295	1.001524	9662.29	-396.2896
28	8155	9396,697	142.8946	0.881275	8455,564	-300,564
29	10284	9372,288	114,221	1.111614	10604.34	-320,3433
30	9601	9351,287	91.04568	1.037543	9842,664	-241,664
31	10565	9331,872	72.11425	1.141907	10782,27	-217,267
32	9735	10003.25	174.8199	0.93281	8772,132	962,868
33	9255	10163,42	172.3094	0.911568	9277,999	-22.9994
34	12352	11121,16	306.9219	1.056754	10922,32	1429,679
35	14797	15275.01	966,234	0.81958	9366,227	5430,773
36	12784	12961.66	404.1561	1.206927	19602	-6817,997
37					13371.37	
38					12366.58	
39					14195.73	
40					12847,47	
41					16654.69	
42					15964,26	
43					18031.57	
44					15106.77	
45					15131,17	
46					17968,21	
47					14266.73	
48					21497,21	

After the forecasting and error values are obtained, the Root Mean Square Error (RMSE) calculation is performed with the help of excel using the formula$RMSE = \left(\frac{\sum(Y_{i-}\hat{Y}_i)}{n}\right)^{\frac{1}{2}}$so that the RMSE value is 2503.206552.

Next is the calculation of the Mean Absolute Percentage Error (MAPE) value, which functions to determine the accuracy of forecasting results where the PEt calculation can be seen in Table 4. .$MAPE = \frac{\sum_{i=1}^{L}|PE_t|}{L} \times 100\% PE_t = \left|\frac{X_t - S_t}{X_t}\right|$

Table 4. Calculation of PEt values

PERIOD	FORECASTING	ACTUAL	PEt
14	5941.048006	5402	0.099786747
15	6818,192588	6024	0.131838079
16	6001,104237	5301	0.13207022
17	7482,774237	6686	0.119170541
18	6875,891265	6241	0.101729092
19	7448,335131	6868	0.084498417
20	5996,083137	7767	0.228005261
21	7219.031954	7592	0.049126455
22	9074,144705	15057	0.397347101
23	10545,44344	6825	0.545119918
24	13002,28626	10051	0.293631108
25	9655,698767	9256	0.043182667
26	8691,872582	8310	0.045953379
27	9662,289594	9266	0.042768141
28	8455,563976	8155	0.036856404
29	10604,34327	10284	0.031149676
30	9842,663968	9601	0.025170708
31	10782,26696	10565	0.020564785
32	8772,131993	9735	0.098907859
33	9277,999404	9255	0.002485079
34	10922,3207	12352	0.115744762
35	9366,226876	14797	0.367018526
36	19601,99719	12784	0.533322684
∑			**3.54544761**

Based on the calculation of the PEt value, a total value of 3.54544761 is obtained. Then look for MAPE using a formula based on MAPE calculations, it can be said that the level of forecasting accuracy reaches 90.1515344%, which can be said to be a good forecast. Forecasting results can be seen in Table 4.$MAPE = \frac{3{,}54544761}{36} \times 100\% = 9{,}8484656\%$

Table 5. Forecasting Results of GMO Tempe Demand for the Next 12 Periods

PERIOD	FORECAST (Pcs)	ROUNDING FORECAST (Pcs)
37	13371,368	13372
38	12366,58328	12367
39	14195,72526	14196
40	12847,4682	12848
41	16654,68662	16655

PERIOD	FORECAST (Pcs)	ROUNDING FORECAST (Pcs)
42	15964,25717	15965
43	18031,57073	18032
44	15106,76992	15107
45	15131,17008	15132
46	17968,21283	17969
47	14266,73205	14267
48	21497,21381	21498

CONCLUSION

The results of forecasting the demand for GMO tempe products at Indonesian tempe houses using Holt-winters have a high level of forecasting accuracy, 90.1515344%, which means it is very good at predicting the demand for tempe in the future. Forecasting results in periods 37 to 48 respectively are 13372PCS, 12367PCS, 14196PCS, 12848PCS, 16655PCS, 15965PCS, 18032PCS, 15107PCS, 15132PCS, 17969PCS, 14267PCS, 21498PCS. The suggestion in this study is to compare the Holt-winters method and other time series methods to see the forecast with the best accuracy.

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