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Analyzing the Performance of Multi Seeds Smart Dryer (MSSD) with Low Cost and Low Energy Consumption (LCEC)

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Abstract. *Seeds drying technology is essential for ensuring the quality of agricultural products, particularly seeds. Although technological developments have resulted in more effective drying methods, challenges such as high energy consumption persist among small-scale farmers with limited resources. Therefore, this research aimed to analyze the performance of Multi Seeds Smart Dryer with Low Cost and Low Energy Consumption (MSSD-LCEC), a machine designed to solve the inadequacies of traditional seeds drying methods. The machine used low-energy components and environmentally friendly concepts to achieve sustainable seeds drying while remaining affordable for small-scale farmers. Using corn, peanuts, and soybeans as test materials, the performance of MSSD-LCEC was analyzed through the use of factors such as drying rate, energy consumption, temperature, humidity, and moisture content (MC). The results showed that the machine effectively dried seeds in acceptable MC levels, meeting quality standards for seeds certification. This research also discussed the economic benefits of MSSD-LCEC, highlighting the stable performance and efficient energy use. By optimizing the machine's operation and minimizing energy costs, small-scale farmers could enhance their profitability while contributing to environmental sustainability. In conclusion, further refinement of the control system had the potential to enhance both economic benefits and environmental sustainability in seeds processing applications.*
Keywords: *MSSD, Multi Seeds, Smart, Dryer, 300 Watt.*

Type of the Paper: Regular Article.

1. Introduction

Seeds drying is one of the agricultural stages that has a major impact on product quality [1]. With technological developments, seeds drying method are subjected to significant transformation [2–4]. This method has experienced rapid improvements in efficiency, speed, and quality. Several reviews have compared drying method for analyzing the physical and chemical properties of plants that have bioactive compounds [5] and evaluated the impacts of drying method on coffee's physical, biological, and chemical properties [6], as well as investigated energy consumption in paddy drying [7]. These developments address the increasing demand for high-quality seeds in the global market [8]. The growing need for seeds correlates with increased food consumption, for instance, Indonesian companies demand roughly 29.7 Million Metric Tons (MMT) of corn, and

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rice consumption remains stable at 35.2 MMT from 2022-2023 [9]. In addition, seeds production is closely related to institutional policies and stakeholder interactions, including research institutions, certifying authorities, producers, and technology developers. Rapid and appropriate responses to these challenges can increase seeds availability for producers [10].

Technical problems have arisen with the advancement of seeds drying technology, one of which is high energy consumption [11]. High energy consumption results in increased electricity bills and has a negative impact on the environment, particularly in areas that depend on fossil resources [12,13]. Therefore, developing technology that prioritizes low energy consumption is necessary. For instance, IoT technology in drying operations may be useful for real-time control and small energy consumption [14].

Effective seeds drying technology is particularly crucial for small-scale farmers, who frequently have limited resources, such as energy and capital. Many farmers in Indonesia are considered poor, with average land ownership of less than 1 hectare [15,16]. By designing drying technology [17], small-scale farmers can improve seeds quality without incurring excessive financial costs [18,19].

Based on the above description, this research explores recent developments in seeds drying technology, with a focus on energy efficiency. Menon et al. and Alam et al. [20,21] found that using low-energy components resulted in a more efficient drying method than solar energy. The technology provides an efficient solution for small-scale farmers, promoting the production of high-quality seeds while also improving the environment and agricultural sustainability [22,23].

Multi Seeds Smart Dryer with Low Cost and Low Energy Consumption (MSSD-LCEC) [24] is an improvement on the previous MSSD machine [25]. MSSD-LCEC is designed to dry various seeds by prioritizing eco-friendly principles and saving energy [24]. The machine is also inexpensive to build, as it uses commonly accessible and low-cost components, such as multiplex with a layer of aluminum foil. Furthermore, MSSD-LCEC is designed with more efficient components, including a heater with light-emitting diode (LED) lights and a low-energy fan. LED has several benefits such as reduced energy use, a longer lifespan, and the elimination of dangerous chemicals [24].

This research aims to analyze the performance of MSSD-LCEC drying machine using corn, peanut, and soybean seeds. The evaluated parameters included drying speed, energy consumption, temperature and humidity of drying process, and material moisture content (MC).

