KADIKMA: Jurnal Matematika dan Pendidikan Matematika
Vol. 13, No. 2, Agustus 2022, Hal. 101-106
e-ISSN : 2686-3243 ; p-ISSN : 2085-0662
https://jurnal.unej.ac.id/index.php/kadikma
https://doi.org/10.19184/kdma.v13i2.31522

THE PETRI NET SIMULATION OF TEMPEH PROCESSING PROSESS WITH FOUR OPERATORS

Deny Murdianto[1]*
[1]Universitas Borneo Tarakan, Indonesia
*E-mail: denymurdianto@gmail.com

Article History:
Received: 27-03-2022; Revised: 30-04-2022; Accepted: 03-06-2022

ABSTRAK

Model yang diperoleh dalam penelitian ini diharapkan dapat menggambarkan dinamika sumber daya dan pengolahan kedelai menjadi tempe. Pemahaman mengenai proses produksi tempe diperoleh dari pengamatan langsung dan juga dari referensi yang sesuai. Selanjutnya dibuat model petri net dan simulasi proses produksi tempe dengan beberapa asumsi yang telah disesuaikan dengan hasil pengamatan di lapangan. Didapatkan sebuah petri net yang terdiri dari 14 place dan 10 transisi. Dari hasil simulasi, $\boldsymbol{x}_{18}$ harus dapat dijangkau untuk mencapai keadaan akhir yang telah ditentukan dengan beberapa asumsi.

Keywords: petri net, simulasi, tempeh

ABSTRACT

The model obtained in this study is expected to be able to describe the dynamics of the resources and processing of soybeans into tempeh. An understanding of the tempeh production process is obtained from direct observation and also from appropriate references. Furthermore, a petri net model and simulation of the tempeh production process was made with several assumptions that have been adjusted to the results of observations in the field. Obtained a petri net consisting of 14 places and 10 transitions. From the simulation results, $\boldsymbol{x}_{18}$ must be reachable to reach the final state that has been determined with several assumptions.

Keywords: petri net, simulation, tempeh

INTRODUCTION

Tempe Making Process

The main raw materials for making tempeh are soybeans and tempeh yeast. Tempeh yeast is the seed used to make tempeh. So it is often referred to as a tempeh starter. Tempeh yeast contains Rhizopus sp fungus which is also known as tempeh mushroom. In some places, the fermentation process does not only use tempeh yeast, but also uses tapioca flour and tempeh yeast (Rhizopus oligosporus) [1]. In general, the process of making tempeh is passed down from generation to generation, so it varies widely between regions or craftsmen in the same location. But in principle, the process of making tempeh has the same stages which include washing soybeans, soaking, boiling, adding yeast, packaging, and fermentation [3].

The initial stages of making tempeh are sorting and washing soybeans. Sorting is done to get good soybean seeds. In the washing process, soybeans are usually placed in a large basin and then washed while removing impurities from floating soybeans [6]. Furthermore, the first boiling is carried out which aims to soften the soybean skin and to kill the enzymes that cause the unpleasant odor of soybeans [4].

Soybeans that have been boiled, soaked overnight to produce acidic conditions. The next day, the epidermis is peeled off. The epidermis is peeled by putting the soybeans in water, then kneading it while hulling it until finally getting soybeans. Soybean chips are washed again, in the same way as washing rice that is about to be cooked. After separating the skin, it was washed again before the second boiling.

Soybean chips are put in a container and then cooked, much like cooking rice. Ripe soybeans that have been removed, spread thinly on a winnowing tray. Wait until it cools down, the water drips off, and the soybean chips dry out. The next process is to add yeast. Giving yeast to soybeans is mixed while stirring until evenly distributed. Its size, 1 kg of soybeans uses about 1 gram of yeast.

Soybeans that have been mixed well with yeast are wrapped in banana leaves or plastic. If the packaging is in the form of plastic, the fermentation process is carried out on bamboo awnings placed on shelves. If the wrapping is in the form of leaves, the fermentation process is carried out in a bamboo basket covered with burlap. Fermentation is done overnight, the next day the tempeh is finished and ready to be consumed.

