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Consumer Attitudes and Preferences about Upholstered Furniture

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Abstract

This study focuses on learning the knowledge, opinions, and preferences of consumers about upholstered furniture. This study further aims to discover how the preferences arising from the knowledge and thoughts of the consumers are reflected in the home-type upholstered furniture purchase process. A survey was designed and implemented for this study. Survey data were analyzed using descriptive statistics and independent samples t-test. Results of the study indicate the following: consumers from Kayseri plan to use their upholstered furniture for 6 to 10 years, do not replace their furniture before it is worn out, and when considering replacement, they give importance to aesthetic features, ease of use, and moderate prices. It was also found that, when purchasing furniture, consumers pay attention to the quality of the fabric, the cleanable and washable qualities, and timeless design.

1. INTRODUCTION

People furnish and decorate their living spaces with furniture and furnishings to transform them into more comfortable and aesthetic environments. It is essential that people consume several goods and services to make such amendments and transformations in their living spaces. The use of goods and services to satisfy the needs of people is called consumption [1], and the consumer is the person that buys or consumes any goods or services to fulfil their requirement and desires [2]. The focal point in understanding the attitudes of consumers is how a consumer decides on the consumption of limited resources (money, time, energy). In this context, questions such as who buys several products, why such products are used, why certain brands or models are chosen, how such product or model is selected, how the payment is made, when the product is needed, and where the product is bought from are the basic issues for which an answer is sought [3].

Furniture is commercial consumer goods that have an important place in human life. They are basically divided into two groups: soft furniture and hard furniture. Furniture made of materials such as wood or metal is considered hard furniture, whereas furniture that consists of pillows and cushions and is made from fabric or leather is considered soft furniture or upholstered furniture [4]. People encounter upholstered furniture in many living spaces, including houses, workplaces, and schools, which are a part of daily life. As well as the services such furniture offers, such as studying or resting by sitting or lying down, they also have decorative purposes in that the spaces appear aesthetically improved. Upholstered furniture comes in a multitude of forms, including chairs, armchairs, couches, and sofa beds, that can be used as a set or single furniture items.

A production technique that ensures comfort and convenience is used in the manufacturing of upholstered furniture. This technique has a slower process compared to other manufacturing techniques and depending on the skills of the craftsperson, it can be labor-intensive [5]. The solidity, comfort, and quality of the furniture are created from the elements underneath the upholstery material. The upholstering

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process has five phases: frame, webbing, woven textiles coating (Hessian, Scrim, etc.), springs assembly, filling and wadding, and decorative fabric coating and finishing touches [6].

It is essential to analyze what factors lie behind the preferences and behaviors of consumers to understand their attitudes concerning upholstered furniture. However, most of the academic studies on upholstered furniture report results from a variety of tests (mechanical, dust, combustion tests) on fabrics, filling materials, or springs. A review of the literature indicates that consumer attitudes regarding upholstered furniture were analyzed in very few studies. For example, Arslan et al. (2010), in their study conducted in Turkey, identified the types of problems encountered by consumers regarding upholstered furniture. These problems were "wearing out of fabrics," "squeaking and noise making," and "disintegration on the joints." Additionally, they found that consumers replace their upholstered furniture because it "expired its economic life" [7].

Dangelico et al. (2013) conducted investigated textile and upholstered furniture in a manufacturing sector in Italy to underline the importance of environmental problems. Results of the study indicated that the integration of environmental sustainability issues with product design would open new markets and product arenas for the companies, increase their financial performance, and create new opportunities [8]. In another study, Goa et al. (2014) attempted to determine the qualifications of ideal upholstered furniture through the use of numerous scientific branches, including design methodology, psychology, applied human engineering, marketing, graphics, and statistics. Ultimately, they aimed at creating the "rules for upholstered furniture" that may serve as a guide for consumers and the upholstered furniture industry [9]. Arisut and Ayan (2017), in their study conducted in Turkey, examined the criteria affecting the preference of consumers in upholstered furniture purchasing. According to their results, consumers give foremost importance to the price factor and payment options followed by fabric and color factors in terms of design attributes when purchasing upholstered furniture [10].

This study seeks to identify the knowledge, thoughts, and preferences of consumers regarding household upholstered furniture, such as armchairs, sofas, chairs, and sofa beds. Further, this study aims to explore how such knowledge, thoughts, and preferences are reflected in consumers' preferences while selecting furniture. More clearly, it is further intended to analyze how the experiences and attitudes of the consumers arising from their knowledge and opinions affect their attitudes in the process of selecting, purchasing, and using upholstered furniture. Analyzing these issues will help to understand the preferences and attitudes of consumers about upholstered furniture, set a sample for the studies to be conducted about furniture in the future, and obtain the presumptions that may have a positive impact on product sales in the upholstered furniture sector.

2. RESEARCH METHODOLOGY

2.1. Data Collection

This study was planned and conducted in order to analyze the knowledge, opinion and preferences of the consumer in Kayseri province about upholstered furniture. Kayseri, a developed province in terms of its furniture industry has shown improvement in the upholstered furniture sector. According to Central Anatolian Development Agency (ORAN) (2017), Kayseri is Turkey's most important furniture center. Twenty of the largest furniture manufacturers in Turkey, eleven of them are in Kayseri [11]. According to Central Anatolia Exporters' Association (OAIB) (2016), the rise of the furniture sector in Kayseri began with the manufacturing of couches, armchairs, and beds. Exports from Kayseri province are largely from the home furniture industry (armchairs, couches, sofa sets, etc.) [12]. Therefore, consumers living in Kayseri are offered a wide range of products in terms of design, pricing, quality, and other attributes. This access to a large number of alternatives in upholstered furniture means consumers have a varied experience of consumption.

Originally, the researchers intended to sample consumers throughout Turkey. However, it became necessary to narrow the scope of the study to a certain area since companies are not willing to share such information and it is difficult to contact consumers. Moreover, the existence of logistical problems, such

as transportation, personnel requirement, and financial and time constraints, had to be addressed. Therefore, the researchers decided upon a purposive sampling method restricted to the consumers living in Kayseri for this research. According to Sencer (1989) purposive sampling is to make the most appropriate part of the universe as an observation subject [13]. Although only Kayseri province was selected for this study, future research is planned to explore the preferences and behavior of consumers living in other major Turkish cities. According to the data of the Turkish Statistical Institute (TUIK), the population of Kayseri province in 2018 was 1,389,680 [14]. For regions with a population size of 250,000 or above, the sample size is 384 with a 95% confidence level and 5% confidence interval [15- 17].

The survey technique was used to obtain data that may reveal the impact of the preferences of the consumers arising from their knowledge and opinions regarding upholstered furniture on purchase behaviors of the same. The research was carried out in a store based in Kayseri that sells a variety of upholstered furniture and accessories. Necessary permissions were obtained from the store authorities to conduct the survey. The participants were informed before the survey and their verbal consent was obtained. Initially, a target sample of 384 individuals who visited the store was sought. However, the response rate was better than expected and 450 surveys were completed and examined for the study.

2.2. Analysis of Procedures

To obtain high quality, unbiased and comprehensive data from the survey form, the face-to-face interview survey method was preferred. Face-to-face interviewing has the highest potential with respect to types of questions and questionnaire complexity. İt has also the highest potential regarding coverage and sampling, but again it can be very costly, especially if the country is large and sparsely populated [18]. This method has some advantages and disadvantages. One advantage is that some questions and items could be clarified with the help of an interviewer. In contrast, one disadvantage is that the responders are not able to spend as much time answering questions in comparison to alternative methods [19]. During the implementation of the survey, explanatory information was given to the individuals about significant points of attention and efforts were made to ensure that the participants understood the survey correctly and clearly.

The survey form consisted of four parts. In the first part, participants were asked to answer demographic questions relating to income, gender, age, marital and educational status. The second part contained questions related to the preferences and behaviors of the individuals in the process of purchasing and using upholstered home furniture. In the third part, participants were asked about the general technical specifications and upholstery fabric of their existing home sofa sets. Finally, in the last part, participants were asked to rate a variety of sentences on a Likert scale in terms of how they relate to their opinions, experiences, and Preferences about upholstery furniture and the purchasing process. According to Sullivan (2009), a Likert Scale is a rating measure used widely in survey questionnaires to assess respondents' attitudes, preferences, and subjective responses to statements. Developed by Rensis Likert, a set of items presents users with statements and standardized response categories on a continuum, such as strongly agree, agree, neither agree nor disagree, disagree, and strongly disagree. Likert items are usually presented along a horizontal line on which the subject circles or checks his or her response [20].

The data of this survey were analyzed in the WEKA 3.9 statistical software. Waikato Environment for Knowledge Analysis (abbr. WEKA) has general public license, and was developed at the University of Waikato, New Zealand [21]. The obtained data were presented through tables and graphics.

2.3. Hypothesis

Consumers take into account many quality features such as the quality of the material or fabric when purchasing upholstered furniture. In this section, it has been investigated whether there is a significant relationship between the averages of these quality features and the gender factor. This for investigation, the following two hypotheses have been established.

- **h_0:** There is no meaningful difference between the quality features that consumers pay attention to when buying upholstered furniture and gender.
- **h_1:** There is a meaningful difference between the quality features that consumers pay attention to when buying upholstered furniture and gender.

3. RESULTS

3.1. Demographic Findings

To begin, the demographic attributes of the individuals taking part in the survey were examined (Table 1). The survey sample was composed of 48.9% women and 51.1% men. Among these individuals 82.2% were married and 17.8% were single, and 34.4% were between the ages of 36 and 45 and 30% were between the ages of 45 and 65.

