Design and Performance Test of Multi Intake Foods Product Cutting Machine

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Abstract. Appropriate technology is one of the answers to support small and medium enterprises in the sustainability of their business production. This research aims to design and test the performance of multi-intake food product cutting machines, this cutting machine can be applied to cutting food products such as tempeh, crackers, fruits, or tubers. This machine is called multi intake because it can cut more than one material at the same time and produce more cuts in a relatively short time. This machine is equipped with an automatic propulsion system that can produce pieces of uniform thickness. The results showed that the construction of a multi-intake cutting machine for cutting food ingredients in the form of tempeh has a capacity of 120 kg h^{-1} to 173.5 kg h^{-1}, the most optimal performance of the cutting machine for foodstuffs and can increase the capacity and quality of the stripping results achieved in the use of an electric motor with power 375 Watt with engine shaft rotation (n) = 327 rad s^{-1} and a thrust speed of 0.370 cm s^{-1} which can produce a cutting capacity of 173.5 kg h^{-1} with intact, not defective, and flat cut quality.

Keywords: Appropriate technology, efficiency improvement, food processing optimization, increase productivity, tempeh.

1 Introduction

The COVID-19 pandemic has economic, social, and political implications in almost all countries, including Indonesia [1, 2]. In the economic field, this pandemic has a huge impact on the sustainability of Small and Medium Enterprises (MSMEs) businesses. Small businesses have been hardest hit by the COVID-19 crisis, many have temporarily closed businesses, and further face cash flow constraints [3]. Sia [4] describes the results of a survey that shows that 96 % of SMEs admit that they have experienced the negative impact of COVID 19 on their business processes. As many as 75 % of them experienced a

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significant drop in sales. Not only that, 51 % of MSME players believe that the business they run will only last 1 mo to the next 3 mo. As many as 67 % of MSME actors experience uncertainty in obtaining access to emergency funds, and 75 % feel they do not understand how to make policies in times of crisis. Only 13 % of MSMEs believe that they have a crisis management plan and find solutions to sustain their business.

Until now, Indonesia is known as the largest tempeh producer and consumer country in the world and is the largest soybean market in Asia [5] with consumption reaching 0.146 kg capita^{-1} wk^{-1} in 2018. This is evidenced by Arief [6] that the production volume of tempeh and tofu by the end of 2019 could reach 5.7×10^6 t from the previous year's realization of 5.5×10^6 t. One of the typical foods that are quite well known in Indonesia is tempeh chips. Tempeh chips have a very thin shape, resulting in a soft and very crunchy texture. One of the processes that determine the quality and taste of tempeh chips is the process of cutting tempeh so that it has a uniform shape and thickness. In fact, many tempeh chip business operators still use manual cutting [7]. As for several previous studies that have implemented tempeh cutting machines such as tempeh cutting mechanization for chips using a rotating knife by Romli *et al.* [8], design of a multi-function tempeh slicing machine by Garside and Sudjatmiko [9], design of a microcontroller based automatic tempeh chopper system by Risyandi *et al.* [10]. However, the various slicing or cutting machines still use a single intake system with an average capacity of 6 kg h^{-1}, so the resulting capacity is not optimal.

Several researchers have carried out optimizations to increase the cutting capacity of foodstuffs. Taking into account the ease of operation. Onifade [11] increased the number of hooper/intake from one hole in the previous study [12] to three holes. It was found that the banana cutting capacity increased from 50.49 g s^{-1} to 116.88 g s^{-1} using the same propulsion of 1 HP. Research on cutting speed on the capacity and efficiency of banana cutting was carried out by Sonawane *et al.* [13] by varying the cutting speed at (360, 410, 630, and 720) rad s^{-1}. It was found that the faster-cutting speed increases the capacity but decreases efficiency. Sonawane's research [13] concluded that at 360 rad s^{-1}, it could produce an efficiency ranging from 93 % to 94 % and a capacity of 100 kg h^{-1} by using an electric motor 1 HP or 2 HP. The piston model suppression system was developed by Magpili *et al.* [14] and Hatwar *et al.* [15] for a more stable cut than being pushed by hand. The success rate using piston-type plungers can reach an efficiency of 95.63 % [14].

