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Research article

Trend and seasonality analysis of milk production from dairy cooperatives in Chiang Mai

Veerasak Punyapornwithaya [1], Kunnanut Klaharn [2], Chalutwan Sansamur [3] and Warangkana Kitpipit [3,*]

[1]*Department of Food Animal Clinics, Faculty of Veterinary Medicine, Chiang Mai University, Chiang Mai 50100 Thailand*
[2]*Bureau of Livestock Standards and Certification, Department of Livestock Development (DLD), Bangkok 10400 Thailand*
[3]*Akkhraratchakumari Veterinary College, Walailak University, Nakhon Si Thammarat 80160 Thailand*

Abstract

Analysis of trend and seasonality for production data is essential for establishing planning and strategy for future marketing. The aims of this study were 1) to determine the trend and seasonality of milk production and 2) to compare the quantity of milk among dairy cooperatives in Chiang Mai. Monthly milk production data from 7 dairy cooperatives and a company collected during 2016-2020 were analyzed for trend and seasonality using time series methods. Overall milk productions in 2019 was compared among dairy cooperative using a general linear mixed model. Results showed that most of the dairy cooperatives showed an increasing trend for milk production. The milk productions from all dairy cooperatives had a similar seasonality pattern as the highest milk production was found in the period of March to May. Among dairy cooperative, Chaiprakarn was the top rank in milk production (2581.73±50.46 tons/month). This study provided essential information for dairy cooperative boards, government sectors, private sectors, and other stakeholders to plan and manage the amount of milk in the future.

Keywords: Chiang Mai, Dairy cooperative, Milk production, Time series model, Trend, Seasonality

Corresponding author: Warangkana Kitpipit, Akkhraratchakumari Veterinary College, Walailak University, Nakhonsithammarat 80160 Thailand. Tel: +66 86403 4200, E-mail: warangkana.ki@mail.wu.ac.th

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INTRODUCTION

Milk production data from dairy farms are collected every day by dairy cooperatives. Each month, a total of milk collected is summarized. The dairy cooperative boards use this data to manage their collecting capacity and plan for trading with milk purchaser companies or organizations.

Milk production data from dairy cooperatives are time-series data as data points are collected over a period of time as a sequence of time. One of the commonly used methods to analyze such data is time series analysis. This analysis is commonly used for determining a pattern, trend, and seasonality of the data (Ward et al., 2020). Exploratory analysis using time series methods provides the chance to identify key characteristics of the serial data. A primary approach is a decomposing the series into trend, seasonality and irregular component. The application of time series analysis provides useful information for milk trading between dairy cooperative and purchasers from milk processing plants. For instance, the dairy cooperative boards need to keep the milk production level that meets the milk buying quota from purchasing companies. Thus, the determination of trends allows them to make the proper decision. For dairy farmers, seasonality analysis helps them for farm management such as nutrition and reproductive management.

Although many studies were conducted on dairy farms in Chiang Mai (Phinidsorn et al., 2015), several studies focused on milk quality, such as somatic cell counts (Kongsook and Nantawichain, 2020) and bacterial contamination (Rojanasthien et al., 2006) in milk. Studies on milk production in Chiang Mai are very limited and not up to date (Seetakoses et al., 1991). None of the studies were designed to investigate the milk production trend using longitudinal data.

Due to the limitation in reports on milk production trend in Chiang Mai as well as several concerns on an oversupply of milk, especially during school semester breaks and the increasing trend of herd size (Office of Regional Livestock 5, 2020), it is necessary to explore the trend of milk production. Thus, this study aimed to analyze trends and seasonality of milk production data from dairy cooperatives in Chiang Mai using time series methods. In addition, milk productions among dairy cooperatives were compared.

MATERIALS and METHODS

Data

A series of monthly total milk production data (January 2016 - August 2020) from dairy cooperatives in Chiang Mai including Chaiprakarn, Chiang Mai, Mae On, Mae Wang, Sankamphang, Mae Jo, Pha Tung and the Fresh Milk company were used. Figure 1 indicates a regional distribution of dairy cooperatives.