Table 1. *Demographic characteristics of participants*

Sex	**(%)**	**Educational Status**	**(%)**
Male	48.9	Primary school	17.8
Female	51.1	High school	21.1
Age	**(%)**	Associate Degree	18.9
18-25	14.4	Bachelor Degree	23.3
26-35	18.9	Master / Ph.D.	18.9
36-45	34.4	**Income Status (monthly)**	**(%)**
46-65	30	Minimum wage or below (380 USD and below)	25.6
66 and upper	2.2	Minimum wage upper -3000 TL (381-515 USD)	24.4
Marital Status	**(%)**	3001-5000 TL (516–858 USD)	27.8
Married	82.2	5001-7000 TL (859–1,200 USD)	15.6
Single	17.8	7001 TL and upper (1,201 USD and upper)	6.7

The majority of the participants had attained a high school (21.1%) or a bachelor's (23.3%) education. Demographic characteristics of the participants were investigated in monthly income. According to The Republic of Turkey Minister of Family, Labour and Social Services (2019), monthly minimum wage in Turkey is 2,020.90 Turkish lira net (Turkish lira is the official currency of Turkey, and is symbolized as TL) [22]. In terms of monthly income, 27.8% earned 3001–5001 TL (516–858 USD) and 25.6% earned monthly minimum wage 2,020.90 TL (380 USD) or lower.

3.2. Findings on the Preferences of the Use and Purchasing of Upholstered Furniture

This section examines the preferences and behavior of the individuals living in Kayseri that participated in the survey in the process of purchasing upholstered furniture for their homes. Firstly, the participants were asked whether they were satisfied with the upholstered furniture they used at home: 58.9% of the individuals said they were satisfied, 11% said they were not satisfied, and 30% said they were partially satisfied. It was understood that more than half of the individuals (51.1%) replaced their upholstered furniture within a period of between 6 and 10 years, and 35.6% replaced it after a period of 11 years or more.

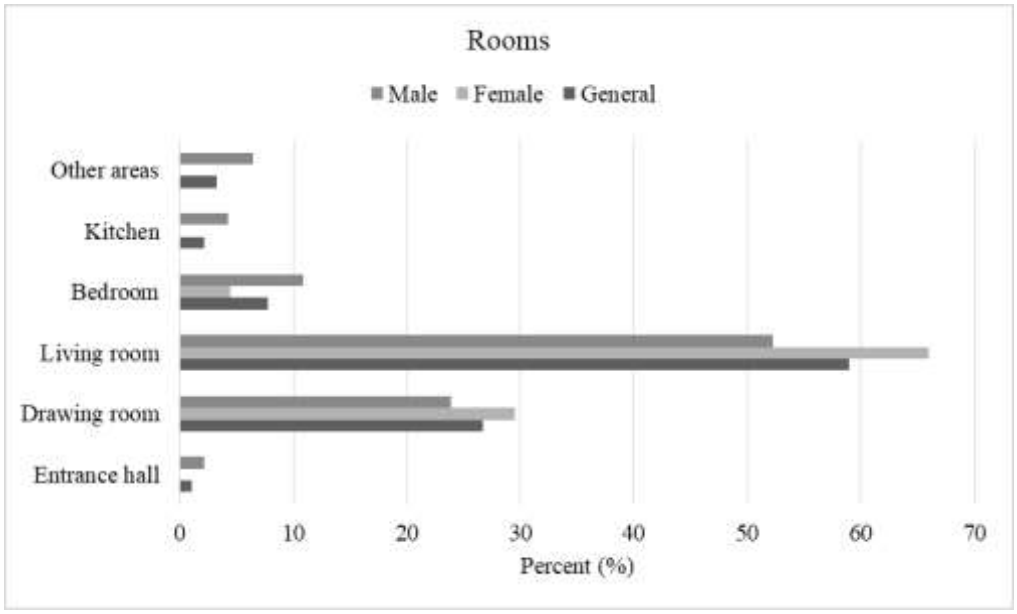


Figure 1. *Rooms that most frequently want to replace by participants*

The participants were most frequently willing to replace their living-room furniture designed for everyday use of household members, including the sofa sets (58.9%). When the individuals were asked about which furniture they had replaced most recently, 55.6% noted that they replaced their sofa sets and 17.8% said they replaced only their couches. 66% of the participants who want to change the living room and 29.5% of the participants who want to change the drawing room are women. Women mostly want to change sofa sets (%59.1), Couch (%15.9) and chairs (%13.6). Similarly, men mostly want to change their sofa sets (%56.5), Couch (%21.9) and chairs (%6.5) (Figure 1 and Figure 2).

The participants were offered various groupings regarding the functional positioning of sofa sets. According to the participants, the most functional positioning of furniture (46.7%) was two triple sofas and two single armchairs. Erdinler and Koc (2016) stated that the criteria for functionality is at the forefront for consumers in their selection of furniture [23].

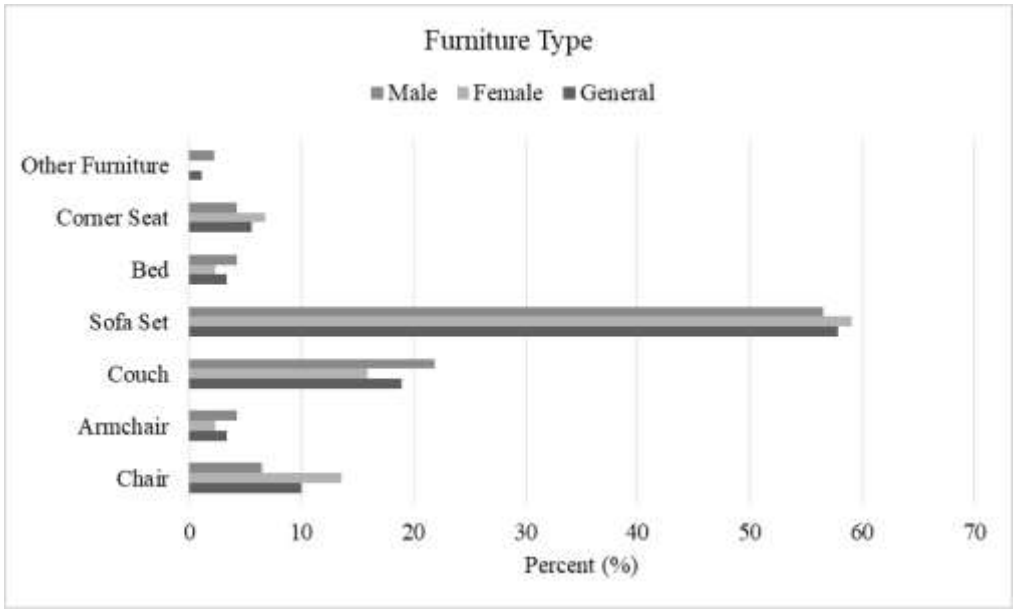


Figure 2. *Upholstered furniture that most frequently wants to replace by participants*

The participants were asked about their reasons for purchasing upholstered furniture. More than half of respondents (61.1%) indicated that the reason was that their old furniture was wearing out and 16.7% indicated that they were replacing their furniture because of marriage. In light of this information, it appears people living in Kayseri do not replace their furniture unless it is necessary. Additionally, it was also found that individuals referred to the internet and social networks to gather information before purchasing (34.4%) as well as family and friends (28.9%). Lihra et al. (2008) indicated the internet is an important instrument for furniture sales both for the manufacturers and the consumers [24]. Andac and Guzel (2017) and Andac Guzel (2020) stated that a large majority of the consumers make use of internet before buying furniture [25, 26].

When asked about purchasing location, most of the participants prefer to purchase their upholstered furniture from a store (85.6%) and more than half preferred to purchase from a renowned brand (54.4%), followed by a local brand (40%). Andac (2008) and Cabuk et al. (2012) stated that a large majority of the consumers buy their furniture from the dealers of famous brands [27, 28]. Erdinler and Koc (2016) stated that as the level of income increases, the demand for the branded products also increases [23].

In reference to the first and most dominating factor consumers pay attention to when purchasing a piece of upholstered furniture, 27.8% of the participants noted that they paid attention to the ease of use, 24.4% paid attention to the quality of the material in the first instance, and 12.2% said they considered the aesthetic attributes. Burdurlu et al. (2004) stated that it is the other predictive factor after price that indicates the product is high quality and easy of use [29] (Figure 3). Likewise, Mowla (2019) also stated that quality is important in the purchase decision when buying furniture. In this section, an analysis made according to gender regarding the upholstered furniture purchasing process. The first ease of use that women pay attention to when buying upholstered furniture (36.4%) is the material quality of men (32.5%).

In this survey, the influence of the aesthetic attributes in the process of purchasing were also examined. According to the findings, the participants first prefer classical and timeless design style (41.1%) followed by a casual look and comfort (36.7%) in the style of upholstered furniture. According to gender analysis, women first prefer a casual and comfortable design style, while men prefer to first classical and timeless design style in upholstered furniture (Figure 4). The majority of participants preferred flamboyant furniture with Socio-economic status implications (70%) for their drawing rooms, whereas they preferred more comfortable, easy-to-use, and functional upholstered furniture for their living rooms. Burdurlu et al. (2004), Andac and Guzel (2017), and Isac and Badshah (2019) stated that consumers prefer furniture that are easy of use [29, 25, 30].