From these problems, this research was conducted as an effort to optimize the production of processed food by designing multi-intake food product cutting machines and conducting performance tests to increase capacity and ensure the quality of production results.

2 Methods

2.1 Preparation of multi intake food product cutting technology

This multi-intake food product cutting machine (Figure 1) is designed to be able to cut food products such as tempeh, crackers, fruits, or tubers that may be placed on the material trajectory. The main parts of this machine include: (i) the frame as a support for all machine components; (ii) an electric motor as a driver; (iii) belts and pulleys as transmissions; (iv) transport shaft for automation plunger; (v) transporter shaft road controller; (vi) transmission cover; (vii) cutting mechanism; (viii) material trajectory; (ix) plunger; and (x) the track base. This machine has six material trajectories, so it is said to be a multi-intake that can produce more cuts in a relatively short time. This machine is also equipped with an automatic plunger system that can produce pieces of product with uniform thickness.

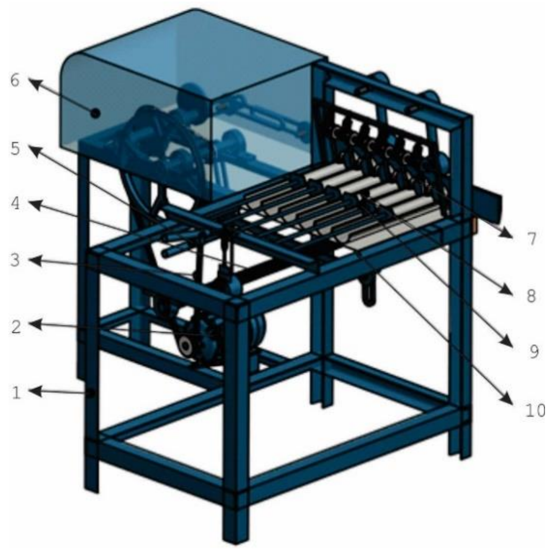

Fig. 1. Multi intake food product cutting technology.

2.2 Experimental design

To produce a multi-intake system for cutting tempeh products according to the needs of the Small and Medium-sized Enterprises (SMEs) for food products made from tempeh, the following procedures are required: (i) study of exploration to small industries/businesses of food products based on tempeh ingredients, (ii) data analysis of the results of the exploration study and comparing with the results of literature studies, to design a tempeh product cutting machine according to the conditions of SMEs, calculate the power required for cutting tempeh products, (iii) design and manufacturing a tempeh product cutting machine according to the design results, (iv) perform a performance test of a tempeh product cutting machine by combining the following variables: (a) cutting capacity (kg h^{-1}), (b) required motor power (Watt), (c) optimal shaft rotation (rad s^{-1}), (d) pushing speed (cm s^{-1}), and uniformity of cutting, and (v) prototype improvement to produce engineered products the form of a tempeh product cutting machine with a proven multi-intake system.

2.3 Treatment application and data collection

To obtain the optimal performance of the tempeh product cutting machine, the independent variables will be tested by power, push speed, blade speed, and the time required for the cutting process. The dependent variable is the capacity of the tempeh cut. The control variables were the flatness of the cut, the thickness of the cut, and the uniformity of the cut. Instrumentation/measuring instruments used are stop-watch, calipers, tachometer (rotation measuring instrument, rad s^{-1}), cutting speed (m s^{-1}), and weight scales (g). Variant (Anova) to know the optimum and best performance of the tempeh product cutting machine in the various combinations of variables tested in Equation (1).

