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Original Article

Investigation of the Relationship Between Blood Lipid Peroxidation and the Prevalence of Aflatoxin M1 in Milk Samples from Mothers and Cows Living in Kars and Surrounding Villages

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Aflatoxin,
dairy product,
exposure,
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Abstract: Aflatoxins are highly toxic secondary metabolites produced by molds. They cause various deformations in living systems. One of these is lipid peroxidation in mammals. Aflatoxins in milk are one of the most important factors that can increase lipid peroxidation in living life. Infants and children fed with milk and dairy products containing aflatoxin M1 (AMF1) have a greater effect.

In this study, aflatoxin levels were determined in 80 healthy cows and 80 breast milk samples from the same region, and the relationship between feeding patterns of mothers fed with these milk and their effects on blood lipid peroxidation were tried to be determined. Immunoassay kit (Ridascreen, Riedel-de Haen cat no. R1121 R-Biopharm GmbH, Darmstadt, Germany), a competitive enzyme, was used to determine AFM1 levels. Lipid peroxidation levels and AFM1 correlations were demonstrated in blood samples of mothers infected with AFM1. Samples were analyzed in 4 stages (collecting literature material, experimental applications, statistical analysis and report writing stage) in 24 months.

According to the results obtained in this study, it can be said that good agricultural practices should be adopted in order to maintain and maintain official control and implementation mechanisms at all stages from milk production to consumption, where aflatoxins in milk and dairy products are one of the biggest threats to public health.

Kars ve Çevre Köylerde Yaşayan Anne ve İneklerden alınan Süt örneklerinde Kan Lipit Peroksidasyonu ile Aflatoksin M1 Prevalansı Arasındaki İlişkinin Araştırılması

Anahtar Kelimeler:
Aflatoksin,
aflatoksin metabolizması,
serbest radikaller,
Antioksidan enzimler.

Özet: Aflatoksinler küfler tarafından üretilen yüksek düzeyde toksik sekonder metabolitlerdir. Canlı sistemlerde çeşitli deformasyonlara neden olurlar. Bunlardan biri, memelilerde lipid peroksidasyonudur. Sütteki aflatoksinler, canlı yaşamında lipid peroksidasyonunu artırabilen en önemli faktörlerden biridir. Aflatoksin M1(AMF1) içeren süt ve süt ürünleri ile beslenen bebek ve çocuklarda etkisi daha büyüktür.

Bu çalışmada, aynı bölgeden sağlıklı 80 inek ve 80 anne sütü numunesinde aflatoksin seviyesi belirlenerek, bu sütlerle beslenen annelerin beslenme şekilleri arasındaki ilişki ve kan lipid peroksidasyonuna etkileri belirlenmeye çalışıldı. AFM1 seviyelerini belirlemek için rekabetçi bir enzim olan immunoassay kiti (Ridascreen, Riedel-de Haen kedi no: R1121 R-Biopharm GmbH, Darmstadt, Almanya) kullanıldı. Sütleri AFM1 içeren annelerin kan örneklerinde lipit peroksidasyon düzeyleri ile AFM1 ilişkileri ortaya kondu. Örnekler 24 ayda 4 aşamada (literatür materyali toplama, deneysel uygulamalar, istatistiksel analizler ve rapor yazma aşaması) analiz edildi.

Bu çalışmada elde edilen sonuçlara göre süt ve süt ürünlerindeki aflatoksinler, halk sağlığını tehdit eden en büyük unsurlardan biri olduğu süt üretiminden tüketimine kadar her aşamada, resmi kontrol ve uygulama mekanizmalarının sağlanması ve sürdürülmesi için iyi tarım uygulamalarının benimsenmesi gerektiği söylenebilir.

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1. INTRODUCTION

The formation of aflatoxins is closely related to the development of molds Aflatoxins are secondary metabolites and are produced by *Aspergillus flavus* (*Asp. Flavus*) and *Aspergillus parasiticus (Asp. Parasiticus)*. (Jamali et al., 2012, Bennett, 2010; Iqbal et al., 2013).

This mycotoxin group, which has a toxic effect on the liver, is found in many cereal products due to improper storage, especially in cereal products, and in edible tissues of animals consuming contaminated cereal products. Milk and milk products containing aflatoxin residues; affects children who are more sensitive than adults. Therefore, aflatoxins in milk and dairy products consumed in large amounts constitute one of the important problems that threaten public health (Bennett, 2010; Coppock et al.2012;. Pitt, 2014).

When aflatoxin B1 and G1 are taken by the animals in the lactation period, a small portion (1-2%) of the aflatoxin M1 (AFM1) and M2 (AFM2) are excreted with milk. Aflatoxin M1 is 4-hydroxy aflatoxin B1, aflatoxin M2 is a derivative of 4-hydroxy B2. AFM1 is the toxic metabolite of AFB1, AFM2 is the hydroxylated form of AFB2 (Coppock et al.2012; Kalantari and Kalantari, 2007; Pitt, 2014).

This mycotoxin group, which is particularly toxic to liver, is found in many contaminated with products in poor storage conditions after harvesting of nutrients such as straw, grain, legumes, nuts, and peanuts. Therefore, if AFM1 residues are found in the most commonly consumed milk, this poses a potential risk to public health. Because aflatoxins cannot be completely destroyed from foods and feeds, It is emphasized by the relevant experts that measures should be taken by countries to limit the intake of aflatoxins via diet to minimize potential risks to health and to limit the consumption of aflatoxin containing foods at levels that can not be reduced. This is common in regions where the winter months are long. (Kamkar, 2008; Mulunda et al.,2013; Rahimi et al., 2009). The distribution of AFM1 in the milk of the animal fed with contaminated food is not homogeneous in milk (Ayyildiz, 2012; Galvano et al., 1996).

For babies' health, it is recommended that all infants receive breast milk during the first 6 months. Therefore, it is important to identify unwanted toxins and metabolites that can be found in human milk and pass on to the baby. Studies about the content of mycotoxins in the human milk are limited and show differences between countries.

Although aflatoxin B1 (AFB1) is a potent hepatotoxic and hepatocarcinogenic mycotoxin, the mechanism of cellular damage is not fully explained. A linear relationship between aflatoxin B1 and the amount of aflatoxin M1 in milk was reported (Kamkar et al., 2011; Tavakoli et al., 2013).

The level of malondialdehyde (MDA), which is an end product lipid peroxidation, is an indirect indicator of injury induced by reactive oxygen species (ROS). The most common radical damage in the organism is lipid peroxidation. In the cell membrane, oil (L.) radicals are formed by the emergence of a hydrogen from the fatty acids, and eventually the aldehydes, which are the cytotoxic products, form hydrocarbon gases such as pentane. Malonaldehyde, which is the most recent step of aldehydes from these toxic products, is used to determine lipid peroxidation. (Freeman and Crapo, 1981).

Mycotoxin, ochratoxin, zearalenone and deoxinivalenol levels were within different limits in previous studies. Variable findings on human milk aflatoxin levels indicate geographical differences in dietary aflatoxin exposure of nursing women, possibly depending on dietary habits. Breastfeeding is a necessary food for babies. For this reason, mothers need to stay away from aflatoxin as much as possible while feeding.

Aflatoxins are a group of mycotoxins having mutagenic, carcinogenic and immunosuppressive properties. Aflatoxin M1 (AFM1) is the main hepatic carcinogenic metabolite of Aflatoxin B1 (AFB1). Aflatoksin M_1 (AFM_1), Aflatoksin B_1 (AFB_1)' in başlıca hepatik karsinojenik metabolitidir. Feeding of milk-giving animals and mothers with food contaminated with AFB1, this toxin passes into milk as 1-6% AFM1. The presence of AFM1 in dairy products has proven to be a potential risk for human health, particularly for infants and children. Aflatoxins undergo metabolic changes in the liver and become toxic after being converted to various epoxide derivatives. These derivatives, which are responsible for toxic and carcinogenic effects, affect liver cells at the molecular level. It disrupts protein synthesis by inhibiting DNA and RNA synthesis, causing carcinogenic, genotoxigenic, teratogenic, nephrotoxigenic, hepatotoxigenic, reproductive diseases, immunosuppressive effects, mental retardation and development disorders. The short life of the pasture during the vegetation period of Kars and the cold and rainy period of the rest of the year brings the necessity of keeping the animal foods closed. Negative environmental conditions (humidity, heat, ventilation etc.) accelerates the formation of aflatoxins and passes directly to humans and animals in contact with these nutrients. It is inevitable that the aflakoxins that reach the mother and children fed the milk fed with these nutrients bring with them many negative health problems. In our country, very few studies have been found on AFM1 in breast milk and cow's milk. Therefore, a new and comprehensive study is needed. In the study, AFM1 ratio was determined in milk samples in the region. The relationship between lipid peroxidation and blood samples was determined in determining the transmission and protection methods of AFM1. By demonstrating the relationship between AFM1 and peroxidation, a new model for direct and carcinogenic effects of toxins will be contributed (Kamkar et al., 2011; Tavakoli et al., 2013; Freeman and Crapo, 1981).

Thus, problems that may occur due to toxins in milk and other foods have been identified, preventive measures have been taken, health and economic problems will be reduced.

Different AFM1 contamination levels were determined in many foods consumed in our country. Turkey also AFM 1 levels in food are important for biological metabolites and it is important that the specified standards. Prevention of aflatoxin contamination can be achieved by strict control over agricultural, production and storage conditions. It would also be helpful to disseminate the study to a large scale by taking into account the dimensions of rural and urban regions.

The aim of this study is to determine the presence of aflatoxins in milk and dairy products at all stages from milk production to consumption, draw attention to risk limits. In addition, blood samples were taken and lipid peroxidation levels were determined and their relationship with AFM1 was tried to be revealed.

2. MATERIAL AND METHODS

All experimental applications in the study were performed in the research laboratories of the Faculty of Veterinary Medicine, University of Kafkas and Faculty of Science.

Sampling

Fifteen milliliters of milk samples were taken using sterile milking machines from 80 breastfeeding mothers whose volunteering certificates were obtained and consuming cow's milk daily, and from 80 cows in the regions where the mothers lived. The collected milk was brought to the laboratory with a -4 oC cooler until the experiment day. The samples were frozen within one day and kept at -20 ° C until

analysis for aflatoxins and heavy metals. Blood samples taken into heparinized vacuuming tubes were divided into plasma and red blood cells by sniffering. The plasma was frozen (−20 ˚C) and stored until further analysis. RBC samples were washed three times with 0.9% NaCl and held for 20 hours at 20 ºC until analysis time.

Quantitative Analysis of AFM1 Concentration

Immunoanalytic german kit was used to measure the AFM1 levels in the milk taken in the designated regions (Ridascreen, Riedel-de Haen cat no: R1121 R-Biopharm GmbH, Darmstadt, Germany). Samples were centrifuged at 3500 g for 10 minutes and their oil-free sub-phases were taken and incubated in the dark for 30 minutes at room temperature (RT). After removing the supernatant, it was washed twice with 250 µl wash buffer. In the next step, 100 µl of peroxidase conjugate AFM1 was added to each sample and allowed to darken for 15 minutes. Then 1000 µl of substrate / cromogen was added. After waiting for fifteen minutes, the reagent was measured at 450 nm in ELISA after addition and shaking.

Measurement was performed by assuming the 0.5, 10, 20, 40 v3 80 ng / l (ppt) AFM1 standard provided by the kit. The AFM1 concentrations of samples were evaluated by using RIDASOFTVIN program, provided by R-Biopharm.

Analytical procedures

Lipid peroxidation was determined by measuring the amount of thiobarbituric acid-reacting substance (TBARS) in plasma according to the method of Placer (1966) et al.

The values of MDA reactive material were expressed in terms of TBARS (nmol/ml plasma).

Statistical Analysis:

In the analyzes made using the SPSS software program, P values below 0.05 were considered statistically significant.

3. RESULTS

AFM1 values and antioxidant relationships between lipid peroxidation showed differences in the study conducted with 80 cows in the same region and milk samples taken from 80 mothers fed daily cow milk in the same region.

Accordingly, the distribution of aflatoxin M1 in cow milk samples (Table.1), the distribution of aflatoxin M1 in breast milk samples (Table 2), and descriptive statistics for breast milk and cow milk samples are given in the results (Table 3). In addition, lipid peroxidation levels were determined in the examination of the blood samples taken (Table 4).

Among the investigated breast milk from volunteers, 40 out of 80 samples (58.75 %) were found to be contaminated with AFM1 with the range of 0.00 and 17.86 ng/l. In breast milk, the AFM1 milk sample was 55% while the average value was 3.87 ng / kg. MDA levels in the mother blood were found to be 5.20 1.41 nmol/ml plasma.

Table 1. Aflatoxin M1 distribution in cow milk samples

Samples	**AFM_1 (ng/kg)**	**Rate (%)**	**Total (%)**	**Min-Max (ng/kg)**
33	0.00	41,25	41,25	0.00-17.86
7	1.00-3.90	8,75	58,75	
17	4.00-6.90	21,25		
5	7.00-9.90	6,25		
8	10.00-12.90	10,0		
4	13.00-15.90	5,0		
6	16.00-18.90	7,5		
80(Total)		100.0		

Table 2. Aflatoxin M1 distribution in breast milk samples

Saples	**AFM1 (ng/kg)**	**(%)**	**(%)**	**Min-Max (ng/kg)**
36	0.00	45	45	0.00-6.68
28	1.00-3.90	35	55	
16	4.00-6.90	20		
80 (Total)		100.0	100.0	

Table 3. Descriptive statistics and test results for breast milk and cow milk samples

Samples	**n**	$\bar{x}$ **AFM_1(ng/kg)**	**SH**	**95%CI**	**t**	**p**
Breast milk	80	3.87	0.24	0.35-1.35	0.81	0.422
Cow milk	80	9.28	0.32	0.63-1.93		
$\bar{x}$ ***: mean,*** ***SH:*** *Standard error; 95%CI: 95% confidence interval*						

Table 4. MDA analysis results in mother blood samples

MDA (nmol/ml plasma **)** $\bar{X}$				
		S	**F/t**	**p**
Breast milk	5,20	1,41	0,63	0,54

4. DISCUSSION

Milk and dairy products, which make up a large proportion of the food source of vulnerable children, pose a significant risk to public health if they carry AFM1 residues.

Aflatoxin B1 is taken into the body with moldy grains, sacrificial products that are eaten by pregnant women and moldy feeds of animals. In some studies, some animals exposed to aflatoxins prenatally showed growth retardation as fetal. It was found that AFM1 was found in breastmilk and the mothers were exposed to

AFB1 by feeding them and therefore, babies fed with breast milk received AFM1 and they were found to have forward cancer risk. Due to the reasons mentioned above, many foods, especially breast milk and baby food have been investigated in terms of aflatoxin M1 content. Although there are very few studies about infant formula in our country, no study on breast milk was found. Today, people living in rural areas have very limited time to follow the developments in the field of health. With such projects, science will be transformed into products.

Aflatoxins are a group of mycotoxins having mutagenic, carcinogenic and immunosuppressive properties. These are the secondary metabolites of Aspergillus flavus, Aspergillus parasiticus and Aspergillus nomius. Aspergillus are major contaminants in foodstuffs. Major toxins AFB1 and AFB2 produced by Aspergillus flavus are AFG1 and AFG2 produced by Aspergillus paraciticus. Aflatoxin B1 is the most hepatotoxic and carcinogenic of the natural toxins. AFB1 has been under the control of the FDA in recent years because of being extremely toxic and extremely common in basic food and nutrients. Aflatoxin M1 is the main hepatic carcinogenic metabolite of Aflatoxin B1, fed to AFB1-contaminated foods of milk-giving animals and mothers.

In this first study in Kars, AFM1 analysis results of milk samples were found to be positive by 55%. The mean AFM1 concentration of our samples was 3.87 ± 0.24 ng / l. It is not possible to make local comparisons. Turkey and some other countries are working on this issue is available.

The presence of AFM1 in dairy products has proven to be a potential risk for human health, especially for infants and children. Considering that infants and children have to consume more milk than adults and their bodies are more sensitive than adults, it is emphasized that AFM1, which may occur in milk and dairy products, is an important source of health. Aflatoxins undergo metabolic changes in the liver and become toxic after being converted to various epoxide derivatives. These derivatives, which are responsible for toxic and carcinogenic effects, disrupt the protein synthesis by inhibiting DNA and RNA synthesis by affecting the liver cells at the molecular level (Tirmenstein & Mangipudy, 2014).

Aflatoxins are highly soluble in fat. They are rapidly absorbed from the area of exposure, particularly in the respiratory and gastrointestinal tract (Agag, 2004). Aflatoxins are more absorbed when ingested by the mouth. Aflatoxin M1 can be detected in milk within 6-24 hours after AFB1 is taken with feed and reaches maximum level in 12-48 hours (Kamkar et al. 2014; Tsakiris et al., 2013). Aflatoxins are primarily metabolized by the liver to the hydroxylate or the reactive epoxide for aflatoxin M1 which is less harmful (Bbosa et al., 2013).

