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Research Article

Determining the Drying Rates of Fabrics with Different Knit Structures by Fuzzy Logic Method

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Abstract:

Drying is a process applied to reduce the amount of water in a product or to reduce it to very low levels. The constantly changing conditions during the drying process make it difficult to determine the most suitable operating conditions to perform the drying process, such as drying time, energy consumption and product structural characteristics. In terms of a suitable drying, it is important to be able to control the factors affecting the drying depending on the characteristics of the product. Among these factors, the drying method and the pre-treatments that can be applied are also effective on drying. The high temperatures applied during drying and other conditions that are not chosen correctly can cause negative results in both the appearance of the product. The drying process in the textile industry is an expensive and laborious process that requires a lot of energy. The main purpose of the drying process is to provide maximum energy saving and energy efficiency at minimum time and cost without compromising the quality and structural properties of the material used. In this study, four fuzzy models were created depending on fabric fiber blend ratios and knitting structure in order to determine the effect on drying speed depending on time and temperature by using fuzzy logic method, which is one of the artificial intelligence methods. Average values in 100% cotton and 50% pes-cotton blend ratios; at 50 °C, the drying rate reaches the highest value of 1.9 over time, from 0.5 at the beginning, and 0.8 at the end of drying. At 60 °C, the drying rate starts at 1.2, reaches the highest value of 1.8, and completes at 1.1 at the end of drying. While the drying rate at 70 °C is 1.3 at the beginning, it reaches its highest value at 2.3 and completes it at 1.4 at the end of drying.

1. Introduction

Drying process is carried out in many areas of industry and various dryers are used. One of these areas is the textile industry. The most important factor to be considered in the drying process is the use of minimum energy consumption and maximum possible drying speed in order to obtain the material with the required and desired properties. In order to achieve a more effective drying, it is necessary to know the operating principles of the dryers used in the industry, their forms, the characteristics of the products to be dried, and the capacity. Other factors affecting the drying process are; type of material, structure, ambient conditions, quality and speed of air. The main function in the drying process is to control the parameters that affect the drying or the removal of moisture. In this respect, fuzzy logic, which is one of the artificial intelligence methods, is the most useful method in the drying process.

Artificial intelligence methods are successfully applied in many areas. In most and even almost all of the studies, artificial intelligence methods are used in parameter estimation, evaluation of certain data, monitoring of a certain situation, diagnosis, classification, grading, detection, control, selection, optimization, etc. is used. Since all artificial intelligence methods are based on data, the developed artificial intelligence methods produce results in the data range in which they were developed, and at the same time, the output or result is tried to be estimated depending on the known variable parameters with these methods. One of the most important abilities bestowed on human beings by the creator is the ability to predict. In other words, human beings can make very successful predictions in the face of situations that are different from these examples, but similar to these examples, based on many examples they have experienced for the same or a similar job. This is called experience in real life. The fuzzy logic method, one of the artificial intelligence methods, is an artificial intelligence method created based on the fuzzy inferences expressed as a result of the ability of human beings to make predictions. The fuzzy set concept, which was introduced by Lütfi Zadeh [1,2] in 1965, was developed by Mamdani [3-5] and many other researchers, and the fuzzy logic method took its current form. In the fuzzy logic method, the process flow is from the input parameters to the output as in other artificial intelligence methods. In other words, the current algorithm of the fuzzy logic method is estimation and classification, etc., rather than design. enables such studies. Recently, modern methods have found application in the textile industry [6-9]. Expert systems are among the leading techniques [10]. Fuzzy logic, which is the basis of expert systems, is best known for allowing systems based on common sense assumptions or using expert data to be modeled mathematically [11-13]. Therefore, the main use is in system control [14,15]. With these systems, energy consumption is reduced without compromising the quality of the product [16]. In this study, four fuzzy models were created depending on fabric fiber blend ratios and knitting structure in order to determine the effect on drying speed depending on time and temperature by using fuzzy logic method, which is one of the artificial intelligence methods. When the studies in the literature were examined, no study was found in which the temperature and time parameters and artificial intelligence programming method were used together in the drying process of yarn mixture ratios in knitted fabrics. The textile sector is one of the most developed sectors in Turkey and the detection of measurement results with artificial intelligence methods comes to the fore [17,18].