2. Materials and methods

2.1. Drying Unit

The specifications of MSSD-LCEC included the dimensions of 130x50x100 cm^3 with an energy consumption of 1300 Wh. The frame of the machine was built of stainless steel hollow iron

2.5x2.5 cm^3 (11) with 10 racks measuring 100x50 cm^2 (14), as shown in Fig. 1. Fig. 2 presented the layout, which included a side-mounted lamp and fans. There were 6 lamps of 40-watt bulbs and 6 Direct Current (DC) fans with a total energy consumption of 10 Watt-hours (8).

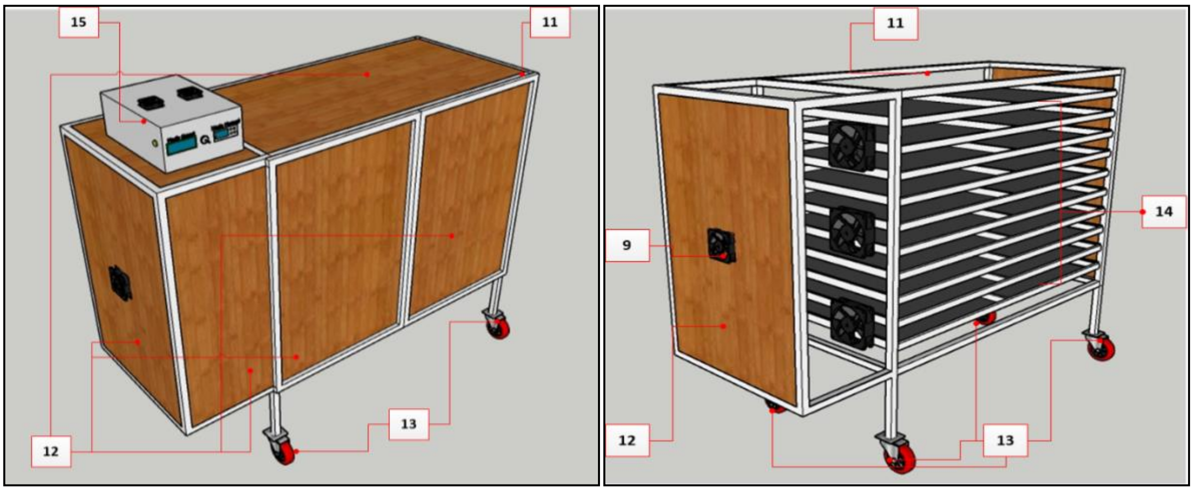

Fig. 1. MSSD perspective from the front and without cover

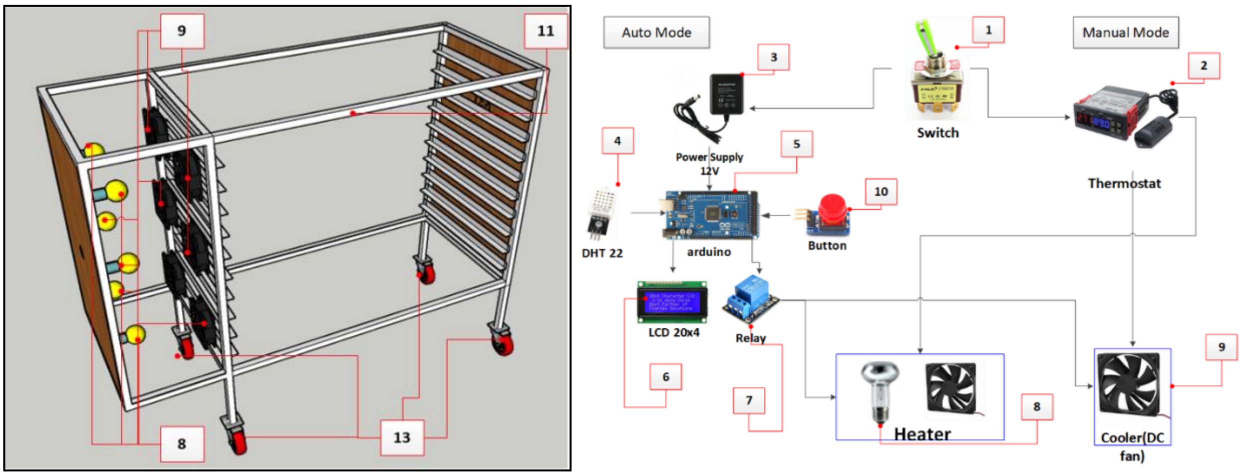

Fig. 2. MSSD-LCEC frame and block diagram of the machine's working system

The control component of the system consisted of a switch for selecting drying mode (1), a thermostat for manual engine control (2), and an energy supply to power the Arduino and other electronic components (3). Furthermore, DHT22 sensor functioned to detect the temperature and humidity in drying room [26]. The Arduino Mega also functioned as the brain or central controller of the control system [27]. Additionally, liquid crystal display (LCD) (20x4) cm^2 assisted in showing temperature information directly (6). A relay regulated the on and off of the actuator in accordance with the desired temperature. The button module was used to change temperature settings according to the type of beans being dried (10). The machine walls were made of 8 mm thick multiplex and insulated with aluminum foil (12). The machine was also equipped with 3-inch wheels that could rotate at 36°C and included brakes for stability (13). Moreover, a control box ensured the security and support of the Arduino Mega microcontroller (5) and energy supply (3).

2.2. Material

The test materials contained 3 types of seeds, including corn, peanuts, and soybeans, which were examined for their initial MC. Although MSSD-LCEC had a capacity of 30 kg of seeds, the material weight was set at 20 kg in this experiment, as shown in Table 1.

Table 1. Material test

No	Material	X initial MC	Weight (kg)
1	Corn	23.5	20
2	Peanuts	25.53	20
3	Soybeans	18.43	20

2.3. Procedure