Petri Net

In a processing production process that requires stages to be carried out sequentially, the limited number of resources and a long time to complete a job will cause queuing problems. This queuing problem is a discrete system problem that is often encountered. Petri net (PN) is a tool that can model the dynamics of the discrete state or event system. In general, marked PN consists of place ($P = \{p_1, p_2, \dots, p_n\}$), transition ($T = \{t_1, t_2, \dots, t_m\}$), arc ($A \subseteq (P \times T) \cup (T \times P)$), weight ($w: A \to \{1, 2, 3, \dots\}$), and token ($\boldsymbol{x}_0: P \to \{0, 1, 2, 3, \dots\}$).

Although the tofu and tempeh processing industry is only a household scale, it is important to be able to ensure that each process is carried out in a well-scheduled manner based on available resources. Production processes always have a partially identical sequence of using shared system resources. Therefore, the job structure utilizes shared resources, but the processing time of each job is not symmetrical. The purpose of flexible manufacturing system scheduling is to determine the assignment of resources in the production process by considering several criteria (eg, time cost and avoidance of deadlocks) [7]. The model obtained in this study is expected to be able to describe the dynamics of these processes and resources.

RESEARCH METHOD

In this study, the data used were the stages of making tempe, starting from soybean raw materials to becoming ready-to-market tempeh. Data were obtained through interviews with respondents, the results of field observations, and studies on several references that were used as references [2]. Interviews and field observations on respondents were carried out using observation sheets so that observations could be carried out systematically. The process of making tempeh is observed starting from the initial process of production to the end of production in the form of tempe which is ready to be marketed.

After the process of processing soybeans into tempeh has been obtained and understood well, the next step is to create a petri net model of the tempeh production process. The simulation is carried out with several assumptions that have been adjusted to the results of observations in the field.

RESULT AND DISCUSSION

The results of this study are described in the results section in the form of images of the petri net model of the tempe processing process, as well as the initial and final conditions of the simulation carried out. The dynamics of the petri net are explained in the discussion section.

A. Result

Based on the results of a literature review and direct observation in one of the household-scale tofu processing industries, the petri net is obtained as shown in Figure 1. The petri net consists of 14 places and 10 transitions.

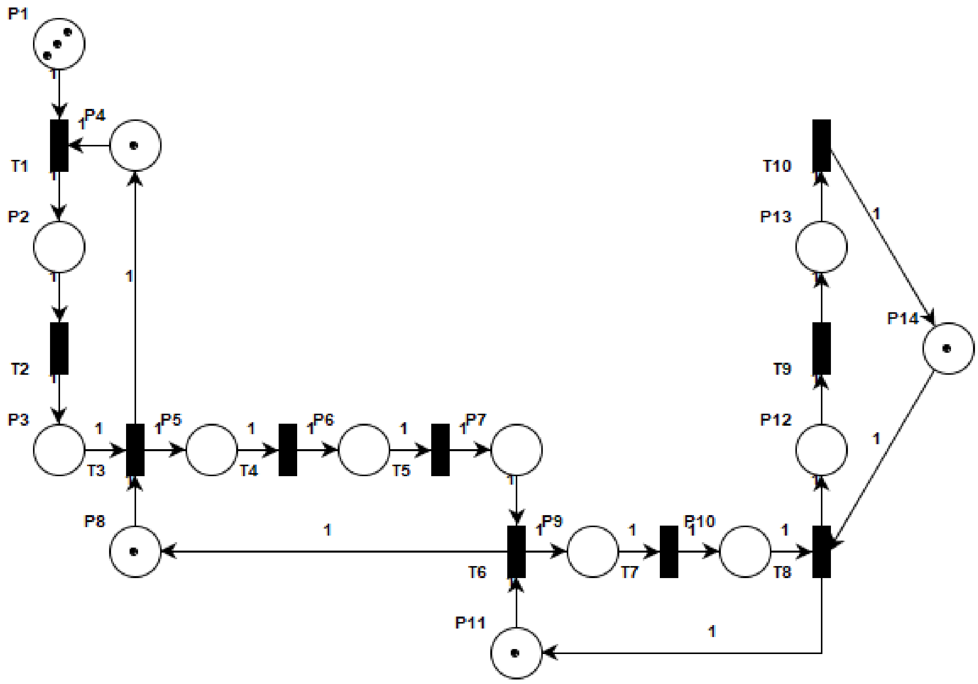

Figure 1. Petri Net Tempeh Processing Process with 4 Operators

description:

$P1$	:	soybeans	$T1$	:	sorting & washing
$P2$	:	clean soybeans	$T2$	:	1^{st} boiling
$P3$	:	1^{st} stew	$T3$	:	immersion
$P4$	:	operator 1	$T4$	:	peeling & washing
$P5$	:	marinade	$T5$	:	2^{nd} boiling
$P6$	:	peeling results	$T6$	:	Drain
$P7$	:	2^{nd} stew	$T7$	:	yeast
$P8$	:	operator 2	$T8$	:	packaging
$P9$	:	draining result	$T9$	:	fermentation
$P10$	:	fermentation results	$T10$	:	finish
$P11$	:	operator 3			
$P12$	:	packaging result			

$P13$: tempeh
$P14$: operator 4

The simulation is carried out with the assumption that every enable transition will fire immediately. If there is more than one enabled transition at the same time, then all of the enable transitions will be fired simultaneously. Figure 2 shows the initial state of the petri net simulation, while Figure 3 shows the final state of the simulation.

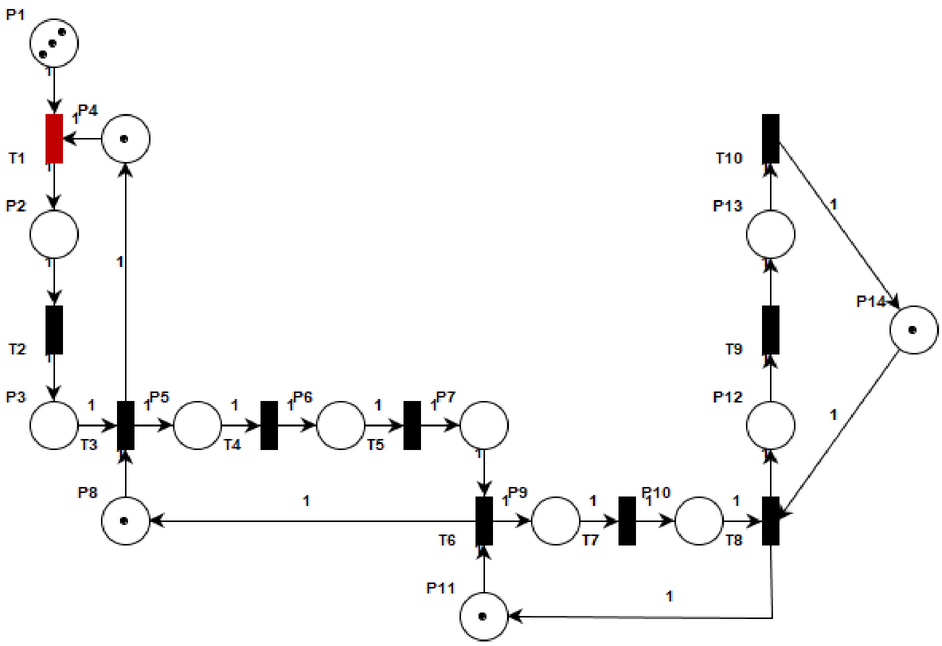

Figure 2. Initial State of Petri Net Tempeh Processing Process

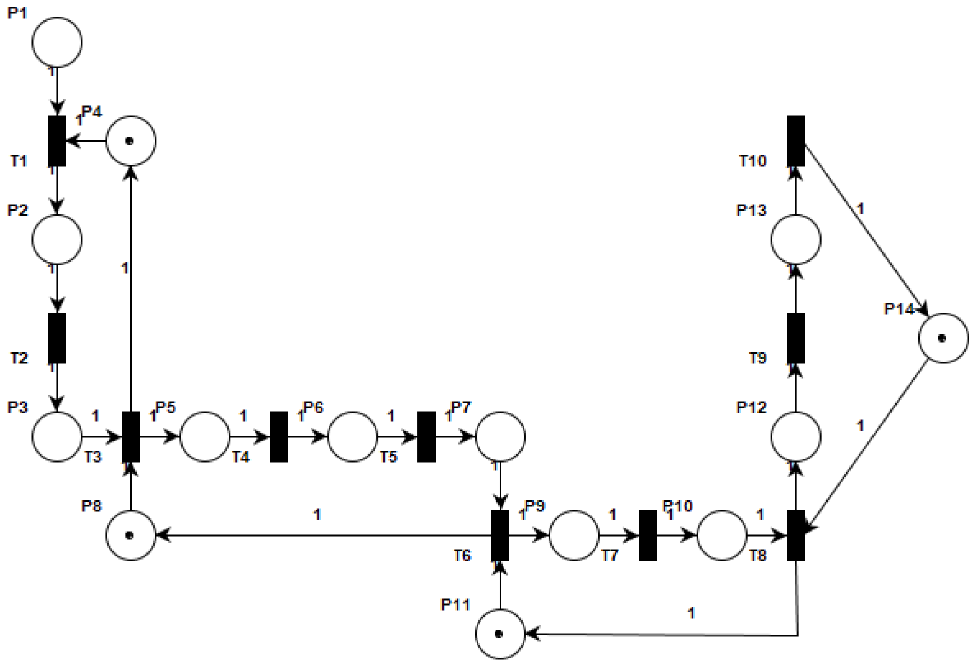

Figure 3. Final State of Petri Net Tempeh Processing Process

In the initial simulation, it is known that there are tokens in place $P1$, $P4$, $P8$, $P11$, and $P14$, each amounting to 3, 1, 1, 1, and 1. Tokens in place $P1$ totaling 3 are the assumption that soybean processing is carried out in one day into tempeh 3 times with a certain quantity. While the tokens, which amount to one in place $P4$, $P8$, $P11$, and $P14$ state the number of operators working. Operator 1 is in charge of sorting & washing soybeans, as well as carrying out the first boiling process. Then the process of soaking, peeling & washing, and the second boiling are carried out by operator 2. After the second boiling is complete, the process of draining and sowing the yeast is carried out by Operator 3. Operator 4 carries out packaging and ripening or fermentation, until it becomes tempeh.