2. Material and Methods

In the drying process, 30x30 fabric samples with different properties such as yarn raw material (fiber type), density, fabric weight, and weaving construction were used. The properties of the materials used are given in Table 1. Fabric samples were first conditioned for 24 hours under laboratory conditions. (65% humidity, 20±2 °C). The conditioned fabric samples were weighed in the ambient humidity measured with a hygrometer and their weight in the ambient humidity was determined. Dry weights were found by weighing at certain intervals in the oven. After the samples were wetted with distilled water so that the entire surface was evenly moistened, they were mechanically dried and pre-drying was carried out. The total moisture weight was determined by weighing again. In the meantime, the dryer was brought to the temperature conditions foreseen for the experiment and placed in the desired regime. The image of the dryer used in the study is given in Figure 1. For the drying experiments, fabrics with 4 different properties were selected and the experiments were carried out at 5 different temperatures (50 °C, 55°C, 60 °C, 65 °C and 70 °C). For the precision of the test results, the experiments were repeated three times to confirm the accuracy of the results. Since the drying air speed is constant in the textile industry, the examination has been made depending on the temperature and the change in the properties of the fabric products. Considering that the test conditions predicted did not change during the drying process, attention was paid to keep the temperature and air velocity constant.

Table 1. *Fabrics with different knit structures.*

Sample	Weight (g/m^2)	Raw materials	Weaving and Knitting Structure
1	290	%100 Cotton	Lacoste
2	354	%50 Cotton %50 PES	1x1 Rib
3	500	%100 Cotton	Supreme
4	276	%50 Cotton %50 PES	interlock

Figure 1. *The dryer used in the study*

3. Results and Discussions

The fuzzy logic model created in this study was created using the MATLAB program, and the resulting data were examined. With the fuzzy logic module of the MATLAB program, the Mamdani model with two inputs and one output has been established. This model is based on the center of gravity method. The first of the input membership function sets is the 'Temperature' parameter. As seen in Figure 2 below, the values are processed into the fuzzy logic module of the MATLAB program. The second of the input membership function sets is 'duration'. As seen in Figure 3 below, the values are processed into the fuzzy logic module of the MATLAB program. The 'drying rate' was chosen as the set of the output membership function. As seen in Figure 4 below, the values are processed into the fuzzy logic module of the MATLAB program.

