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Original Article

Aggregate Production Planning of Galangal Manufacturing in Thailand

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***Abstract** - Small industries are increasing in Thailand, especially in the agriculture sector, in which management is mainly based on the experience of executives without much reliance on technology or computer systems. It increases production costs that can escalate dramatically due to the lack of demand forecasts, aggregate production planning, proper strategic control of warehouse inventory, etc. This study aims to introduce guidelines for forecasting and planning production using a mathematical method and six strategic production models. It will help improve product forecasting and production planning processes for small galangal factories that have never used such methods before. This research uses the techniques of time series analysis forecasting and production planning with the application of linear programming. The results show that the best forecasting method is the simple exponential method due to its low mean absolute error percentage of 1.5. The second strategy involves additional investment in galangal washing machines. The total production cost is 686,779 baht, and it can reduce production costs by 22,080 baht.*

***Keywords** - Forecasting method, Aggregate production planning, Galangal product.*

1. Introduction

The agricultural sector is a key economic sector that employs many Thai people. However, most farmers in Thailand continue to live in poverty with debts and possession of the lands they farm. Thailand's agricultural sector has had a low capacity and unsustainable cultivation and harvesting development for a long time. Attempts to raise farmers' income have been unsuccessful to date, soil deterioration has resulted in lower crop yields, and the uncertainties of land, weather, natural disasters, and pest infestations have led farmers to adopt populist policies. Farmers face vocational uncertainty, lack of advancement opportunities, and lower quality of life than other vocational groups. As a result, Thai farmers have become low technology workers. Therefore, there is a dire need for new models of agricultural development.

Agricultural products are highly competitive in terms of commerce, quantity, and quality. Consequently, farmers must build their work and production capacities to reduce costs and maximize using limited resources. For example, people, machinery, materials, equipment, work methods, and costs must yield maximum benefits. Therefore, proper material management, washing quality control, and production plans are essential for developing current work systems.

This study investigates the problems of a group of galangal producers in Nang Phaya, Uttaradit province, Thailand. The galangal producers were losing money because they had to sell their produce at a lower price than it cost. According to the retrospective data collected on galangal production over 52 weeks between January and December 2020, there was an upward trend between weeks 23 and 40 when rainfall was heavy. This led galangal farmers to produce less, as shown in Figure 1. According to additional data and inquiries with farmers, their problems included labor costs, outdated equipment, the inability to forecast customer demands, the weather, etc. [1]. These problems failed to meet deadlines and high production costs.

Consequently, opportunities, income, and customer confidence were lost. Aggregate production planning's widespread application across industries for all production-planning processes demonstrates its significance. It assists businesses in developing an operational road map. Aggregate planning is a proven method that provides manufacturing with foresight and stability. It assists management in achieving the company's long-term goals. The benefits of aggregate planning include reducing fluctuations within the workforce, determining resources for the short-term, maximizing space utilization, adjusting capacity to satisfy demand, minimizing costs associated with inventory stocking, decreasing capital expenditures, matching supply with demand and minimizing customer waiting, lowering operating costs and improving supply chain relationships.

Various researchers have used aggregate production planning, like A. Techawiboonwong [2], who applied linear programming and conducted a study on developing aggregate production planning models (APP) and setting schedules for manufacturing television parts and electrical equipment. He forecasted quantity demands for products under set numbers of work hours, labor, warehouse inventory, wages, overtime, and additional machinery. According to the findings, adding more employees and increasing shifts increased expenses. However, if the demand for product quantities increased substantially, adding machinery would cause a reduction in production costs. Paiva and Morabito worked in the sugar and ethanol milling industry, using mixed integer aggregate production planning programming [3]. César Rosero-Mantilla et al. enhanced production capacity in the rubber line industry by using the APP model to improve production efficiency [4].