B. Discussion

Assuming all enable transitions will be fired immediately, and the demonstration will be carried out from the front transition [5]. Then the possible dynamics of the PN state are shown in Table 1 below:

Table 1. The dynamics of the state of the Petri Net (PN)

State	Fired Enable Transition
$\boldsymbol{x_0} = [3,0,0,1,0,0,0,1,0,0,1,0,0,1]$	$T1$
$\boldsymbol{x_1} = [2,1,0,0,0,0,0,1,0,0,1,0,0,1]$	$T2$
$\boldsymbol{x_2} = [2,0,1,0,0,0,0,1,0,0,1,0,0,1]$	$T3$
$\boldsymbol{x_3} = [2,0,0,1,1,0,0,0,0,0,1,0,0,1]$	$T1, T4$
$\boldsymbol{x}_4 = [1,1,0,0,0,1,0,0,0,0,1,0,0,1]$	$T2, T5$
$\boldsymbol{x}_5 = [1,0,1,0,0,0,1,0,0,0,1,0,0,1]$	$T6$
$\boldsymbol{x}_6 = [1,0,1,0,0,0,0,1,1,0,0,0,0,1]$	$T3, T7$
$\boldsymbol{x}_7 = [1,0,0,1,1,0,0,0,0,1,0,0,0,1]$	$T1, T4, T8$
$\boldsymbol{x}_8 = [0,1,0,0,0,1,0,0,0,0,1,1,0,0]$	$T2, T5, T9$
$\boldsymbol{x}_9 = [0,0,1,0,0,0,1,0,0,0,1,0,1,0]$	$T6, T10$
$\boldsymbol{x}_{10} = [0,0,1,0,0,0,0,1,1,0,0,0,0,1]$	$T3, T7$
$\boldsymbol{x}_{11} = [0,0,0,1,1,0,0,0,0,1,0,0,0,1]$	$T4, T8$
$\boldsymbol{x}_{12} = [0,0,0,1,0,1,0,0,0,0,1,1,0,0]$	$T5, T9$
$\boldsymbol{x}_{13} = [0,0,0,1,0,0,1,0,0,0,1,0,1,0]$	$T6, T10$
$\boldsymbol{x}_{14} = [0,0,0,1,0,0,0,1,1,0,0,0,0,1]$	$T7$
$\boldsymbol{x}_{15} = [0,0,0,1,0,0,0,1,0,1,0,0,0,1]$	$T8$
$\boldsymbol{x}_{16} = [0,0,0,1,0,0,0,1,0,0,1,1,0,0]$	$T9$
$\boldsymbol{x}_{17} = [0,0,0,1,0,0,0,1,0,0,1,0,1,0]$	$T10$
$\boldsymbol{x}_{18} = [0,0,0,1,0,0,0,1,0,0,1,0,0,1]$	$-$