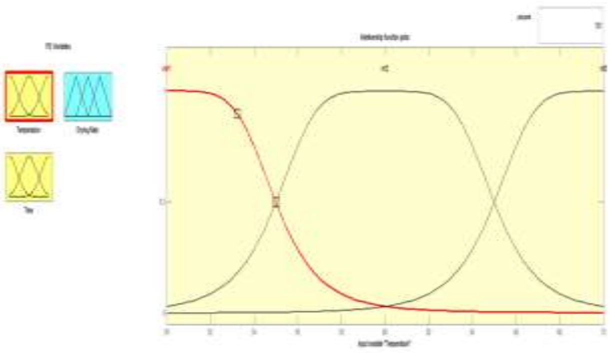

***Figure 2.** Temperature membership functions, which is the first set of inputs.*

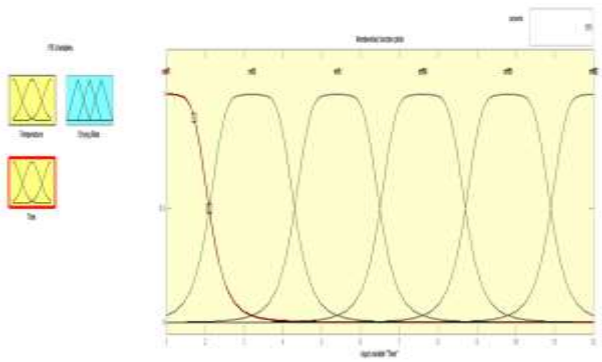

***Figure 3.** Time membership functions, the second set of inputs*

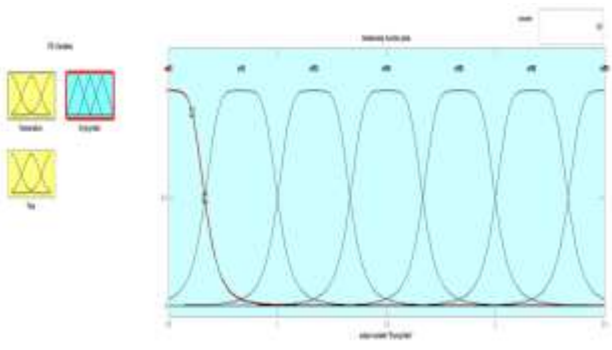

***Figure 4.** Drying rate membership functions as output set*

In the study, the gbellmf method was chosen in the type of membership functions used in the input and output sets. Thus, a trapezoidal shape, which is a geometric shape, was obtained. In this way, approximate values are obtained within the framework of fuzzy logic rules. A total of two hundred fuzzy rules were created and used for the output graphs. The created Fuzzy Logic Method and the rule table are given in Figure 5 and Figure 6.

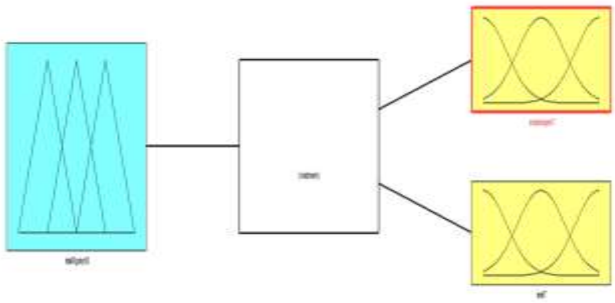

***Figure 5.** Fuzzy logic model*

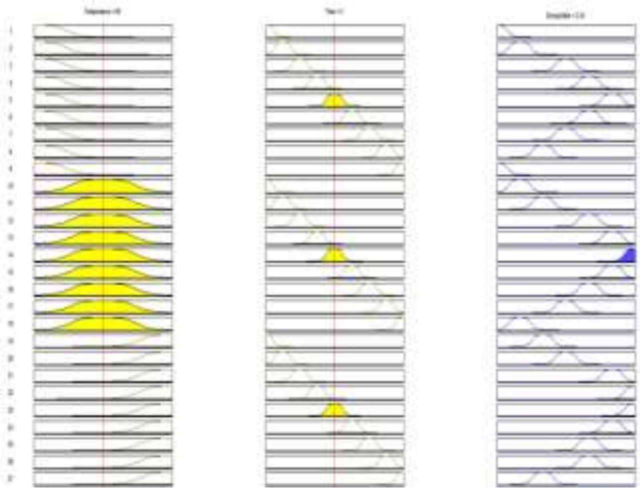

***Figure 6.** Rule table*

After the membership functions are entered in the MATLAB fuzzy logic editor, the values of the membership function are also entered in the rule editor. After the rule entries were completed, the results were monitored with the rule viewer. During the creation of the results, the center of gravity method was chosen as the clarification method.
Measurement results obtained from each experiment as a result of experimental studies The system, which was simulated with the MATLAB program after processing all the data, gave the following results for the drying speed of the fabric with 100% cotton and lacoste knit structure. As can be seen in Figure 7, the drying rates increased depending on the time as the drying temperature increased. At 50 °C, the drying rate reaches 1.2 at the beginning, to the highest value of 1.4 over time, and to 1.2 at the end of the period. At 55°C, it reaches the highest value of 1.6 from 1.4 at the start of the time and completes it at 1.2 at