$$CC = (P, n, V, t)\ (\text{kg h}^{-1}) \quad (1)$$

Where,

CC = Tempeh product cutting machine capacity (kg h^{-1})
P = Required power (Watt)

n = Motor shaft speed (rad s^{-1})
V = Push speed (m s^{-1})
t = Time required in the cutting process (s)

The parameter of the amount of material cut is six cylindrical bar tempeh. CC (tempeh product cutting machine capacity) is the dependent variable, while the independent variables are:

(i) The power variable is tested at the value of P = (375 Watt; 562.5 Watt ; 750 Watt) based on the calculation of a minimum power required of 375 Watt so that the optimal power is used for cutting products will be sought.
(ii) Variable n (drive shaft speed), the speed of the electric motor used is 1 400 rad s^{-1}, for research this tempeh product cutting machine is done by changing the diameter of the pulley transmission wheel to obtain an appropriate speed ratio, the test is carried out at the distance between the shafts. The pulley wheel on an electric motor with the pulley wheel axle on the cutting disc is 32 cm with the speed ratio as follows:
Speed n1 = 233 rad s^{-1} (ratio of wheel reduction d1 = 5 cm and d2 = 30 cm),
Speed n2 = 280 rad s^{-1} (ratio of wheel reduction d1 = 6 cm and d2 = 30 cm),
Speed n3 = 327 rad s^{-1} (ratio of wheel reduction d1 = 7 cm and d2 = 30 cm),
Speed n3 = 467 rad s^{-1} (ratio of wheel reduction d1 = 10 cm and d2 = 30 cm),
(iii) The push speed for this cutting process is tested on a product with a length of 0.4 m each with a total of six bar tempeh with velocity in (m s^{-1}), the push speed is used to determine the thickness, uniformity, and evenness of the cut product.
(iv) Capacity is measured by the results of cutting the product obtained kg h^{-1}.
(v) For the treatment combination on these variables, a performance test is carried out with each repetition of three times to produce the cutting capacity of the product as shown in the results, then a graph is made of the average production capacity for each combination of variables.

3 Results and discussion

3.1 Design and working principle of multi intake food product cutting technology

The following is a design of a multi-intake food product cutting machine (Figure 2) using a computer-aided design (CAD) program.

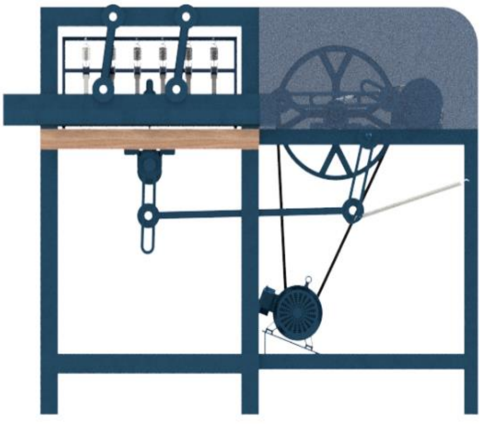

Fig. 2. Design of multi intake food product cutting technology.

Fig. 3. Physical model of multi intake food product cutting technology.

The operation of this multi-intake food product cutting machine is very simple and easy to operate with the following steps: (i) put food/tempeh on the material trajectory, (ii) then adjust the thickness of the cutting on the road setting of the transport shaft, (iii) turn on the engine, so that the cutting and pushing mechanism will move, so that the tempeh can be cut with a uniform thickness and a perfectly intact shape (not broken).

3.2 Performance test results

Table 1. Combination of treatment variables to average capacity (kg h^{-1}) and quality of cutting results.