The procedure included (1) installing a Digital Watt Meter to monitor the energy consumption of the machine, (2) arranging the observation materials equally over the racks, (3) drying each sort of material alternately, with 3 tests for all of them, and (4) turning on the machine to activate the 6 LED lights and DC fans, which started the heat transmission process. The exhaust fan directed the generated heat to the right side and onto the racks, ensuring consistent temperature distribution. The next procedure to take while testing the material was to set the maximum temperature points with the intelligent control box, including 40°C for corn and soybeans, as well as 35°C for peanuts. The temperature set was established based on preliminary research data, and the machine operated on a closed-loop system principle. When the air temperature reached the desired level, the heating lamps would switch off, and the hot air was expelled with the assistance of the exhaust fan. The smart control system recorded and showed the actual temperature and humidity level in the machine. Every 3 hours, use a Grain Moisture Meter that operated on conductometric principles to check the MC of seeds [28]. The drying process was considered complete when MC met the specified criteria. Drying rate profile during drying was determined using Equation (1) [29], as follows:

$$\frac{dM}{dt} = \frac{M_{t1} - M_{t2}}{\Delta t} \tag{1}$$

dM/dt: Drying Rate (%d.b/min)
Mt1: MC of the material at time t1
Mt2: MC of the material at time t2
∆t: Difference between t1 and t2 (minutes)

3. Results and Discussion

3.1. Drying Rate

Fig. 3 presented the distribution of air temperature and humidity on each rack, maintaining temperatures of 35°C and 40°C [30]. The duration of 29, 22, and 36 hours was used for drying corn, peanuts, and soybeans, respectively. Data collected every 10 minutes showed that drying room temperature for all 3 materials stabilized at 30-35°C. However, in comparison to room temperature, humidity levels in drying room fluctuated according to the machine's operational system. When the heating components were active, aerobic respiration and water evaporation occurred in the materials, leading to changes in drying room's humidity as MC of the materials decreased [31]. The results supported the idea of enhancing the energy efficiency of drying process while preserving the necessary quality of seeds material [32].