Based on Table 1, the assumption of processing soybeans into tempeh 3 times with a certain quantity in one day, can be completed when $\boldsymbol{x}_{18}$ is reached. Simultaneous firing of $T1, T3, T6$, and $T8$ transitions never occurs. This means that the four operators never start work at the same time. This happens because there is a process where one operator has to wait for the previous operator to finish the job. For example, when $\boldsymbol{x_2}$, operator 2 must wait for operator 1. When the transition $T3$ is fired, then $\boldsymbol{x_3}$ is reached and it means that operator 2 has just started its work, while operator 1 is in stand-by condition.

From Table 1 it can also be seen that starting from $\boldsymbol{x_0}$ to $\boldsymbol{x_1}$ only operator 1 works. When $\boldsymbol{x_3}$ to $\boldsymbol{x_4}$ only operator 1 and operator 2 work. Operator 3 starts working when the $T6$ transition is fired and $\boldsymbol{x_6}$ occurs. Then operator 4 starts working when the $T8$ transition is fired and $\boldsymbol{x_8}$ occurs.

Operator 1 finishes doing work at $\boldsymbol{x_{11}}$, i.e. when the token in place $P1$ is exhausted and makes the transition $T1$ never enable again. Operator 2 and operator 3 respectively finish doing work at $\boldsymbol{x_{14}}$ and $\boldsymbol{x_{16}}$, i.e. when transitions $T3$ and $T6$ can no longer be fired.

CONCLUSION

The petri net model of the tempe processing process has been successfully created with 14 places and 10 transitions. With some of the assumptions described in the previous section, the simulation has been completed to a state of $\boldsymbol{x_{18}}$. From the simulations carried out, in the initial state, operators 3 and 4 are ready even though they have not done any work. Meanwhile, at the end of the day, the opposite is true, operators 1 and 2 have finished their work. In fact, in the field, this industry not only produces tempeh, but also produces tofu. Operators 3 and 4 can be used as operators in the early stages of tofu production, and vice versa for operators 1 and 2.

The petri net model can still be developed because in this model the only resource that is considered is the availability of the operator. Concurrent use of tools and working time in each processing process have not been considered.

BIBLIOGRAPHY

[1] Alvina, A., & Hamdani, D. (2019). Proses Pembuatan Tempe Tradisional. *Jurnal Pangan Halal*, *1*(1), 9–12.

[2] Fadhlirrobbi, Sopiandi, A., Suliah, L., Savitri, & Sunarya, E. (2022). Analisi Pengendalian Kualitas (Quality Control) Dalam Meningkatkan Kualitas Produk (Studi Kasus Rumah Produksi Tempe Azaki). *JIP Jurnal Inovasi Penelitian*, *2*(10), 3269–3272.

[3] Kusumawati, I., Astawan, M., & Prangdimurti, E. (2020). Proses Produksi dan Karakteristik Tempe dari Kedelai Pecah Kulit. *Pangan*, *29*(2), 117–126.

[4] Manurung, G., Sumbogo, T. A., & Lensun, R. A. (2014). *Seri Pemberdayaan Masyarakat: Pelatihan Usaha Tempe Tahu*. Amerta Publishing.

[5] Murdianto, D., & Santoso, D. (2022). Pemodelan Mesin Pencacah Limbah Pertanian Menggunakan Petri Net. *J-PEN Borneo: Jurnal Ilmu Pertanian*, *5*(1), 1–5.

[6] Setyowibowo, S., & Prasetyo, A. (2017). Pengembangan Industri Tahu dan Tempe Sebagai Alternatif Pangan di Desa Curahmalang Kecamatan Rambipuji Kabupaten Jember. *PEDULI - Jurnal Ilmiah Pengabdian Pada Masyarakat*, *1*(2), 11–19.

[7] Xu, G., & Chen, Y. (2022). Petri-Net-Based Scheduling of Flexible Manufacturing Systems Using an Estimate Function. *SS Symmetry*, *14*(5).