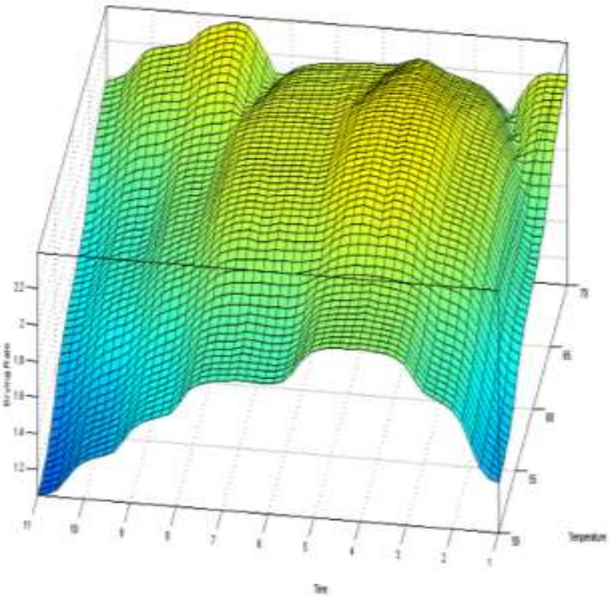

Figure 7. *Data obtained with MATLAB program for 100% cotton and lacoste knitting*

the end of the time. It starts at 1.6 at the beginning of 60°C time, reaches the highest value of 1.8, and completes at 1.4 at the end of the time. At 65 °C, it reaches the value of 2 at the beginning of the time and completes it at the value of 1.8 at the end of the time. At 70 °C, it reaches the value of 2.2 at the beginning, and the highest value of 2,4, and completes the value of 2 at the end of the time.
The drying speed of the fabric, which has a 100% cotton and single jersey knit structure, is given in the system simulated with the MATLAB program.

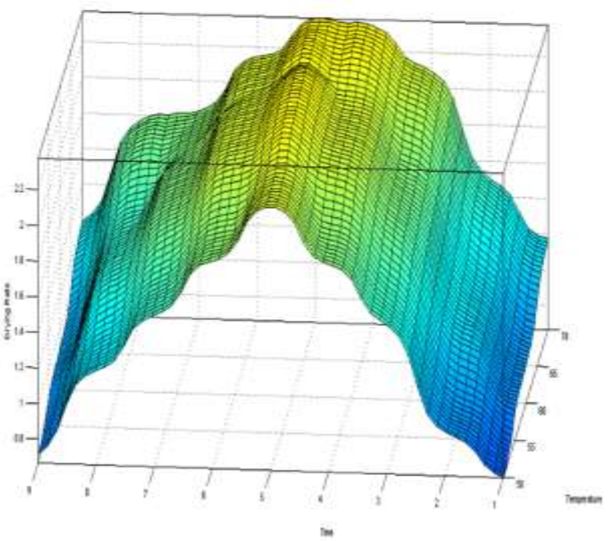

Figure 8. *Data obtained with MATLAB program for 100% cotton and single jersey knitting*

As seen in Figure 8, at 50 °C, the drying rate is 0.5 at the beginning and reaches the highest value of 1.4 over time and 0.6 at the end of the period. At 55°C, it reaches the highest value of 1.6 from 0.8 at the start of the time and completes it at 0.8 at the end of the time. It starts at 1 at the start of 60°C time, reaches the highest value of 1.8, and completes at 1.2 at the end of the time. At 65 °C, it reaches 1.2 at the beginning of the time and reaches the highest value of 2, and then completes it at the value of 1 at the end of the time. At 70 °C, it reaches the highest value of 1.4 at the beginning, and the highest value of 2.4, and completes it at the value of 1.2 at the end of the time. The system simulated with the MATLAB program is 50% cotton - 50% PES and the drying speed of the fabric with interlock knit structure is given.

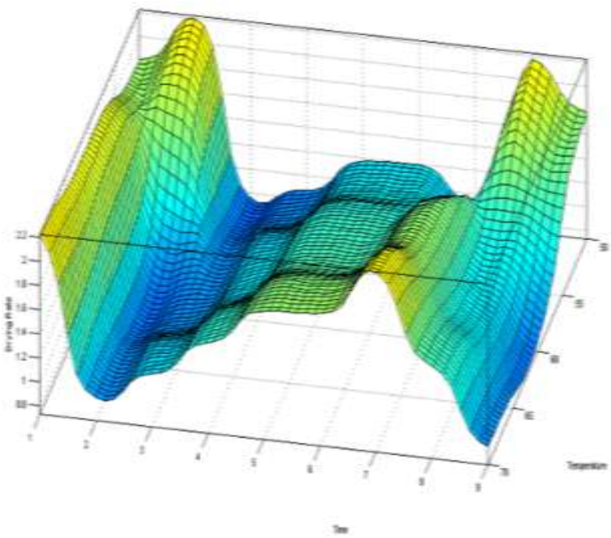

Figure 9. *Data obtained with MATLAB program for 50% cotton - 50% PES and interlock knitting*