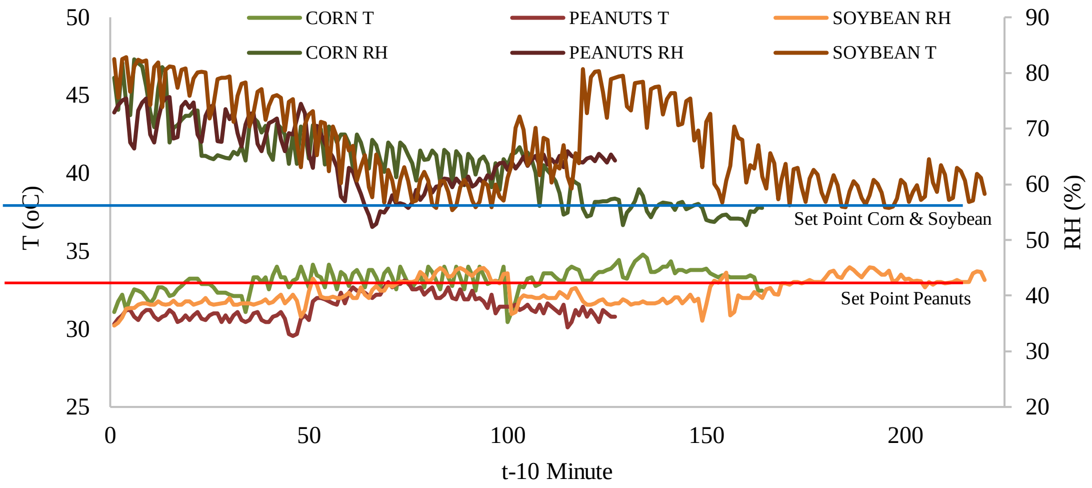

Fig. 3. Performance Graph of MSSD-LCEC Machine

3.2. Moisture Content (MC) and MSSD-LCEC Performance

MC testing determined the amount of MC in seeds and the loss, which was represented as a percentage of the initial seeds weight [33]. According to MC Standards for Approving Food Plant Seeds Certificates [34], the net MC of seeds should be 11%. The average initial MC for corn, peanuts, and soybeans was 23.5%, 25.53%, and 18.43%, respectively, with final values of 12.3%, 10.7%, and 10.7%. The final MC of corn surpassed seeds criteria established by the Directorate General of Food Crops in 2019. However, Minister of Agriculture Decree 620/HK.140/C/0.4/2020 concerning Technical Instructions for Food Crop Seeds Certification included quality standards in laboratories and allowed a maximum MC of 13% for corn [35]. Therefore, the final MC of the 3 materials was acceptable for seeds quality standards.

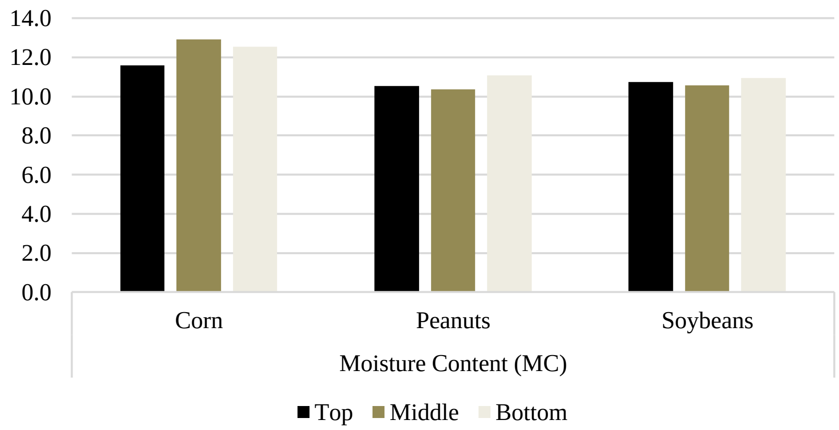

Fig. 4. MC for Each Rack Position

Fig. 4 presented that the differences in final MC results were not significant at each rack position. This case was typically influenced by rolling or moving racks every 3 hours. According to Purnamasari et al. [36], MC of materials decreased with time due to evaporation. MC played an important role in drying process because it influenced both drying time and physical changes in the material caused by chemical reactions [37].

Table 2. MSSD-LCEC Performance Test

No	Material	Set Point Max of drying (ºC)	Drying time (hour)	Energy Consumption (KWH)	X Final MC (%)	Drying Costs (1 kwh = Rp. 605,-) power 900 VA
1	CORN	40	29	4.40	12.3	2.664
2	PEANUTS	35	22	3.88	10.7	2.349
3	SOYBEAN	40	36	7.03	10.7	4.253

Table 2 presented those soybeans required a longer drying process than other materials because the seeds coat was thicker, resulting in slower water diffusion [38]. During testing, the Digital Watt Meter showed reliable machine performance with an electrical energy consumption of roughly 237 watts, continuously falling in the 230-watt range. By calculation, the combined energy consumption of the 6 LED lights (40 watts/LED) and DC fans (10 watts) would be 250 watts. The observed energy consumption was lower because the control system guaranteed that LED lights and fans did not function at the same time, resulting in less power use.

