MULTIDIMENSIONAL ASSESSMENT TOOLS OF SOLAR DRYERS: 4E, 7E AND 7E+Q ANALYSIS

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Abstract: Drying of food and agricultural products using solar dryers is one of the priority areas for the effective use of solar energy. There is an opportunity to improve and increase the efficiency of solar dryers through multidimensional assessment. In this work, the most widely used in scientific research to assess the performance of solar dryers, 4E analysis, 7E and 7E+Q analyses, which further complement the 4E analysis, are considered. By adding 3E analysis (energoeconomic analysis, exergoeconomic analysis and enviroeconomic analysis) to the 4E analysis (energy, exergy, economic and environmental analysis), it is possible to improve the multidimensional assessment. The addition of Quality Analysis to the 7E analysis allows for a more complete multidimensional assessment and more complete evaluation of the performance of solar dryers.

Keywords: Solar Energy, solar dryer, 4E analysis, 7E analysis, Quality, energy, exergy.

Аннотация: Сушка пищевых продуктов и сельскохозяйственной продукции с использованием солнечных сушилок является одним из приоритетных направлений эффективного использования солнечной энергии. Существует возможность улучшить и повысить эффективность солнечных сушилок посредством многомерной оценки. В данной работе рассматриваются наиболее широко используемые в научных исследованиях для оценки производительности солнечных сушилок анализы 4E, 7E и 7E+Q, которые дополняют анализ 4E. Добавление анализа 3E (энергоэкономического анализа, эксергоэкономического анализа и эколого-экономического анализа) к анализу 4E (энергетического, эксергетического, экономического и экологического анализа) позволяет улучшить многомерную оценку. Добавление анализа качества к анализу 7E позволяет провести более полную многомерную оценку и более полную оценку производительности солнечных сушилок.

Ключевые слова: Солнечная энергия, солнечная сушилка, анализ 4E, анализ 7E, качество, энергия, эксергетический анализ.

Annotatsiya: Quyosh quritgichlari yordamida oziq-ovqat va qishloq xo’jaligi mahsulotlarini quritish quyosh energiyasidan samarali foydalanishning ustuvor yo’nalishlaridan biri hisoblanadi. Quyosh quritgichlarining faoliyatini ko’p o’lchovli baholash orqali takomillashtirish va samaradorligini oshirish imkoni mavjud. Ushbu ishda quyosh quritgichlari faoliyatini baholash uchun ilmiy tadqiqotlarda eng keng qo’llaniladigan 4E tahlili, 4E tahlilini yanada to’ldiruvchi

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7E va 7E+Q tahlillari ko'rib chiqilgan. 4E (energiya, eksergiya, iqtisodiy va atrof-muhit) tahliliga qo'shimcha 3E tahlil (energoiqtisodiy tahlil, eksergoiqtisodiy tahlil va ekologik-iqtisodiy tahlil) qo'shish orqali ko'p o'lchovli baholashni takomillashtirish imkoniyatiga ega bo'linadi. 7E tahlilga qo'shimcha ravishda Sifat tahlili qo'shilib, 7E+Q tahlili o'tkazilishi ko'p o'lchovli baholashni yanada to'liqroq bo'lishiga va quyosh quritgichlarining faoliyatini to'liqroq baholanishiga imkon yaratadi.

Kalit so'zlar: Quyosh energiyasi, quyosh quritgichi, 4E tahlili, 7E tahlili, Sifat, energiya, eksergiya.

Introduction

By 2050, the population is expected to exceed 9 billion, requiring an increase in food production of approximately 70% [1]. In many countries, total losses in agricultural food production amount to 30-40 percent after harvest, which is one of the main reasons for the increase in food prices [2]. One way to prevent losses is to store agricultural food products in a dried form [3]. When agricultural food products are dried, they are stored for a longer period of time, the weight and volume of the product are reduced, and they also help reduce packaging and transportation costs [4].

One of the traditional methods of industrial food processing is drying. This process involves evaporating excess water from the product to remove a certain amount of moisture. Various agricultural products typically have a moisture content of 70% to 90% [5, 6], and this moisture removal requires a large amount of energy. In developed countries, approximately 12% to 40% of the fossil fuels used for industrial purposes are used for drying products [7]. The greenhouse gases (CO_2) released during this process cause environmental problems [8]. Currently, many countries are transitioning to sustainable energy production methods to reduce carbon emissions. Considering environmental concerns and the amount of fossil fuels, further reducing the use of fossil fuels in product drying systems requires the efficient use of sustainable energy for drying agricultural products [9]. Nowadays, food security, rising fuel prices, and environmental problems create difficulties in the production and storage of agricultural products. Various drying methods are used for long-term storage of fruits and vegetables, with drying products in solar dryers being the most economically efficient and safe [10].

Methodology

There are several multidimensional evaluation tools for comprehensively evaluating the performance of solar dryers. The most widely used in scientific research is the 4E analysis, which includes energetic, exergetic, economic and environmental analyses of solar dryers [11]. In a number of scientific studies, additional 3E analysis: energoeconomic, exergoeconomic and enviroeconomic

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indicators are also analyzed in order to further analyze and gain a clearer picture of the performance of solar dryers. Also, the 7E+Q analysis (Figure 1) is considered the most complete analysis, since the quality indicators of the dried product are analyzed in terms of physical, chemical and nutritional aspects [6].