Motor power	Shaft speed (rad s^{-1})	Push speed (m s^{-1})	Average capacity (kg h^{-1})
375 Watt	n1 = 5 : 30 × (1 400) = 233 rad s^{-1}	Nd1 = 0.002 27	120.6 kg h^{-1}
	n2 = 6 : 30 × (1 400) = 280 rad s^{-1}	Nd2 = 0.002 85	124.2 kg h^{-1}
	n3 = 7 : 30 × (1 400) = 327 rad s^{-1}	Nd3 = 0.003 70	173.5 kg h^{-1}
	n4 = 10 : 30 × (1 400) = 467 rad s^{-1}	Nd4 = 0.005	187.2 kg h^{-1} (10 % broken)
562.5 Watt	n1 = 5 : 30 × (1 400) = 233 rad s^{-1}	Nd1 = 0.002 27	123.5 kg h^{-1}
	n2 = 6 : 30 × (1 400) = 280 rad s^{-1}	Nd2 = 0.002 85	127.5 kg h^{-1}
	n3 = 7 : 30 × (1 400) = 327 rad s^{-1}	Nd3 = 0.003 70	176.5 kg h^{-1}
	n4 = 10 : 30 × (1 400) = 467 rad s^{-1}	Nd4 = 0.005	190.5 kg h^{-1} (20% broken)
750 Watt	n1 = 5 : 30 × (1 400) = 233 rad s^{-1}	Nd1 = 0.002 27	127.5 kg h^{-1}
	n2 = 6 : 30 × (1 400) = 280 rad s^{-1}	Nd2 = 0.002 85	131.5 kg h^{-1}
	n3 = 7 : 30 × (1 400) = 327 rad s^{-1}	Nd3 = 0.003 70	180.5 kg h^{-1} (25 % broken)
	n4 = 10 : 30 × (1 400) = 467 rad s^{-1}	Nd4 = 0.005	194.5 kg h^{-1} (35 % broken)

The construction of this multi-intake mower for cutting foodstuffs or tempeh can operate with a capacity of 120 kg h^{-1} to 173.5 kg h^{-1}, the most optimal mechanization performance of food material cutting machines, and can increase the capacity and quality of the stripping results achieved in the use of electric motors with power 375 Watt with engine shaft rotation (n) = 327 rad s^{-1} and a thrust speed of 0.370 cm s^{-1} which can produce a cutting capacity of 173.5 kg h^{-1} with a complete and even thickness of the result. The use of motor power 562.5 Watt or 750 Watt causes inefficientes use of electricity in addition to causing damage to cutting results.

280	124.2	127.5	131.5

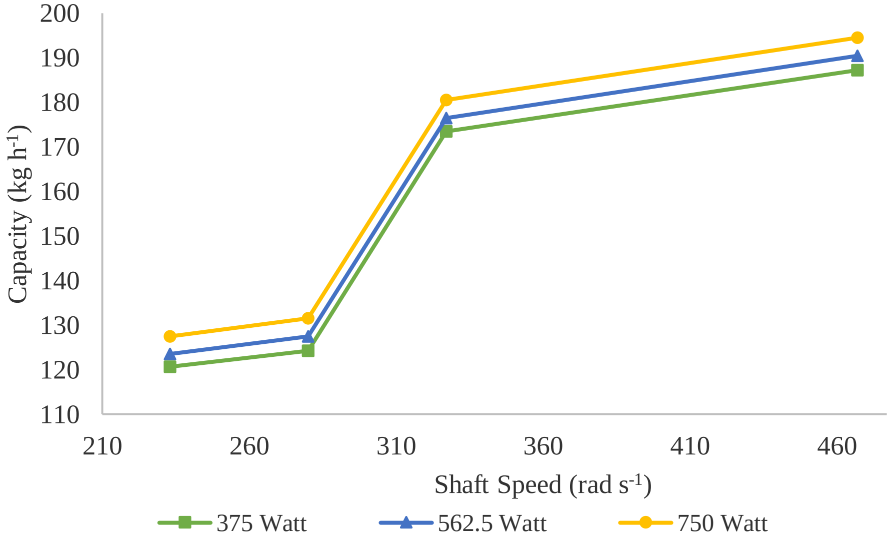

Fig. 4. Results of the performance test for the combination of treatment variables against the average cutting capacity (kg h^{-1}).