From an economic perspective, considering the energy consumption and electricity tariffs (above Rp. 5000 for a 900 VA electricity tariff and above Rp. 3000 for a 450 VA electricity tariff), a careful assessment was required to optimize the machine's operation and minimize energy costs. The stability and efficiency of the machine were indicated by consistent energy consumption readings. This suggested potential economic benefits with strategic operation and control adjustments, particularly for farmers.

4. Conclusions

In conclusion, MSSD-LCEC showed promising performance in seeds drying, with considerations for optimizing energy consumption and cost-effectiveness. Further refinement of the control system could enhance economic benefits while maintaining environmental sustainability. The ability of the machine to accommodate different materials and the stable performance made it a valuable asset for seeds processing applications, particularly for small-scale farmers.

Abbreviations

DC	direct current
LCEC	low cost and low energy consumption
LCD	liquid crystal display
LED	light-emitting diode

MC	moisture content
MMT	million metric tons
MSSD	multi seeds smart dryer
VA	volt ampere

Data availability statement

Image (Figure 4, 5, & table 2) are publicly available via the following link: (https://bit.ly/MSSD-LCEC_data).

CRediT authorship contribution statement

Indarto Indarto: Conceptualization, Investigation, Methodology, Resources, Formal analysis, Funding acquisition, supervision. Priza Pandunata: Validation, Formal analysis, Conceptualization. Rufiani Nazdirah: Conceptualization, Data curation, supervision. Amal Bahariawan: Conceptualization, Formal analysis. Mohamad Wawan Sujarwo: Writing – original draft, Writing review & editing, Validation, Data curation, Formal analysis, Methodology, Formal analysis. Chairiyah Umi Rahayu: Project administration, supervision.

Declaration of Competing Interest

The authors of this manuscript declare no conflict of interest or competing interest.

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References

[1] Chakraverty A, Mujumdar AS, Raghavan GSV, Ramaswamy HS. Handbook of Postharvest Technology Cereals, Fruits, Vegetables, Tea, and Spices. New York: MARCEL DEKKER, INC; 2003. https://doi.org/10.1201/9780203911310.ch23.

[2] Arsenoaia VN, Roșca GR, Cârlescu P, Băetu M, Rațu R, Veleșcu I, et al. Drying Process Modeling and Quality Assessments Regarding an Innovative Seed Dryer. Agriculture (Switzerland) 2023;13. https://doi.org/10.3390/agriculture13020328.

[3] Chojnacka K, Mikula K, Izydorczyk G, Skrzypczak D, Witek-Krowiak A, Moustakas K, et al. Improvements in drying technologies - Efficient solutions for cleaner production with higher energy efficiency and reduced emission. Journal of Cleaner Production 2021;320. https://doi.org/10.1016/j.jclepro.2021.128706.

[4] Jimoh KA, Hashim N, Shamsudin R, Man HC, Jahari M, Onwude DI. Recent Advances in the Drying Process of Grains. Food Engineering Reviews 2023;15:548–76. https://doi.org/10.1007/s12393-023-09333-7.

[5] Belwal T, Cravotto C, Prieto MA, Venskutonis PR, Daglia M, Devkota HP, et al. Effects of different drying techniques on the quality and bioactive compounds of plant-based products: a critical review on current trends. Drying Technology 2022;40:1539–61. https://doi.org/10.1080/07373937.2022.2068028.