The association of high amounts of aflatoxin hepatocellular carcinoma with food has been widely discussed in epidemiological studies. In the first investigations, samples from different geographical areas were studied and a connection was made with primary liver carcinoma. The important coincidence of the possible role of aflatoxin in hepatocellular carcinoma has led to studies on the association of unknown diseases such as Kwashiorkor and Reyeors syndrome. Although there was no general opinion on the definition of Kwashiorkor, the relationship between edema and hypoalbumin and kwashiorkor was accepted in international scientific circles. Many international studies have shown the relationship between aflatoxin and kwashiorkor. Therefore, accurate exposure of AFM1 exposure and necessary precautions should be taken.

According to Turkish Food Codex Contaminants Regulation, the maximum limit of aflatoxin M1 in milk used in the production of raw milk, heat-treated milk and milk-based products is 0.050 μg / kg. This level is 0.025 μg / kg in infant formulas and continuation

formulas (Ulven et al., 2011). It is known that AFM1, which has a toxic effect on liver, has many negative effects on health (Bbosa et al., 2013; Abbès et al., 2010; Williams et aı. 1998).

In our study, AFM1 levels in breast milk were determined as 3.87 ng / l. and many other studies (Turkey, Cyprus, Iran, Colombia and Cyprus) showed a significant parallelism (Diaz and Sanchez, 2015; Atasever et al., 2014; Mahdavi et al., 2010; Jurewicz et al., 2013; Kunter et al, 2016). Researchers found AFM1 levels in breast milk between 60.90 and 299.99 ng/l in Turkey (Gürbay et al., 2010). Some other studies reported that the mean of AFM1 levels was found to be 401 ng/l in Sudan (Elzupir et al., 2012), 664 ng/l in Thailand (El-Nezami et al., 1995), ng/l in Australia, and 25 ng/l in Nigeria (Adejumo et al., 2013).

In this study, AFM1 level in cow milk was found to be 9.28 ng/kg. In our study, AFM1 values in both breast milk and cow milk were low. This may be due to the climate and geography of the region. That is to say, the incidence of aflatoxin in foods in the cold regions is less than the hot regions.

There is little research showing the relationship between blood lipid peroxidation and blood milk contaminated with AFM1. In this study MDA and AFM1 contamination levels found in breast milk were low. In the literature, different studies are compatible with this study (Shen et al.,1994; Souza et al., 1999; Grintzalis et al., 2014)..

In all studies, there was a parallel relationship between milk AFM1 levels and blood MDA levels. In our study, MDA levels in the mother blood were found to be 5.20 1.41 nmol/ml plasma.

Milk and dairy products containing aflatoxin; children who are more sensitive than adults are also consumed in large amounts. Therefore, aflatoxins in milk and dairy products are one of the major problems that threaten public health. It has been determined that AFM1 levels in commercially consumed milk are within legal limits. However, it is still stated that it may pose a risk for children fed with milk for a long time (Madali and Ayaz, 2017).

In our country, studies on nutrients in various regions showed that the rates of alfatoxin were high. Therefore, we needed to make this study because of possible contamination through food chain. If aflatoxin is present in food in a region, all living things in this region, especially infants, are at risk.

This study is the first to use breast milk and cow's milk in the region. For this reason, we think that it will be an important guide to studies on breast milk and other dairy products. In addition, taking into account the seasonal changes in the regions in the future, making new measures and practices regarding the storage, transportation and preservation methods of winter animal food will be important in terms of developing health and agricultural policies in preventing import and export losses.

5. REFERENCES

Abbès S, Salah-Abbès JB, Abdel-Wahhab MA, & Ouslati R. (2010). Immunotoxicological and biochemical effects of Aflatoxins in rats prevented by Tunisian Montmorillonite with reference to HSCAS. *Immunopharmacology and Immunotoxicology. 32*(3), 514-522.

Adejumo O, Atanda O, Raiola A, Somorin Y, Bandyopadhyay R, Ritien A. (2013). Correlation between aflatoxin M1 content of breast milk, dietary exposure to aflatoxin B1 and socioeconomic status of lactating mothers in Ogun State, *Nigeria. Food Chem Toxicol.* 56:171–177. doi: 10.1016/j.fct.2013.02.027.

Agag B. (2004) Mycotoxins in foods and feeds: 1-aflatoxins. Ass. Univ. Bull. *Environ Res.* 7(1), 173- 205.

Atasever M., Yildirim Y., Atasever M., Tastekin A. (2014). Assessment of aflatoxin M1 in maternal breast milk in Eastern Turkey. *Food Chem Toxicol*. 66:147–149. doi: 10.1016/j.fct.2014.01.037.

Ayyildiz T. (2012). Organik Süt ve Süt Ürünlerinde Aflatoksin M1 Varlığının Araştırılması. (Yüksek Lisans Tezi Yüksek Lisans Tezi), Celal Bayar Üniversitesi, Manisa.

Bbosa G.S, Lubega A, Kyegombe DB. Lubega A, Ogwal Okenng J, Anokbonggo WW, Kyegombe DB. (2013). Review of the biological and health effects of aflatoxins on body organs and body systems. In M. Razzaghi-Abyaneh (Ed.), *Aflatoxins - Recent Advances and Future Prospects*. 239-266.

Bennett JW. (2010). An overview of the genus Aspergillus, *Caiser Academic Press*, Portland, ISBN: 978-1-904455-53-0.

Coppock RW, Christian R G, & Jacobsen BJ. (2012). Chapter 88- Aflatoxins. In R. C. Gupta (Ed.), *Veterinary Toxicology* (Second Edition*)*, Boston: Academic Press. (pp. 1181-1199).

Diaz GJ, Sánchez MP. (2015). Determination of aflatoxin M 1 in breast milk as a biomarker of maternal and infant exposure in Colombia. Food Addit Contam Part A. doi:10.1080/19440049. 1049563, 0049: 150511035939005.

El-Nezami HS, Nicoletti G, Neal GE, Donohue DC, Ahokas JT. (1995). Aflatoxin M_1 in human breast milk samples from Victoria, Australia and Thailand, *Fd. Chem. Toxic*. 33(3): 173-179.

Elzupir AO, Abas ARA, Fadul MH. Eh M. Modwy AK, Ali NM, Jadian AFF, Ahmed N A A, Adam S Y A, Ahmed N A M, Khairy A, Khalil E AG. (2012). Aflatoxin M1 in breast milk of nursing Sudanese mothers. *Mycotoxin Res.* 28:131–134. doi:10.1007/s12550-012-0127-x

Freeman B.A, Crapo J. (1982). Biology of disase, free rad cals and tissus injury Lab. *Invest.* 47(5), 412-425.

Galvano F., Galofaro V., & Galvano G. (1996). Occurrence and stability of aflatoxin M1 in milk and milk products: a worldwide review. *Journal of Food Protection*. 59(10), 1079-1090.

Grintzalis K., Vernardis SI., Klapa MI. and Georgiou CD. (2014). Role of Oxidative Stress in Sclerotial Differentiation and Aflatoxin B1 Biosynthesis in Aspergillus flavus. Appl Environ Microbiol. 80(18): 5561–5571.

Gürbay A, Sabuncuoğlu SA, Girgin G, Sahin G, Yiğit S, Yurdakök M, Tekinalp G. (2010). Exposure of newborns to aflatoxin M1 and B1 from mothers' breast milk in Ankara, Turkey. *Food Chem Toxicol.* 48(1):314-9. doi: 10.1016/j.fct.2009.10.016.

Iqbal S.Z, Asi M.R, & Ariñ A. (2013). Aflatoxins. In S. Maloy & K. Hughes (Eds.), *Brenner's Encyclopedia of* Genetics, USA: Institute of Molecular Scieces. (2 ed., pp. 43–47).

Jamali M, Ebrahimi M.A, Karimipour M, Shams Ghahfarokhi M, Dinparast Djadid N, Kalantarı S, Pilehvar Soltanahmedi Y, Amani A, Razzaghi Abyan (2012). An insight into the distribution, genetic diversity, and mycotoxin production of Aspergillus section Flavi in soils of pistachio orchards. *Folia Microbiologica*, *57*(1), 27-36.

Jurewicz J, Radwan M, Sobala W, Ligocka D, Radwan P, Bochenek M & Hanke W. (2014). Lifestyle and semen quality: role of modifiable risk factors. *Syst Biol Reprod Med.* 60(1):43-51. doi: 10.3109/19396368.2013.840687.

Kalantari H, & Kalantari G. (2007). Evaluation Of Aflatoxins Contamination In Baby Food Supplements (Mamana & Ghoncheh). *Jundushapur Journal of Natural Pharmaceutical Products. 6*(1), 42-50.

Kamka A, Khaniki G.R. J, & Alavi S. (2011). Occurrence of aflatoxin M1 in raw milk produced in Ardebil of Iran. *Iranian Journal of Environmental Health Science & Engineering*, 8(2), 133-140.

Kamkar A, Fallah A. A., & Mozaffari Nejad A.S. (2014). The review of aflatoxin M1 contamination in milk and dairy products produced in Iran. *Toxin Reviews*, 33(4), 160-168.

Kamkar A. (2008). Detection of aflatoxin M1 in UHT milk sample by ELISA. *J Vet Res.* 63(2), 7-12.

Kunter İ. Hürer N, & Gülcan H O. (2016). Assessment of Aflatoxin M1 and Heavy Metal Levels in Mothers Breast Milk in Famagusta,

Cyprus, *Biol Trace Elem Res,* DOI 10.1007/s12011-016-0750-z.

Madali B, Ayaz A. (2017). Aflatoxin M1 in Dairy Products Aflatoxin M1 in Dairy Products: Exposure and Health Risks, H.Ü. *Sağlık Bilimleri Fakültesi Dergisi* 4(1):1-14.

Mahdavi R, Nikniaz L, Arefhosseini SR, Vahed Jabbari M. (2010). Determination of aflatoxin M1 in breast milk samples in Tabriz- Iran. *Matern Child Health J*. 14:141–145. doi:10.1007/s10995- 008-0439-9.

Mulunda M, Bakunzi F, Motsei L, Bakunzi F. (2013). A Decade of Aflatoxin M1 Surveillance in Milk and Dairy Products in Developing Countries (2001-2011): A Review. In H. A. Makun (Ed.), *Mycotoxin and Food Safety in Developing Countries*. 39-60. Croatia: INTECH Open Access Publisher.

Pitt J I. (2014). Mycotoxins: Aflatoxins. In Y. Motarjemi (Ed.), *Encyclopedia of Food Safety*, 289-294) Waltham: Academic Press.

Placer ZA., Cushman LL., Johnson BC. (1996). Estimation of product of lipid peroxidation (Malonyl dialdehyde) in biochemical systems, *Anal Biochem*. 16: 359-364.

Rahimi E, Shakerian A, Jafariyan M, Ebrahimi M, & Riahi M. (2009). Occurrence of aflatoxin M1 in raw, pasteurized and UHT milk commercialized in Esfahan and Shahr-e Kord, Iran. *Food Security.* 1(3), 317-320.

Shen HM., Shi CY., Lee HP., Ong CN. (1994). Aflatoxin B1-induced lipid peroxidation in rat liver. *Toxicol Appl Pharmacol.* 127(1):145-50.

Souza MF., Tomé AR., Rao VS. (1999). Effects of aluminosilicates on lipid peroxidation and antioxidants in aflatoxin B1-induced tissue injury in chickens. *J Pharm Pharmacol.*51(2):125-9.

Tavakoli H.R., Kamkar A., Riazipour M., Mozaffari Nejad A, & Rafati H. (2013). Assessment of aflatoxin M1 levels by Enzyme-linked Immunosorbent Assay in yoghurt consumed in Tehran, Iran. *Asian J Chem.* 25, 2836-2838.

Tirmenstein M.A., & Mangipudy R. (2014). Aflatoxin. In P. Wexler (Ed.), *Encyclopedia of Toxicology*, 104-106. Oxford: Academic Press.

Tsakiris I.N, Tzatzarakis M.N., Alegakis AK, Vlachou M. (2013). Risk assessment scenarios of children's exposure to aflatoxin M1 residues in different milk types from the Greek market. *Food and Chemical Toxicology, 56*, 261-265.

Ulven S.M, Kirkhus B, Lamglait A, Basu S, Elind E, Haider T, Berge K, Vik H, Pedersen J. (2011). Metabolic effects of krill oil are essentially similar to those of fish oil but at lower dose of EPA and DHA, in healthy volunteers. *Lipids*, 46(1), 37-46.

Williams J. H., Phillips TD., Jolly PE, Stiles JK, Jolly CM, Aggarwal D. (2004). Human aflatoxicosis in developing countries: a review of toxicology, exposure, potential health consequences, and interventions. *The American Journal of Clinical Nutrition. 80*(5), 1106- 1122.

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Original Article

A Review of Glass Material Properties Effects on PV/T Systems

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Abstract: Energy has become an indispensable part of our lives today and our energy needs are increasing day by day with technological developments. In addition, the rapid depletion of natural resources and the deterioration of the ecological balance forced humanity to find and use new and clean energy resources. Renewable energy sources gained importance rapidly and dozens of studies were conducted on them. Photovoltaic panels are the basis of these studies, which started with the production of electricity from solar energy. Photovoltaic panels consist of many solar cells. The energy coming from the sun with photons is directly converted into electrical energy in these cells. The studies that started with the aim of generating electricity with photovoltaic panels were later developed to gain thermal efficiency in the same system and hybrid systems called Photovoltaic-Thermal were created. Photovoltaic-Thermal Systems (PV / T) transfers the thermal energy generated in photovoltaic panels to one or more fluids and aims to increase system efficiency by using the thermal energy generated during electricity generation.
In this study, it will be investigated how the properties of glass, which is the first part of solar energy, affect the thermal and electrical efficiency of a PV / T system working with air and water fluids. Three glasses were selected in the system and experiments were conducted under similar outdoor conditions. The experiment data were transferred to the computer environment by means of a program specially written for the system and daily. The electrical and thermal efficiency of the transferred data was calculated by mathematical formulation, and it was investigated how glasses affect the efficiency of the system. This system can be further developed and used in daily use in hotels and dormitories. The study will also trigger the use of alternative glasses with different properties in the system and will take a step towards increasing efficiency.

Cam Malzeme Özelliklerinin PV/T Sistemleri Üzerindeki Etkilerinin Araştırılması

Anahtar Kelimeler:
Cam Malzeme Özellikleri
PV/T Sistemleri
Yenilenebilir Enerji
Güneş Enerjisi
Verim Araştırması

Özet: Enerji bugün hayatımızın vazgeçilmez bir parçası haline gelmiştir ve teknolojik gelişmelerle birlikte enerji ihtiyaçlarımız her geçen gün artmaktadır. Buna ek olarak, doğal kaynakların hızla tükenmesi ve ekolojik dengenin bozulması insanlığı yeni ve temiz enerji kaynakları bulmaya ve kullanmaya zorlamıştır. Yenilenebilir enerji kaynakları hızla önem kazanıp üzerinde onlarca çalışma yapılmıştır. Güneş enerjisinden elektrik üretimi ile başlayan bu çalışmaların temelinde fotovoltaik paneller yer almaktadır. Fotovoltaik paneller birçok güneş hücresinden oluşur. Güneşten fotonlarla gelen enerji doğrudan bu hücrelerde elektrik enerjisine dönüştürülür. Fotovoltaik panellerle elektrik üretme amacı ile başlayan çalışmalar, daha sonra aynı sistemde termal verim de kazanmak amacıyla geliştirilmiş ve Fotovoltaik-Termal adı verilen hibrit sistemler oluşturulmuştur. Fotovoltaik-Termal Sistemler (PV/T), fotovoltaik panellerde üretilen termal enerjiyi bir ya da daha fazla akışkana aktarır ve elektrik üretimi sırasında oluşan ısıl enerjiyi de kullanarak, sistem verimini artırmayı amaçlar.
Bu çalışmada, hava ve su akışkanları ile çalışan bir PV/T sisteminde, güneş enerjisini karşılayan ilk kısım olan cam özelliklerinin, sistemin termal ve elektrik verimliliğini nasıl etkilediği araştırılacaktır. Sistemde üç adet cam seçilmiş ve benzer açık hava koşullarında deneyler yapılmıştır. Deney verileri günlük ve sistem için özel yazılmış olan program aracılığıyla bilgisayar ortamına aktarılmıştır. Aktarılan veriler matematiksel formülizasyon ile elektriksel ve termal verim hesaplanıp camların sistemdeki verime nasıl etki ettiği araştırılmıştır. Bu sistem daha da geliştirilerek otellerde ve yurtlarda günlük kullanımda kullanılabilir. Çalışma aynı zamanda farklı özelliklerde olan alternatif camların sistemde kullanılmasını da tetikleyebilecektir ve verimi artırmaya yönelik bir adım atacaktır.