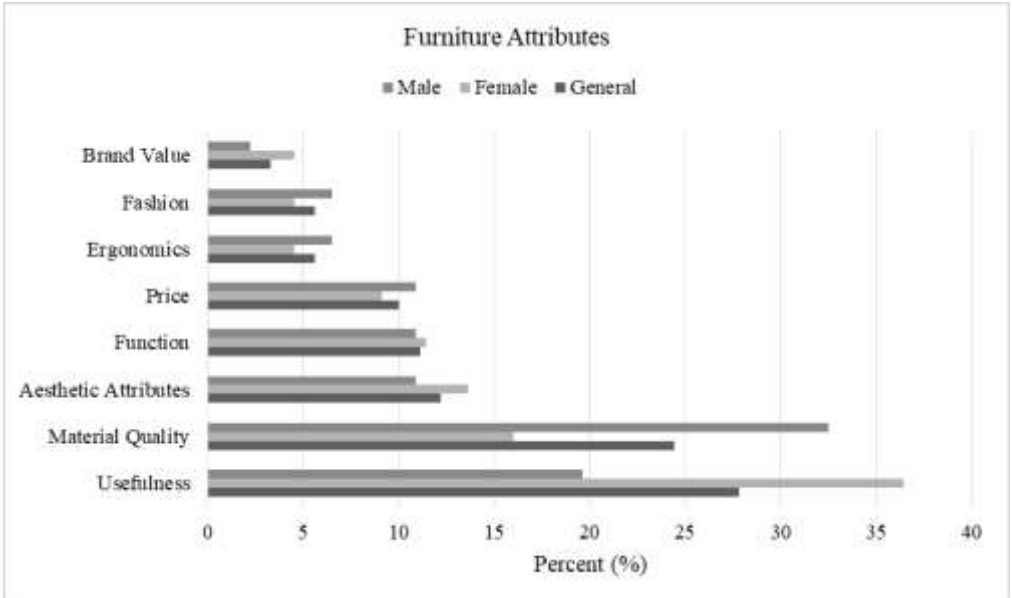


Figure 3. *Furniture features that most frequently considered by participants in purchasing*

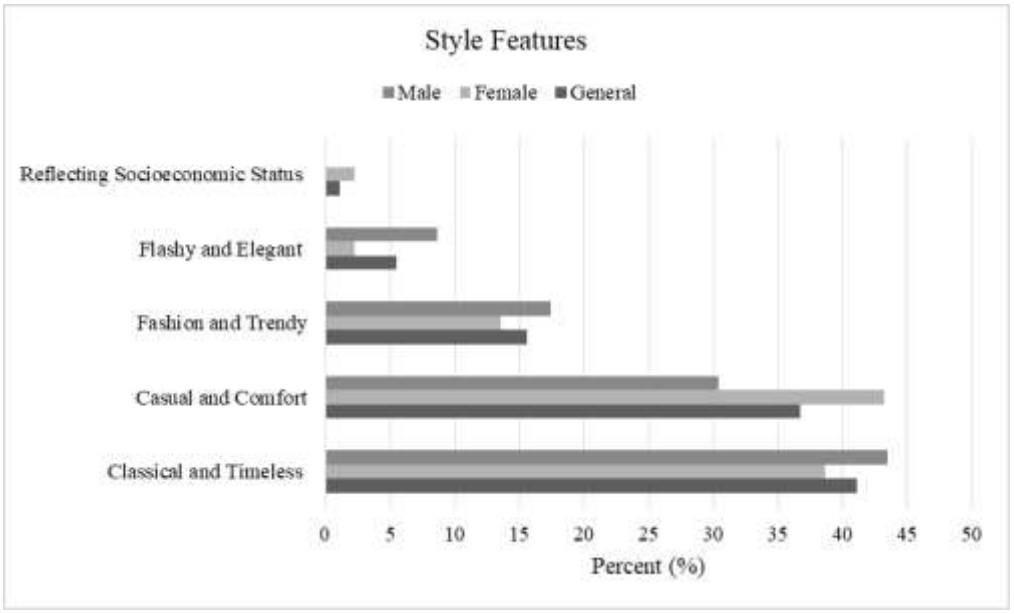


Figure 4. *Upholstered furniture style features that most frequently want by participants*

3.3. Findings on the Materials and Technical Specifications of Upholstered Furniture

In this survey, the technical specifications and upholstery fabric material used on the surface of the existing upholstered furniture that the participants were currently using in their homes were also examined. According to the results, almost half of the participants noted that the upholstered furniture in their homes was made using a spring system (47.8%) or non-spring system (42.2%), whereas 10% of the participants said they did not have any idea about the subject. Additionally, the participants noted that the surface of their upholstered sofa set furniture was made of natural fabric (30%) or synthetic fabric (70%).

The consumers were asked about the most important quality of the upholstery fabric when purchasing upholstered furniture. Almost half of the respondents (45.6%) indicated that cleanable and washable fabrics were important. Other qualities indicated by the consumers included the use of natural material (17.8%), durable fabrics that resist wearing out and abrasion (15.6%), noise and squeak-free when there is motion of sitting or repositioning on the upholstered surface (8.7%), does not cause sweating when it is sat on (6.7%), and does not collect dust and hair on the surface fabric (5.6%) (Figure 5). Arisut and Ayan (2017) stated that the color and the fabric characteristics are the most important factors in an upholstered furniture purchase [10]. Arslan et al. (2010) stated that consumers consider fabric wear, squeaking and noise making, and disintegration on the joints of fabrics in the selection of upholstered furniture [7]. According to gender analysis, both women and men want upholstered furniture fabric to be cleanable and washable. Only men want the fabric's features to be noise and squeak-free (Figure 5).

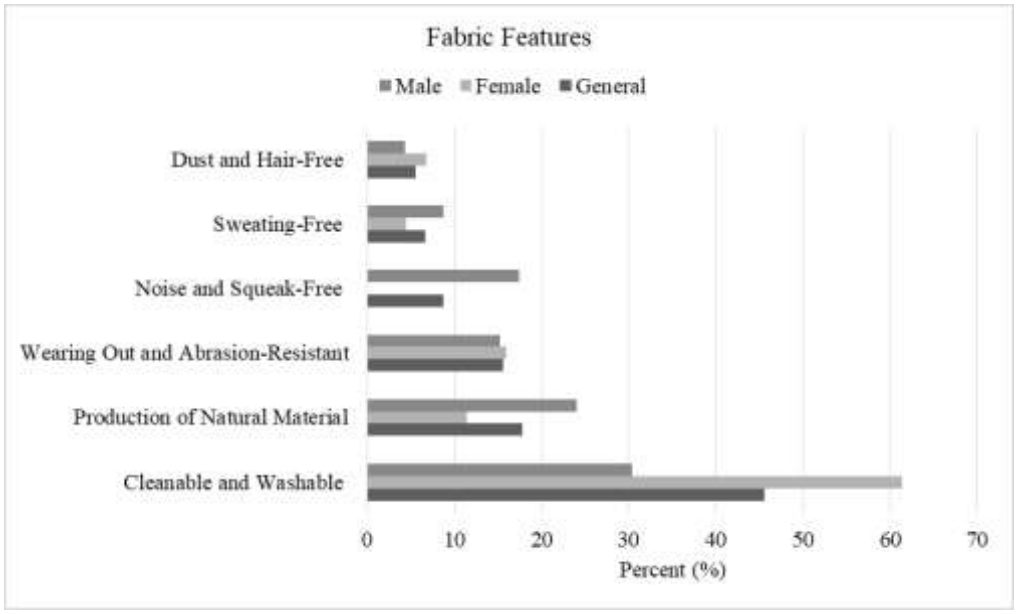


Figure 5. *Upholstered fabric features that most frequently want by participants*

The elements that are important for consumers regarding the durability and quality of material when purchasing upholstered furniture were also investigated. It was found that the most important factor is the quality of the upholstery fabric (26.7%). The second most important factor is the quality of the sponge and filling material (22.2%), and the third is the quality of the frame case of the upholstered furniture (21.1%). Other important elements include the quality of the particleboard and MDF used in visible parts of the furniture (15.6%), the quality of upholstery spring (5.6%), the quality of the accessories used on the furniture and cushions (tassel, fringe, cords, decorative button, beads, etc.) (4.4%), the quality of the jointing points on the upholstery fabric and the stitches (3.3%), and lastly, the quality of the assembly elements (zipper, velcro, etc.) (1.1%). In addition, an independent samples T-test was performed for this section (Table 2). With this test, the effect of the upholstered furniture features on the purchasing process was investigated.

3.4. Findings on Judgments about Upholstered Furniture

In this section, various judgment sentences were set up for the purpose of analyzing the opinions and experiences as well as purchasing behavior of the participating individuals about upholstered furniture. Agreement with sentences was recorded using a 5-point Likert scale (1 = *strongly disagree* to 5 = *strongly agree*, with a midpoint of *neutral*).

According to the results obtained, 40% of participants regard upholstered furniture as the most comfortable, and 51.1% relate comfort in furniture with ergonomic design. All participants agreed that the most persuasive element when purchasing furniture is aesthetic design. Further, all participants indicated that in addition to ergonomic design and aesthetics, ideal upholstered furniture should be functional. Participants stated that they agree with these sentences. Only 5.6% of the participants disagree that upholstered furniture is the most comfortable type and this comfort is related to ergonomic design (Figure 6).

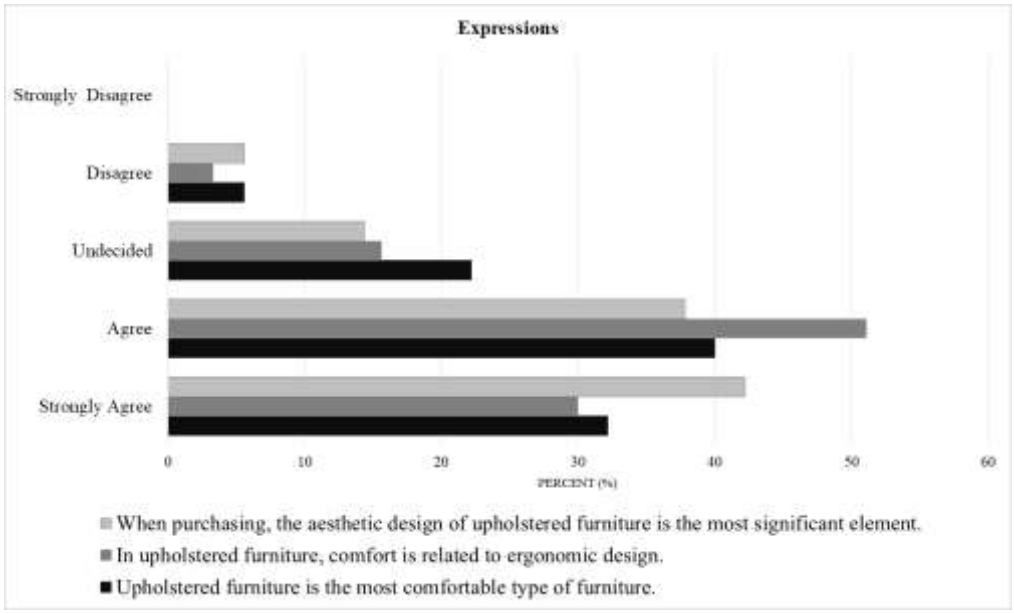
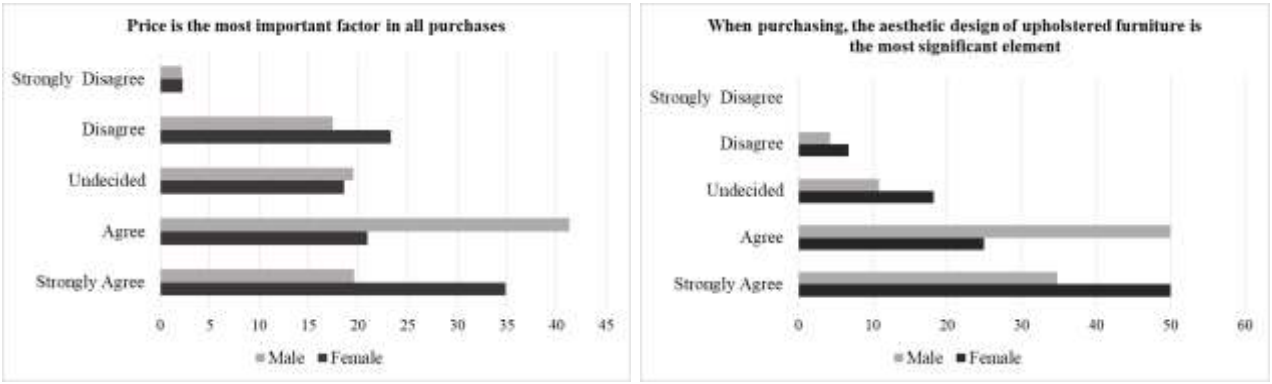