Antonio Campo et al. [5] created an aggregate production planning model for a textile company to select acceptable solutions. Demirel [6] investigated flexible production planning under uncertain demands in procurement, and after making improvements, the findings indicated that warehouse inventory and the number of late deliveries were reduced. Brazhkin [7] and Ramūnas [8] used the theory of constraint, who studied the management of resources in warehouses. In 2015, Dan [9] studied production planning and warehouse inventory control. The objective was to reduce average expenditures per time unit. In 2018, Pasura et al. introduced three meta-heuristic methods to solve the problem of fuzzy linear programming aggregate production planning and found that using the hybridization meta-heuristic method yielded better values by using speed to estimate performance in advance. Chanipa et al. [10] studied problems in production planning by using a mathematical model in combination with linear programming relaxations in problem-solving. Several researchers applied meta-heuristic methods to solve aggregate production planning problems, such as harmony search algorithms [11] and elevator kinematics optimization [12].

As previously stated, this study proposes the aggregate production planning method, using labor to wash galangal and using washers under uncertain conditions. The objective is to reduce production costs.

2. Aggregate Production Planning

2.1. Forecasting and Demand Behavior

Timeframe and demand behavior are the main components of demand forecasting. They are essential in selecting appropriate forecasting methods. The timeframe consists of short-term and short-to-mid-range forecasting. It is consistent with the production planning timeframe and is normally set on a daily, weekly, or monthly basis. Long-range forecasting has a timeframe of more than two years and is usually used for strategic planning.

If sufficient demand data for types of products in the past were analyzed with a graph, demand could be seen to have risen and dropped randomly. In some cases, trends were shown as a model forecasting demand in the following period. There are three main types of demand behavior (other than random behavior): trends, cycles, and seasonal patterns.

2.2. Forecast Methods and Their Accuracy

Forecasting can be divided into two categories: qualitative and quantitative. Quantitative forecasting can be based on time or building mathematical relationships and relationships between the factors involved. In this study, time series analysis forecasting was used. This technique uses data collected in the past to forecast future needs. It includes the moving average method, the simple exponential smoothing method, the double exponential smoothing method, etc. Mathematical forecasting is done by considering relationships between data and using retrospective data to create models that forecast future events, such as using simple linear regression.

Measuring forecast accuracy aims to assess the accuracy of each forecasting method: low error values indicate high accuracy. Many methods were used to measure forecast errors, such as mean absolute deviation (MAD), mean square error (MSE), and mean absolute percent error (MAPE) [13]. In this study, we used MAPE, as shown in equation 1, which compared the effectiveness of forecasting methods.

$$MAPE = \frac{1}{n}\sum_{i=1}^{n}\frac{|A_t - F_t|}{A_t} \qquad (1)$$

MAPE = mean absolute percentage error
n = number of times
A_t = actual value
F_t = forecast value

The mean absolute percent error measures forecasting and actual values compared to other forecasting methods. The lower the MAPE value, the higher the accuracy.

2.3. Mathematical Model of Aggregate Production Planning

Production planning and control is the arrangement of production systems to be consistent with customer demand. After forecasting, production plans must be made with maximum suitability to meet customer needs. [14] Aggregate production planning is the consideration of an organization's production capacity to meet customer demand in the next 6–18 months with the possibility of increasing or reducing production capacity by hiring or dismissing employees, increasing work shifts, subcontracting, doing overtime work, maintaining product inventories, or reducing product inventories. The main goal of aggregate production planning is determining an organization’s resource allocation plans. Planning consideration is given to marketing related to the volume of demand for products. The allocation of resources must meet demands within the capacity of existing resources. If existing resources are insufficient, they must be increased. Consideration must also be given to strategic goals, organizational principles, and capital conditions, which can be input factors in aggregate production planning systems. The number of employees, normal and overtime production amounts, subcontracting volume, advanced purchase orders, and the number of products missing from stocks are obtained from aggregate production planning systems to determine the most cost-effective strategy to meet product demand. Equation (2) is the objective equation, which shows the costs of raw material, labor and overtime, hiring and dismissal, inventory, and product shortage. Equations (3) and (8) show the limitations of production, labor, overtime limitations, and variable type in full numbers [15,16].

$$\text{Min } Z = \sum_{t=1}^{6} RcW_t + \sum_{t=1}^{6} OcO_t + \sum_{t=1}^{6} HcH_t + \sum_{t=1}^{6} LcL_t + \sum_{t=1}^{6} ScS_t + \sum_{t=1}^{6} McP_t + \sum_{t=1}^{6} CcC_t + \sum_{t=1}^{6} IcI_t \tag{2}$$