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1. INTRODUCTION

Solar energy is used in two different ways. These are thermal solar systems where the incoming solar radiation is converted to heat and photovoltaic (PV) systems where solar energy is converted to electrical energy. Thermal solar systems are used in applications such as water heating, space heating and power generation. Photovoltaic systems are used in clocks, calculators and large-scale power generation applications. Hybrid systems in which these two systems are used together are called photovoltaic/thermal (PV/T) systems. The aim of these systems is to obtain both heat and electrical energy from a single system. (Abu Bakar M.N. et al., 2013)

In recent years, PV/T technology has attracted worldwide attention. Many researches conduted by researchers such as Xondag H.A. (2008), Tyagi et al. (2012), Hasan et al. (2010), Chaar et al. (2011).

In the reported PV/T systems, both air and water were used in the thermal part of the system. A number of design principles and solar cells have been developed that capture light and effectively convert it into electrical current. Overall progress in this area has been studied by many researchers.

N.A. Manaf et al. (2013), studied the air and water based PV / T system. In their studies, they determined the effects of single-pass and two-fluid solar collectors on total thermal equivalent efficiency performance and electrical efficiency using MATLAB simulation program. In the simulation results, it was observed that the system works more efficiently with water fluid compared to only air fluid.

Kalogirou and Tripanahnostopoulos (2006), in their studies, hybrid photovoltaic/ thermal (PV/T) systems consisting of polycrystalline-silicon (pc-Si) and amorphous-silicon (aSi) coupled to the thermal collector, installed and tested at the University of Patras, TRNSYS It has been modeled and simulated with the program. As a result of the study, they reported that the PV system produced 38% more electricity than the PV/T system, but the PV/T system met the hot water need of the building to which it is connected.

There's also many research articles about PV/T systems in Turkey. Ahmet Kabul and Fatih Duran (2014) aimed to increase the efficiency, which decreases as a result of the increase in panel temperature during electricity generation from solar energy, by cooling the panel with water. With this goal, they cooled the panel by placing pipes on the back surface of the photovoltaic panel and passing water through the pipes installed. They circulated the water whose temperature increased by taking the heat in the panel in a water tank and transferred it to the water in the tank. Thus, they both increased the efficiency of the system and managed to provide hot water. As a result of their experiments, they obtained approximately 35% power and 7% efficiency increase in electricity generation.

Mert Gürtürk et al. (2011), investigated the effects of temperature changes on glasses used in photovoltaic modules in their study. They chose 2 glass types with 4 mm thickness and different transmittance values, first cooling and then heating. As a result, they observed that the energy efficiency varied between 1.24% and 2.06% with the measurements made on the reference solar glass placed on the solar cell.

However, no detailed and comprehensive study on two-fluid PV/T systems was obtained by comparing experimental results with numerical results and investigating the effect of the type of glass used on these systems to efficiency. This study aims to fill the gap on this subject.

2. MATERIAL AND METHOD

Konya Province was chosen for the study. Konya has a latitude of 37˚N and a longitude of 32˚E. For this reason, the inclination angle of the system was chosen as 33° throughout the year. Irradiation map of Konya is as follows:

Fig.1. Konya Province Solar Irradiation Map

Three types of glass were selected for the experiment. The first glass is 4 mm transparent flat glass. Three experiments were performed with this glass. The second glass is 4 mm low-e coated glass. This glass is coated with metal oxide and keeps the thermal gain inside. The third and last glass is double transparent glass cut in thickness of 4+12+4 mm. One day experiment was carried out with this glass. There is an air gap between them. All windows are the same size and 808 * 1630 mm. After the experiments were completed with one glass, the glass was disassembled and the other glass was installed. The same weather conditions were tried to be provided.

The system we used has 3 continents: cooling system, electrical system and data system. The test apparatus is shown in the figure 2, the system comprises these parts (Atmaca M., Pektemir İ.Z. (2018):

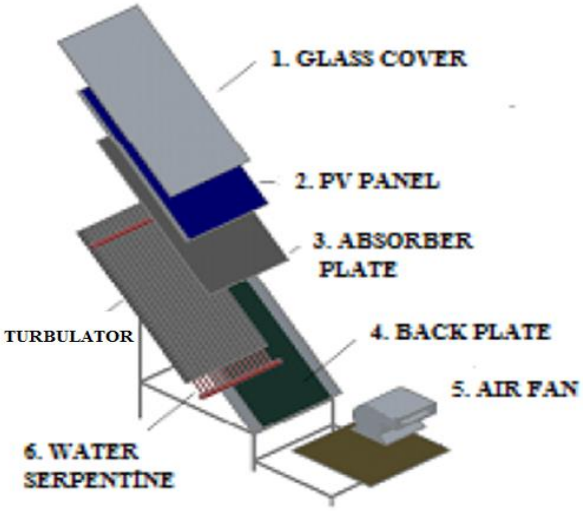

Fig.2. Parts of the System

1)Glass Cover: 4 mm transparent flat glass, 4 mm low-e coated glass, 4+12+4 mm double transparent glass, all three are has same size 808*1630 mm.

2) PV Panel: TPSM6U Monocrystal 200 W, 200 W, V_{oc}:45.4 V, I_{sc}:5.77 A.

3)Absorber Plate: 0.4 mm thickness, Aluminum alloy (200W/mK), painted to black.

4)Back Plate: Steel, 2 mm thickness.

5)Air fan: With electronic communication system.

6)Water Serpantine: Collector outer diameter: 32 mm, pipe outer diameter: 10 mm, material: copper (394 W/mK).

7)Turbulator: honeycomb, thickness 1.5 mm, length 1580 mm, material: aluminum (200W/mK).

Cooling system explained in figure 3 (Atmaca M., Pektemir İ.Z., 2019). The system can work with both air and water. In this review, system worked with only air cooling.

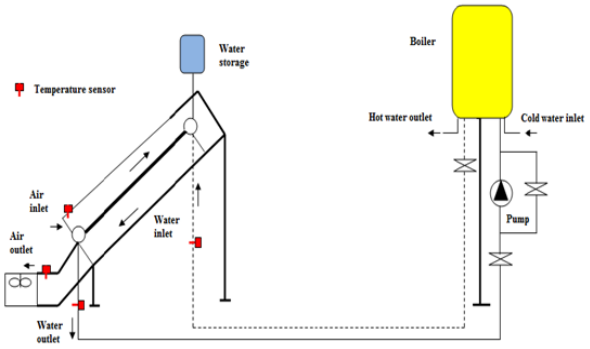

Fig.3. Air and Water Cycle

To receive and process data, PT-100 temperature sensors, air speed sensor for measuring air velocity, pyronometer for solar radiation, humidity and temperature sensors for comparing outdoor weather conditions, anemometer for measuring wind speed velocity values are used. And for electricity, current and voltage sensors are used. The data were transferred to the computer with a software specially prepared by İztekno Company and examined. This program shows all the data needed in the experiment such as outdoor temperature, irradiance values, wind speed and amper values produced in the system. Program also shows this values in a tables and allows us to track minute to minute changes. Figure 4 shows the interface of the program.

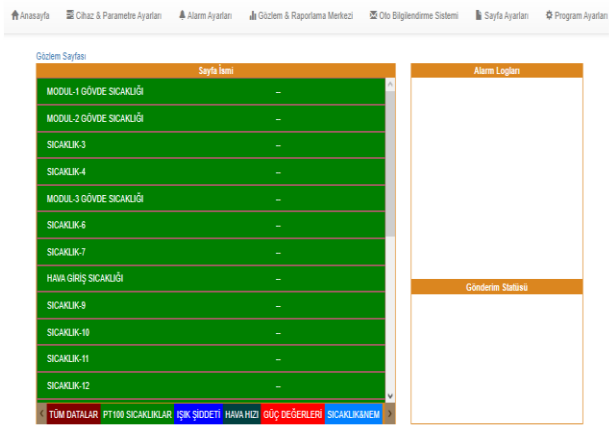

Fig. 4. Interface of the program to which data is transferred

The electrical circuit has a 1000 W full sine inverter, a 12/24 V 20 A charge controller, 6 12 V, 102 Ah batteries. Figure 5 show these devices. The electricity produced in the system is made usable in the connected devices and panels. Since the system is not connected to the grid, the energy requirement of the batteries has been eliminated even when the energy is insufficient. [11-12]

Fig. 5. Electrical Circuit of the System

The experimental results were calculated using the following three formulas and comparisons were made accordingly:

$Q = I_t \cdot A_p$ (1)

Q = Gained energy from the solar power (W)

I_t = Average irradiance value calculated according to the figure (W/m^2)

A_p = Surface area of the panel: 1.2766 m^2

$P_{th\text{-}a}=\dot{m}_{air} x C_{p(air)} x (T_o - T_i)$ (2)

$P_{th\text{-}a}$= Air circuit power of the system (W)

$\dot{m}_{air} = V_{air} . A_h . \rho$ (kg/s)

V_{air} = Air velocity (m/s)

A_h= Cross-sectional area of the air duct =0.6x0.35 = 0.21 m^2

ρ = Air density (kg/m^3)

$C_{p(air)}$ = 0,24 kcal/kg.°C

T_o= Air out temperature (°C)

T_i= Air in temperature (°C)

η(%)=(Eq 2/Eq 1)x100 **(3)**

η: System Efficiency

3. RESULTS

The experiments and the results of the experiments are examined in this section. Experiments under similar weather conditions; outdoor temperature values were made close to each other, on windless and windy days, under open air conditions. Experimental data were examined separately for three glasses; The first of these three glasses is 4 mm flat glass. The second test glass was selected as 4 mm low-e coated glass. The third glass used was chosen as 4+12+4 mm ordinary double glazing and efficiency calculations were made for each glass separately. In the results section, the results of the experiments are examined comparatively. (Akıskalıoğlu E.)

Experiments with 4 mm flat glass

The first experiment was held in 25.08.2019. Data for this experiment are given below:

Outdoor Temperature: Outdoor temperature data has been added to indicate similar weather conditions. Figure 6 shows the air temperature on August 25, 2019 between 10.00 and 12.00. The maximum temperature was 28.2 ° C at 11.50 h and the minimum temperature was 25.8 °C at 10.04 h. According to the figure 6, the average temperature value was calculated as 27.4°C.

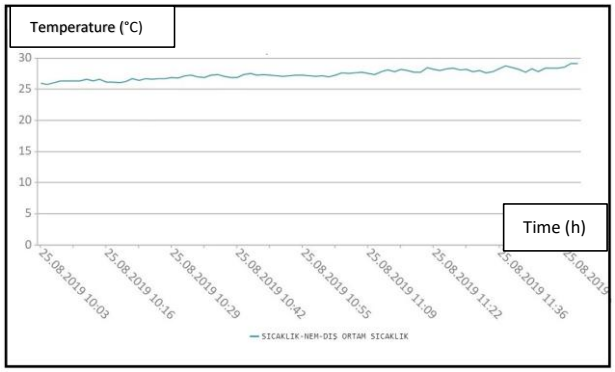

Fig. 6. Outdoor Temperature Values on 25.08.2019 (°C)

Irradiation Value: The values read from the pyranometer in the same time zone, between 10.00-12.00 pm are shown in Figure 7. The minimum irradiation value is 1003 W/m^{2}K at 10.00 and the maximum irradiation value is measured as 1247 W/m^{2}K at 11.49 when the sun goes upright. The average of all values was calculated as 1136 W/m^{2}K with Microsoft Excel.

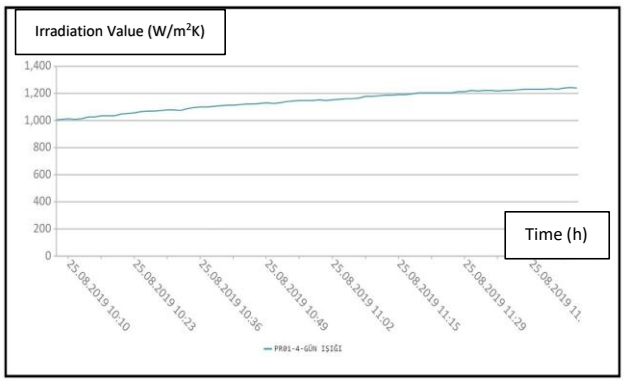

Fig.7. Irradiation Value on 25.08.2019 (W/m^{2}K)

Air Speed: The fan is operated at 15 watts. The differences are caused by outdoor wind. Outdoor wind speed was measured at 15 minute intervals. On August 25, 2019, the average wind speed in Konya was determined as 0.3 m/s. The average air velocity circulating in the system is calculated by using Microsoft Excel according to figure 8 and found to be 0.48 m/s.

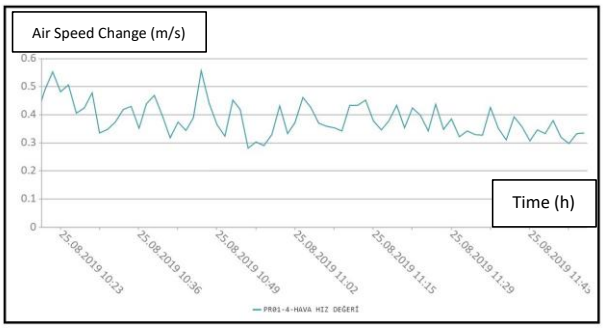

Fig. 8. Air Speed Change on 25.08.2019

Panel Current Value: The electrical current value formed on the panel with flat glass on August 25 is given in figure 9. These values are added to compare whether other glasses affect the current. The current value of the panel increased with the rising of the sun to the upright position. The maximum value was measured as

4.24 amps and the minimum value was 3.44 amps. The current comparison will be examined in the results section.

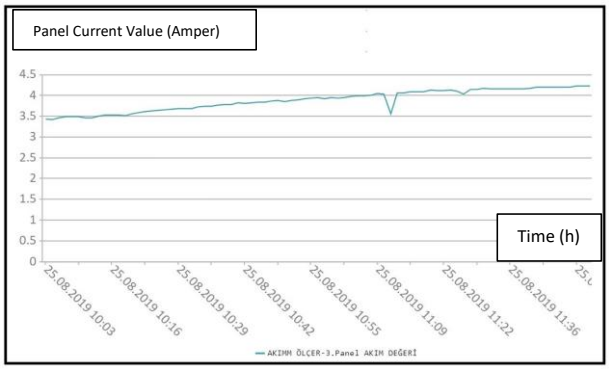

Fig.9. Ampere Change on 25.08.2019

Air Inlet-Outlet Temperature Values: Air inlet-outlet temperatures are shown in Figure 10. The fan lowered the air inlet temperature after switching on and transferred the incoming air temperature to the outlet air. The temperature difference 5.4°C was calculated as the Microsoft Excel program.

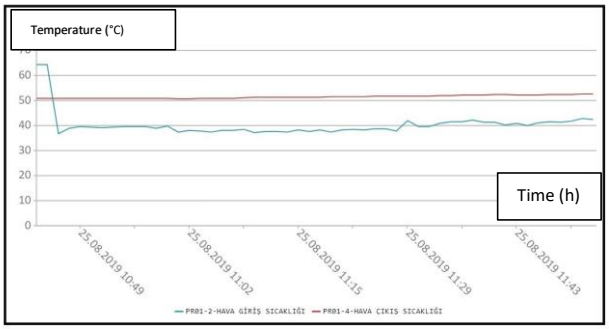

Fig. 10. Air Inlet and Outlet Temperature Values (°C)

System efficiency is calculated from the following formula according to the values read in the tables.

$Q = 1136 * 1.27 = 1442.72$ W **(1)**

$P_{th\text{-}a}=0.21*0.48*0.24*4.18*1000*5.4=728.08$ W **(2)**

$\eta(\%)= 50.46.$ **(3)**

The second experiment was held in 15.09.2019. Data for this experiment are given below:

Outdoor Temperature: In the experiment conducted on 15.09.2019, as a result of outdoor temperature measurements, the minimum temperature value was measured as 22.9°C and the maximum temperature value was measured as 24.9°C and shown in Figure 11. Average outdoor temperature was calculated as 23.6°C with Microsoft Excel.

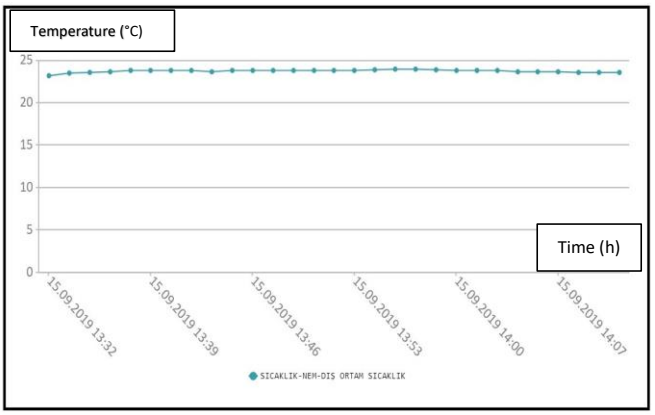

Fig.11. Outdoor Temperature Values on 15.09.2019

Irradiation Value: On 15 September 2019 the experiment was conducted between 13.30 and 14.30. Therefore, the graph produced a decreasing radiation values. The values read from the pyranometer are shown in figure 12. One hour average radiation value was calculated as 392 W/m^{2}K using excel program.

