Jurnal Pijar MIPA
https://jurnalfkip.unram.ac.id/index.php/JPM

ISSN 1907-1744 (Print)
ISSN 2460-1500 (Online)

Analysis of Corn Drying Rack Position on Tray Type Dryer on Drying Rate

Rudy Sutanto*, Hendry Sakke Tira

Department of Mechanical Engineering, Faculty of Engineering, University of Mataram, Mataram, Indonesia.
*E-mail: r.sutanto@unram.ac.id

Received: June 9, 2024. Accepted: September 6, 2024. Published: September 30, 2024

Abstract: This research aims to determine the drying characteristics of corn kernels using a tray-type dryer, including the moisture content of the corn kernels over time, the mass of the tested corn kernels over time and the drying rate over time. This research uses the experimental method. The drying process uses an incoming drying hot air temperature of 65ºC with an incoming hot drying air speed of 2 m/s, repeated three times until a water content of 14 ± 0.5% is reached. The dryer in this study used four stacking shelves counting from the bottom, which were filled with 500 grams per shelf. This research shows that the further the shelf is positioned from the incoming hot drying air, the lower the drying rate. Vice versa, the closer the drying Shelf is to the incoming hot air, the greater the drying rate. The average decrease in corn kernel mass was 0.95% for shelf 1, 0.93% for shelf 2, 0.90% for shelf 3 and 0.88% for shelf 4 during a drying period of 3.5 hours. The average decrease in water content was 4.4% for shelf 1, 4.29% for shelf 2, 4.15% for shelf 3 and 4% for shelf 4 during a drying period of 3.5 hours. The further the position of the shelf from the hot air dryer, the less air content contained in the material on the shelf can be absorbed by the hot air dryer and vice versa. The average drying rate was 16.8% for shelf 1, 15% for shelf 2, 13.6% for shelf 3 and 12.8% for shelf 4 during a drying period of 3.5 hours at a drying hot air temperature of 65ºC with a drying air speed of 2 m/s. The research data analysis results showed that the hot air dryer should not be passed from below but rather from the side. This affects the drying process in the dryer and makes it evener.

Keywords: Corn; Dryer; Drying Rate; Mass; Water Content.

Introduction

An artificial drying system is needed as an alternative to overcome post-harvest problems. Various forms of drying devices are currently circulating in society. Rack-type drying devices are one type of dryer that is often used in the drying process. The drying process with a tray drier can be done anytime or not, depending on the weather and space. In addition, drying with a rack type does not require a lot of manpower [1]. Fast drying time is obtained at high air temperatures. Conversely, long drying times are obtained at low air temperatures. In this study, variations in air temperatures of 55°C, 60°C and 65°C were used, obtaining results that at an air temperature of 65°C the drying time was the fastest compared to drying at temperatures of 55°C and 60°C. In comparison, the longest drying time was obtained at an air temperature of 55°C. Drying corn in a fluidized bed device obtained results that the higher the airspeed, the faster the corn drying time; in this study, using a drying air speed of 7 m/s produced the fastest drying time, while an air speed of 5 m/s obtained the longest drying time [2]. The higher the drying temperature, the higher the drying rate [3]. This is in line with research, which states that the higher the temperature, the higher the drying rate [4].

Drying is an important stage to maintain the quality of corn during storage. Currently, corn drying is carried out in two ways: direct sunlight and artificial heating. Drying in the first model is constrained by dependence on the season, where drying can only be carried out if the intensity of sunlight is sufficient and the day does not rain. Besides that, the drying process results have a non-uniform water content depending on the relative humidity of the surrounding air during the drying process. Meanwhile, artificial drying is hampered by low efficiency, which is still below 60%, and corn's protein content degradation, especially if the air temperature for the drying process is more than 60°C [1]. Corn has a high selling price if the water content in the corn kernels meets the standards desired in the market. The Indonesian national standard determines the water content in corn, namely 13-14% [5]. A multi-level Shelf-type cocoa dryer that flows hot air into the drying chamber. The inlet air temperature varied, namely 60ºC, 65ºC, and 70ºC, with the airflow rate kept constant at 6.37 m/s. The research results show that the time needed to reduce the moisture content of cocoa from 72.9% to 7.5% is 1.75-3.25 hours. Drying efficiency was obtained at 23.34% at an inlet air temperature of 60ºC, 26.56% at 65ºC, and 29.21% at an inlet air temperature of 70ºC [6].