Figure 6*. Some results of analyses on judgments about aesthetic and ergonomic design*

To analyze the impact of aesthetic design on the sale of furniture in greater detail, the participants were offered another set of judgment sentences. Notably, 31.1% of participants would still purchase upholstered furniture that lacked functionality if it had a highly aesthetic design and 30% would purchase furniture with a poor ergonomic design if it were aesthetically pleasing. Moreover, 38.9% of participants believed that consumers prefer to purchase stylish and aesthetically designed upholstered furniture to highlight their social level. Individuals stated that they agree with these sentences. Barut and Gunes (2018) stated that consumers with higher purchasing power request flamboyant products more often when buying furniture, and Erdinler and Koc (2016) suggested that consumers pay great attention to the image the furniture creates when buying furniture [31, 23]. In view of Isac and Badshah (2019), consumers prefer to buy products that appear nice aesthetically [30]. According to gender analysis, women pay more attention to both aesthetics and price of upholstered furniture than men and strongly agree with the sentence describing this view (Figure 7).



(a) (b)

Figure 7. *Some results of analyses on judgments about upholstery furniture*
a- Analysis of price by gender, b- Analysis of aesthetic design by gender

Another significant factor shown to have an impact on the salability of upholstered furniture is the price (Figure 7 and 8). According to 32.2% of participants, price is the most important factor in all purchases. While individuals stated that they strongly agree with this sentence, only 2.2% stated that they strongly disagree with this sentence. Interestingly, 37.8% of participants said a modest price was more important than aesthetics, functionality, or ergonomic design. Burdurlu et al. (2004), Andac (2008), Bednarik and Pakaine Kovats (2010), Serin and Andac (2009, 2012); Arpaci and Obuz (2013). Andac and Guzel (2017); Arisut and Ayan (2017); Andac Guzel (2020) stated that price is one of the most predictive

factors while buying furniture [29, 27, 32, 33, 34, 35, 26]. Further, the perspectives of participants concerning brand and branded products were also examined. When asked why branded products have higher prices, 35.6% answered this was due to very good aesthetic design and high quality (Figure 8). Mowla (2019) stated that the brand is important in the purchase of the product and there is a significant relation between the price and brand loyalty [36]. Barut and Gunes (2018) stated that the price and the brand of the product in a furniture purchase is an alternative way used by the consumers to show their social levels [31].

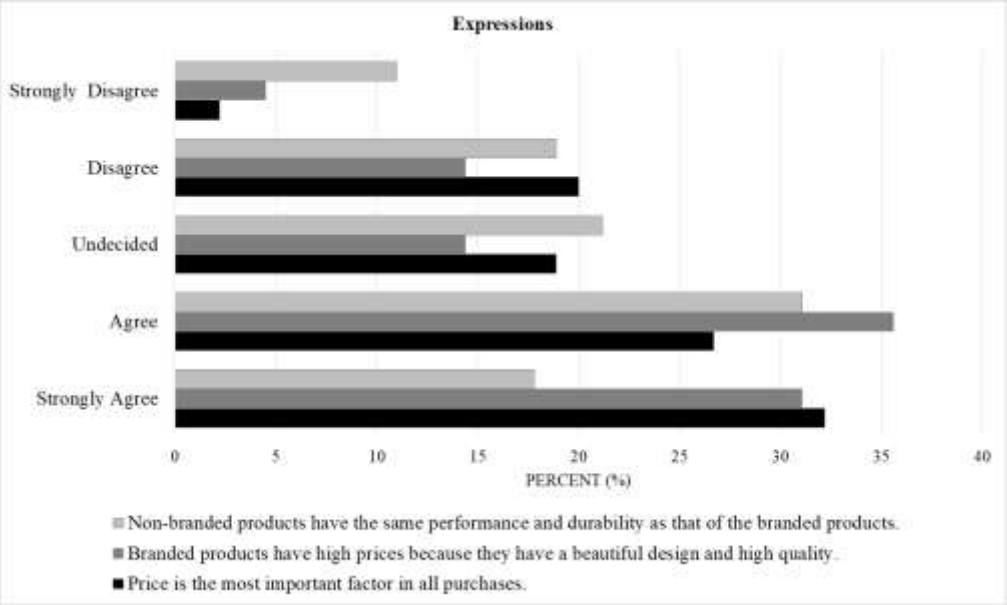


Figure 8. *Some results of analyses on judgments about price and brand*

However, results indicated participants do not consider only branded produces as having high performance, durability, and quality. Similarly, Andac (2009) also stated that higher price does not represent the quality of the product on its own [33]. In fact, 31.1% of participants believe that non-branded products may also have the same performance and durability standards as branded products. When asked how they initially evaluate furniture during the purchasing process, 26.7% of participants indicated they consider technical specifications, such as the quality and performance of the assembly equipment and mechanisms used in upholstered furniture. They agree that the technical specifications of furniture are important. Burdurlu et al. (2004) stated other predictive factors after price is quality and that it is easy to use [29]. Okcu and Kekec Morkoc (2017) stated that the consumers make their final decision to buy the furniture based on the durability and usefulness of the furniture [37]. Additionally, 24.4% indicated the use of environmentally friendly materials is not an initially important quality concerning their purchase decision. However, for 17.8% of individuals, it strongly disagrees with the idea that furniture is not environmentally friendly. They wanted the furniture to be environmentally friendly. Similarly, Andac Guzel (2020) found an eco-label contributes to the purchase of the good, and Isac and Badshah (2019) stated that consumers would like to purchase eco-friendly products [26, 30]. Dangelico et al. (2013) reported that it is important to develop environment-friendly products in the upholstered furniture sector [8].

Consequently, the participants noted that an ideal piece of upholstered furniture is a product with a high level of aesthetics, functionality, and ergonomic design made with high-quality and durable materials that communicate brand value. However, economic conditions and price create a tendency among these consumers towards equivalent products without brand value but with reasonable aesthetics, functionality, ergonomic design, and quality (with the admission of the risks that they may create because the item is not made with environmentally friendly materials). Burdurlu et al. (2004), Andac (2008), Serin and Andac (2009, 2012), Lihra et al. (2012), Andac and Guzel (2017), Okcu and Kekec Morkoc (2017), Isac and Badshah (2019), and Andac Guzel (2020) all found that price, aesthetic features, quality, brand, and

usefulness of the furniture are important factors regarding the preferences of consumers [25- 27, 29, 30, 33, 34, 37, 38].

3.5. Independent Samples T-Test Findings

Costumers care about a variety of factors when users are buying upholstered furniture. These are factors such as durability and quality of material, the quality of the upholstery fabric, the quality of the sponge and filling material, the quality of the frame case of the upholstered furniture, the quality of the particleboard and MDF used invisible parts of the furniture, the quality of upholstery spring, and the quality of the accessories. In this section, the effect of these factors on purchasing is compared with the gender factor. For this examination, an independent samples t-test was used, and it was investigated whether there was a significant difference between the two groups (Table 2).

Among the quality features of upholstered furniture features and gender, a meaningful result was obtained from gender factors (p-value: 0.000). Therefore, hypothesis (1) as "There is a meaningful difference between the quality features that consumers pay attention to when buying upholstered furniture and gender" is acceptable. As a result of the analysis, the ratio of female consumers to pay attention to the quality features of furniture was found to be higher in the process of buying upholstered furniture than male consumers.

Table 2. *T-test results for the upholstery furniture of quality features with gender*

Group Statistics				
	Gender	***n***	***Mean***	***SD***
Furniture features	Female	220	4.4432	0.63404
	Male	230	4.0978	0.64932
Independent Samples Test				
			t-test for equality means significant (two-tailed)*	
Furniture features			0.000	

* p > 0.05 means there was no bond between data; p < 0.05 means there was a bond between data

4. CONCLUSION

In this study, the perspectives of consumers living in Kayseri province of Turkey concerning upholstered furniture were examined. A summary of results is provided below.

1. Consumers in Kayseri regard upholstered furniture as the most comfortable type of furniture. These consumers define an ideal piece of upholstered furniture as high-level products in terms of aesthetics, functionality, and ergonomic design, and as products made of high-quality materials with a long span of life and brand value.
2. Consumers in Kayseri make use of their furniture for a long period of time and they only replace it when necessary. For this reason, they tend to prefer products that are useful, made of high-quality materials, and have an aesthetic but timeless design. It is thought and recommended that companies keep such products in their product range to gain new customers.
3. Consumers frequently make use of the internet and social networks before purchasing upholstered furniture. Therefore, it would be beneficial for companies to effectively promote their products on these platforms and carry out activities to increase their brand value.
4. In the process of purchasing upholstered furniture, consumers give importance to the quality of surface upholstery fabric as well as their cleanable and washable qualities. Therefore, companies who allocate store space for this type of product are likely to realize an increase in sales.
5. The price of upholstered furniture has an impact on purchasing. It was found that consumers tend to purchase equivalent products that are not branded and are reasonable in terms of quality, aesthetics, functionality, and ergonomic design. However, doing so means they are will to risk purchasing furniture that is not considered environmentally friendly.
6. In the gender analysis, it was determined that female consumers pay more attention to the aesthetic attributes of the upholstered furniture, to be in a casual and comfortable design style, and to the price

compared to male consumers. In addition, according to the result of the t-test analysis, the ratio of female consumers to pay attention to the quality features of furniture were found to be higher in the process of buying upholstered furniture than male consumers. If furniture companies in Kayseri want to grow their customer base and sales, they should do Research and Development (R&D) studies for upholstered furniture that will attract the attention of female consumers.