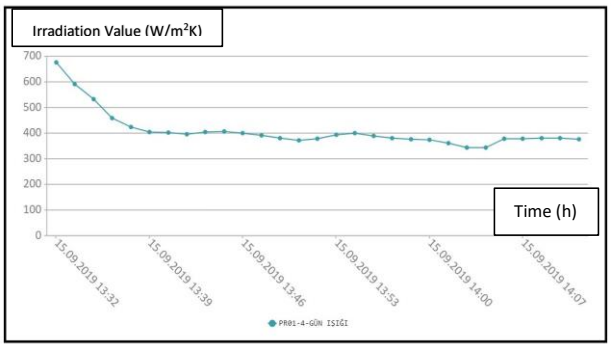

Fig.12. Irradiation Value on 15.09.2019 (W/m^{2}K)

Air Speed: The fan is operated at 15 watts. The speed change of the air circulating in the system on September 15, 2019 is shown in Figure 13. The average air velocity circulating in the

system was calculated as 0.57 m/s with Microsoft Excel.

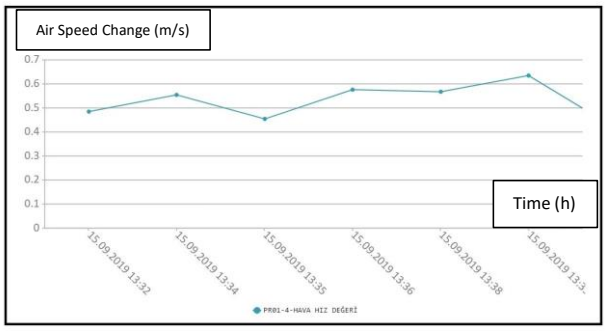

Fig. 13. Air Speed Change on 15.09.2019 (m/s)

Panel Current Value: The change in the current value of the panel on the date of 15 September is given in Figure 14. The maximum current value in the panel was 1.93 amps at 13.30 and then decreased.

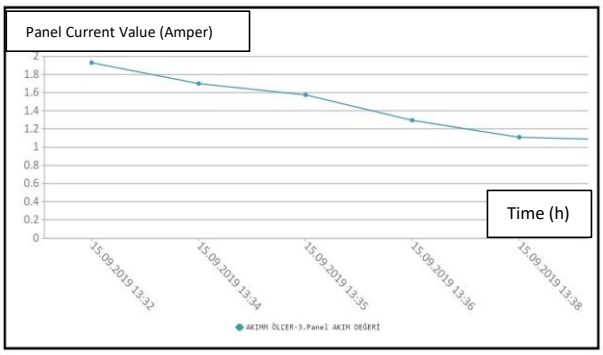

Fig.14. Ampere Change on 15.09.2019

Air Inlet-Outlet Temperature Values: Air inlet-outlet temperatures are shown in Figure 15. The temperature difference was calculated as 1.7°C using Microsoft Excel.

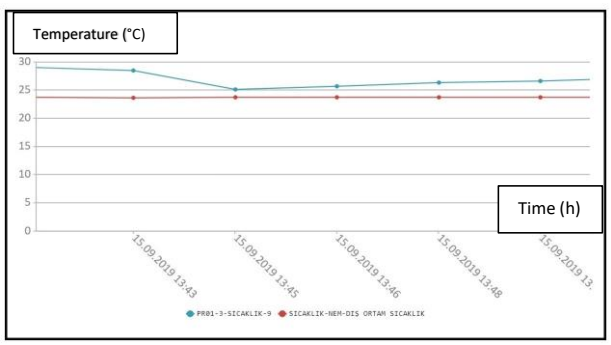

Fig. 15. Air Inlet and Outlet Temperature Values (°C)

Second the experiment conducted on September 15, 2019,the system efficiency was calculated as follows:

$Q = 429*1.27 = 544.83$ W **(1)**

$P_{th-a}=0.21*0.57*0.24*4.18*1000*1.7=204.14$ W **(2)**

η (%)= 37.46 **(3)**

The third experiment was held in 16.09.2019. Data for this experiment are given below:

Outdoor Temperature Value: The change of outdoor temperature according to hours on September 16 is shown in figure 16. The outdoor temperature is measured as minimum 18.3°C at 16.49 pm and maximum 24.1°C at 15.57 pm. The average outdoor temperature was calculated as 22.9°C.

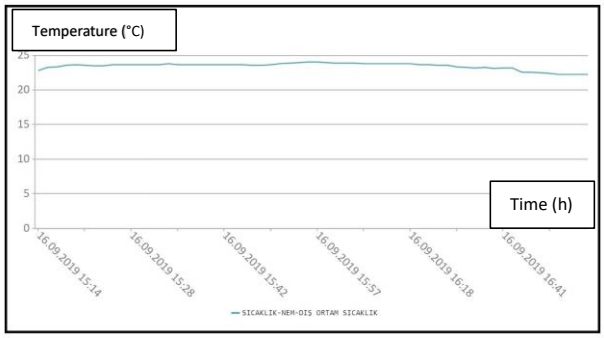

Fig.16. Outdoor Temperature Values on 16.09.2019

Irradiation Value: Values read from pyranometer are shown in figure 17. The average radiation value was calculated as 745 W/m^2K in excel program.

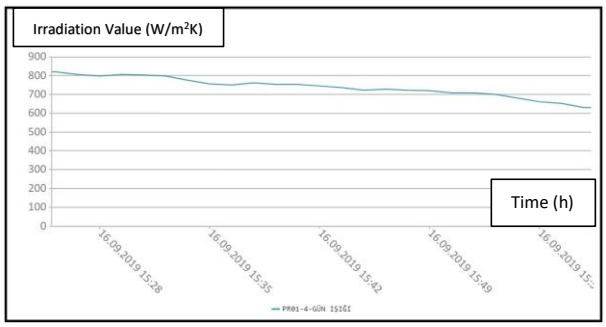

Fig.17. Irradiation Value on 16.09.2019 (W/m^2K)

Air Velocity: In this experiment, the fan is not operated due to the decrease in the power of the batteries and the charge. Outdoor wind speed measured by 15 minutes and calculated as 0.7 m/s.

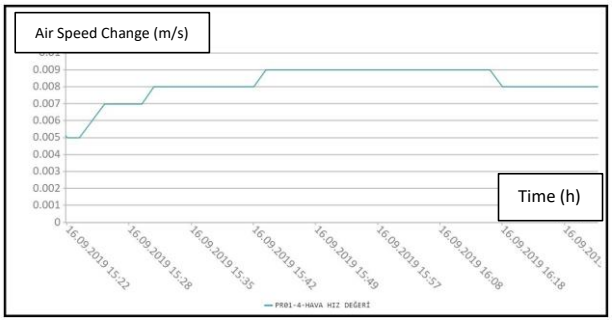

Fig. 18. Air Speed Change on 16.09.2019 (m/s)

Panel Current Value: The change of panel current measurement according to time is given in figure 19. The peaks in the table are due to the fact that the experiment was carried out on a cloudy day. The moments when the clouds were closing the sun reflected to the figure 19 as peak. The maximum ampere readings were calculated as 2.9 amps at 15.15 and the minimum amps as 0.39 amps at 16.12. In the conclusion section, comparisons will be made.

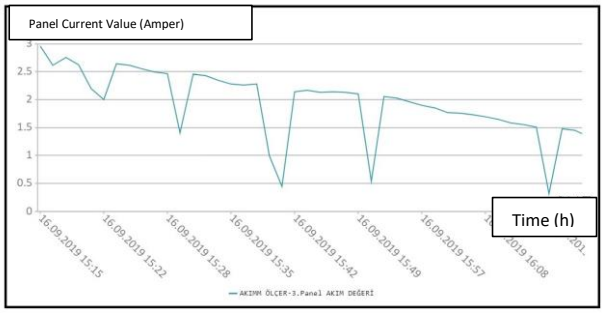

Fig.19. Ampere Change on 16.09.2019

Air Inlet - Outlet Temperature Values: Change of air inlet-outlet temperatures are shown in figure 20. The temperature difference was calculated as 3.6°C.

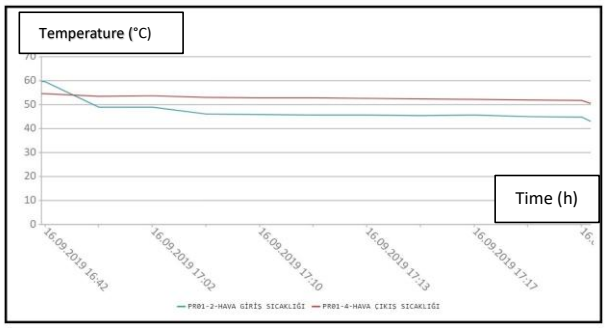

Fig.20. Air Inlet and Outlet Temperature Values (°C)

The efficiency of the system in the experiment conducted on 16 September 2019 was calculated as follows:

$Q = 745 * 1.27 = 946.15$ W **(1)**

$P_{th-a}=0.21*0.7*\ 0.24\ *\ 4.18*1000*3.6=505.6$ W **(2)**

$\eta\ (\%)= 53.44$ **(3)**

As a result of 3-day experiments with 4 mm flat glass, the minimum efficiency of the system was %37.46 and the maximum system efficiency was calculated as %53.44. Average system efficiency was calculated as %47.12. After these experiments, 4 mm flat glass was disassembled and replaced with mm low-e coated glass. Experimental data with this glass are given below.

Experiments with 4 mm low-e coated glass

The first experiment was held in 12.10.2019. Data for this experiment are given below:

Outdoor Temperature: The outdoor temperature was 28.4°C at 15.00 and 22.8°C at 17.24. The variation of the values is shown in Figure 21, with an average temperature of 26.2°C.

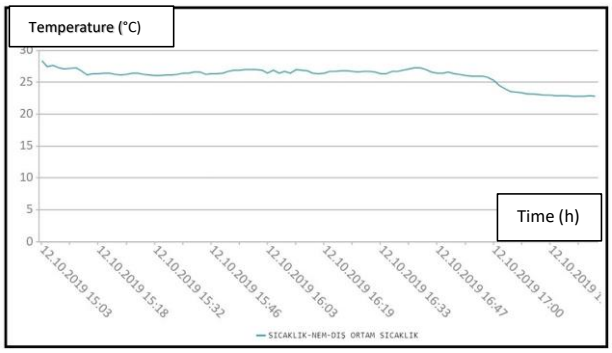

Fig.21. Outdoor Temperature Values on 12.10.2019

Irradiation Value: Values read from pyranometer are shown in figure 22. The maximum radiation value was 848 W/m^{2}K at 15.00 and the minimum radiation value was 594 W/m^{2}K at 16.03. The average radiation value was calculated as 770 W/m^{2}K in excel program.

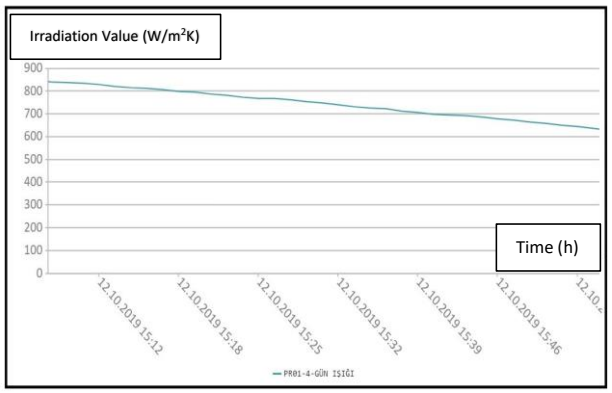

Fig.22. Irradiation Value on 12.10.2019 (W/m^{2}K)

Air Speed: The system fan is operated at 15 watts. The air velocity change is shown in Figure 23 and the average value is calculated as 0.741 m/s.

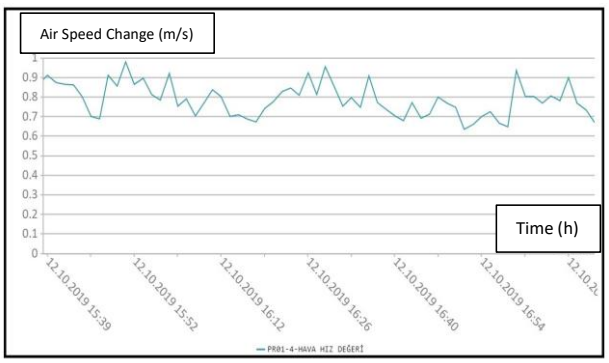

Fig. 23. Air Speed Change on 12.10.2019 (m/s)

Panel Current Value: Electricity production starts at 2.37 amp at 15.00 and reset at 17.09 with the sunset. Figure 24 shows the change of ampere values in the panel according to the hour.

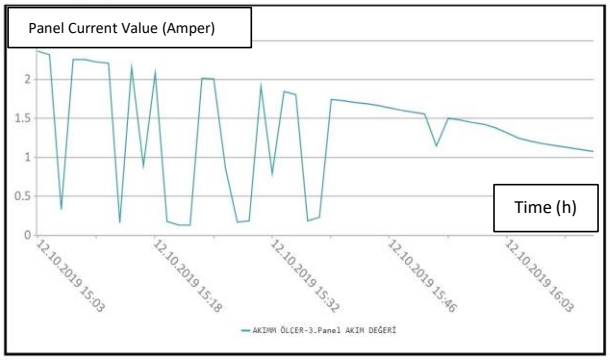

Fig.24. Ampere Change on 12.10.2019

Air Inlet-Outlet Values: The fan was operated at 15.30. The variation of the air inlet temperature values is shown in Figure 25 and the average difference is calculated as 3.9°C.

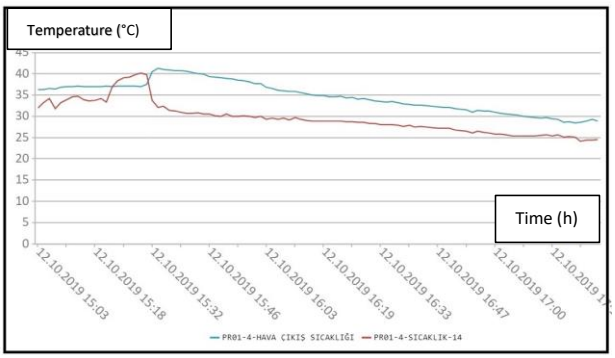

Fig.25. Air Inlet and Outlet Temperature Values (°C)

The efficiency calculation according to the values read from the tables was calculated from the same formula made with 4 mm flat glass. Accordingly, the air circuit efficiency of the system on October 12:

$Q = 770 * 1.27 = 977.9$ W **(1)**

$P_{th\text{-}a} = 0.21 * 0.741 * 0.24 * 4.18 * 1000 * 3.9 = 608.82$ W **(2)**

η (%)=62.25 **(3)**

The second experiment was held in 13.10.2019. Data for this experiment are given below:

Outdoor Temperature: The outdoor temperature is measured as 16.4°C at 09.00 and 25.8°C at 11.48 and is shown in Figure 26. The average is calculated as 19.7°C.

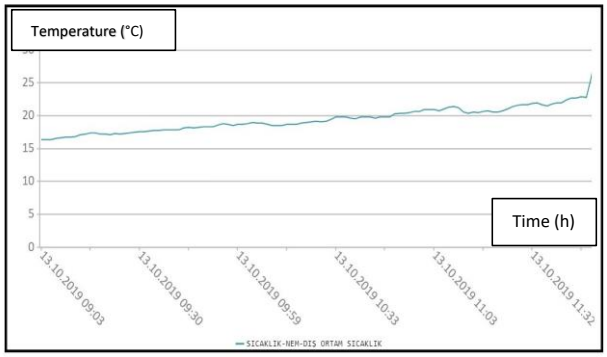

Fig.26. Outdoor Temperature Values on 13.10.2019

Irradiation Value: The values read from the pyranometer are shown in Figure 27. The average was calculated as 1117 W/m^{2}K.

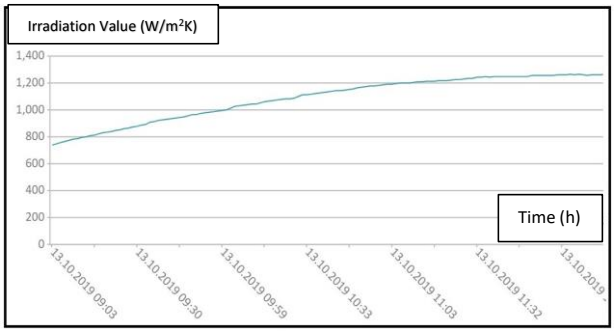

Fig.27. Irradiation Value on 13.10.2019 (W/m^{2}K)

Air Velocity: Outdoor wind has also increased the air velocity circulating in the system. Outdoor wind speed was measured in 15 minute intervals. With this effect, the circulating air velocity in the system was calculated as 1.13 m/s. Figure 28 shows the change of values.