The drying process used a temperature below 55°C repeated 3 (three) times until it reached a water content of 8-10%bk. The observation results showed that the Rh outside the dryer was recorded between 83.28%-89.50% during the drying process. Also, the Rh inside the dryer was observed and recorded, ranging from 86.58%-97.91%. The water content of nutmeg seeds during the drying process decreased from 38.75% to an average of 18.05%, with details on rack one 6.54%, rack two 8.28% and rack three 9.70% [7]. Drying corn using a vertical cylinder-type dryer. The research was carried out three times, based on water content of 29% bw, 27.5% bw and 26% bw. The research results show that the time used to dry corn until it reaches a 12-14% moisture content varies in each test. Performance test 1 takes 8 hours, performance test 2 takes 7 hours, and

How to Cite:
Sutanto, R., & Tira, H. S. (2024). Analysis of Corn Drying Rack Position on Tray Type Dryer on Drying Rate. *Jurnal Pijar Mipa, 19*(5), 888–892. https://doi.org/10.29303/jpm.v19i5.7027

performance test 3 takes 6 hours. However, the drying rate for each performance test has almost the same value of around 5 kg H_2O/hour. So, the total drying efficiency in Performance Test 1 was 23.56%, Performance Test 2 was 26.90%, and Performance Test 3 was 23.57% [8]. The quality of corn kernels is determined by its water content. Drying aims to reduce the water content in the corn kernels to a condition where the water content in the corn kernels cannot reduce the quality of the corn kernels, and the corn kernels do not grow mould. Based on the energy source, corn drying can be divided into natural and artificial [9].

Modelling and optimizing the rice drying process using two heating sources, infrared and warm air fluidized bed dryers, at three air temperature levels, namely 40ºC, 50ºC and 60ºC [10]. Research on drying equipment using a turbine ventilator. The results of this research obtained a drying rate of 3.77 grams/minute, and the efficiency of the corn drying system was 52% using a turbine ventilator. In contrast, without a turbine ventilator, the drying rate was 4.23 grams/minute, and the efficiency was 32% [11]. Drying garlic using hot air. The hot air is the result of heating by heated fluid in the pipes installed in the solar collector [12].

Optimized the temperature of the rotary microwave dryer to keep the moisture below one percent by using a genetic algorithm, as the cost function of genetic algorithm optimization can be adapted with the output variations [13]. The solar dryer of paddy using GA was optimized [14]. The integrated dryer consists of three different air heating sources: solar, biomass and electricity [15].

The drying airflow can be either generated by natural or forced convection. In forced convection, the airflow is generated by blowers or fans [16], increasing the drying rates and decreasing drying time. The necessary power can be generated from renewable energy [17]. Photovoltaic-ventilated solar dryers have been reported in the literature. The performance of a hybrid portable tunnel dryer in the drying of peppermint was assessed [18]. An indirect solar dryer with a shaped corrugated absorber plate to dry green chilli and okra was studied [17].

Heat recirculation is one of the most common approaches to saving energy in an energy-consuming system and is also widely used in agricultural product drying. More specifically, during the drying process, the exhaust air was separated from the material flux and mixed with fresh air in the drying chamber; the experimental results showed that the methodology effectively improved the energy efficiency of the spray dryer [19]. A grain heat-pump drying system with an outlet air-waste heat-recovery function; the exhaust air was exhausted to the cold-water chamber, and the water was heated up to 30 °C and further used to prepare the hot water (60–80°C); the results showed that almost 18% of the total energy consumption was recovered [20]. Waste-heat recovery from tractor exhaust: their results showed that the recovered energy could be used to dehydrate 3–6% of moisture from wet grains [21]. According to the analysis above, recovery of waste heat from exhaust drying air is an effective way to save energy; however, few works have focused on waste-heat recovery from exhaust flue gas, while there is huge heat-recirculation potential in the exhaust flue gas of the heat exchanger.