7. Furniture companies in Kayseri must produce and present high quality, durable, and useful products that are less harmful to the environment and human health but also look good and appeal to the taste of consumers within the scope of their potentials. If they offer such products, which have the foregoing characteristics to the target group with reasonable price options, they are likely to have the chance to increase their sales. Furthermore, they may have the chance to develop within the sector both nationally and internationally.
8. Lastly, Kayseri is one of the leading furniture centers in Turkey, and the rise of furniture sector in Kayseri started with upholstered furniture production (OAIB 2016). Therefore, it may set a sample for the furniture companies in other regions if the local furniture companies in Kayseri understand the preferences and expectations of the consumers correctly and deliver useful solutions. This may result in the emergence of new designs throughout Turkey for the furniture sector in the future as well as the discovery of new materials, formation of production processes, and creation of new marketing strategies.

CONFLICT OF INTEREST

No conflict of interest was declared by the authors

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PART A: ENGINEERING AND INNOVATION

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Performance Analyses of the Industrial Cooling System with Microchannel Condenser: An Experimental Study

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Abstract

Increasing the efficiency in equipment used in energy systems has a growing interest in the matter of energy efficiency and environmental effects. Microchannel heat exchangers, which will increase the efficiency of heat exchangers in cooling systems and reduce the amount of refrigerant charge, are of great importance. In this study, the theoretical and experimental results of classical and microchannel condensers used in a basic vapor compression cooling system were represented using R449a refrigerant. Two separate industrial systems with classical and microchannel condensers were designed, manufactured and tested under the same conditions. According to the test results performed for 24 hours, the average coefficient of performance, exergy efficiency and CO_2 emission values of the system with classical condenser and microchannel condenser were calculated as 2.086, 2.351; 23.950%, 25.564% and 16.357, 14.438 kg/hour, respectively. As a result, it has been seen that microchannel heat exchanger usage provides an advantage in terms of total energy consumption and total CO_2 emissions compared to the classical system at the rate of approximately 11% and using microchannel heat exchanger in industrial cooling systems has been recommended.

Nomenclature

α ..... molar mass
e_x ..... specific exergy (kJ/kg)
$\dot{E}_x$ ..... exergy rate (kJ/s)
h ..... enthalpy (kJ/kg)
$\dot{m}$ ..... mass flow rate (kg/s)
P_r ..... pressure ratio
$\dot{Q}_{con}$ ..... condenser capacity (kW)
$\dot{Q}_e$ ..... evaporator capacity (kW)
s ..... specific entropy (kJ/kg K)
$\dot{W}_{comp}$ ..... compressor capacity (kW)
W_R ..... total uncertainty (%)
w_1, w_2, w_n ..... uncertainties in the independent variables
T ..... temperature (K)
T_0 ..... dead state temperature (K)

Abbreviations

COP ..... coefficient of performance
GWP ..... global warming potential
NHV ..... net heating value

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Subscripts

c ..... condensation
$comp$ ..... compressor
$dest$ ..... destroy
e ..... evaporation
el ..... electrical
mec ..... mechanical
0 ..... dead state
r ..... refrigerant

1. INTRODUCTION

Heat exchangers that provide enhanced heat transfer are the most important equipment in energy systems. Condenser and evaporator, which are heat exchangers, are two basic equipments of basic vapor compression refrigeration cycles [1]. Both environmental and energy related problems of refrigeration cycles have motivated researchers to design more efficient evaporators, condensers, and utilize alternative refrigerants [2].

In recent years, microchannel heat exchangers are preferred as condenser and evaporator in cooling systems because of their advantages such as providing high heat transfer coefficients, being lightweight with their small dimensions, having low working fluid amount and being portable [3,4]. In the literature, there are a number of studies on which microchannel heat exchangers were used in cooling systems. Zhan et al. (2020) numerically investigated the performance of the vertical microchannel evaporator used in data center cooling systems using Icepack software. They found the maximum air side temperature difference as 9.5 ℃ and the vapor quality difference on the outlet side of the refrigerant to 0.15 in uneven conditions [5]. Tosun et al. (2019) examined the use of microchannel condenser in a household refrigerator with different amounts of refrigerant and the different sizes of capillary integration. As a result of experimental studies, the best combination of 50 g refrigerant and 3.25 m capillary for better performance was found [6]. Xu et al. (2013) examined the frost and defrost performance of two types of microchannel heat exchangers in a heat pump system using a CCD camera. After four operating cycles, they observed that approximately 800 grams of water were retained in the microchannel heat exchanger, and as a result, the effective operating time was reduced by 40 minutes. The capacity of the system was decreased by 27% compared to the starting value [7]. Xu et al. (2016) experimentally and numerically analyzed the performance of a microchannel condenser used in a domestic air conditioning system with R290 refrigerant. Results showed that the cooling capacity of the microchannel condenser system increased by 1.6% and the system refrigerant charge decreased by 28.3% [8]. Zhou and Hrnjak (2015) presented the experimental results of the distribution of R410a and R134a refrigerants in a reversible outdoor microchannel heat exchanger. It was shown that the inertia of R410a was higher than that of R134a and the high-quality R410a distribution was worse than R134a [9].

Microchannel heat exchanger can sometimes be used both as the evaporator and condenser of the cooling system. Cremaschi and Yatim (2019) investigated the retention of oil in a microchannel condenser and evaporator of an R134a cooling system and evaporator and the effect of circulating oil on heat transfer capacities and pressure drops in the microchannel heat exchangers. It was emphasized that the heat capacity of the evaporator varied between 5% and 12% and the pressure drops increased significantly [10].

R448a and R449a refrigerants have been used as an alternative to R404a. Makhnatch et al. (2017) were demonstrated that R449a can be used instead of R404a owing to its suitable thermodynamic properties and acceptable maximum discharge temperature in the supermarket refrigeration system. They confirmed that a 4% increase in refrigerant charge can provide a similar COP between R404A and R449A [11]. Vaitkus and Dagilis (2017) reported the reduction was 13% in cooling capacity and the decrease was 4%

in energy consumption for R448a and R449a according to R404a. They showed that the components of R448a and R449a were very close and therefore the performance criteria were the same [12].
In this study, two basic vapor compression industrial cooling systems, one with a classical (iron tube) condenser and the other with a microchannel condenser were designed and investigated experimentally. In both systems, all equipment was identical except for the condensers, and the refrigerant was R449a. The objective of this study is to analyze and compare energy, exergy and environmental aspects of classical and microchannel condensers. Another important purpose is to increase the cooling efficiency, to reduce energy consumption and to reduce carbon emissions for the industrial cooling system. The structure of this study is summarized in Fig. 1.

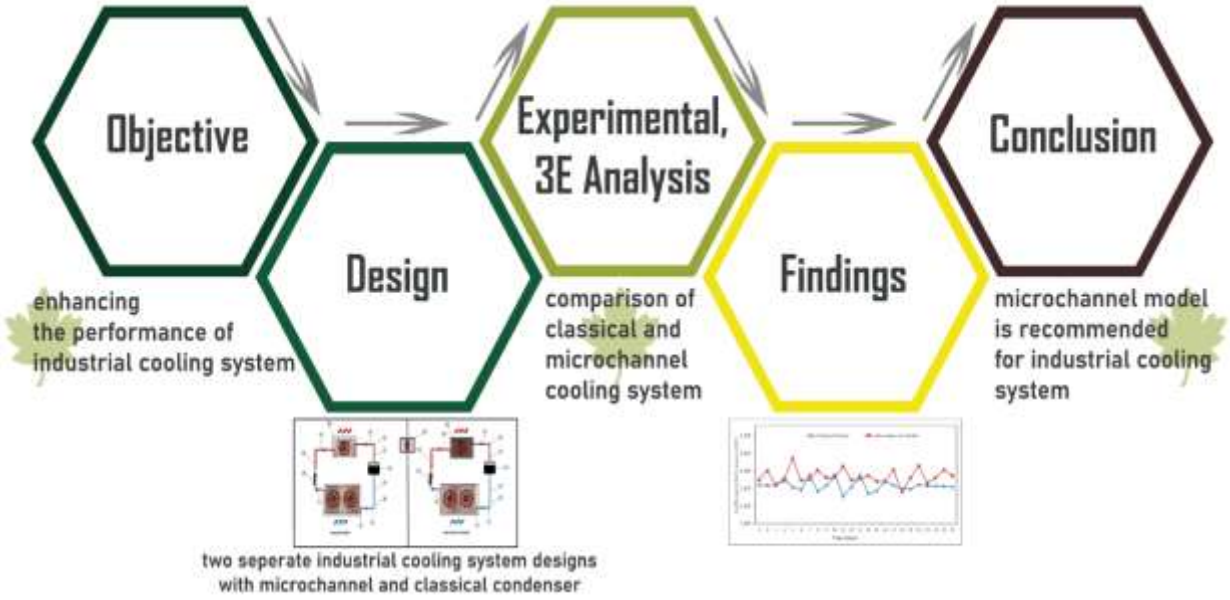
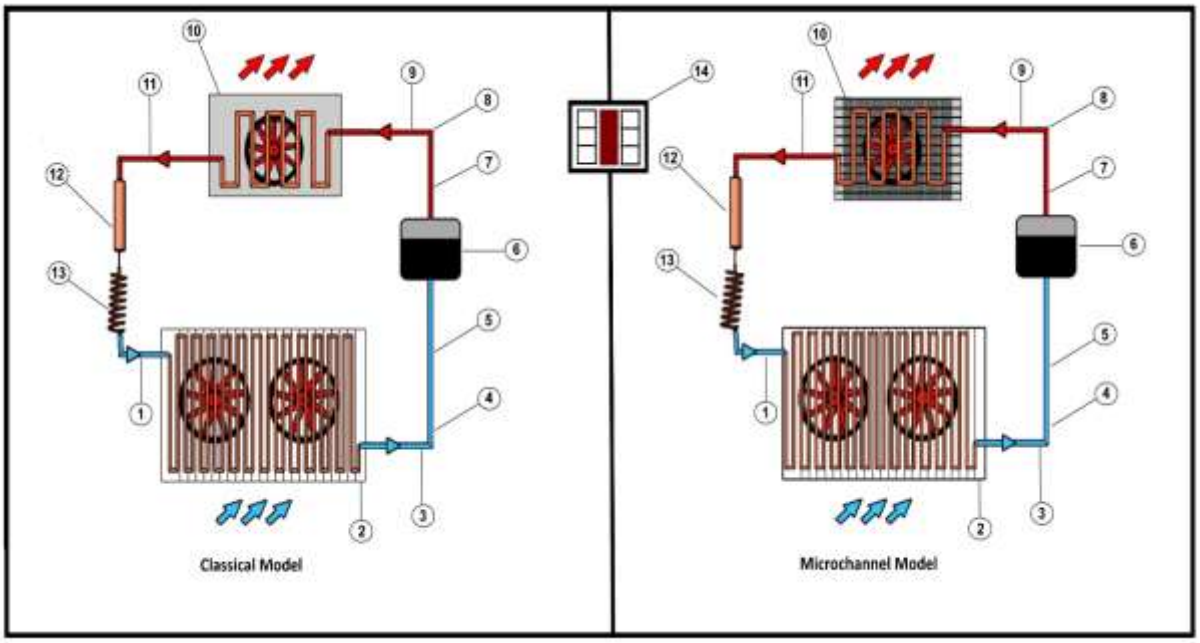