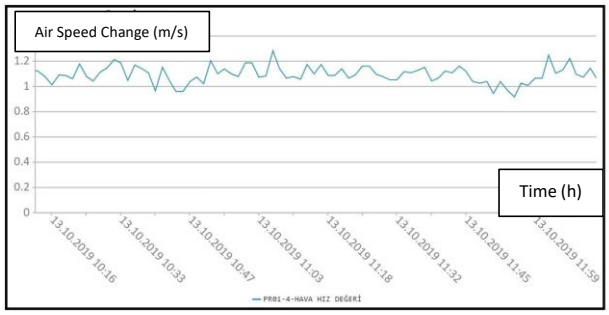

Fig. 28. Air Speed Change on 13.10.2019 (m/s)

Panel Current Value: The system started to produce 2.18 amps electricity at 09.00. This value reached 3.74 amps at 12.03. The variation of ampere values produced in the panel is shown in Figure 29.

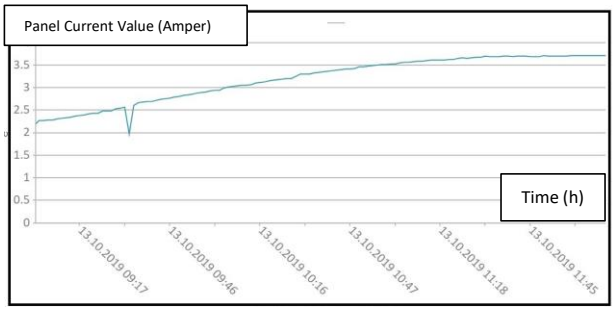

Fig.29. Ampere Change on 13.10.2019

Air Inlet-Outlet Temperature Values: The fan was operated at 10.00 am. The temperature difference at the air inlet and outlet after the fan is turned on is calculated as 4.7 ° C and is shown in Figure 30.

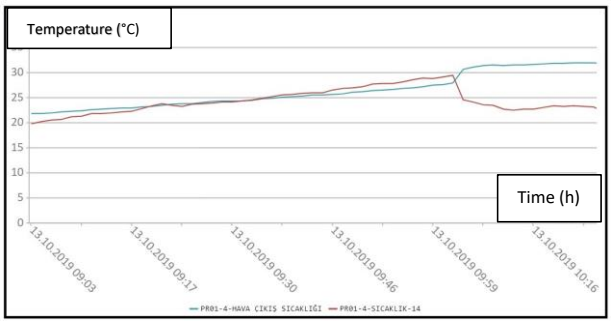

Fig.30. Air Inlet and Outlet Temperature Values (°C)

The efficiency of the system on October 13 was calculated as follows:

$Q = 1117 * 1.27 = 1418.6$ W **(1)**

$P_{th-a}=0.21*1.13*0.24*4.18*1000*4.7=938.4$ W **(2)**

η (%)= 65.72 **(3)**

The third experiment was held in 23.11.2019. Data for this experiment are given below:

Outdoor Temperature Value: The average outdoor temperature is measured as 17.3°C and the change in temperature values is given in Figure 31.

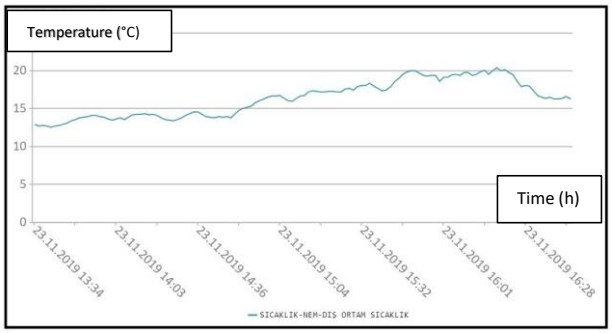

Fig.31. Outdoor Temperature Values on 23.11.2019

Irradiation Value: On November 23, there was a cloudy day in Konya. This is the reason for the peaks in the table. The average irradiation value is calculated as 765 W/m^{2}K in the light of the values in figure 32.

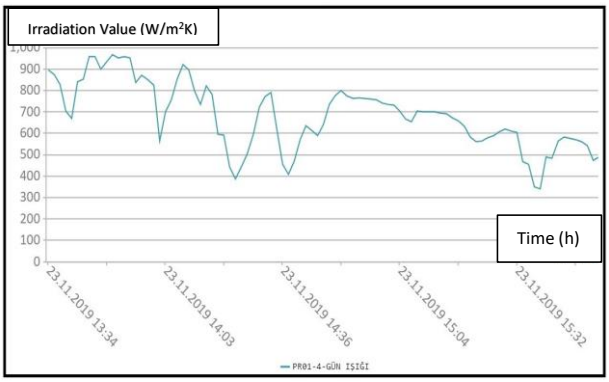

Fig.32. Irradiation Value on 23.11.2019 (W/m^{2}K)

Air Velocity: On November 23, measurements were made on a windless day. The fan was operated at 15 watts. The average air velocity circulating in the system is calculated as 0.42 m /s and its variation according to the hour is shown in Figure 33.

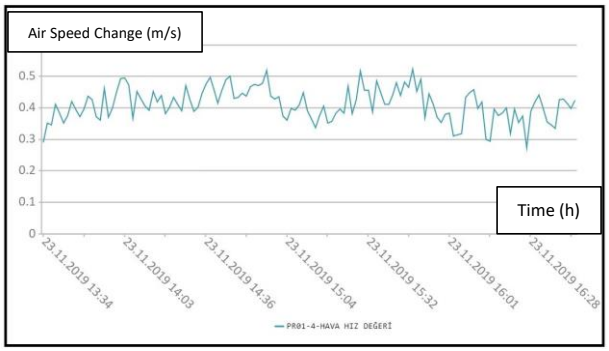

Fig. 33. Air Speed Change on 23.11.2019 (m/s)

Panel Current Value: The current value was seen as 2.69 amps at 13.45. At 16.43, this value has dropped to 0.51 amperes as the sun approaches sunset. Current variations are shown in Figure 34.

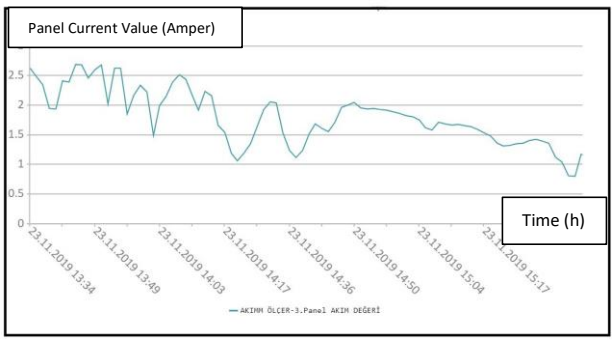

Fig.34. Ampere Change on 23.11.2019

Air Inlet-Outlet Temperature Values: The average temperature difference value is calculated as 4.2°C and the values are shown in figure 35.

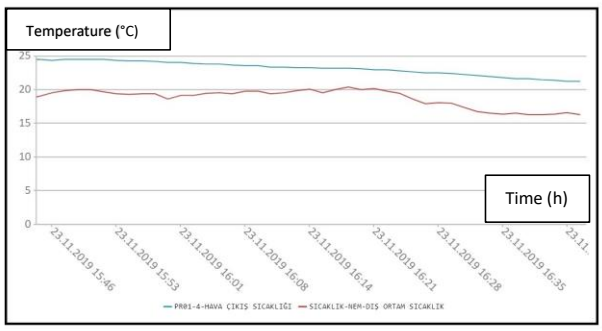

Fig.35. Air Inlet and Outlet Temperature Values (°C)

On 23 November the air circuit efficiency of the system was calculated as follows:

$Q=586*1.27=744.22$ W **(1)**

$P_{th-a}=0.21*0.42*0.24*4.18*1000*4.2=371,62$ W **(2)**

η (%)= 49.9 **(3)**

As a result of 3-day experiments with 4 mm low-e coated glass, the minimum efficiency of the system was %49.9 and the maximum system efficiency was calculated as %65.72. Average system efficiency was calculated as %59.29. After these experiments, 4 mm low-e coated glass was disassembled and replaced with 4+12+4 mm double glass. Experimental data with this glass are given below.

Experiments with 4+12+4 mm double transparent glass

The first experiment was held in 24.11.2019. Due to weather conditions, only one experiment applied with double glass. Data for this experiment are given below:

Outdoor Temperature Value: The average outdoor temperature is measured as 11.8°C and the change in temperature values is given in Figure 36.

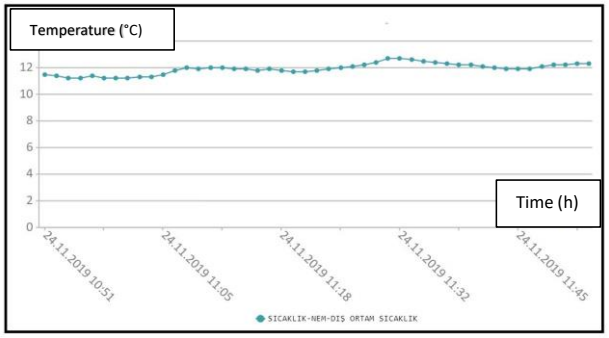

Fig.36. Outdoor Temperature Values on 24.11.2019

Irradiation value: Daylight values are low because of the measurement on a rainy and cloudy day. The minimum radiation value was 274 W/m^{2}K at 11.15 and the maximum radiation value was calculated as 856 W/m^{2}K at 11.29. The average radiation value was calculated as 420.375 W/m^{2}K. The variation of the values is shown in figure 37.

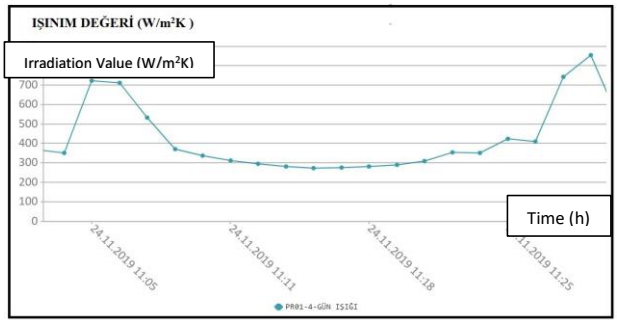

Fig.37. Irradiation Value on 24.11.2019 (W/m^{2}K)

Air Velocity: Since it is a windy and rainy day, the air velocity is high. The system fan is operated at 15 watts. The average air velocity circulating in the system is calculated as 0.7 m/s and the change of values is given in Figure 38.

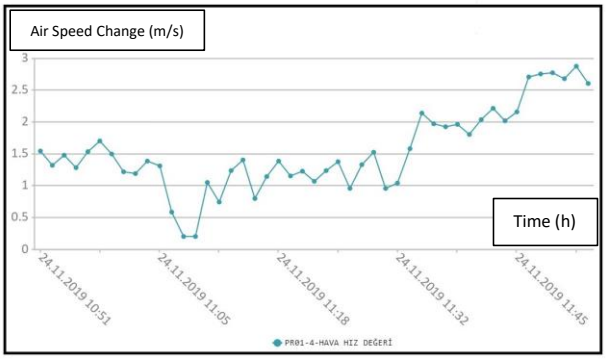

Fig. 38. Air Speed Change on 24.11.2019 (m/s)

Panel Current Value: The maximum current value of the panel is 2.58 amperes at 11.15. The time-dependent variation of panel current values is shown in Figure 39.

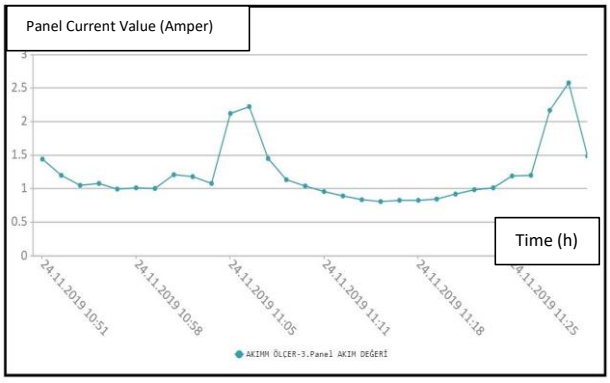

Fig.39. Ampere Change on 24.11.2019

Air Inlet-Outlet Temperature Values: Air inlet-outlet temperature difference is calculated as 2.2°C, is shown in Figure 40.

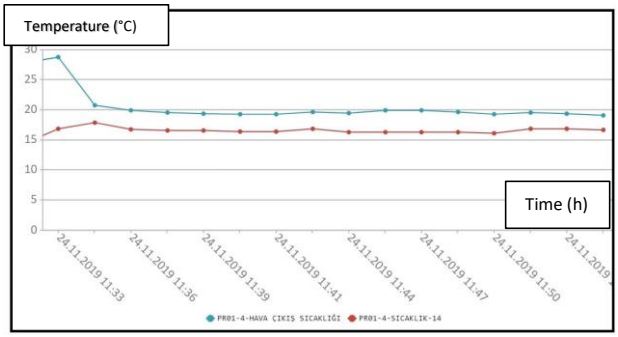

Fig.40. Air Inlet and Outlet Temperature Values (°C)

On 24 October 2019, the efficiency of the system was calculated as follows:

$Q = 420.375 * 1.27 = 533.88$ W **(1)**

$P_{th-a} = 0.21 * 0.7 * 0.24 * 4.18 * 1000 * 2.2 = 324.43$ W **(2)**

η (%)= 60.76 **(3)**

The second experiment was held in 07.03.2020. Data for this experiment are given below:

Outdoor Temperature Value: The outdoor temperature was measured as 17.2 ° C on average and the change of temperature values is given in figure 41.

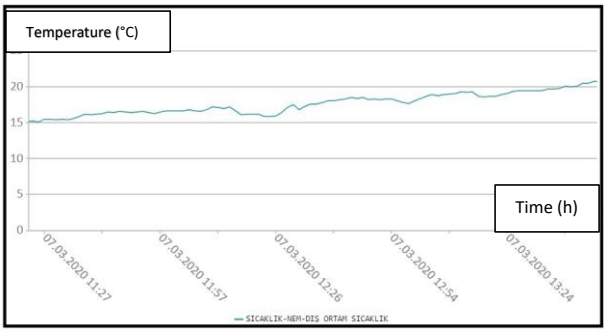

Fig. 41. Outdoor Temperature Value (°C)

Irradiance value: The average irradiance value is calculated as 1257 W/m^2. The change of values is shown in Figure 42.

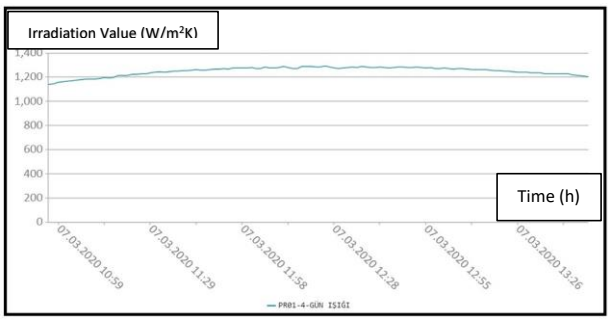

Fig. 42. Irradiance Value (W/m^2)

Air Velocity: System fan was operated at 15 watts. The average air velocity circulating in the system is calculated as 0.54 m/s, and the change of values is given in figure 43.

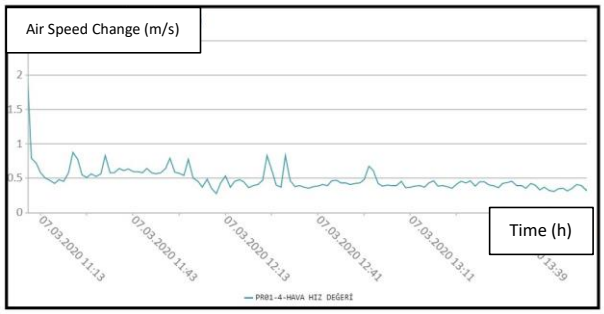

Fig. 43. Air Speed Change (m/s)

Panel Current Value: The maximum current value formed in the panel was measured as 3.9 amperes at 12.57. The change of panel current values depending on time is shown in Figure 44.

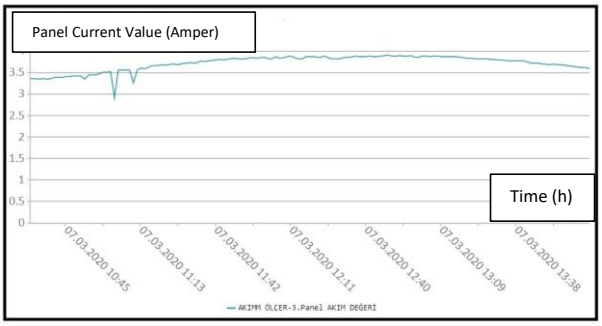

Fig.44. Ampere Change on 07.03.2020 (Amper)

Air Inlet-Outlet Temperature Values: The air inlet-outlet temperature difference has been calculated as 7.6 ° C and is shown in Figure 45.