4 Conclusion

The construction of a multi-intake cutting machine for cutting food product or tempeh has been produced with a capacity of 120 kg h^{-1} to 173.5 kg h^{-1}, the most optimal mechanization performance of food material cutting machines and can increase the capacity and quality of the results is achieved by using an electric motor with a power of 375 Watt with engine shaft rotation (n) = 327 rad s^{-1} and a push speed 0.370 cm s^{-1} which can produce a cutting capacity 173.5 kg h^{-1} with an intact and even thickness of the result.

References

1. S. Susilawati, R. Falefi, A. Purwoko, Budapest Int., Res. Critics Institute J., **3**,2: 1147–1156 (2020) https://doi.org/10.33258/birci.v3i2.954
2. A.K. Pakpahan, J. Ilmiah Hubungan Internasional, 59–64 (2020) https://doi.org/10.26593/jihi.v0i0.3870.59-64
3. T.H. Baker, K Judge, Colombia Law Econ. Working Paper, **620**: 1–12 (2020) https://dx.doi.org/10.2139/ssrn.3571460
4. V. Sia, *Strategi jitu agar UKM bisa bertahan hadapi krisis akibat corona* [The right strategy so that SMEs can survive the crisis due to corona] [Online] from https://www.jurnal.id/id/blog/strategi-jitu-agar-ukm-bisa-bertahan-hadapi-krisis-akibat-corona/ (2020) [Accessed on 2 May 2021] [in Bahasa Indonesia]
5. N.R. Novita, Z. Abidin, J. Pusat Inovasi Masyarakat, **2**,6: 925–930 (2020) [in Bahasa Indonesia] https://journal.ipb.ac.id/index.php/pim/article/view/33262
6. A.M. Arief, *Produksi tempe bisa melesat tahun depan* [Tempeh production could rise next year] [Online] from https://ekonomi.bisnis.com/read/20190910/257/1146349/produksi-tempe-bisa-melesat-tahun-depan (2019) [in Bahasa Indonesia] [Accessed on 2 May 2021]

7. C. Pramono, E. Mawarsih, H. Kurniawan, J. Mech. Eng., **1**,1: 18–24 (2017) [in Bahasa Indonesia] http://dx.doi.org/10.31002/jom.v1i1.364
8. R. Romli, S. Rizal, T. Widagdo, J. Austenit, **3**,2: 35–45 (2011) [in Bahasa Indonesia] https://doi.org/10.5281/zenodo.4544237
9. A.K. Garside, Sudjatmiko, Senaspro, 513–519 (2016) [in Bahasa Indonesia] http://research-report.umm.ac.id/index.php/research-report/article/view/851
10. D. Risyandi, A. Triwiyatno, S. Sumardi, Transient: J. Ilmiah Teknik Elektro, **6**,1: 133–139 (2017) [in Bahasa Indonesia] https://doi.org/10.14710/transient.v6i1.133-139
11. T.B. Onifade, Am. Sci. Res. J. Eng. Technol. Sci., **17**,1: 61–80 (2016) https://asrjetsjournal.org/index.php/American_Scientific_Journal/article/view/1384
12. F.B. Akande, T.B. Onifade, Innov. Syst. Des. Eng., **6**,10: 41–52 (2015) https://www.iiste.org/Journals/index.php/ISDE/article/view/26415.
13. S.P. Sonawane, G.P. Sharma, A.C. Pandya, Res. Agric. Eng., **57**,4: 144–152 (2011) https://doi.org/10.17221/35/2010-RAE
14. J.P.E. Magpili, R.S. Datu, J.S. Reyes, P.B. Manalo, Int. J. Res. Appl. Sci. Eng. Technol., **6**,1: 253–259 (2018) http://dx.doi.org/10.22214/ijraset.2018.1039
15. R.M. Hatwar, K.T. Rahandale, M.G. Trivedi, Int. J. Sci. Res. Dev., **4**,2: 449–452 (2016) https://www.ijsrd.com/Article.php?manuscript=IJSRDV4I20814