Far infrared drying is an efficient and energy-saving method widely used in grain drying owing to its advantages of high drying quality, simple structure and high efficiency. The quality of dried corn kernels was significantly affected by far infrared wavelengths when the temperature was 45°C. Far infrared-assisted hot air-drying technology could effectively decrease specific energy consumption [22]. When a fresh paddy with a thickness of 10 mm was heated up to 60°C by far infrared drying technology, the wet paddy's moisture could be removed using natural wind drying technology [23]. Average solar radiation and ambient temperature of 710 W/m^2 and 30°C, respectively, the average thermal efficiency obtained was 21%, and the exergy efficiency ranged between 10% and 66%, with an average value of 23%. It was observed that the corn grains reached the desired moisture content of 13% in 8.5 hours [24].

Research Methods

This research is experimental with a scheme as shown in the following figure.

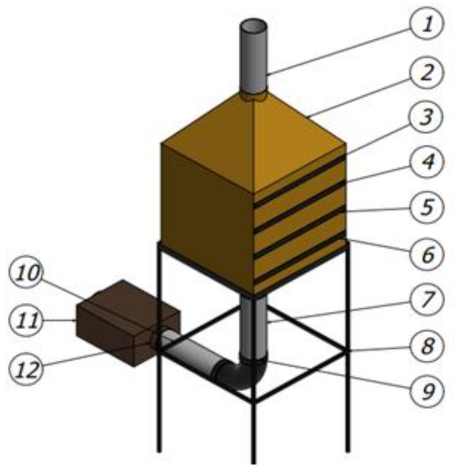

Figure 1. Dryer installation. 1. output pipe, 2. drying box, 3. shelf 4, 4. shelf 3, 5. Shelf 2, 6. shelf 1, 7. input pipe, 8. frame, 9. keni, 10. sensor controller, 11. heater box, 12. blower pipe

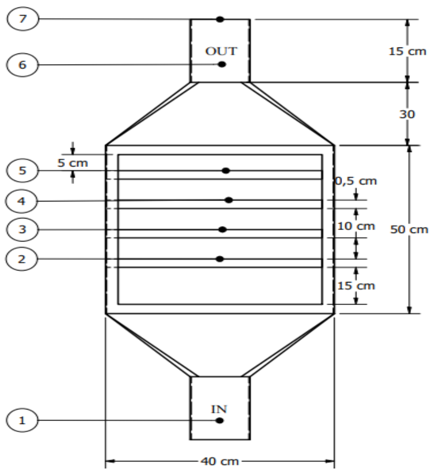

Figure 2. Layout of measuring instruments in the drying room in the research drying equipment installation. 1. input pipe, 2. shelf 1, 3. Shelf 2, 4. Shelf 3, 5. Shelf 4, 6. output pipe, 7. anemometer

In this study, two types of variables were used, namely, the dependent variable and the independent variable. The dependent variable is a variable that is influenced by other variables, such as the power used. By analyzing the dependent variable, it is hoped that an answer or explanation can be found regarding the problem being tested. The dependent variables in this research are drying rate and drying hot air temperature. Independent variables can be adjusted and determined according to testing needs. The independent variables used in this research are variations in the position of shelf 1, shelf 2, shelf 3 and shelf 4 (figure 2).