Constraints

$$Min\, W \leq W \leq MaxW \tag{3}$$

$$Ot_t \leq Otmax \tag{4}$$

$$P_t = (W_h * W_i + Ot_i) * P_r \tag{5}$$

$$W_t = W_{t-1} + H_t - L_t \tag{6}$$

$$I_{i-1} + P_t + C_t = D_t + S_{t-1} + I_t - S_t \tag{7}$$

$$W_t, O_t, H_t, L_t, I_t, S_t, P_t \text{ and } C_i \geq 0 \tag{8}$$

Decision Variables

t = Time forecasting
N = Number of products
W_t = Workforce size
O_t = Summary overtime hours per month
H_t = Summary of employees hired per month
L_t = Summary of employees laid off per month
S_t = Summary of out-of-stock/backlogged units
P_t = Summary of produced units
C_t = Summary of subcontracted units
I_t = Summary of inventories at the end

3. Research Methodology

3.1. Data for APP Problems

APP is the initial process of manufacturing systems. It is a decision-making policy in approximating and assigning resources such as man-hours, capacity machines, and the number of materials.

This study was divided into the following three research processes:

1. Retrospective data collection on previous galangal production in Uttaradit province found that this product is cultivated on more than 1,000 rai, 12.5% of the entire agricultural area. The data was collected over 52 weeks between January and December 2020, as shown in Table 1 and Figure 1.
2. Reducing washing time by switching to using washing machines.

Based on the data collected, manually washing galangal significantly affects costs in terms of time and produce quality after washing, which affects selling prices and production costs. To reduce production time, we developed a galangal washer, reducing the burden of washing and the costs of importing expensive machines. The washer was designed to use water pressure to rinse away large amounts of galangal. The structure consisted of a washing grate, a motor-driven set, and high-pressure water sprayers. It works on the principle of spraying water from high-pressure pumps at 20–35 kg/cm2 through 12 stainless steel nozzles (No. 0.04). Washing with the machine begins by filling up cut galangals in plastic baskets and pouring six baskets onto the tray. Produce is then transported and moved in cages with dispersed nozzles. The cages rotate to turn the galangal back and forth for 15 minutes before coming out from the other way into net bags. Each washing cycle takes 20 minutes, as shown in Figure 2. Figures 3 and 4 show the product after the cleaning processes.