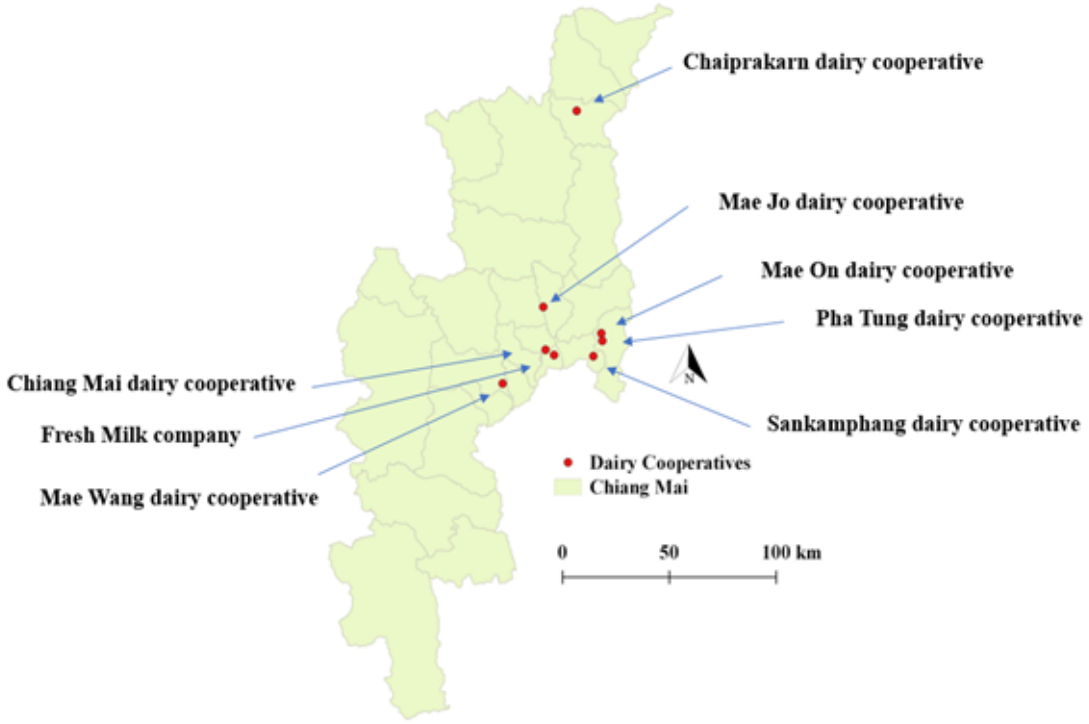

Figure 1 A map shows the locations of dairy cooperatives and a dairy company in Chiang Mai.

Statistical analysis

Two methods of time series, including decomposition and seasonality analysis, were applied to milk composition data. Time series models can be defined as additive or multiplicative models.

The additive decomposition model for a time series y_t is written as;

$$y_t = T_t + S_t + I_t$$

Where y_t = the series observation at time t

T_t, S_t = trend and seasonal effects

I_t = irregular component of the series at time t

Based on the decomposition technique, $\hat{T}_t$, $\hat{S}_t$ and $\hat{I}$ can be estimated.

The multiplication model includes multiplication of the components is defined as;

$$y_t = T_t * S_t * I_t$$

Milk production data from dairy cooperatives were analyzed separately. Time series decomposition was carried out to decomposed raw data of milk production into trend, season and irregular components thus the trend and seasonal component can be observed. Decomposition functions from R statistical software (R Core Team, 2020) and some packages including "*xts*" (Ryan et al., 2020), "*forecast*" (Hyndman and Khandakar., 2008) and "*TSstudio*" (Krispin, 2020) were used to determine trend, seasonal and irregular

components for the data. The additive model is defined if the amplitude of the seasonal component remains the same over time. On the other hand, the model was classified as a multiplicative model if the magnitude of the seasonal component increases or decreases by some multiplicity from month to month over the study period (Jebb et al., 2015). In addition, the seasonality of the data was tested using Webel-Ollech overall seasonality test (Ollech, 2019).