The research procedures carried out are as follows. The initial water content determination stage of corn kernels is to determine the initial water content of corn kernels through the following stages. First, the corn kernels are placed on an oven tray with a known weight as a sample and then weighed carefully on a digital scale weighing 1 kg. Next, the corn kernels and the oven tray are put into an electric oven set at 80°C ± 1°C for 30 minutes. After that, the corn kernels are weighed to determine their mass. Then, put them back in the oven for 30 minutes and repeat steps 2 and 3 until the weight is obtained without decreasing or changing.

In the drying stage, the procedure is as follows: first turn on the power to the dryer, then set the dryer's temperature using the specified temperature, and then adjust the airflow rate by the fan according to the testing needs. The study was continued by inserting corn kernels into the dryer weighing 2 kg with each rack 0.5 kg. After that, weigh the corn kernels every 30 minutes and record the mass of the corn kernels and the air speed until the maximum water content of the corn kernels is 14 ± 0.5%.

Results and Discussion

During the research, data were collected every half hour after placing the corn kernels in the dryer for 3.5 hours. Based on Figure 3, the graph of the relationship between mass and time is obtained. The mass of dried corn kernels is directly proportional to the time used to dry them. The longer the time used for the drying process of corn kernels, the less mass of water in the corn kernels that can be dried. This follows the results of other researchers' research [7]. This happens because the longer the drying time, the less water content in the corn kernels and as a result, the water in the corn kernels becomes more difficult to evaporate. The average decrease in corn kernel mass was 0.95% for shelf 1, 0.93% for shelf 2, 0.90% for shelf 3 and 0.88% for shelf four during a drying period of 3.5 hours. This decrease in the mass of corn kernels is due to the drying process, where the corn kernels absorb heat energy from the drying air, meaning that there is a convection heat transfer process from the drying air absorbed by the corn kernels [2]. Then, the water slowly evaporates from the corn kernels into the drying air. This means that when evaporation occurs, the corn kernels slowly lose their mass, or in theory, it is called mass transfer. So, the mass of corn kernels continues to decrease as the drying process takes longer (figure 3).

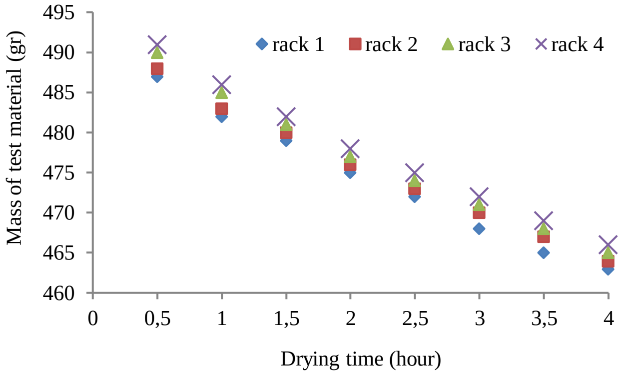

Figure 3. Graph of the relationship between test corn kernel mass and drying time

The effect of the position of the drying Shelf shows that the further the Shelf is from the incoming hot drying air, the lower the mass reduction of corn kernels [6]. Vice versa, the closer to the drying Shelf with hot air entering, the greater the decrease in corn kernel mass (figure 3). This can happen because when the air enters the drying room, it will hit shelf 1 for the first time; on shelf 1, a mass transfer occurs, and then some of the mass on shelf 1 is carried to the next shelf up to shelf 4. Because of this, the farther the position of the shelf is from the incoming hot air-drying room, the decrease in the mass of corn kernels will be smaller.

Figure 4 shows that the initial moisture content of corn kernels is 20.7%, requiring a drying time of 210 minutes (3.5 hours). In the first 30 minutes, the moisture content of corn kernels decreased by 10.2% for shelf 1, 9.42% for shelf 2, 7.82% for shelf 3 and 7% for shelf 4. The decline in corn grain moisture content was relatively fast at the beginning of drying, then decreased slowly until it approached the specified water content, around 14 ± 0.5%. The average decrease in corn kernel moisture content was 4.44% for shelf 1, 4.29% for shelf 2, 4.15% for shelf 3 and 4% for shelf four during a drying period of 3.5 hours. The effect of the position of the drying Shelf shows that the further the Shelf is from the incoming hot drying air, the lower the corn kernel moisture content decreases. Meanwhile, the closer the drying Shelf is to the incoming hot air, the greater the corn kernel moisture content decreases.