Figure 1. *Methodology of the current study*

2. MATERIALS AND METHOD

2.1. Experimental Procedure

The technical drawing of a basic vapor compression industrial cooling system is represented in Fig. 2. This system mainly included an evaporator, a compressor, a condenser, and a capillary tube. In this study, two cooling systems with classical and microchannel condensers were used and, R449a was used as a refrigerant in these systems. R449a was preferred because it was the main replacement gas with a global warming potential (GWP) value of 1397, and suitable for use in commercial and industrial applications at low and medium temperatures [13].



1- Evaporator Input	5- Compressor Suction Line	9- Condenser Inlet	13- Capillary Tube
2- Evaporator	6- Compressor	10- Condenser	14- Control Unit
3- Evaporator Output	7- Compressor Outlet Line	11- Condenser Outlet	
4- Low Pressure Line	8- High Pressure Line	12- Dryer	

Figure 2. *The schematic diagram of the cooling systems*

As shown in Fig. 2, the cooling system consisting of condenser iron tubes is called as the classical model, and the cooling system consisting of condenser microchannel is called as the microchannel model. The position of the measurements are the numbered Fig. 2 on both cooling systems. Temperature and pressure values were measured using the apparatus given in Table 1.

Table 1. *Technical specifications of the measurement devices*

Apparatus	Measurement Range	Accuracy
Thermometer	-40 / +150 °C	± % 0.02
Pressure transmitter	0-30 bar	± 0.1
Pressure transmitter	0.5-8 bar	± 0.01
Thermohygrometer	0-100 %RH	± % 1.5
	0 / +50 °C	± 0.03
Anemometer	0-2 m/s	± 0.01
Vacuum Pump	0,04-0,8 Pa	±0.02
Digital Gas Scales	0-100 kg	± % 0,05
Digital Manifold	-50 / +150 °C	± 0.1
	-1 / +60 bar	± 0.01
Energy analyzer	95-240 V AC	± % 0.1
	0.001-7.4 A	± % 0.2
Flowmeter	0-1000 kg/h	± % 0.1

2.2. Energy, Exergy and Environmental (3E) Analyses

The performance analyses of cooling systems given in Fig. 2 were conducted by applying the first law and the second law of thermodynamics. With the development of technology and industry, gases emitted to the atmosphere create certain destructions in the ozone layer. Therefore, when evaluating energy systems, it is of great importance to calculate energy and exergy analysis of the system as well as CO_2 emission value.

2.2.1. Energy analysis of system

In the heat pump system, the evaporator capacity ($\dot{Q}_e$) is determined by the equation given below [14]:

$$\dot{Q}_e = \dot{m}_r(h_3 - h_1) \tag{1}$$

Here, $\dot{m}_r$, h_1, h_3 represent the mass flow rate of the refrigerant, the inlet enthalpy of refrigerant to the evaporator and the outlet enthalpy of refrigerant from the evaporator, respectively. The power of the compressor ($\dot{W}_{comp}$) is also proportional to the difference of enthalpy of the refrigerant entering (h_5) and exiting (h_7) the compressor as shown in Eq. (2) [15].

$$\dot{W}_{comp} = \dot{m}_r(h_7 - h_5) \tag{2}$$

The electrical power applied to the compressor is calculated by dividing the compressor power by electrical and mechanical efficiencies [16].

$$\dot{W}_{comp,el} = \frac{\dot{W}_{comp}}{\eta_{el}\eta_{mec}} \tag{3}$$

The energy balance in the classical and microchannel condensers can be calculated with the following equation [17]:

$$\dot{Q}_c = \dot{m}_r(h_9 - h_{11}) \tag{4}$$

where h_9 and h_{11} state the enthalpies of the refrigerant entering and leaving the condenser. Pressure ratio (P_r) can be defined as the ratio of the high pressure to the low pressure in a cooling system.

$$P_r = \frac{P_c}{P_e} \tag{5}$$

The coefficient of performance of the heat pump system is determined by the following equation [18]:

$$COP = \frac{\dot{Q}_e}{\dot{W}_{comp}} \tag{6}$$

2.2.2. Exergy analysis of system

The exergy is a measure of the potential of the flow or system that causes a change as a result of its stable balance compared to the reference environment. Therefore, it is necessary to analyze the second law of thermodynamics to the system to obtain accurate results. The general exergy balance for a continuous flow system is explained in Eq. (7) [18].

$$\sum \dot{E}_{x,dest} = \sum \dot{E}_{x,in} - \sum \dot{E}_{x,out} + \sum \left[\dot{Q}\left(1 - \frac{T_0}{T}\right)\right]_{in} - \sum \left[\dot{Q}\left(1 - \frac{T_0}{T}\right)\right]_{out} + \sum \dot{W}_{in} - \sum \dot{W}_{out} \tag{7}$$

Where $\dot{E}_{x,dest}$, $\dot{E}_{x,in}$ and $\dot{E}_{x,out}$ are exergy destroyed, inlet exergy and outlet exergy of the system, respectively. Also, T_0 represents the dead state temperature. The specific exergy (e_x) and total exergy rate ($\dot{E}_x$) can be expressed as in Eq. (8) and Eq. (9) [14]:

$$e_x = (h - h_0) - T_0(s - s_0) \quad (8)$$
$$\dot{E}_x = \dot{m}_r e_x \quad (9)$$

The exergy destruction equations for each equipment of the heat pump system are shown in the following equations [18]:

For the evaporator:

$$\dot{E}_{x,dest,e} = \dot{E}_{x,3} - \dot{E}_{x,1} + \left[\dot{Q}_e(1 - \frac{T_0}{T_e})\right] \quad (10)$$

For the compressor:

$$\dot{E}_{x,dest,comp} = \dot{E}_{x,7} - \dot{E}_{x,5} + \dot{W}_{comp,el} \quad (11)$$

For the condenser:

$$\dot{E}_{x,dest,c} = \dot{E}_{x,9} - \dot{E}_{x,11} + \left[\dot{Q}_c(1 - \frac{T_0}{T_c})\right] \quad (12)$$

For the expansion valve:

$$\dot{E}_{x,dest,ex} = \dot{E}_{x,1} - \dot{E}_{x,11} = \dot{m}_r T_o(s_1 - s_{11}) \quad (13)$$

The second law efficiency of the heat pump system is given below [18]:

$$\eta_{ıı} = \frac{\dot{E}_{x,3} - \dot{E}_{x,1}}{\dot{W}_{comp,el}} \quad (14)$$

2.2.3. Environmental analysis of system

Since electrical energy is used in the vapor compression industrial cooling systems, the environmental impact of the production source of electrical energy is important. The quantity of CO_2 emitted needs to be reduced for preventing greenhouse gases released into the atmosphere. CO_2 emissions rate in kg/hour can be calculated using the model of Smith and Delaby [19].

$$CO_2 emission = \frac{Q_{fuel}}{NHV} \times \frac{C\%}{100} \alpha \quad (15)$$

here, NHV means the net heating value, $C\%$ is the carbon content depending on the type of fuel and α symbolizes the molar masses and is equal to 3.67.

2.2.4. Uncertainty analysis

When measuring a value for uncertainty analysis, the total error calculation can be made according to the equation given in Eq. (16), taking into account the errors caused by fixed, random and some errors [20].

$$\mathrm{W_R} = \left[\left(\frac{\delta \mathrm{R}}{\partial \mathrm{x_1}} \mathrm{w_1}\right)^2 + \left(\frac{\delta \mathrm{R}}{\partial \mathrm{x_2}} \mathrm{w_2}\right)^2 + \cdots + \left(\frac{\delta \mathrm{R}}{\partial \mathrm{x_n}} \mathrm{w_n}\right)^2\right]^{1/2} \quad (16)$$

3. RESULTS AND DISCUSSIONS

In this study, energy, exergy and environmental analyses of two cooling systems with classical and microchannel condensers used in an industrial cooling system were carried out. R449a was used as the refrigerant in both systems. The values obtained as a result of 24-hour analysis are presented in the graphics.

Fig. 3 and Fig. 4 show the operating pressure ranges of classical and microchannel model, respectively. While classic model operated in the range of high pressure 17-20, low pressure 2.9-5 bar, microchannel model also operated in the range of high pressure 13.5-15.6, low pressure 2.7-5 bar. The average low and high pressure values were as 3.821 and 18.741 bar for the classical model and 3.704 and 14.689 bar for the microchannel. In this case, it was observed that the high-pressure value was 4.052 bar lower at the microchannel condenser. Since the heat transfer was better in microchannel condenser, heat extraction occurred better at lower pressure.