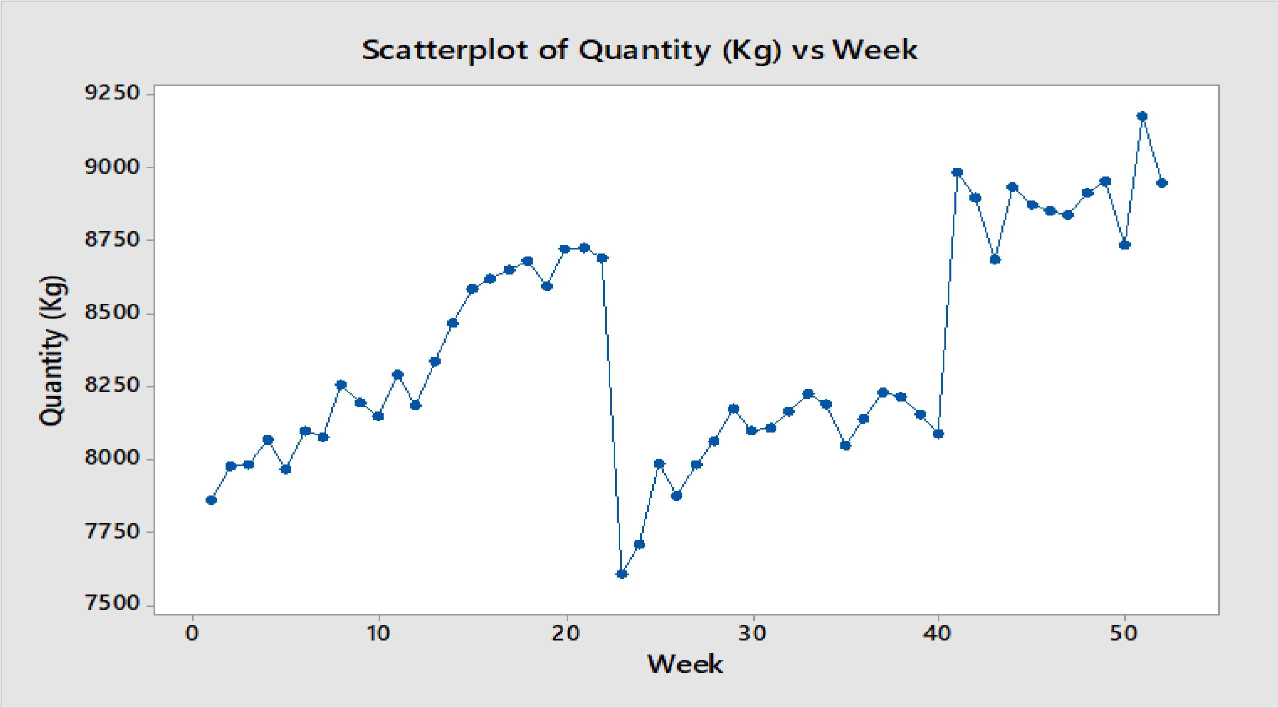

Fig. 1 The graphical plot of demand from 52 weeks

Table 1. The amount of galangal per week

Wee k	Quantity (Kg)	Wee k	Quantity (Kg)	Wee k	Quantity (Kg)
1	7,865	21	8,725	41	8,985
2	7,977	22	8,693	42	8,896
3	7,985	23	7,608	43	8,687
4	8,070	24	7,710	44	8,935
5	7,970	25	7,990	45	8,872
6	8,100	26	7,878	46	8,854
7	8,080	27	7,985	47	8,835
8	8,254	28	8,067	48	8,915
9	8,198	29	8,174	49	8,953
10	8,150	30	8,101	50	8,738
11	8,290	31	8,110	51	9,175
12	8,185	32	8,163	52	8,950
13	8,335	33	8,227		
14	8,468	34	8,190		
15	8,585	35	8,050		
16	8,620	36	8,138		
17	8,650	37	8,233		
18	8,682	38	8,217		
19	8,595	39	8,154		
20	8,723	40	8,091		

3. Cost comparison between manually washing galangal and using washing machines.

Washing an average of 9,624 kilograms of galangal per week using labor costs 1,468.44 baht per day or 44,053.2 baht per month. On average, 9,624 kilograms of galangal can be washed weekly, which takes 6 days. In comparison, the production cost of washing galangal with the washers is 1,468.44 baht per day or 44,053.2 baht per month, which takes 2 days. The machine cost of washing galangal is 65,000 baht per machine, with a repair and maintenance cost of approximately 168 baht per week.