The generalized linear mixed model was carried out to determine differences in means of milk productions among dairy cooperatives. Milk production data were clustered within dairy cooperative. To account for the clustering effect of monthly milk production data, the random effect model was constructed using nlme function (Pinheiro et al., 2020) in R. The model is written as;

$$y_{ij} = \beta_0 + \beta_1 Coop_i + b_j + \varepsilon_{ij}$$

Where y_{ij} denote the milk production of the i^{th} dairy cooperative from j^{th} clusters. β_0 is the intercept. β_1 is the regression coefficient. The term is a fixed effect due to i^{th} dairy cooperative. The random effect b_j is assumed to vary independently across clusters with $b_j \sim N(0,\sigma_2^2)$. The errors, ε_{ij} are assumed to vary independently across clusters with $\varepsilon_{ij} \sim N(0,\sigma_1^2)$.

A Tukey's method was used for Post Hoc multiple comparisons. A level of significance was set as α=0.05 for all statistical analyses.

RESULTS

Milk productions from dairy cooperatives were illustrated in figure 2. Chaiprakarn dairy cooperative, Fresh Milk company and Chiang Mai dairy cooperative were the top three for milk production.

The decomposition provided a trend for milk production by removing the seasonal effect thus a real trend can be examined (Figure 3). None of the time series data was the multiplication model. There was an increasing trend for milk production for Chaiprakarn dairy cooperative. On the other hand, a decreasing trend was observed from Chiang Mai dairy cooperative. For Fresh Milk company, an increasing trend was found during 2015-2018 then milk production decreased from 2018 to 2020. Interestingly, milk production from five dairy cooperatives was sharply dropped in 2017.

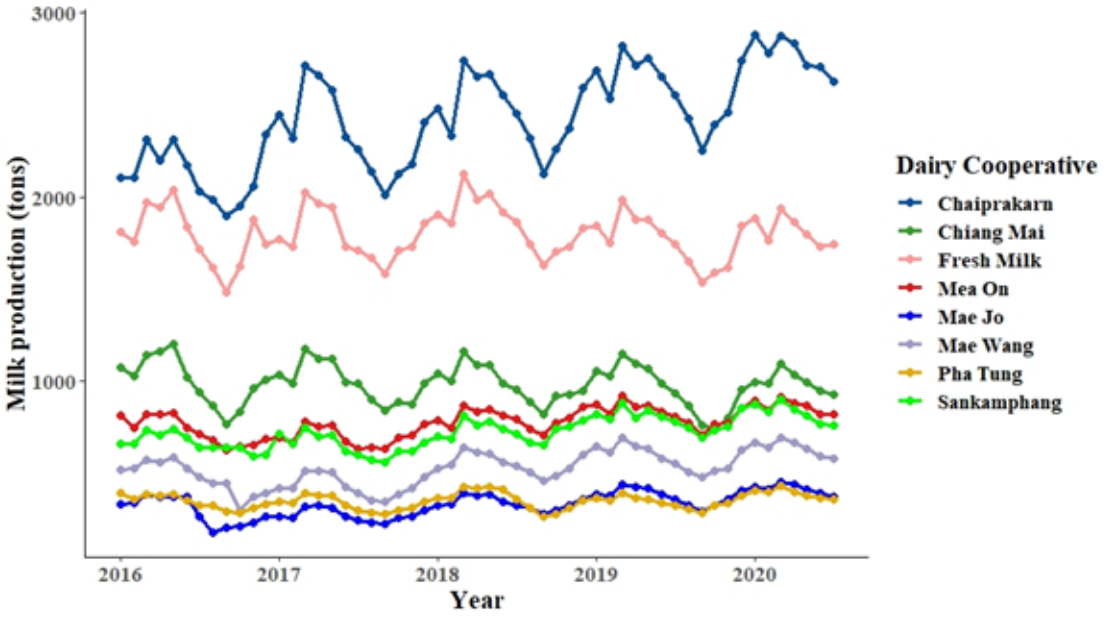

Figure 2 Monthly milk production data from dairy cooperatives in Chiang Mai during 2016-2020.