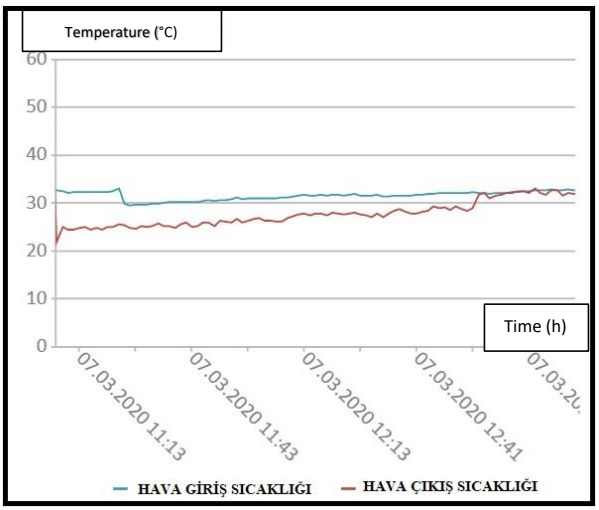

Fig. 45 Air Inlet and Outlet Temperature Values (°C)

$Q = 1257x1.27 = 1596.39$ W **(1)**

$P_{th-a} = 0,54x0,21x0,24x4,18x1000x7,6 = 864,6$ W **(2)**

η (%)= 54.16 **(3)**

4. DISCUSSION

As a result of 3-day experiments with 4 mm flat glass, the minimum efficiency of the system was %37.46 and the maximum system efficiency was calculated as %53.44. Average system efficiency was calculated as %47.12.

As a result of 3-day experiments with 4 mm low-e coated glass, the minimum efficiency of the system was %41.5 and the maximum system efficiency was calculated as %62.25. Average system efficiency was calculated as %59.29.

As a result of 2-day experiments with 4+12+4 mm double glass, overall system efficiency calculated as %57.46.

The above data is a comparison of the thermal efficiencies of the system. When the electrical efficiency of the system is compared, the measurements made with three glasses are based on the amperage production at the same radiation values. This value was selected as 700 W/m^{2}K.

At 700 W/m^{2}K radiation, the amperage of 4+12+4 mm double glass was read as 2.05 amps average. At the same radiation on 12.10.2019 at 15.13 amperage of 4 mm low-e glass was read as 2.02 amps. In the experiment conducted with 4 mm flat glass on 16.09.2019, when the pyranometer read the value of 700 W/m^{2}K at 15.53, the amps produced at the same hour were measured as 2.11. These values indicate that the thickness of the glass does not affect electricity production. Reduction in electrical current was calculated due to coating only on low-e glass. However, this decrease can be ignored due to the increase in thermal gain.

The thermal efficiency gain and the change in electrical efficiency are shown in Table 1 below:

Table 1. Thermal and electrical efficiency comparision

Glass Type	Avr. Thermal Efficiency (%)	Electrical Production at 700 W/m^{2}K Irradiation Value
4 mm flat glass	47.12	2.11 Ampere
4 mm low-e glass	59.29	2.02 Ampere
4+12+4 mm double glass	57.46	2.05 Ampere

As a result of the experiments, the use of solar low-e coated glass doesn't affect much the electrical efficiency and increases the thermal efficiency in the system. It has been found appropriate using of low-e glass. But the studies about material efficiency are still continuing. Energy sources and uses are a very large subject and important for our next generations. We tried with 3 different glasses but in the future, other researches can research of different materials and may increase whole system efficiency much more.

5. ACKNOWLEDGMENT

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6. REFERANCES

Abu Bakar M.N, Othman M, Din M.H, Manaf N.A, Jarimi H. (2013) "Development of an Improved Photovoltaic/Thermal (PV/T) Solar Collector With Bi-Fluid Configuration", International Journal of Chemical and Environmental Engineering, 4,4,240-243.

Akıskalıoğlu E. (2020). Cam Kapak Özelliklerinin Hava ve Su Bazlı PV/T Sistem Performansı Üzerindeki Etkilerinin Araştırılması. Yüksek Lisans Tezi, Marmara Üniversitesi, Fen Bilimleri Enstitüsü, İstanbul.

Atmaca M., Pektemir İ.Z. (2019) "Investigation on the effect of the total efficiency of water and air used together as a working fluid in the photovoltaik thermal systems", Processes, 7, 516

Atmaca M., Pektemir İ.Z. (2018) Investigation of possibilities obtain heating, hot water and electricity from same solar panel by means of a new design called "Solenam" (Solar energy absorber machine), 3th International Multidisciplinary Congress, Kiev 5-6 October 2018

Chaar L.E. , Lamont L.A., Zein L. (2011) Review of photovoltaic technology, Renew. Sustainable Energy Rev. 15 2165–2175.

Gürtürk M., Benli H., Koçdemir Ertürk N. (2011) Determination of the effects of temperature changes on solar glass used in photovoltaic modules, Elsevier, Renewable Energy 145, 711-724

Hasan M.A., Sumathy K. (2010) Photovoltaic thermal module concepts and their performance analysis: a review, Renew. Sustainable Energy Rev. 14, 1845–1859.

Kabul A, Duran F. (2014) Isparta İlinde Fotovoltaik/ Termal (PV/T) Hibrit Sistemin Performans Analizi, SDU International Technologic Science, 6,1,31-33.

Kalogirou S.A, Tripanagnostopoulos Y. (2006) Hybrid PV/T Solar systems For Domestic Hot Water and Electricity Production, Energy Conversion and Management, 47:3368-3382,

Manaf N.A, Abu Bakar M.N, Jarimi H, Muhamed S. Othman M. (2013) Design of Single-Pass Bi-Fluid Photovoltaic/ Thermal (PV/T) Solar Collector, İnternational Journal of Chemical and Environmental Engineering, 4,4,240-243.

Xondag H.A. (2008) Flat-plate PV-thermal collectors and systems: a review, Renew. Sustainable Energy Rev. 12, 891–959.

Tyagi V., Kaushik S., Tyagi S. (2012) Advancement in Solar Photovoltaic/ Thermal (PV/T) Hybrid Collector Technology, Renewable and Sustinable Energy Reviews, 16,3, 1383-1398.

http://www.yegm.gov.tr/MyCalculator/Default.aspx , (20.11.2019)

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Original Article

A Structural and Spatial Investigation on Mimar Sinan's Mosques

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Mimar Sinan,
Mosque

Abstract: It is difficult to distinguish between period and architect in constructions with globalization in developing countries and even this situation is impossible. However, it has been observed in the historical process that architects put forth unique technical and design properties. Structures of Architect Sinan have significant attributes which put forth the experience of the architect in Turkish architecture. Architect Sinan is the most important master who has imprinted his name on the classical period of the Ottoman Empire. It is obvious that his success has plenty of special place among monumental structures. It is thought that Mimar Sinan has taken part in the construction of many monumental structures either as an architect or leader during his apprenticeship, journeyman and mastery periods. In this study; The ten mosques in which the Kurşunlu Mosque, one of Sinan's the hardly known works, also took place are compared. Plans, obtained sections and views, construction materials, in the periods during which they were built were examined while making the comparison. Selatin mosques of Sinan, which are among the mosques studied, are known more than other mosques, and the provincial mosques have become an important part of the city with their modest identities. Sinan's selatin and provincial mosques generally have a classical Ottoman architectural plan understanding with courtyard, fountain and last narthex application. When the samples of Selatin mosque are examined, it is seen that the main space proportional to the scale of the building has also grown. Therefore, in addition to the body walls, large-scale carrier columns stand out in the main space. When the plan types of provincial mosques, which can be defined as small-scale, are examined, four facades rise with their main walls and the narthex is connected to the main wall at the entrance facade. Within the scope of this study, Kurşunlu Mosque, which was not worked on although it was in the city where Sinan was born, is the structure that stands out among Sinan's provincial mosques. It is important that the works handled are in harmony with each other and that the Kurşunlu cami is in this harmony. It is hoped that the study will contribute to future studies related with the subject.

Mimar Sinan Camileri Üzerine Yapısal ve Mekânsal Bir İnceleme

Anahtar Kelimeler:
Yapıların Karşılaştırması,
Mimar Sinan,
Cami

Özet: Gelişmekte olan ülkelerde küreselleşme ile birlikte yapılarda dönem ve mimar ayrımına varmak zorlaşmakta hatta imkânsızlaşmaktadır. Ancak tarihsel süreçte mimarların kendine has teknik ve tasarım özelliklerini koydukları görülmüştür. Türk mimarisi içerisnde Mimar Sinan'ın yapıları da mimarın kendi tecrübesini ortaya koyduğu belirgin özelliklere sahiptir. Mimar Sinan, Osmanlı İmparatorluğu'nun klasik dönemine imzasını atan büyük ustadır. Döneminde, pek çok anıtsal yapıda imzasının olduğu açıktır. Mimar Sinan'ın çıraklık, kalfalık ve ustalık dönemlerinde mimar veya öncü olarak birçok anıtsal yapının inşasında yer aldığı düşünülmektedir. Bu çalışmada;

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Sinan'ın pek bilinmeyen eserlerinden olan Kurşunlu Cami'nin de yer aldığı on camisi karşılaştırılmıştır. Karşılaştırma yapılırken yapıların plan şemaları, elde edilen kesit ve görünüşleri, yapı malzemeleri, yapıldıkları dönemler ele alınmıştır. İncelenen camiler arasında yer alan Sinan'ın selatin camileri diğer camilere göre daha fazla bilinmekte ve taşra camileri mütevazı kimlikleriyle şehrin önemli bir parçası haline gelmiştir. Sinan'ın selatin ve taşra camileri genel olarak avlu, çeşme ve son narteks uygulaması ile klasik Osmanlı mimari plan anlayışına sahiptir. Selatin Cami örnekleri incelendiğinde, yapının ölçeğiyle orantılı olarak ana mekânın da büyüdüğü görülmektedir. Bu nedenle ana boşlukta gövde duvarlarının yanı sıra büyük ölçekli taşıyıcı kolonlar öne çıkmaktadır. Küçük ölçekli olarak tanımlanabilecek taşra camilerinde plan tipleri incelendiğinde ise dört cephe ana duvarları ile yükselmekte ve narteks giriş cephesinde ana duvara bağlanmaktadır. Bu çalışma kapsamında Sinan'ın doğduğu şehirde olmasına rağmen üzerinde çalışılmayan Kurşunlu Cami, Sinan'ın taşra camileri arasında ön plana çıkan yapısıdır. Ele alınan eserlerinin birbiriyle uyumu ve Kurşunlu camisinin de bu uyumda yer alması önemlidir. Çalışmanın konu üzerinde yapılacak çalışmalara katkı sağlaması umulmaktadır.

1. INTRODUCTION

The word mosque means that which gathers and brings together. In this regard, it is the sanctuary where Muslims gather together for worship. The word *mescit* is used in the first historical sources instead of the word mosque. Whereas *mescit* is the name given to the location where muslims "kotow" during prayer, it can be generally stated that mescits are constructed in neighborhoods, mosques in districts and grand mosques in cities (Cami, 2016).

Many different types of structures were constructed during the transformation of the Ottoman from chiefdom to kingdom in order to meet the demands of the society. Mosques are which indicators of the economic wealth of the state as well as a religious symbol stand out among these architectural works. When the mosques of the Ottoman era are examined, it is clear that there has been a period of development in terms of architecture reaching its pinnacle with the contributions of Mimar Sinan.

The mosques built during the reign of sultans in the Ottoman Empire are known as "Selatin Mosques". There are certain conditions for the construction of selatin mosques in the Ottoman palace tradition. First of all, a sultan had to win an important military victory and lay hold of a significant spoil of war to be able to order the building of a selatin mosque (Selatin Cami, 2017).

In this study, Classical Ottoman period structures built by Architect Sinan were compared with respect to various properties such as plan typologies, construction materials. Among the grand, large-scale Selatin mosques by Architect Sinan, his apprenticeship period piece Şehzadebaşı, qualification period piece Süleymaniye and master period piece Selimiye Mosque were taken into consideration. The periods known as apprenticeship, qualification and master put forth the development of the structures as well as the architectural development of Sinan.

Within the scope of the study, 6 mosques, namely Bali Pasha, Hadım İbrahim Pasha, Rüstem Pasha, Tekirdağ Rüstem Pasha, Behram Pasha, Pertev Pasha, which are close to the scheme of the Kurşunlu Mosque, described as the provincial mosque of Mimar Sinan, were determined. When the carriers of the selected buildings of the Classical Ottoman period of Mimar Sinan are analyzed comparatively, it is seen that the main walls are similarly constructed. In this context, it is aimed to reveal the structural similarities between the 7 mosques determined typologically. In addition, it is aimed to reveal Sinan's development in the architectural process by comparing the plan

schemes, building materials and the periods they were built among the 6 provincial mosques determined by Sinan's selatin mosques.

Significant mosques of Architect Sinan and his applications and (most known works) similar to the plan of Kurşunlu Mosque were examined based on plan, cross-section, appearance and technical drawings. The analyses carried out put forward the similarities of the mosques of Sinan as well as the position of the Kurşunlu Mosque among these works. Including small scale mosques by Sinan was important for putting forth the importance given by him to the small scale structures as well as his style of approach.

2. MATERIAL AND METHOD

Within the scope of the study, the life and mosques of Mimar Sinan were mentioned, and the mosques determined from the works of the Classical Ottoman Period were discussed in detail. Three mosques, namely Şehzade, Süleymaniye, Selimiye, were selected from Sinan's Selatin Mosques. 7 mosques, namely Bali Pasha, Hadım İbrahim Pasha, Rüstem Pasha, Tekirdağ Rüstem Pasha, Behram Pasha, Pertev Pasha, Kurşunlu Mosque, which we can call as provincial mosques, were examined. Accordingly, literature surveys were carried out on 3 mosques in large scale and 7 mosques that we can define as small scales.

Ten mosques examined within the scope of the article; historical, formal, spatial fictions and architectural features were evaluated separately. Therefore, the plan, section and view data of the 10 mosques determined were accessed from various sources. In order to better read the developments in the building, the data obtained were tabulated. A typological comparison was made by classifying the architectural drawings of the mosques from the table. Structural interpretation were made on Sinan mosques determined by evaluating the analyzes. Similar and different aspects of structural development in Mimar Sinan's mosques are tried to be revealed.

Sinan Mosques have preserved their importance from the time they were built until today. Sinan's technical and design approaches are the characteristics that make mosques unique. The mosques discussed as a result of the examinations reveal Sinan's development in the architectural process. It has been determined that there is no examination on the Kurşunlu Mosque in Kayseri, which is one of the rare mosques of Sinan in Anatolia, and is discussed in detail within the scope of this study.

2.1. Mosque of Mimar Sinan

Sinan was born at the Ağırnas Village of Kayseri but his date of birth is not known for sure. However, majority of the opinions indicate the birth year as 1489. He is known as “Mimar Sinan”, “Chief Architect Mimar” and “Koca Sinan” due to his contributions to architecture as well as the expert solutions he put forth especially for dome architecture during a time when technical abilities were very limited (Mimar Sinan-Eserleri, 2016). Sinan passed away in 1588 leaving behind many mosques built during the Ottoman empire for a total of 375 works comprised of 81 Mosques, 51 mescits, 55 medrasahs, 26 darül-kurra, 17 mausoleums, 17 almshouses, 3 hospitals, 5 aqueducts, 8 bridges, 20 caravanserais, 36 palaces, 8 cisterns and 48 Turkish baths (Benian, E., 2011). However, his greatest desire was to build a bright and spacious mosque with full unity of space that encompassed the congregation much like the sky. The hills reigned supreme over the city with social complexes including mosques. His first important work was the Şehzade Mosque in Istanbul. He has characterized this as the work during his apprenticeship period. Süleymaniye Mosque which was built during his

qualification period. Selimiye Mosque in Edirne was defined by him as a master stage work (Mimar Sinan-Eserleri, 2016). In this study, the three works characterized by Sinan as mosques of apprenticeship, qualification and master stage works were taken into consideration and the mosque typology was examined. Among these, Kurşunlu Mosque which corresponds to the Ottoman classical period was examined with regard to material cost.

2.1.1. Şehzade Mosque Structural and Spatial Analysis

Şehzade Mosque located at the Fatih District, Laleli Quarter of Istanbul was the first step of the three main stages of the architectural genius of Mimar Sinan (Figure 1). Şehzade Mosque was ordered to be built in 1543 by Kanuni Sultan Süleyman in the name of his son Şehzade Mehmet who passed away when he was 22 and there is a mausoleum in the garden of the mosque for Şehzade Mehmet. Şehzade Mosque which is one of the most beautiful mosques of art by Mimar Sinan which he characterizes as one of his apprenticeship stage pieces was completed in 1548 within a period of 4 years. Şehzade Mosque is also the first monumental structure within the Ottoman Classical Architecture (Şehzade Cami, 2016). The mosque has a square form (Figure 2, Figure 3 and Figure 4). There is a central dome with a diameter of 18.42right at the center of this square plot of land. This dome is carried by four main crowns on which four semi-domes rest. This four semi-dome mosque type that was to be applied in many mosques later on was first tried for the Şehzade Mosque. This structural plan was later used in the Eminönü Yeni Valide Mosque, Sultanahmet Mosque ve Fatih Mosques (Saraçhane Şehzade Mehmet Cami-Mimari Yapı, 2016).