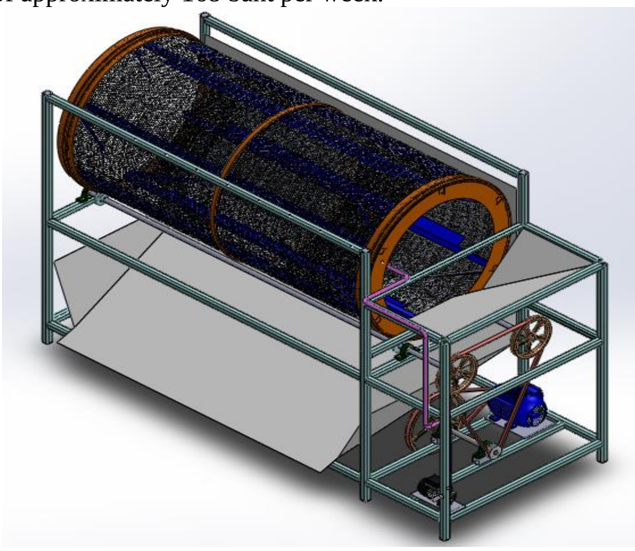

Fig. 2 Isometric drawing of galangal machine

Fig. 3 The galangal machine and product

Fig. 4 The galangal after cleanning

The data used in this study was collected from a galangal sorting and packing factory in Uttaradit province. The data used in the aggregate production planning consisted of material costs of 9 baht per kilogram, transportation costs of 3,000 baht per cargo of 4,500 kilograms, normal production capacity using manual labor of 300 kilogram/person/day, overtime production capacity of 100 kilogram/person/day, galangal washers' production capacity of 350 kilogram/person/day with a cost of 785 baht per day, and total overtime work hours at no more than 30 hours per day. It also included product storage costs (Ic) of 1 baht per kilogram, product shortage costs of (Mc) 10 baht per kilogram, hiring costs (Hc) of 300 baht per employee, layoff costs (Lc) of 500 baht per employee, monthly employee wages (Rc) of 9,000 baht, overtime wages (Oc) of 50 baht per hour (including benefits), and outside contractor hiring costs (Sc) of 16 baht. Furthermore, it included a starting inventory of 0 items, a final inventory of 0 items, a final product shortage of 0 items, and 4 workers and 6 working days per week.

4. Computation Result

When demand for products is uncertain, one or several strategies may be used in aggregate production planning, such as changing the number of employees, maintaining the number of employees while allowing little free time during production, adding overtime work, maintaining production at a constant rate, allowing inventory storage, etc. Table 2 shows forecasting errors in different methods using the Minitab program.

Table 2. Mean Absolute Percentage Error of Forecasting Models

Forecasting Models	MAPE
Moving Average N=2	1.7
Moving Average N=3	1.7
Moving Average N=5	2.2
Single Exponential Smoothing $\alpha = 0.735$	1.5
Double Exponential Smoothing $\alpha = 0.90$ and $\gamma = 0.04$	1.5
Linear Trend Model ($Y_t = 7994.6 + 14.05 \times t$)	3.0
Quadratic Trend Model ($Y_t = 8246 - 13.9t + 0.527 \times t^2$)	3.1
Growth Curve Model ($Y_t = 7999.81 \times (1.00166$^t))	3.0
Winters' Multiplicative Method ($\alpha = 0.5$, $\beta = 0.5$ and $\gamma = 0.5$)	2.1
Winters' Additive Method ($\alpha = 0.5$, $\beta = 0.5$ and $\gamma = 0.5$)	2.1

Demand from forecasting obtained from the single exponential and double exponential smoothing methods shows the lowest MAPE. The single exponential smoothing method can find the lowest MAD and MSE, as shown in Table 1. Figure 5 and Figure 6 show the performance of single and double exponential smoothing for finding the minimum of MAPE compared with other methods. Figure 7 shows the graphical plot of demand from the moving average method. (N=2).