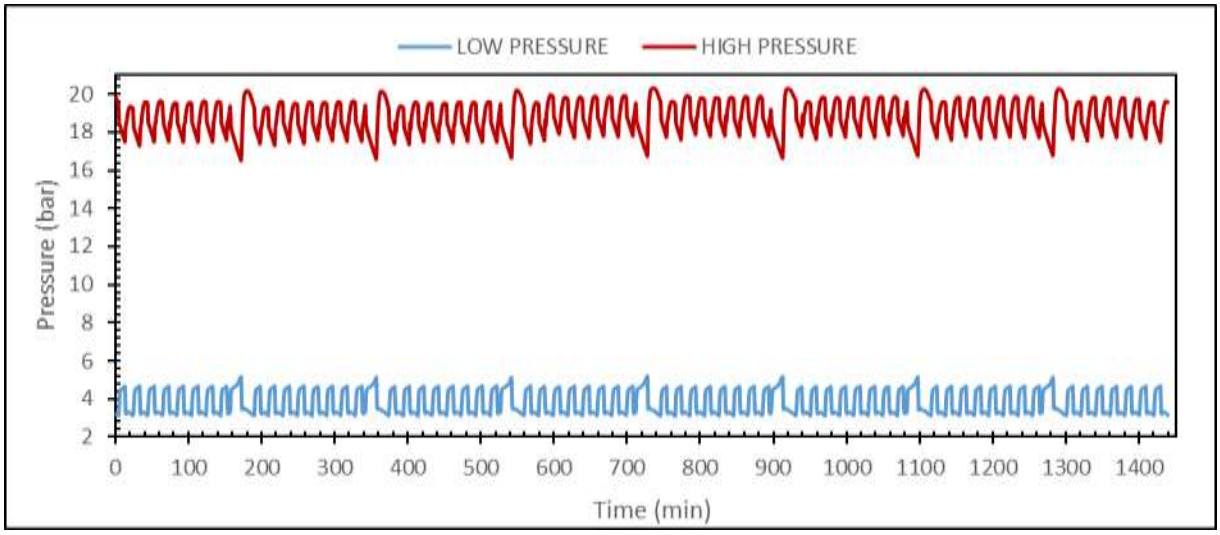


Figure 3. *Time-dependent high and low pressure values of classical model*

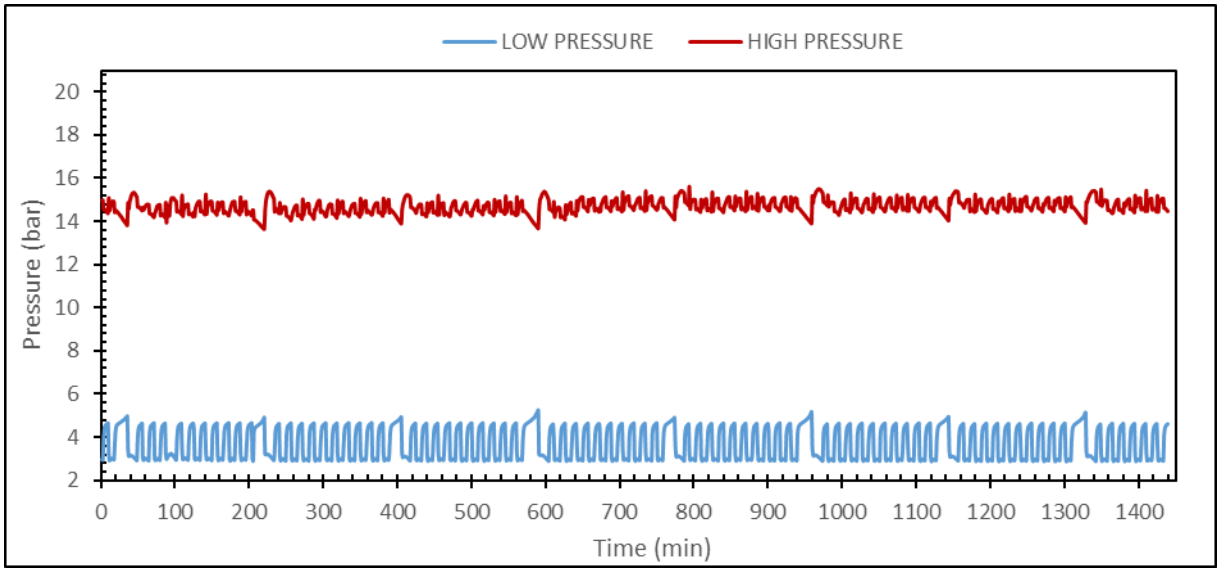


Figure 4. *Time-dependent high and low pressure values of microchannel model*

The time-dependent energy consumed by compressors and fans in classical and microchannel model cooling systems is given in Fig. 5. The compressor in classical model consumed more energy over time. The highest energy consumption was observed as 0.791 kWh at the 11th hour in the classical model and as 0.662 kWh at the 18th hour in the microchannel model. The average energy consumption value of classical model was 0.675 kWh and that of microchannel model was 0.595 kWh. In the microchannel model, the compressor consumed less electricity because the condenser pressure operates at lower values. In addition, the higher efficiency of the microchannel condenser was enabled the compressor to work more efficiently. Thus, it was observed that there was less energy consumption in the microchannel model. Energy consumption has a significant impact on the industrial cooling system. Thus, it is seen that the use of microchannel condenser in cooling systems will provide a great advantage in the long run.

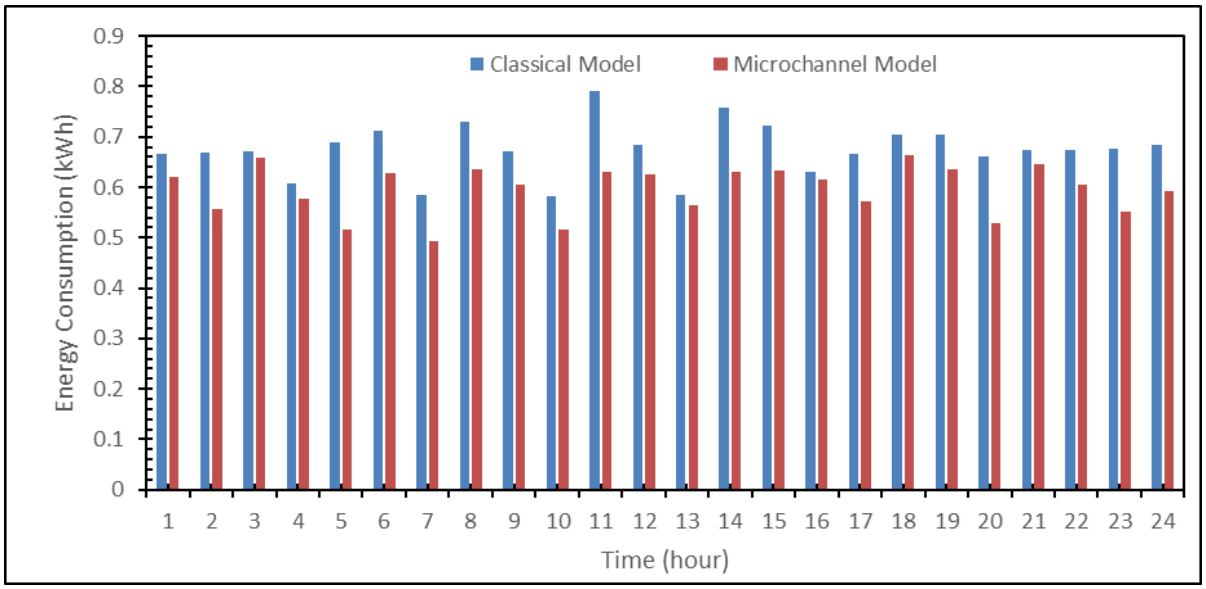


Figure 5. *Energy consumption graph of the cooling system*

Fig. 6 shows the time-dependent cooling COP classical and microchannel model cooling systems. The cooling COP of classical and microchannel models was calculated according to Eq. (6). While the highest COP value was seen as 2.872 in microchannel model at the 5th hour, the highest COP value was seen as 2.402 in classical model at the 10th hour. The average cooling COP value of classical and microchannel model was 2.086 and 2.351, respectively. It is known that in heat pump systems, when the heat transfer in the condenser is better or when the condenser efficiency is increased, the system increases the cooling performance. As the condenser efficiency increased when microchannel condenser was used, it was seen that COP also increased. Pawar et al. (2017) found the average COP of the cooling system which has a microchannel condenser system as 2.64 using R134a refrigerant [21]. Park and Hrnjak (2008) calculated the average COP of the cooling system using refrigerant R410a as 3.40 [3].