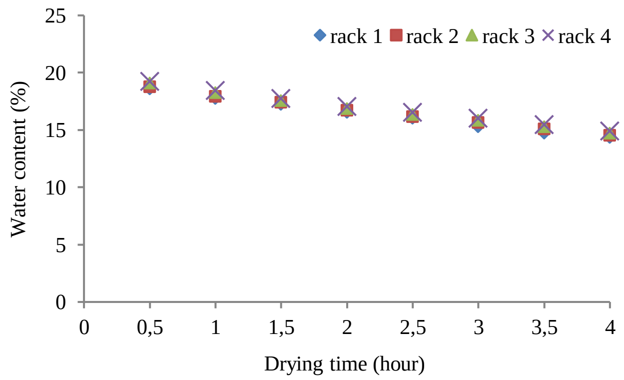

Figure 4. Graph of the relationship between water content and drying time

This decrease in water content is due to the drying process where the corn kernels absorb heat energy from the drying air, meaning that there is a convection heat transfer process from the drying air absorbed by the corn kernels. Then, the water slowly evaporates from the corn kernels into the drying air. This means that when evaporation occurs, the corn kernels slowly lose their mass, or in theory, it is called mass transfer. The water content in corn kernels consists of 3 types of water: the first, free water content, the water content bound to the corn kernels, and the third, the water content chemically bound in the corn kernels. This amount of water will evaporate after receiving or absorbing heat energy from the drying air. Initially, the water evaporates is free water, followed by bound water and chemically bound water (figure 4).

Figure 5 shows that the higher the temperature used to dry the corn kernels, the higher the drying rate in this drying process. This follows the statement that the higher the drying temperature, the higher the drying rate [3]. This follows research that states that the higher the temperature, the higher the drying rate [4]. This is because the higher the drying air temperature, the higher the heat energy carried by air, so the greater the amount of liquid mass evaporated from the surface of the corn kernels. An increase in temperature will increase the temperature of the corn kernels and cause the water vapour pressure in the corn kernels to be higher than the water vapour pressure in the air so that water vapour is transferred from the corn kernels to the air. The closer the drying rack is to the incoming hot air, the higher the air temperature passing through the drying rack, and the further the drying rack is, the lower the air temperature passing through the drying chamber.