Figure 1. Şehzade Mosque (Saraçhane Şehzade Mehmet Cami-Mimari Yapı, 2016)

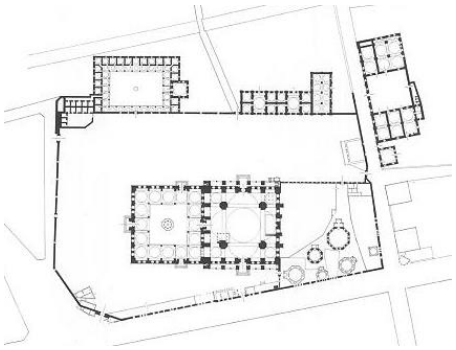


Figure 2. Şehzade Külliye Plan (Şehzade Cami, 2016)

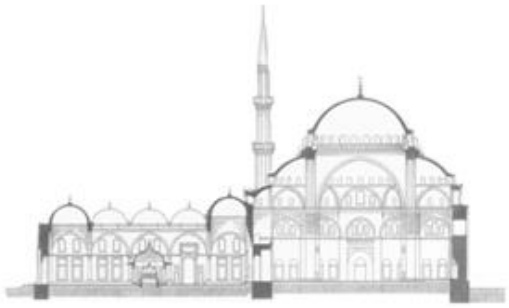


Figure 3. Şehzade MosqueCross Section (Gurlitt, 1912)

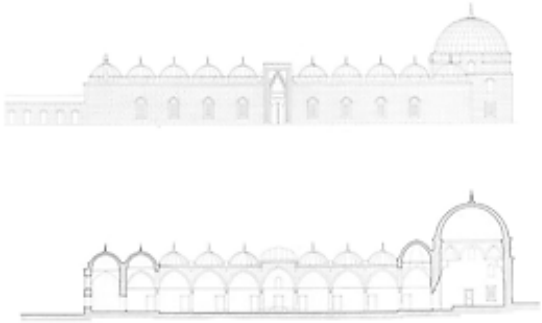


Figure 4. Şehzade Külliye Cross Section and Appearance (Ülgen, 1989)

2.1.2. Süleymaniye Mosque Structural and Spatial Analyses

Süleymaniye Mosque is located at the city of Istanbul in Turkey, Fatih District, Süleymaniye quarter. The mosque was ordered by Mimar Sinan during the 16th century in the name of by Kanuni Sultan Süleyman who was the ruler at the time. The construction work was started in 1550 and was completed in 7 years. Süleymaniye Mosque is one of the qualification stage mosques by Mimar Sinan and is one of the most important examples of Classical Period Ottoman Architecture (Figure 5). Süleymaniye Mosque has been built on four pillars calculated to be 30 tons each. The main dome and upper masonry shell transfer the weight of about 1000 tons to the foundation via two semi-domes and the pillars (Figure 7). There are four main arches between the pillars. "*The main arches have been constructed without tie rods. However, tension ha s been used for the smaller arches at the clearances between the primary semi-domes and secondary semi-domes for the structure that covers the central inner space of the Süleymaniye Mosque*" (Eruyar, 2016).

The main dome of the mosque is located above the main arches and elephant pillars (fil ayakları). There is a total of 32 windows on the dome frame. Two semi-domes support the main dome from the sides. The semi-domes are supported by two smaller domes each which are called exedra. There are five domes of various sizes at sections where there are no semi-domes. In addition, there are twenty eight small domes at the courtyard and four minarets in the mosque (Aslan, 2016) (Figure 8). Many structures were built around the Süleymaniye Mosque located at the center of the külliye. Kanuni and Hürrem mausoleums, medrasahs providing education at different levels, a hadith school, a school of medicine, elementary school, hospital, guesthouse, a structure for Qur'an education, a souphouse called imaret, Turkish bath, inn, library, Sinan's mausoleum and many shops (Figure 6).

Figure 5. Süleymaniye Mosque (Süleymaniye Cami'nin Yapılış ve Özellikleri, 2016)

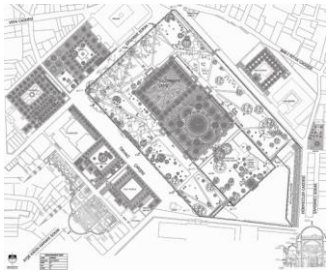


Figure 6. Süleymaniye Mosque Layout Plan (Süleymaniye Cami'nin Yapılış ve Özellikleri, 2016)

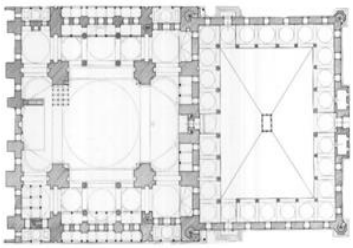


Figure 7. Süleymaniye Mosque Ground Floor Plan (Süleymaniye Cami'nin Yapılış ve Özellikleri, 2016)

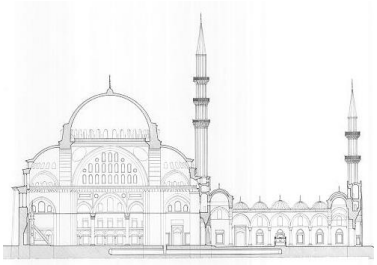


Figure 8. Süleymaniye Mosque (Süleymaniye Cami, 2016)

2.1.3. Selimiye Mosque Structural and Spatial Analyse

The monumental structure built by Mimar Sinan at age 80 which he characterized as "my master stage work" is one of the masterpieces of the Ottoman-Turkish art and history of world architecture (Figure 9) (Ekinci, 2009). It is not known for certain the date when the construction for the Selimiye Mosque was started. However, it has been recorded in the mosque tablet located on the Selimiye Mosque door that the construction work was started in 1568. The mosque, madrasah and Dar-ül Hadis have been placed in a symmetrical manner inside the 190x130 meter courtyard with the mosque at the center and the twin educational structures at the corners. It attracts attention with its four minarets that attract attention from a distance (Köse, 2013).

The mosque located at the center of a courtyard surrounded by walls is comprised of a praying area with a length of about 40 meters and width of 60 meters along with a şadırvan (courtyard with a fountain) that has almost the same dimensions (Köse, 2013). The mosque built of cut stone covers an area of 1.620 m² with its inner section and 2.475 m² in whole. Selimiye Mosque is characterized as a structure that has been built on the widest area of land in architectural history and attracts attention with its dome that has a height of 43.28 m. and a diameter of 31.30m. The dome rests on 8 large pedestals connected together by 6 m wide arches. Four semi-domes at the corners and one semi-dome at the mihrab support the central dome (Ekinci, 2009). It has four minarets (Figure 10).

The outer courtyard of Selimiye surrounds the mosque from three sides. Dar-ül Kur-a and Dar-ül Hadith structures are located in the wide outer courtyard of the Selimiye Mosque surrounded by stone walls. Porticos covered with domes surround the courtyard. The porticos are in total 18 domes over 16 columns (Figure 11, 12). The columns have been built as single piece (Köse, 2013).

Figure 9. Selimiye Mosque (Ekinci, 2009)

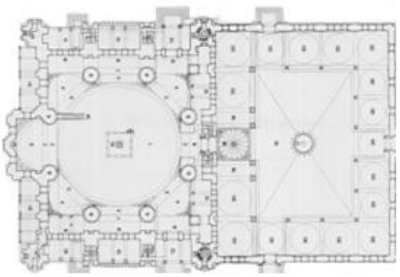


Figure 10. Selimiye Mosque Ground Floor Plan (Köse, A., 2013)

Figure 11. Selimiye Mosque Façade (Çetintaş, 1935)

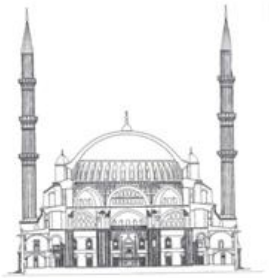


Figure 12. Selimiye Mosque Section (Ekinci, 2009)

2.1.4. Bali Pasha Mosque Structural and Spatial Analysis

The structure located at the Hoca Üveyz Quarter at the Fatih district of Istanbul was built by Architect Sinan during the years of 1546-1548. Bali Pasha started the construction of the mosque which was completed by his wife Hüma Hatun following the death of Bali Pasha (Ekinci, 2009). Hence, it is also known as Hüma Hatun Mosque (Figure 13) (Bali Paşa Cami, 2017). The kiblah main gate of the mosque is located on the Hoca Efendi Street with Battal Gazi Street to the east and Balı Pasha Street to the west. The mosque has a square plan and is surrounded by external walls on an area of 900 square meters (Figure 16) (Bali Paşa Cami, 2017). The mosque has been built using cut stone and is covered with a dome of 12 m diameter. Verses by poet Kenan Hüdai are written on the 1504 dated inscription (Bali Paşa Cami, 2017). Bâli Pasha Mosque is comprised of a five unit square plan narthex covered with five small domes enveloped in turn with a dome of 11.80 m^2 diameter (Bali Paşa Cami, 2017).

Classical Ottoman style can be observed in all aspects of the mosque excluding its proportions put up by using cut sandstones as well as the vertical grooved rails on the portico of the narthex (Figure 17). There is a square planned minaret pedestal at the northwestern corner and a stairwell tower with the same dimensions at the northeastern corner. Two feet placed on the northern, eastern and western main walls each and three lancet arches combining these carries the upper story mahfil (gathering place) covering the sanctuary from three sides. The upper section of the tower including the stairs to the mahfil (gathering place) has been used as a cross vaulted cell (Figure 18).

Columns were used on the walls in 3 directions outside the Kiblah wall. The sections between the columns are also connected by pointed arched niches. There is a mahfil on the niches that surrounds the space from 3 directions. Corner parts on the Kiblah wall are overflowing towards the outside. The way out to mahfil is provided by a ladder located in the last congregation place (Çobanoğlu, 2019) (Figure 14). The upper part of the protrusion made for Mahfil stair was made as a cross vault (Bali Paşa Cami, 2020).

The interior dome of the mosque has been decorated with inscription and writings the minbar of which is made of marble and the mihrab of plaster (Figure 15). It is known that the wooden lectern has been brought in from the Hagia Sophia museum. The rods decorating the single balcony made of stone provide traces of the art of Architect Sinan. The mosque with an interior area of about 300 m^2 has a courtyard, garden and hazier (Bali Paşa Cami, 2017).

Figure 13. Bali Pasha Mosque (Bali Paşa Cami, 2017)

Figure 14. Bali Pasha Mosque (Çobanoğlu, 2019)

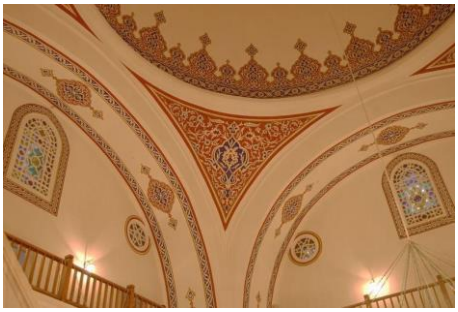


Figure 15. Bali Pasha Mosque
(Bali Paşa Cami, 2017)

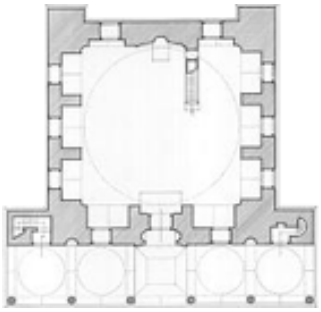


Figure 16. Bali Paşa Mosque Ground Plan
(Ülgen, 1989)

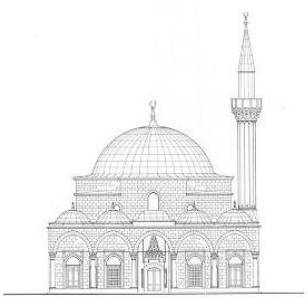


Figure 17. Bali Paşa Mosque Façade
(Ülgen, 1989)

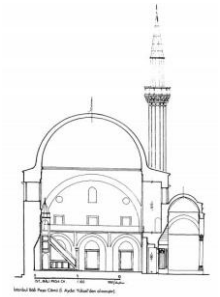


Figure 18. Bali Paşa Mosque Section
(Ülgen, 1989)

2.1.5. Hadım İbrahim Pasha Mosque Structural and Spatial Analysis

Hadım İbrahim Pasha Mosque is located at Silivrikapı, Fatih district of Istanbul in Turkey. It was ordered in 1551 by Hadım İbrahim Pasha, one of the viziers of Kanuni Sultan Suleyman, to be built by Architect Sinan. No traces outside of the wall remains have been left of the Turkish bath and school of the structure built as a small social complex with its mosque, shrine and Turkish bath (Kocamustafa Hadım İbrahim Paşa Cami, 2017). The mosque that is a classical period Ottoman architecture piece has a square plan with a central dome in addition to a modest structure (Figure 19). The main walls of the mosque; southern, eastern and western facades have been built alternatively by cut sandstone and bricks with only sandstone used on the northern facade.

The 12 m diameter dome of the mosque is placed on a cylindrical hoop divided by windows. This hoop has been supported at the corners by a pair of squinches. The dome is placed directly on the mihrab wall in the kiblah direction and on prop feet extending about 2 m from the wall surfaces while is divided by three main walls (Figure 22). Clam shaped squinches have been used at the corners for the passage to the dome (Figure 20). The niches that appear between the prop feet provide a movement and richness to the interior. The interior of the dome and the pediments have been decorated by hand-carvings.

The wooden main gates of the mosque are important examples of xylography (Figure 23). The inner section of the sanctuary entrance along with the columns to the side is covered with marble. There is a small muezzin mahfil to the right of the sanctuary entrance. However, there is no mahfil for women in the mosque. Maksure, which is the high muezzin mahfil close to the mihrab, minbar, mihrab and the muezzin mahfil have been built of marble with a fine workmanship (Figure 21). The narthex extends to both sides outside the square plan of the mosque. Of these extensions, the western minaret with a single balcony comprises the lectern of the minaret, in the eastern section

there is a cell covered with a vault (Hadım İbrahim Paşa Cami, 2017). Of the domes of the narthex carried with six marble columns and five lancet arches, the middle dome is higher with a sliced exterior. This dome sits on consoles with muqarnas on the inside and is fixed to the other domes with transit pendentives (Figure 24). Glazed tiles that are rare to find can be seen above the windows inside the sanctuary and the windows inside the narthex (Çobanoğlu, 2019).

Figure 19. Hadım İbrahim Pasha Mosque (Hadım İbrahim Paşa Cami, 2017)

Figure 20. Hadım İbrahim Pasha Mosque Interior (Kocamustafa Hadım İbrahim Paşa Cami, 2017)

Figure 21. Hadım İbrahim Pasha Mosque Interior (Necipoglu, 2005)

Figure 22. Hadım İbrahim Pasha Mosque Ground Floor Plan (Necipoglu, 2005)

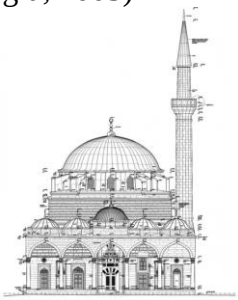


Figure 23. Hadım İbrahim Pasha Mosque Façade (Hadım İbrahim Paşa Cami, 2017)

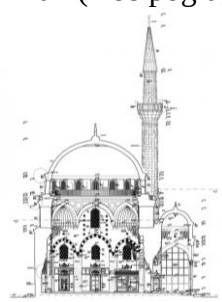


Figure 24. Hadım İbrahim Pasha Mosque Section (Hadım İbrahim Paşa Cami, 2017)

2.1.6. Tekirdağ Rustem Pasha Mosque Structural and Spatial Analysis

The structure which was built in 1552-1553 is located on the Mimar Sinan Street in Tekirdağ city center, across the Tekirdağ municipality building. The autobiographies of Mimar Sinan state that the building was constructed by him. The structure is inside Rustem Pasha Social Complex which has a madrasah, caravanserai, mosque and imaret. The Complex also has a double bath, leather tannery, shops and a school (Figure 25) (Tekirdağ Rüstem Paşa Cami, 2017).

The top of the square planned mosque is covered with a single dome which enables access with trombes. In front of the building constructed with regular cut stone is a double portico narthex and a single balcony minaret on

the northwestern side. The structure is entered through a crown gate located on the mihrab axis with polygon niches on the sides, muqarnas and rectangular edging (Figure 28). Between the suppressed circular arch and the kavsara with muqarnas is the construction book of the building.

Interior of the luminous and spacious structure is also rich with decorations. There are plaster embossment on the sides and center of the dome which has baroque character flowers and garlands. These decorations that are known to belong to the Sultan Abdulmecid period have destroyed the original hard carvings of the mosque. Side backboard and stair railings of the very plain marble minbar are decorated with hemstitch geometric motives.

Five niched narthex is covered with a mirrored vault in the center and double domes on the sides. The external portico has a lead covered sloped wooden roof on columns and round arches. The minaret of the mosque is made of cut stone and polygonal shape as well as covered with a lead cone. The railings of the balcony with muqarnas is carved stone. Entrance to the courtyard of the mosque which is surrounded by walls is through a large gate on the north, with a marble fountain (Figure 29). Lead covered pentagonal roofed fountain that sits on five marble columns with garland heads is understood to be added during the repair in Sultan Abdulmecit period (Rüstem Paşa Külliyesi, 2017).