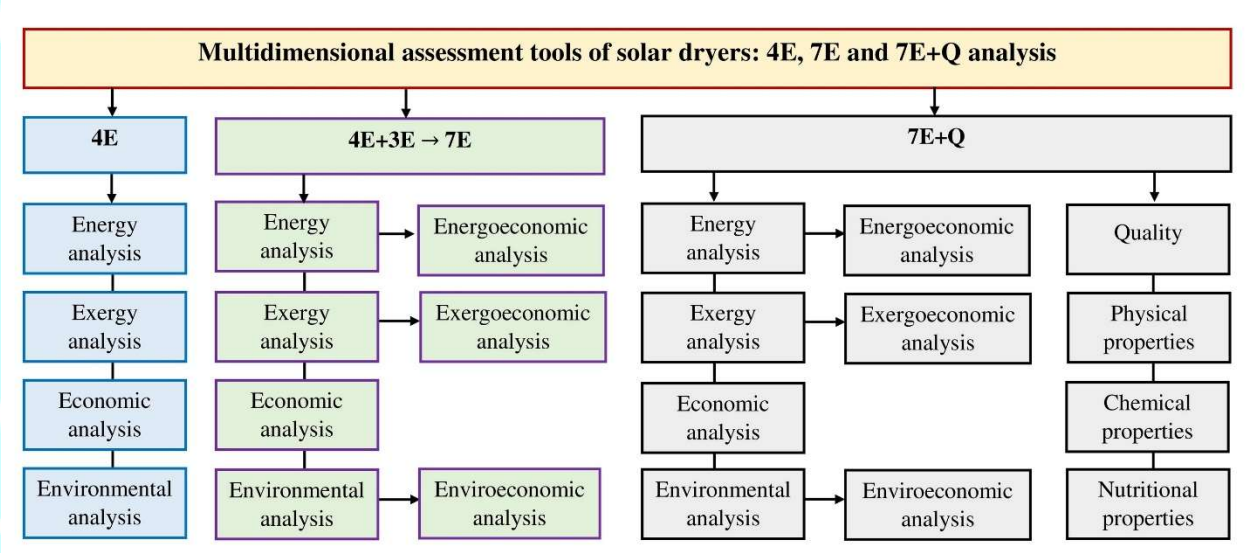


Figure 1. Multidimensional assessment of 4E, 7E and 7E+Q

Results and discussion

Energy analysis. Energy analysis provides an opportunity to determine the efficiency of energy use, consider energy saving options, determine optimal process conditions, determine COP (Coefficient of Performance), and identify and reduce energy losses [12].

Exergy analysis. In solar dryers, exergy analysis can be considered a true measure of energy quality or level. Exergy analysis allows us to determine a value that is equivalent to the maximum amount of work that can be produced by a system or energy [13].

Economic analysis. The main parameters for economic analysis are payback time, cost of the greenhouse dryer, and product drying cost, which allow predicting the real potential benefits over the lifetime of solar dryers [14].

Environmental analysis. It identifies key parameters such as CO2 emission, CO2 mitigation, and carbon credits earned in solar dryers. Particular attention is paid to minimizing environmental problems during the drying process [15].

Although 4E analyses are often performed simultaneously or in certain combinations (e.g., energy-exergy (2E) analysis or energy-exergy-economic (3E) analysis), they are actually independent parameters and are not directly related to each other [16]. Therefore, 4E analysis may not fully explain the performance of solar dryers. To overcome this shortcoming, as in other thermal system studies [16], energy-economic, ekergoeconomic, and environmental economic (additional "3E" analysis) analyses are considered.

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Energoeconomic analysis is a mix between energy and economic analysis, providing additional information about the cost-effective design of a system from an energy perspective.

Exergoeconomic analysis, also known as the principle of exergo cost calculation, uses exergo analysis to determine the cost of exergo output and exergo destruction of a unit and the entire system [17].

Enviroeconomic analysis is a combination of environmental and economic analysis that allows to determine the possibilities of reducing the environmental impact of a system. The main factor is the price of CO_2 produced by the system [18]. In the drying of food and agricultural products, special attention should be paid not only to the 7E multidimensional evaluation of the solar dryer, but also to the quality of the dried product. This is where the 7E+Q analysis method of solar dryers comes into play [16]. The quality of the product is checked based on 3 factors: physical properties (colour, texture, shrinkage), chemical properties (flavour & odour, water activity) and nutritional properties.

Conclusion

Although the most widely used 4E analysis and its components (energy, exergy, economic and environmental analysis) are considered in many scientific studies conducted in the field of solar dryers, the 4E analysis is limited in its ability to fully analyze the performance of solar dryers. By adding additional 3E analysis (energoeconomic analysis, exergoeconomic analysis and enviroeconomic analysis) to the 4E analysis, it is possible to improve the analysis system. Now the energy analysis, exergy analysis and environmental analysis are interconnected with the economic analysis. The addition of Quality analysis in addition to the 7E analysis makes the analysis system more complete and allows for a deeper understanding of the performance indicators of solar dryers.

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