[6] Hu D, Liu X, Qin Y, Yan J, Li R, Yang Q. The impact of different drying methods on the physical properties, bioactive components, antioxidant capacity, volatile components and

industrial application of coffee peel. Food Chemistry: X 2023;19:100807. https://doi.org/10.1016/j.fochx.2023.100807.
[7] Ying T, Spang ES. Paddy Drying Technologies: A Review of Existing Literature on Energy Consumption. Processes 2024;12:532. https://doi.org/10.3390/pr12030532.
[8] Malhotra B. Global vegetable seeds market is increasingly fragmented and diversified. S&P Global Commodity Insights 2021. https://www.spglobal.com/commodityinsights/en/ci/research-analysis/global-vegetable-seeds-market.html (accessed October 25, 2023).
[9] Global Agricultural Information Network. Grain and Feed Annual - 2021. Jakarta: 2023.
[10] Qadir A, Suhartanto MR, Widajati E, Budiman C, Zamzami A, Rosyad A, et al. Commercial rice seed production and distribution in Indonesia. Heliyon 2024;10:e25110. https://doi.org/10.1016/j.heliyon.2024.e25110.
[11] Jittanit W, Srzednicki G, Driscoll R. Energy cost of seed drying. ASEAN Journal on Science and Technology for Development 2017;26:33–41. https://doi.org/10.29037/ajstd.302.
[12] Nwakuba NR, Asoegwu SN, Nwaigwe KN. Energy consumption of agricultural dryers: An overview. Agricultural Engineering International: CIGR Journal 2016;18:119–32.
[13] Urbano DG, Aquino A, Scrucca F. Energy Performance, Environmental Impacts and Costs of a Drying System: Life Cycle Analysis of Conventional and Heat Recovery Scenarios. Energies 2023;16. https://doi.org/10.3390/en16031523.
[14] Mishra N, Jain SK, Agrawal N, Jain NK, Wadhawan N, Panwar NL. Development of drying system by using internet of things for food quality monitoring and controlling. Energy Nexus 2023;11:100219. https://doi.org/10.1016/j.nexus.2023.100219.
[15] Abduh M. Indonesia Agricultural Transformation: How Far? Where Would It Go? vol. 7. 2023. https://doi.org/10.36574/jpp.v7i1.366.
[16] Juliatin N, Suharso P, Mutrofin. Farmer poverty in Wonosari, Penanggal Village, Lumajang Regency. IOP Conference Series: Earth and Environmental Science 2020;485. https://doi.org/10.1088/1755-1315/485/1/012074.
[17] Mihret YC, Delele MA, Hailemesikel ST. Design, development, and testing of rice-husk fueled mixed-flow rice dryer for small-scale rice producer farmers. Heliyon 2023;9:e18077. https://doi.org/10.1016/j.heliyon.2023.e18077.
[18] Agussabti A, Rahmaddiansyah R, Hamid AH, Zakaria Z, Munawar AA, Abu Bakar B. Farmers' perspectives on the adoption of smart farming technology to support food farming in Aceh Province, Indonesia. Open Agriculture 2022;7:857–70. https://doi.org/10.1515/opag-2022-0145.
[19] Shammi S, Hossen MA, Al Mamun MR, Alam Soeb MJ. Temporal and spatial representation of temperature and moisture in drying chamber and its impact on vertical vacuum dehumidifying rice seed dryer performance. Journal of Agriculture and Food Research 2022;10:100424. https://doi.org/10.1016/j.jafr.2022.100424.
[20] Alam MS, Sarker MSH, Hasan SMK, Ahmed M, Wazed MA. Comparison on drying characteristic, efficiency, unit drying cost and quality of maize dried by a novel multi-crop mobile dryer, existing industrial dryer and sun drying method. Journal of Agriculture and Food Research 2023;14:100804. https://doi.org/10.1016/j.jafr.2023.100804.
[21] Menon A, Stojceska V, Tassou SA. A systematic review on the recent advances of the energy efficiency improvements in non-conventional food drying technologies. Trends in Food Science and Technology 2020;100:67–76. https://doi.org/10.1016/j.tifs.2020.03.014.
[22] Kushimov BA, Karimov KA, Mamadaliev KZ. Formulation and development of energy-saving technology for drying seeds of desert fodder plants. IOP Conference Series: Earth and Environmental Science 2021;937. https://doi.org/10.1088/1755-1315/937/3/032056.
[23] Çakmakçı R, Salık MA, Çakmakçı S. Assessment and Principles of Environmentally Sustainable Food and Agriculture Systems. Agriculture (Switzerland) 2023;13:1–27. https://doi.org/10.3390/agriculture13051073.