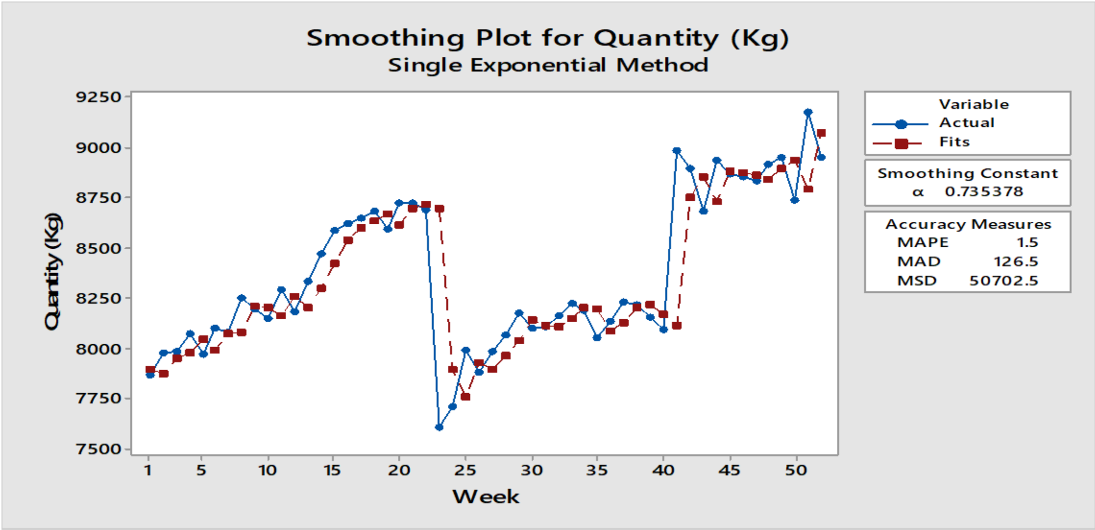

Fig. 5 The graphical plot of demand with single exponential smoothing α = 0.735

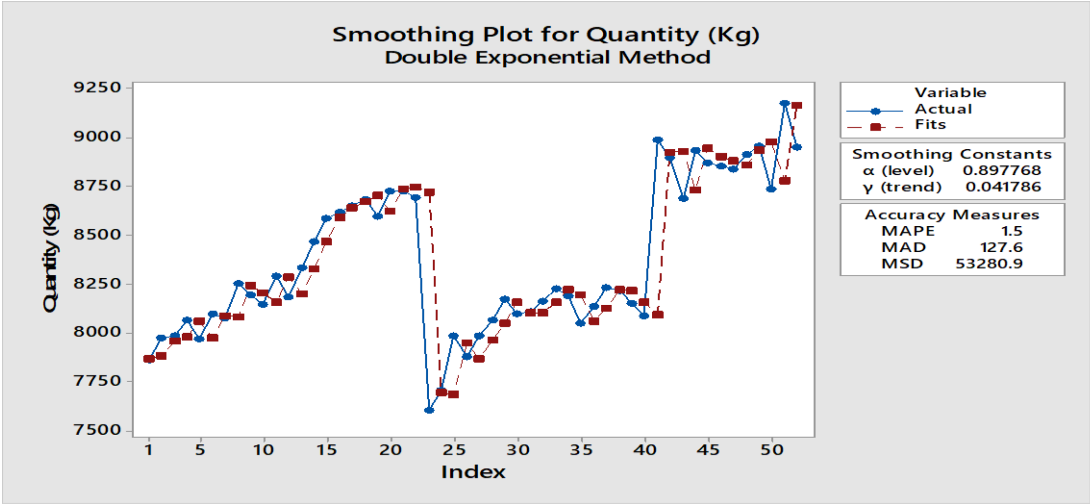

Fig. 6 The graphical plot of demand with double exponential smoothing α = 0.90 and γ = 0.04

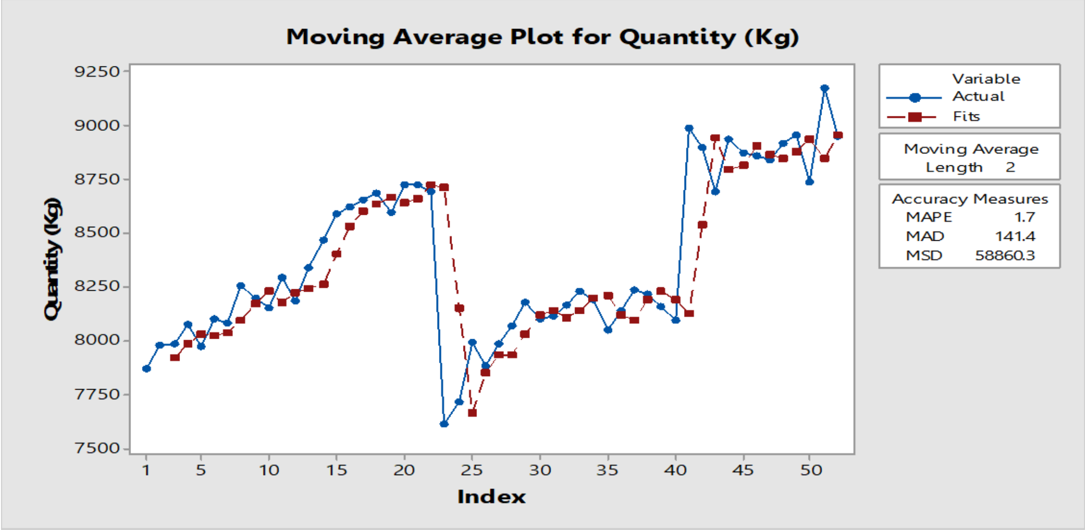

Fig. 7 The graphical plot of demand with the **moving average method (N=2)**

Therefore, we used the single exponential smoothing model for the case study. This study applied mathematical programs to calculate appropriate production planning by creating hypothetical situations to determine solutions before comparing costs in each option. In this study, strategies were designed for the following six cases:

Strategy 1: Forecasting demand using the single exponential smoothing method for manual washing.