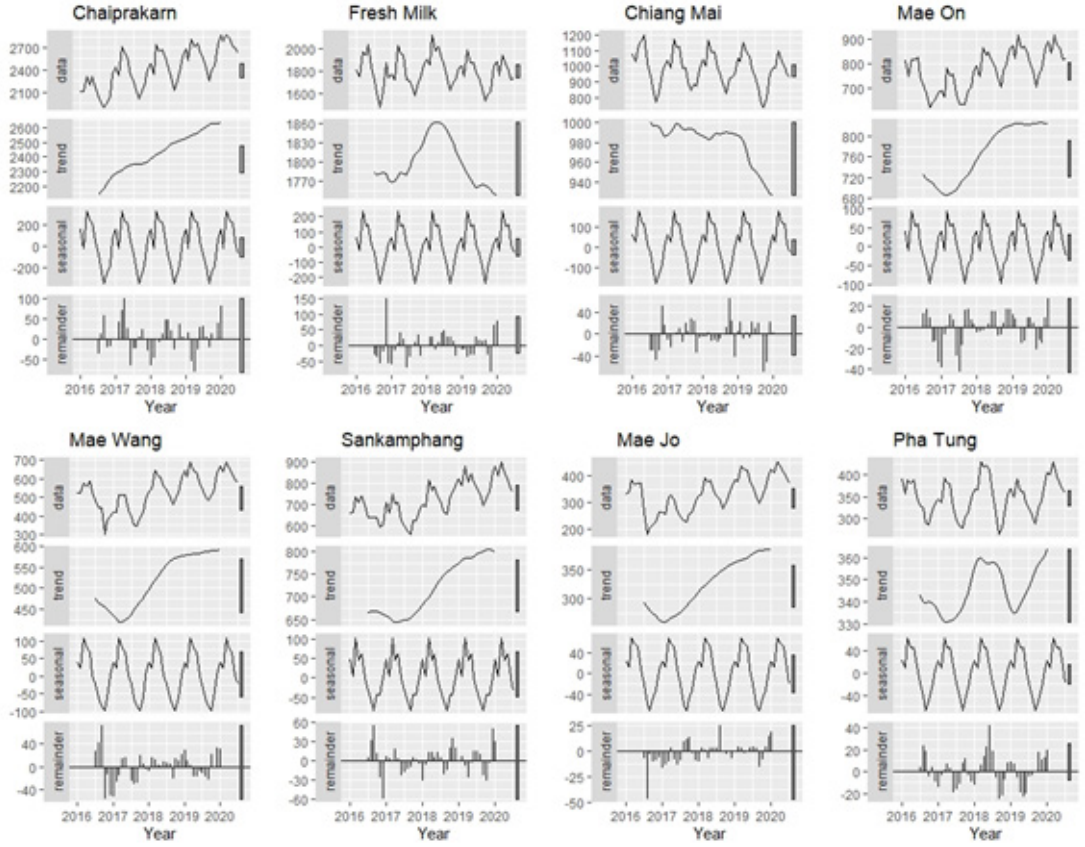

Figure 3 Decomposition of time series data for milk production data from dairy cooperatives in Chiang Mai.

Seasonality plots were clearly shown that there was seasonality for milk production for all dairy cooperatives in Chiang Mai (Figure 4). The seasonality of milk production for all dairy cooperative was confirmed by Webel-Ollech overall seasonality test ($P<0.05$). The milk production was increased from September to February then it reached a peak from March to May. Subsequently, the production gradually decreased from June to August.