[24] Indarto I, Bahariawan A, Sujarwo MW, Pamungkas AIJ, Hakim FL. Pengering Aneka Biji Hemat Daya Tipe Horizontal. S00202307717 Tanggal, 2023.

[25] Indarto I, Pandunata P, Soekarno S, Hariyanto N, Bahariawan A, Pamungkas AIJ. Pengering Cerdas Untuk Aneka Biji. S00202210360 Tanggal, 2023. https://pdki-indonesia.dgip.go.id/detail/e2096671552417101a74a270ce972c45422d2efc8af340684ca29ddb201c20ff%3Fnomor=S00202210360?type=patent&keyword=pengering+cerdas

[26] Liu T. Digital-output relative humidity & temperature sensor/module DHT22. New York : Aosong Electronic, vol. 22, 2015, p. 1–10. https://www.sparkfun.com/datasheets/Sensors/Temperature/DHT22.pdf

[27] Arduino. Arduino MEGA 2560 Rev3 Features. Arduino MEGA 2560, Arduino® MEGA 2560 Rev3; 2022, p. 1–18. www.arduino.cc

[28] Hinotek. Grain Moisture Meter LDS-1G 2017. https://file.hinotek.com/tag-tp/manual/LDS-1G Intelligent Moisture Tester English Manaul.pdf

[29] Doran PM. Bioprocess engineering principles: Second edition. vol. 9780080917. 2nd ed. United Kingdom: Elsevier; 2012.

[30] Krzyzanowski FC, West SH, Neto JDBF. Drying peanut seed using air ambient temperature at low relative humidity. Revista Brasileira de Sementes 2006;28:1–5. https://doi.org/10.1590/S0101-31222006000300001.

[31] Guo HL, Chen Y, Xu W, Xu MT, Sun Y, Wang XC, et al. Assessment of Drying Kinetics, Textural and Aroma Attributes of Mentha haplocalyx Leaves during the Hot Air Thin-Layer Drying Process. Foods 2022;11. https://doi.org/10.3390/foods11060784.

[32] Paziuk V, Tokarchuk O, Vyshnevskiy V, Kupchuk I. Substantiation of The Energy Efficient Schedules of Drying Grain Seeds. Bulletin of the Transilvania University of Braşov 2021;14. https://doi.org/https://doi.org/10.31926/but.fwiafe.2021.14.63.2.13.

[33] Wahyuni A, Simarmata MM, Junairiah PLI, Koryati T, Zakia A, Andini SN, et al. Teknologi dan Produksi Benih. i. Medan: Yayasan Kita Menulis; 2021. https://medium.com/@arifwicaksanaa/pengertian-use-case-a7e576e1b6bf

[34] Direktorat Jenderal Tanaman Pangan Kementerian Pertanian. Petunjuk Pelaksanaan Kegiatan Serealia. Jakarta: Direktorat Jenderal Tanaman Pangan Kementerian Pertanian; 2019.

[35] PPID Balai Besar Pengembangan Pengujian Mutu Benih Tanaman Pangan dan Hortikultura KPRI. Kelebihan Dan Kelemahan Kadar Air dan Kemurnian Sebagai Instrumen Pengecekan Mutu Benih Bantuan Pemerintah. Kementerian Pertanian RI 2023. https://bbppmbtph-tanamanpangan-ppid.pertanian.go.id/index.php/news/view/1087 (accessed November 21, 2023).

[36] Purnamasari I, Meidinariasty A, Hadi RN. Prototype Alat Pengering Tray Dryer Ditinjau Dari Pengaruh Temperatur Dan Waktu Terhadap Proses Pengeringan Mie Kering. Jurnal Kinetika 2019;10:25–8.

[37] Vera Zambrano M, Dutta B, Mercer DG, MacLean HL, Touchie MF. Assessment of moisture content measurement methods of dried food products in small-scale operations in developing countries: A review. Trends Food Sci Technol 2019;88:484–96. https://doi.org/10.1016/j.tifs.2019.04.006.

[38] Krisnawati A, Adie MM. Ragam Karakter Morfologi Kulit Biji Beberapa Genotipe Plasma Nutfah Kedelai. Buletin Plasma Nutfah 2008;14:14. https://doi.org/10.21082/blpn.v14n1.2008.p14-18.