Strategy 2: Forecasting demand using the single exponential smoothing method for washing machines.

Strategy 3: Demand decreased by 10% from washing machines' predicted values.

Strategy 4: Demand increased by 10% from washing machines' predicted values.

Strategy 5: Forecasting demand using the single exponential smoothing method and transportation costs increasing 5%.

Strategy 6: Forecasting demand using the single exponential smoothing method and labor costs increasing 10%.

Analysis of the lowest production costs was performed using the Excel solver program in each scenario, as shown in table 3.

Table 3. Demand per week (kilogram/week)

Demand	Normal Demand	Demand decresed 10%	Demand incresed 10%
Week 1	8,841.00	7,957.00	9,726.00
Week 2	8,896.00	8,006.00	9,785.00
Week 3	8,938.00	8,044.00	9,832.00
Week 4	8,791.00	7,912.00	9,670.00
Week 5	9,073.00	8,166.00	9,981.00
Week 6	8,983.00	8,084.00	9,881.00

Tables 4 and 5 show the number of workers per month, and total overtime per week in strategies 1-6.

Table 4. Summary of workers per week

Strategy	M1	M2	M 3	M 4	M 5	M6
Strategy 1	4	4	4	4	4	4
Strategy 2	4	3	4	3	4	3
Strategy 3	4	3	3	3	3	3
Strategy 4	4	4	4	3	4	4
Strategy 5	4	3	4	3	4	3
Strategy 6	4	3	4	3	4	3

*M = Month

Table 5. Summary of overtime per week

Strategy	M 1	M2	M 3	M 4	M 5	M6
Strategy 1	16.41	16.96	17.38	15.91	18.73	17.83
Strategy 2	15.37	15	15.29	15	18.56	15
Strategy 3	7.69	15	15	15	15	15
Strategy 4	20	20	20	15	15.94	14.81
Strategy 5	15.37	15	15.29	15	18.56	15
Strategy 6	15.37	15	15.29	15	18.56	15

*M = Month

5. Conclusion and Future Work

Aggregate planning is a feature of an advanced planning and scheduling (APS) system for firms that use digital technology in a manufacturing operations management (MOM) ecosystem.

Aggregate production planning can be carried out as a methodology employing paper-based, spreadsheet, or custom software solutions. However, the amount of information that must be considered in aggregate planning has significantly expanded due to the complexity of products, industrial processes, and supply chains. As a result, manufacturers increasingly use APS systems for their overall planning requirements. Aggregation planning aims to reduce operating expenses by aligning output demand to production capacity. An aggregator plan describes what materials and other resources are required and when they should be purchased to get the lowest possible cost.

The research findings on aggregate production planning to enhance production efficiency found that this method reduces costs, use of manpower, and inventory storage. This study applied forecasts and aggregate production planning to analyze problems through mathematical equations to calculate the lowest production costs in various situations. Strategy 1 used manpower to clean galangal and had a production cost of 708,859 baht. Strategy 2, which invested in machines to clean galangal, had a production cost of 686,779 baht, which saved 22,080 baht while reducing manpower, increasing production volume, and creating more customer satisfaction. We recommend designing other experiments to develop appropriate production systems and methods to find solutions. The data in this study may have small variations due to similar production model characteristics and varied manufacturing factors. As a result, experiments can be used to establish appropriate machine parameters, and additional optimization and meta-heuristic methods can solve problems. This paper discusses the impacts of forecasting parameters on the winter method, such as α, β, and γ, and presents a strategy for tuning these parameters. The application of multi-objective optimization on APP problems was suggested by Pasura [17] and the fuzzy set theory study [18]. The new experimental design was applied to generate appropriate machine parameters and save production time. As a result, uncontrollable demand, fuzzy demand [19], scheduling problems [20], and additional problem-solving programs should all be considered to produce better solutions with the least variance.

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