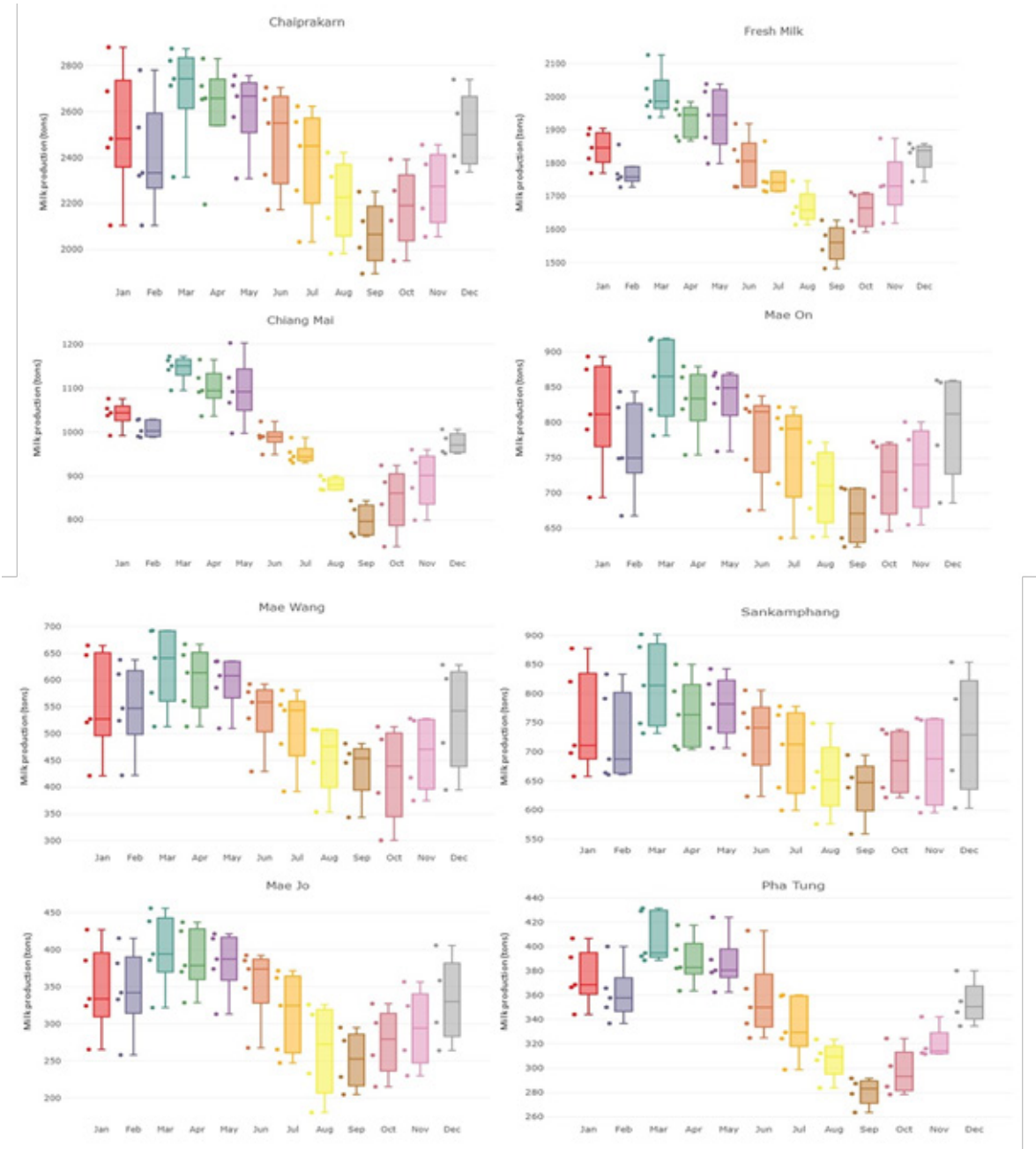

Figure 4 Boxplots indicate seasonality of milk production (2016-2019) for dairy cooperatives in Chiang Mai.

Chaiprakarn dairy cooperative produced the highest amount of milk followed by Fresh Milk company and Chiang Mai dairy cooperative. Mae On and Sankamphang produced a similar amount of milk. On the other hand, Mae Jo and Pha Tung dairy cooperative produced milk lower than other dairy cooperatives in Chiang Mai (Table 1).

Table 1 Comparisons of monthly milk production in 2019 for dairy cooperative in Chiang Mai

Dairy cooperative	Milk production per month (tons) (lsmean±SE)
Chaiprakarn	2581.73±50.46 [a*]
Fresh Milk	1761.01±39.53 [b]
Chiang Mai	953.83±39.15 [d]
Mae On	822.58±17.31 [e]
Sankamphang	792.33±15.51 [e]
Mae Wang	585.18±19.53 [f]
Mae Jo	376.04±12.75 [g]
Pha Tung	344.96±8.88 [g]

*Values with different superscripts indicate statistical difference ($P<0.05$)

DISCUSSION

In this study, milk production from all dairy cooperatives in Chiang Mai was analyzed using the time series model. Trends and seasonality were determined and milk productions among dairy cooperatives were compared.

The increasing trend for milk production for Chaiprakarn dairy cooperative suggested that more milk will be produced in the future. The planning for marketing should be accordingly formulated. The increase in milk production for Chaiprakarn dairy cooperative may be from the increasing average milk production per cow and/or the herd size. Furthermore, it was interesting to explore why milk production from Chiang Mai dairy cooperative and Fresh Milk company decreased. Several factors such as socio-economic factors, lack of ability to hold the dairy farm and outbreaks of some diseases, especially for foot and mouth disease (FMD) should be investigated for future studies.