As seen in Figure 9, at 50 °C, the drying rate reaches the highest value of 2.2 over time, from 1.8 at the beginning, and 1.8 at the end of the period. At 55°C, it reaches the highest value of 1.8 from 2 at the start of the time and completes it at 1.2 at the end of the time. It starts at 1.8 at the start of 60°C time, reaches the highest value of 2, and completes at 1.2 at the end of the time. After reaching the value of 1 at the beginning of the 65 °C period and reaching the highest value of 2, it completes at the value of 1 at the end of the time. At 70 °C, it reaches the value of 2.2 at the beginning, and completes it at the value of 0.8 at the end of the time.
The system simulated with the MATLAB program is 50% cotton - 50% PES and the drying speed of the fabric with rib knit structure is given. As seen in Figure 10, at 50 °C, the drying rate reaches 2 at the beginning and 1.6 at the end of the period. At 55°C, it reaches the value of 2.2 at the start of the time and completes it at the value of 2 at the end of the time. It starts at 1.4 at the start of 60°C time and completes at 2 at the end of the time. At 65 °C it reaches the value of 1.6 at the beginning of the time and completes it at the value of 2 at the end of the time. At 70 °C, it is at the value of 1.5 at the beginning and at the end of the time it is at the value of 2.

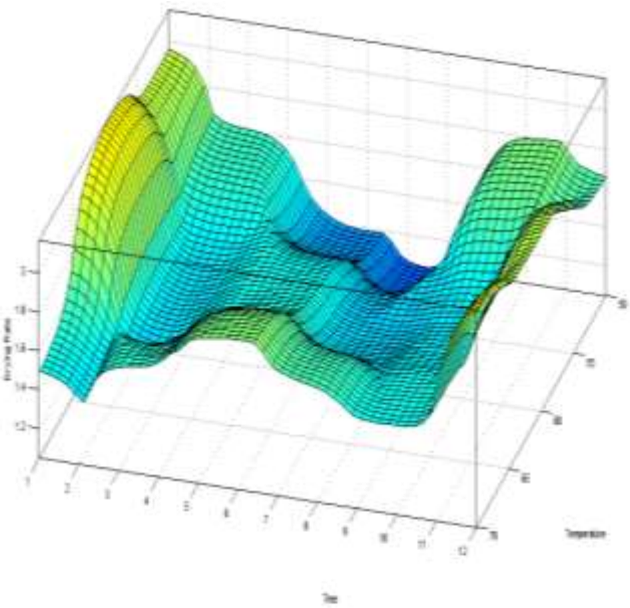

Figure 10. *MATLAB program is 50% cotton - 50% PES and the drying speed of the fabric with rib knit structure*

4. Conclusions

In this study, the drying efficiency of various fabrics with different properties was researched. The drying rate-time graphs of four samples with different parameters for drying temperatures at 50 °C, 55°C, 60 °C, 65°C and 70 °C were evaluated. It has been observed that the slightest change in fabric parameters has a great effect on the drying efficiency. The drying rates in the experiments performed at different temperatures showed similar characteristics, and the drying rates increased as the temperature increased.

The developed fuzzy logic models can be used safely by integrating them into package programs that can make artificial intelligence-based design and strength calculations, either in their current form or by further development. The drying process will be carried out with the contribution of different technological developments with minimum energy consumption and maximum drying speed by determining the properties of the material to be dried. In this study, it has been successfully presented that fuzzy logic is a powerful and alternative method in both estimation and design with its use on numerical data.

Since it is one of the most energy-consuming processes in the industry, more research should be done in order to develop technologies in the field of drying and to obtain higher quality products. One of the key approaches to increasing the energy efficiency of many industrial operations is the application of fuzzy logic control. Published studies have proven that using the fuzzy logic method allows the determination of the parameters that are effective in reducing the drying time.

Author Statements:

- **Ethical approval:** The conducted research is not related to either human or animal use.
- **Conflict of interest:** The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper
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- **Data availability statement:** The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

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