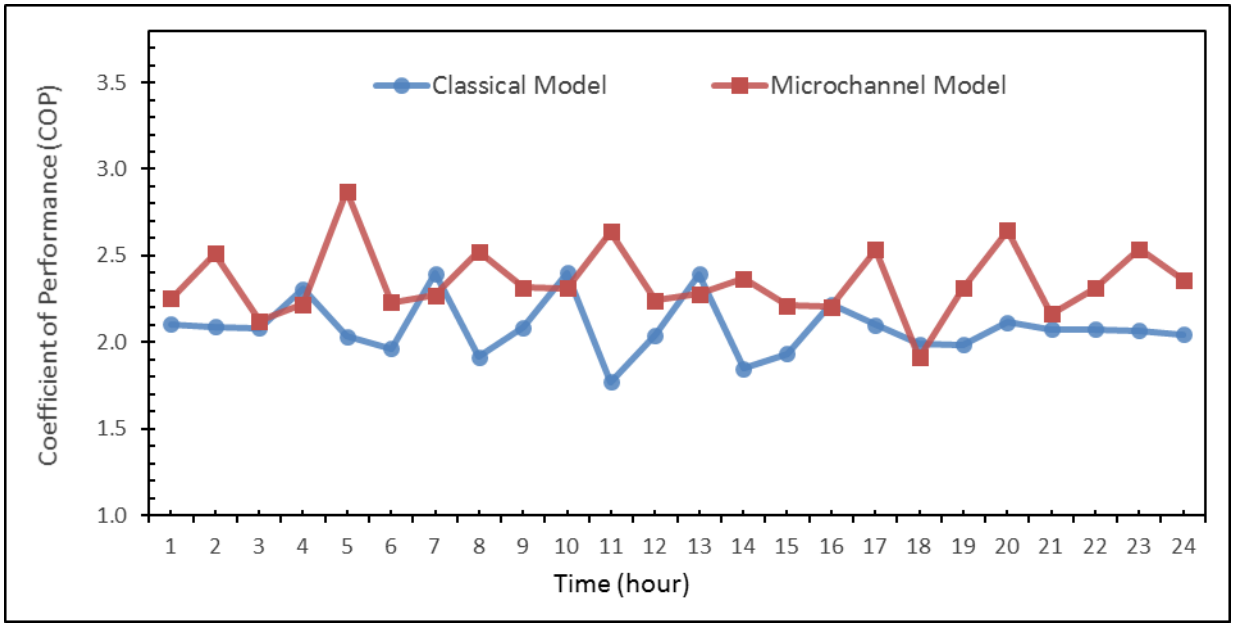


Figure 6. *The cooling COP graph of the cooling system*

Evaporator inlet and outlet temperatures for both cooling system models are given in Fig. 7. The average inlet and outlet temperatures of the evaporators in the classical and microchannel model cooling systems are -4.753℃, -5.638℃ and 1.588℃, 1.011℃, respectively. As can be understood, it is seen that the use of microchannel condenser in the cooling system improves the evaporator capacity. It also means that the higher the cooling capacity, the lower the evaporator inlet temperature and the better its performance.

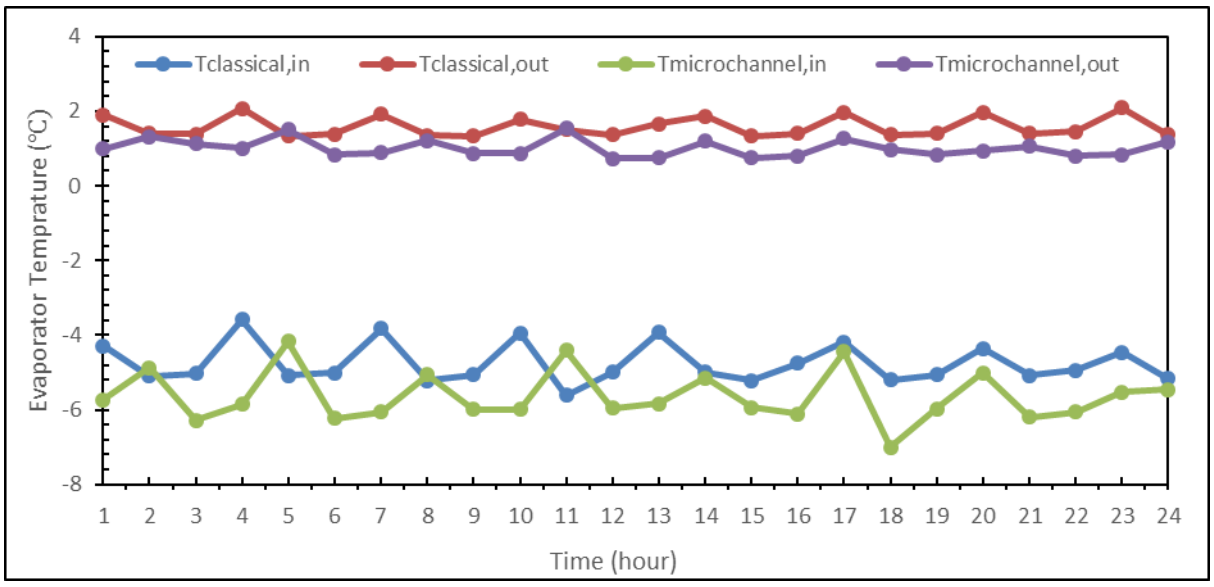


Figure 7. *Evaporator inlet and outlet temperature values of the cooling system*

Exergy analysis is a method for realistically and meaningfully evaluating and comparing energy systems and process changes. Exergy analysis for classical and microchannel models, it has an important place in terms of assessing their cooling performance. Exergy efficiency of cooling systems was calculated using Eq. (14). Exergy efficiencies of the cooling systems reached their maximum value at the1st hour. Then, it gradually decreased and balanced. The highest exergy efficiency for classical and microchannel models

was calculated as 30.872% and 37.571%, respectively. The average exergy efficiency values were found as 23.950 % and 25.564 % for classical and microchannel models, respectively.

Fig. 8 shows CO_2 emission values per hour for classical and microchannel cooling systems. The CO_2 emission value was determined using Eq. (15). These values change in proportion to the energy consumed by the compressor. While the CO_2 emission value of the classical model was at most 19.158 kg/hour, and at least 14.122 kg/hour, the microchannel model was 16.052 kg/hour and 11.923 kg/hour. Average CO_2 emission values of classical and microchannel models were 16.357 kg/hour and 14.438 kg/hour, respectively.

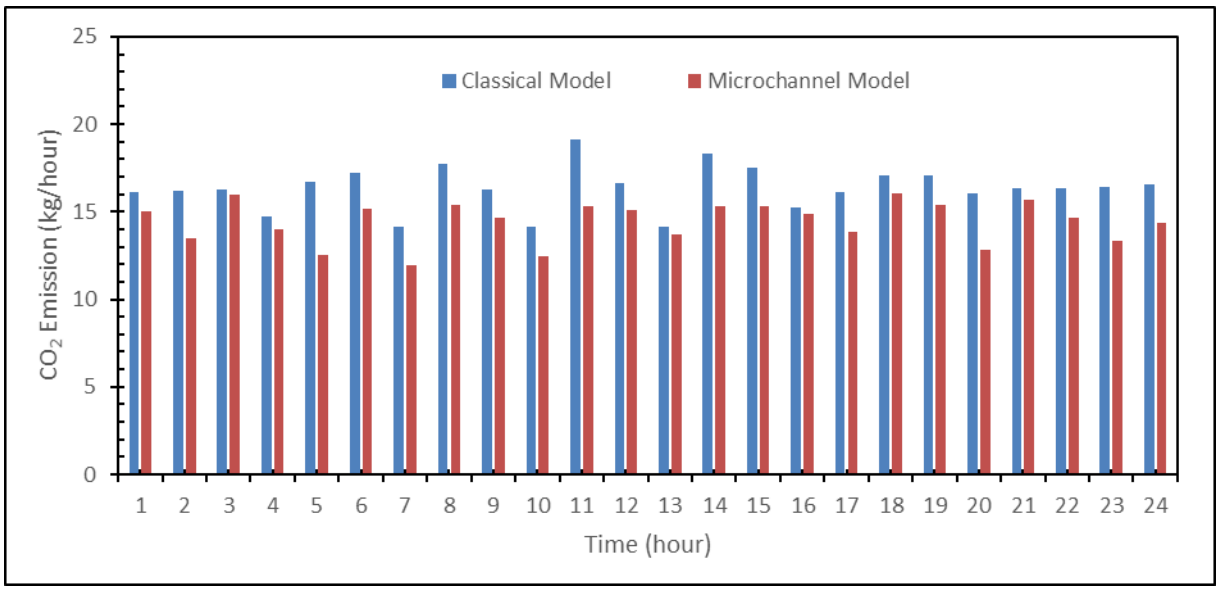


Figure 8. *CO_2 emission graph of the cooling system*

According to Eq. (16), the uncertainties of the cooling COP and exergy efficiencies were calculated by taking into account the experimental measurements. The cooling COP and exergy uncertainty in classical model were calculated as ± 0.0712 and ± 0.2862 %, respectively. The cooling COP and exergy uncertainty in microchannel model were found as ± 0.0524 and ± 0.1973%, respectively.

Table 2. *Summary of the results of this study*

	Microchannel Model	Classical Model
Refrigerant quantity	R449a, 1150 g	R449a, 1450 g
Average pressure ratio*	3.952	4.961
Volumetric air flowrate	600 m^3/h	780 m^3/h
The average current value	3.066 A	3.463 A
Total energy consumption	14.409 kWh	16.202 kWh
The average cooling COP	2.351	2.086
The average exergy efficiency	25.564 %	23.950 %
Total CO_2 emission value	346.524 kg/day	392.575 kg/day

* The ratio of average condensation pressure to evaporation pressure throughout the experiment
** The average current value of the compressor throughout the experiment

According to Table 2, the usage of microchannel condenser was seen to be more effective than classical condensers in large denominators such as pressure, temperature, thermal capacity and efficiency, which was also observed in literature reviews. Besides, the refrigerant charge amount in the microchannel model is 20.689% less than in the classical model. It was also determined that when the microchannel condenser was used in the cooling system, there was less carbon dioxide emission.

On the other hand, the microchannel condenser is lighter and smaller in size than the classical condensers, resulting in a decrease in the total amount of refrigerant in the system and thus a reduction in overall copper pipe length and diameter. Thanks to its high efficiency, the system allows the main equipment to be used at a lower capacity and the last of all, the cost of the cooling system also reduces.

4. CONCLUSIONS

The performances of two industrial cooling systems using classical and microchannel condensers were experimentally investigated and energy, exergy, and environmental (3E) analyses were performed. According to these analyses, the following outcomes can be listed:

- The average amount of energy consumed by the microchannel model is 11.852% less than classical model. Thus, the importance of using microchannel condenser in the cooling system has been further understood.
- The cooling COP determines how effectively the cooling system is used. The average COP of the microchannel model was found as 2.351, and the average COP of the classical model as 2.086.
- The average exergy efficiency value of classical and microchannel model was calculated as 23.950 % and 25.564 %, respectively. These values indicate that the use of microchannel condenser in the cooling system offers increased efficiency.
- The CO_2 emissions of the average classical and microchannel models were determined as 16.357 kg/hour and 14.438 kg/hour. These values show that the proposed system can be an eco-friendly alternative considering the problems related to global warming.
- It is recommended to use the microchannel heat exchanger in the industrial cooling system with regard to energy consumption, COP, exergy efficiency, and CO_2 emission values

CONFLICT OF INTEREST

No conflict of interest was declared by the authors

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