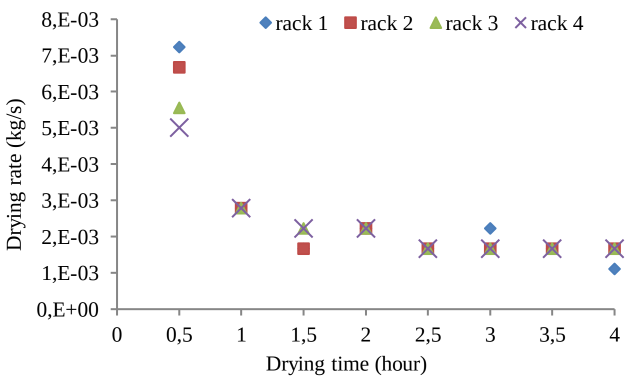

Figure 5. Graph of the relationship between drying rate and drying time

The effect of the position of the drying Shelf shows that the further the position of the Shelf is from the hot incoming drying air, the lower the drying rate. Vice versa, the closer the drying Shelf is to the incoming hot air, the greater the drying rate. The drying rate is calculated by dividing the difference between mass 1 and mass 2 by the difference in observation time taken from data on the weight loss of corn kernels with the assumption that the difference between mass 1 and mass 2 is the amount of water vapor that comes out of the corn kernels or evaporates, at the beginning of the drying process. that is, when the water content was still high, the drying rate increased, then decreased until the 3.5-hour observation of the drying process. The increased drying rate is caused by the corn kernels being hygroscopic (absorbing water) in the form of adsorption or the corn kernels absorbing water vapour from the air. Still, the water only remains on the surface of the corn kernels [6]. When corn kernels receive heat energy from drying air, the water vapour on the surface of the corn kernels, which is free of water, quickly decreases. Next, the drying rate decreases until the final water content is reached. This final water content is considered the water content that represents the water content data at the end of the drying process [7]. In theory, the drying rate starts from an adjustment phase. In a constant drying rate phase, the free water contained in the corn kernels evaporates, followed by a decreasing drying rate, and the drying rate continues to decrease. In this phase, the water that evaporates is the water bound to the corn kernels and the water contained in the corn kernels is chemically bonded (figure 5). The average drying rate was 16.8% for shelf 1, 15% for shelf 2, 13.6% for shelf 3 and 12.8% for shelf 4 during a drying period of 3.5 hours at a drying hot air temperature of 65ºC with a drying air speed of 2 m/s (figure 5).

Conclusion

Based on an analysis of research data, the further the position of the shelf is from the incoming hot drying air, the lower the drying rate. Vice versa, the closer the drying Shelf is to the incoming hot air, the greater the drying rate. The average decrease in corn kernel mass was 0.95% for shelf 1, 0.93% for shelf 2, 0.90% for shelf 3 and 0.88% for shelf 4 during a drying period of 3.5 hours. The average decrease in water content was 4.4% for shelf 1, 4.29% for shelf 2, 4.15% for shelf 3 and 4% for shelf 4 during a drying period of 3.5 hours. The average drying rate was 16.8% for shelf 1, 15% for shelf 2, 13.6% for shelf 3 and 12.8% for shelf 4 during a drying period of 3.5 hours at a drying hot air temperature of 65ºC with a drying air speed of 2 m/s.

References

[1]. Rahmat, M., Patang., & Rais, M. (2019). Uji pengeringan biji jagung (zea mays. sp) menggunakan alat pengering biji bijian tipe rak (tray dryer), *Jurnal Pendidikan Teknologi Pertanian*, 5(4), 222-229.

[2]. Syahrul, S., Romdhani, R., And Mirmanto, M. (2016). Pengaruh variasi kecepatan udara dan massa bahan terhadap waktu pengeringan jagung pada alat fluidized bed. *Dinamika Teknik Mesin*, 6(2), 119-126.

[3]. Taufiq, M., (2004). Pengaruh temperatur terhadap laju pengeringan jagung pada pengering konvensional dan fluidized bed, *Skripsi*, *Universitas Sebelas Maret Surakarta*.

[4]. Hargono, D. M., And Buchori, L., (2012). Karakterisasi proses pengeringan jagung dengan metode mixed-adsorption drying menggunakan zeolite pada unggun terfluidisasi. *Reaktor*, 14(1), 33-38.

[5]. Suprianto, B., Haryudo, S. I., & Baskoro, F. (2021). Pengering jagung dengan elemen pemanas menggunakan sensor dht11 dan sersor kadar air berbasis arduino uno, *Jurnal Teknik Elektro*, 10(1), 163-171.

[6]. Riswandi., Abdul, M., & Mahmuddin. (2020). Unjuk kerja pengering kakao tipe tray dryer dengan mengalirkan udara panas secara zik-zak, *J-Move*, 2(3), 50-56.