The term "seasonality" does not only refer to meteorological season like summer, rainy and winter, but it is defined as increased or decreased observations that display a periodic pattern (Naumova, 2006). It was evident that milk production from all dairy cooperatives had a seasonality characteristic (Figure 4). The high milk production was found during March through May every year. As a result, the high milk production generally occurs during the school semester break. Thus, this is very challenging to government sectors and stakeholders to manage the high volume of milk supplied to the market since milk supplied to the school milk project is one of the primary milk consumptions. Additionally, the identification of seasonality allows researchers to establish strategies to cope with this situation. One of the causes of having high production during March to June is a high proportion of calving

cows occurred during January through March. Thus, reproductive management (e.g., breeding plans) may help dairy farmers distribute the number of calving cows to other months.

The sharp drop in milk production during 2017 is most likely due to several outbreaks of FMD (Figure 3), as previous reports indicated that FMD outbreaks occurred in several districts of Chiang Mai between 2016 and 2017 (Sansamur et al., 2020). One of the FMD control measures is to control FMD dissemination in the outbreak area. For dairy farms with FMD outbreak, dairy farmers were not allowed to sell raw milk to the dairy cooperative until the outbreaks were over and livestock officers gave permission to transport bulk milk from farms to milk collecting centers. With approximately 4 to 5 weeks for FMD quarantine, the losses of milk have a negative effect on the total milk production of dairy cooperatives.

For the purpose of this study, we intended to provide the information on overall milk production at the dairy cooperative level that important for managing the raw milk volume in the province. Thus, the analysis was to compare the milk production of the dairy cooperatives in order to rank them by volume of milk production regardless of the number of members and the number of cows. With 2019 milk production data, the finding from this study confirmed the previous report showed that Chaiprakarn dairy cooperative is the highest rank for milk production among dairy cooperatives in Chiang Mai (Table 1). The high production of milk may come from the high number of dairy cows in the cooperative area and the high performance in dairy farming (Office of Regional Livestock 5, 2020). The Fresh Milk company was the second highest milk collector. This company organizes milk collecting centers located in many districts of Chiang Mai. This approach is unique because dairy farms sell bulk milk directly to the company individually instead of forming a dairy cooperative and selling bulk milk to the company through the dairy cooperative system. In other words, dairy farmers are not registered to any dairy cooperatives. The declining pattern of Fresh Milk's production could be correlated with this condition, and the socio-economic follow-up analysis should be carried out to give a better understanding of the dairy system in Chiang Mai. Additionally, the finding that milk production from Pha Tung and Mae Jo dairy cooperative was lower than other dairy cooperatives may from the smaller cow population compared to other cooperatives.

In comparison to other dairy cooperatives in Thailand, milk production from Chaiprakarn dairy cooperative is higher than Nakorn Pathom dairy cooperative (average = 630 tons/month) located in central and Phatthalung dairy cooperative (average=407 tons/month) in the south but lower than Muaklek dairy cooperative (average = 3,240 tons/month) located in Saraburi and Pakchong dairy cooperative located in Nakhon Ratchasima (average = 2,100 tons/month (Office of Agricultural Economics, 2019).

This study aimed to determine trends and seasonality of milk production data to present the past and current situation. The exploration was done at the dairy cooperative level providing the information for the individual dairy cooperative rather than overall milk production in Chiang Mai. The forecast modeling for milk production data is our objective in the follow-up study.

CONCLUSION

There was the increasing trend for milk production for most of dairy cooperatives in Chiang Mai. The time series decomposition indicated a strong effect of season on milk production. Dairy cooperative boards and stakeholders can use the information from this study to establish the strategy to manage and control the milk production for each dairy cooperative to meet the desired target.

CONFLICT of INTEREST

The authors declare that they have on conflict of interests.

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AUTHOR CONTRIBUTION

Conceived and designed the experiments: VP, WK. Analyzed the data: VP, CS, WK, KK. Software: VP, CS, KK. Wrote the manuscript: VP. All authors read and revised the manuscript.

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