[7]. Rosnawati, M. K., Douwes, D. M., Handry, R., (2017). Uji unjuk kerja alat pengering tipe rak model teta 17 pada pengeringan biji pala, *COCOS*, 9(4), 1-8.
[8]. Putra, M. A., Asmara, S., Sugianti, C., & Tamrin. (2018). Uji kinerja alat pengering silinder vertikal pada proses pengeringan jagung (zea mays ssp. mays), *Jurnal Teknik Pertanian Lampung*, 7(2), 88-96.
[9]. Mardani, J. (2018). Pengaruh variasi temperatur udara dan massa jagung pada alat fluidized bed dengan pipa penukar kalor terhadap waktu pengeringan jagung, *Skripsi, Universitas Mataram*.
[10]. Pourbagher, R., Rohani, A., Rahmati, M. H., & Abbaspour-Fard, M. H. (2018). Modeling and optimization of drying process of paddy in infrared and warm air fluidized bed dryer, *AgricEngInt: CIGR J*, 20(3), 162-171.
[11]. Isman, H., & Zaenuri, M. A. (2020). Rancang bangun pengering jagung energi surya dengan turbin ventilator, *Jurnal Integrasi*, 12(2), 105-111.
[12]. Shringi, V., Kothari, S., & Panwar, N. L. (2014). Experimental investigation of drying of garlic clove in solar dryer using phase change material as energy storage, *Journal of Thermal Analysis and Calorimetry*, 118(1), 533-539.
[13]. Yang, B., Liang, G., Peng, J., Guo, S., Li, W., Zhang, S., Li, Y., & Bai, S. (2013). Self-adaptive PID controller of microwave drying rotary device tuning on-line by genetic algorithms, *Journal of Central South University*, 20(10), 2685-2692.
[14]. Rahman, M. M., Mustayen, A. G. M. B., Mekhilef, S., & Saidur, R. (2015). The optimization of solar drying of grain by using a genetic algorithm, *International Journal of Green Energy*, 12(12), 1222–1231.
[15]. Manikantan, M. R., Barnwal, P., & Goyal, R. K. (2014). Drying characteristics of paddy in an integrated dryer, *Journal of Food Science and Technology*, 51(4), 813-819.
[16]. Yogendrasasidhar, D., & Pydi Setty, Y. (2018). Drying kinetics, exergy and energy analyses of kodo millet grains and fenugreek seeds using wall heated fluidized bed dryer, *Renewable and Sustainable Energy Reviews*, 15, 799-811.
[17]. Aghbashlo, M., Mobli, H., Rafiee, S., & Madadlou, A. (2013). A review on exergy analysis of drying processes and systems, *Renewable and Sustainable Energy Reviews*, 22, 1-22.
[18]. Sansaniwal, S. K., Sharma, V., & Mathur, J. (2018). Energy and exergy analyses of various typical solar energy applications: a comprehensive review, *Renewable and Sustainable Energy Reviews*, 82(1), 1576-1601.
[19]. Golman, B., & Julklang, W. (2014). Analysis of heat recovery from a spray dryer by recirculation of exhaust air, *Energy Conversion and Management*, 88, 641-649. DOI:10.1016/j.enconman.2014.09.012.
[20]. Zhang, X. R., Zheng, Q. Y., Gao, J. Z., & Shi, X. H. (2015). Technology and application of waste heat recovery from tail gas of grain drying system, *International Energy Conservation* and *Environment Protection Convention*, 11, 74–75.
[21]. Bai, J. W., Luo, S. Q., Ye, J., Liu, L., Niu, M.J., & Deng, X. M. (2008). Design of the waste heat utilizing system on multifunctional tractor, *Journal of Agricultural Mechanization*, 12, 195-197.
[22]. Tuncel, N. B., Yilmaz, N., Kocabiyik, H., Öztürk, N., & Tunçel. M. (2010). The effects of infrared and hot air drying on some properties of corn (zea mays), *J. Food Agric. Environ*, 8, 63-68.
[23]. Pan, Z., Khir, R., & Bett-Garber, K. L. (2013). Drying characteristics and quality of rough rice under infrared radiation heating, *Trans. ASABE*, 54(1), 203-210.
[24]. da Silva, G. M., Ferreira, A. G., Coutinho, R. M., & Maia, C. B. (2021). Energy and exergy analysis of the drying of corn grains, *Renewable Energy*, 163, 1942-1950.