Of the social complex that was built in 1550's, only the mosque, the rebuilt bath and the partial madrasah has survived to this day. Since 1552 when it was built to this day when it's surrounded by high rise buildings, it still has an impressive sight on its hill, commandeering the Tekirdağ Harbor. The mosque which was in fact built in a modest size is interestingly surrounded by a double line monumental portico on the front facade (Figure 26). The interior of the mosque is plain but impressive with its large size dome (Cambaz, 2014).

Figure 25. Tekirdağ Rüstem Pasha Mosque (Cambaz, 2014)

Figure 26. Tekirdağ Rüstem Pasha Mosque (Cambaz, 2014)

Figure 27. Tekirdağ Rüstem Pasha Mosque (Tekirdağ Rüstem Paşa Cami İç Mekan Fotoğrafı, 2017)

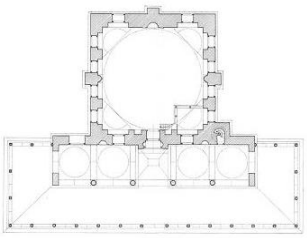


Figure 28. Tekirdağ Rüstem Pasha Mosque Ground Plan (Ülgen, 1989)

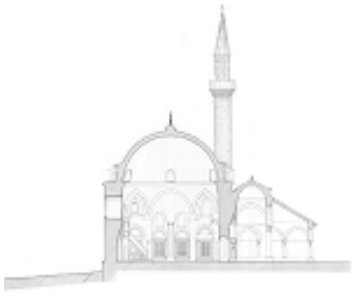


Figure 29. Tekirdağ Rüstem Pasha Mosque Section (Ülgen, 1989)

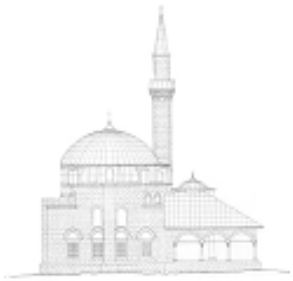


Figure 30. Tekirdağ Rüstem Pasha Mosque Façade (Ülgen, 1989)

2.1.7. Rüstem Pasha Mosque Structural and Spatial Analysis

Rüstem Pasha Mosque was commissioned by Rüstem Pasha, one of the viziers of Kanuni Sultan Süleyman, to Mimar Sinan in 1561 in Istanbul Eminönü (Eminönü Rüstem Paşa Cami, 2017). The mosque that was built 6 meters above the street level had storages and stores under, which enabled better utilization of the sloped area and made the silhouette of the mosque look better (Figure 31). The U-shaped courtyard is accessed by two stairs on the east and west directions. The narrow stairs access is illuminated by windows with iron bars. The narthex with a five domed and six columned portico is covered with a large eaves. The mosque fountain was built on the street level. Minaret is built on the northwestern side of the courtyard after the construction date of the mosque.

The mosque has a rectangular architectural plan (Figure 34). The width of the rectangle is 26.80 meters, and the height is 19.60. The diameter of the great dome is 15.20 meters, with a height of 22.80 meters (Erçağ, 1987). The central dome sits on four elephant pillars via arches. The ceiling cover is shaped with a 15.20 meter diameter middle dome and smaller half and full domes that support this middle dome. These spaces are covered with a vault that is divided by three (Figure 35). Rüstem Pasha Mosque is surrounded by a double line monumental portico on the front facade (Figure 32).

The mosque which was commissioned to Mimar Sinan is a far shot to the simplicity of the period and Sinan himself. What makes this a far shot to simplicity is the decorative elements and of course the İznik tiles (Figure 33). Rüstem Pasha Mosque is covered in tiles up to the dome skirting. Especially the tiles with lily motives are considered to be among the most successful tile examples of the Ottoman period. Hand carvings inside the mosque are in the 18th century baroque style. The tomb is in the courtyard of Şehzade Mosque. Rüstem Pasha Tomb is a single domed octagonal planned structure made with cut stone (Eminönü Rüstem Paşa Cami, 2017).

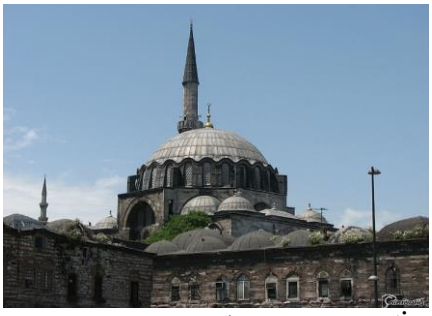


Figure 31. Rustem Pasha Mosque (İstanbul Rüstem Paşa Cami, 2017)

Figure 32. Rustem Pasha Mosque (Rüstem Paşa Cami, 2020)

Figure 33. Rustem Pasha Mosque (İstanbul Rüstem Paşa Cami, 2017)

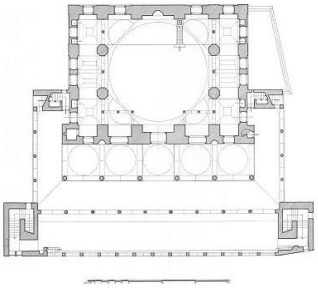


Figure 34. Rustem Pasha Mosque Ground Floor Plan (Ülgen, 1989)

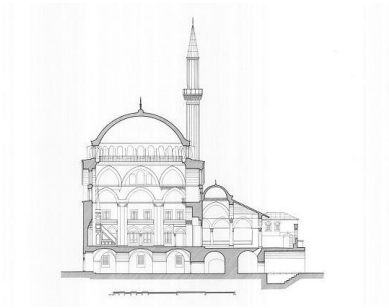


Figure 35. Rustem Pasha Mosque Section (Ülgen, 1989)

Figure 36. Rustem Pasha Mosque Façade (Özdemir, B., 2017)

2.1.8. Behram Pasha Mosque Structural and Spatial Analysis

Behram Pasha Mosque is located near the Mardin Gate of diyarbakir. It was built by the thirteenth governor of Diyarbakr, Behram Pasha. According to the inscription on the sentence door, the construction began in 1564 and was completed in 1572. It is one of the important mosques of Mimar Sinan outside Istanbul (Bali Paşa Câmi, 2020) (Figure 37).

The mosque, built entirely of cut stone, is a single-domed and single-minaret building (Figure 40). The dome sits on an octagonal pulley and the dome is attached to the walls with trombes. There are two iwan-shaped spaces in the north and south and three in the east and west in the square planned harim (Figure 38). These iwan-shaped spaces are covered with pointed arched vaults. Inside the iwan-shaped spaces, there are two windows with flat lintels and two semi-circular mihrab niches on the Kiblah walls (Behram Paşa Câmi, 2020). With these niches in the form of iwan and the wall decorations, the mobility brought

to the harim walls has made the mosque unique (Bali Paşa Câmi, 2020). With the stairs on both sides of the sentence door lead up to the mahfil. The mahfil continues in the form of "U" on 3 fronts except the qibla wall (Figure 41).

The last congregation place of the mosque is double portico. There are two mihrab protrusions on the right and left of the sentence door in the last congregation place. The windows in the last congregation place are framed with a lintel made of two-colored stones and three-slice arches (Behram Paşa Câmi, 2020). The crown door was made with a pointed arch and a muqarnas frame made of two colored stones from the outside. The crown door is also highlighted with a sliced arch and muqarnas on the door (Figure 39).

Only the octagonal fountain and bathhouse have survived from the building, which is thought to have been built as a complex. The fountain is covered with a wide pramidal cone carried by eight columns. Cylindrical columns are made of two colored stones. The minaret is located to the northwest of the building, behind the last congregation place. Minaret has a square base and a cylindrical body (Melek; Demir, 2009).

The fact that two colored stones were used including the last congregation place and fountain of the mosque brought mobility to the mosque. In the harim, the muqarnas on the feet pressed by the trombes have made the mosque remarkable as an architectural decoration element. In addition, the XVI. century Iznik tiles used in the harim walls also join the two-color image at the sentence door.

Figure 37. Behram Pasha Mosque (Yıldız, 2011)

Figure 38. Behram Pasha Mosque (Behram Paşa Cami, 2020)

Figure 39. Behram Pasha Mosque (Çobanoğlu, 2019)

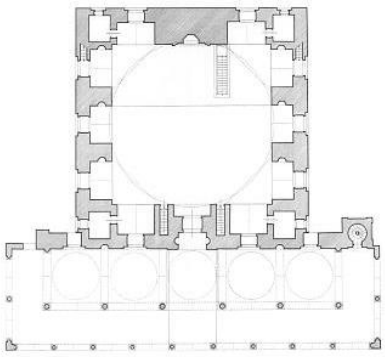


Figure 40. Behram Pasha Mosque Plan (Ülgen, 1989)

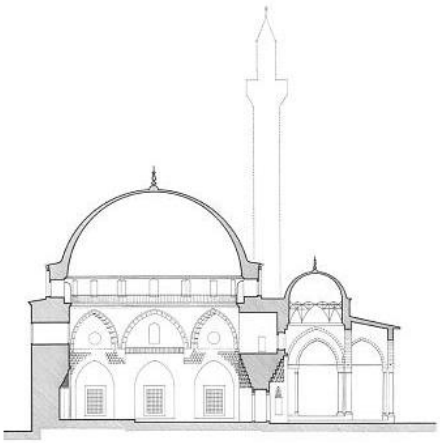


Figure 41. Behram Pasha Mosque Section (Ülgen, 1989)

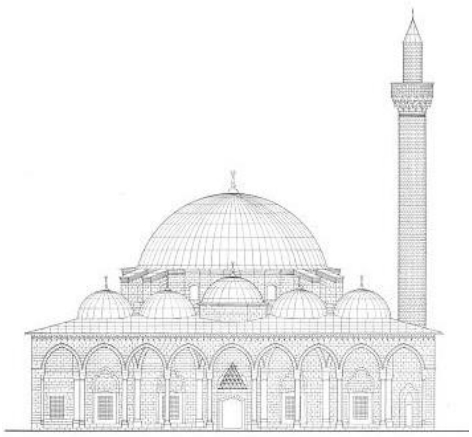


Figure 42. Behram Pasha Mosque Façade (Ülgen, 1989)

2.1.9. Pertev Pasha Mosque Structural and Spatial Analysis

Pertev Pasha Complex, which is a reach complex, was built in 1579 in Izmit by Mimar Sinan. The mosque consisted of a mosque, caravanserai, Turkish bath, primary school, and fountain-water reservoir. However, only mosque, fountain-water reservoir have survived to the present day (Figure 43) (Pertev Paşa Külliyesi, 2020).

The mosque, built of cut stone, has a single minaret and a single dome. The dome of the mosque, which has a nearly square rectangular plan, sits on an octagonal frame and the passage of the dome is provided by pendentive (Figure 46). The central dome is supported by semicircles. It is one of the original features of the mosque that the trombes in the interior are shown on the hoop front (Figure 44). Writing and pen decorations on the harim walls and stained glass on the windows enriched the building (Kishalı; Türkmenoğlu; Şener, 2019). With the help of the octagonal pulley made of two floors, 24 windows were made on the pulley walls. A bright and spacious atmosphere was provided within the structure by adding the daylight provided by the windows on the pulley walls to the height of the mosque body walls (Figure 45).

The last congregation place of the mosque has a double portico structure (Figure 47). The portico, which surrounds the last congregation place consisting of three domes and 2 mirrored vaults, is covered with a sloping roof. It has an outgrow as much as a minaret base on the east and west facades. The use of local Karamürsel stone on the facade walls gave the mosque a unique feature (Kishalı; Türkmenoğlu; Şener, 2019). The dodecagonal planned fountain on the north of the courtyard of the mosque is covered with a wide eave roof. Columns with muqarnas heads are connected with two colored arches and marble stone are placed on each facade (Gündoğdu; Işık, 2017).

Figure 43. Pertev Pasha Mosque (Çobanoğlu, 2019)

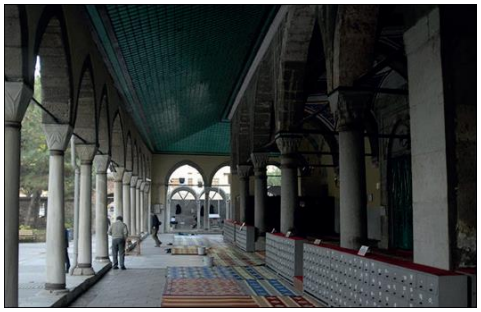


Figure 44. Pertev Pasha Mosque (Çobanoğlu, 2019)

Figure 45. Pertev Pasha Mosque (Çobanoğlu, 2019)

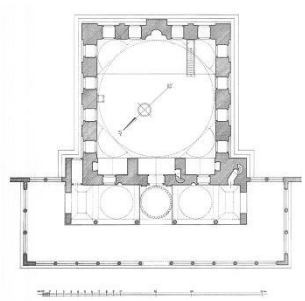


Figure 46. Pertev Pasha Mosque Plan (Ülgen, 1989)

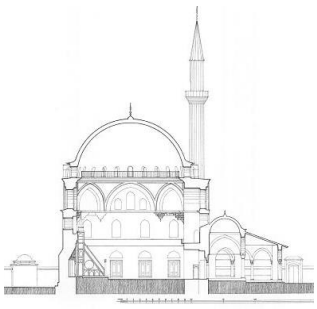


Figure 47. Pertev Pasha Mosque Section (Ülgen, 1989)

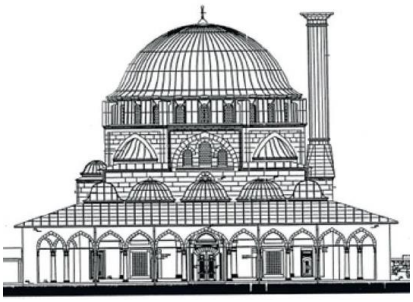


Figure 48. Pertev Pasha Mosque Façade (Sönmez, 2010)

2.1.10. Kurşunlu Mosque Structural and Spatial Analysis

It is located inside the Mimar Sinan Park to the west of the Cumhuriyet Square at the Kocasinan district in the city of Kayseri. Its plan typology is similar to those of the Bali Paşa Mosque and Hadım İbrahim Paşa Mosque which are Beyazıt the Second period structures. In this regard, it is considered to be a Mimar Sinan structure. Kurşunlu Mosque is the only structure by Mimar Sinan that has reached our day from among the two mosques built by him in Kayseri (Figure 51). The structure that has taken its current name from the lead coating of its dome is also known as Hacı Ahmet Paşa Mosque (Özbek; Arslan, 2008).

In 1394-1395, I. Bayezid added Kayseri to the Ottoman lands. Timur took control of Anatolia in 1402 with the Ankara War and passed to Kayseri Karamanoğulları. Fatih Kale Mosque, Yeşilyurt Melik Arslan Mosque (1465) and Merzifonlu Kara Mustafa Paşa Kulliye, which were dated to the last quarter of the 15th century in the city, which was

definitely taken over by the Ottomans in 1515, were built during this period. Kurşunlu Mosque is also thought to have been built between 1585-86 (Solak, 2013).

The last line of the text in the inscription of the mosque was determined as H.994 / M.1585–86 with the ebced account. However, it was stated that Sinan was 97 years old and there were conflicts about whether he built this mosque in person (Solak, 2013).

In the book "Kayseri Turkish Monuments" written by French architect Albert Gabriel in 1954, the construction date of Kursunlu Mosque was specified as 1585. Gabriel also reports that there are some historical documents showing that the mosque was built by Sinan during his researches. Even if the mosque was not built by Sinan himself, it is stated that the mosque plan was passed by the approval of Mimar Sinan because it was built during the his chief architectural period (Solak, 2013).

Yıldıray Özbek and Celil Arslan determined that this mosque was dated H.981 / M.1573 in the letter of concession given to Ahmet Pasha by II. Selim. Özbek and Arslan stated the date of the building as H.981 / M.1573 in the Kayseri Immovable Cultural Heritage Inventory they prepared (Sönmez, 2010).

Even if controversial information was given about the construction date of the building, it was accepted that the building is one of the examples of Classical Ottoman architecture of the *16th* century. The courtyard, the fountain and the last congregation place match the Classical Period Ottoman mosque typology (Orbeyi, 2016).

The mosque is the only structure that has reached our day from the Hacı Ahmet Paşa Külliye comprised of imaret, inn, school and Turkish bath and consists of a single site sanctuary covered with a dome and the narthex at the north façade. The dome that covers up the single site rests on the feet at the corners and pendentives are used to support the dome (Figure 52, 53). There is a minaret with a single balcony at the northwestern corner (Figure 54, 55). The courtyard walls of the mosque have been built later.

The mosque, which has classical Ottoman mosque plan, is surrounded by a wide courtyard and there is a fountain in the center of the courtyard. Harim is reached by passing through the ornamental detail door in the double-stage last congregation place in the south of the courtyard. There is a domed fountain in the courtyard supported by arches on eight pillars (Kurşunlu Cami, 2017). The harim area is covered with a pulley dome carried by pendentives by four columns hidden inside the wall (Figure 56). The feet placed on the south front are supported by outriggers in the outside. Reflecting the style of the Ottoman classical mosque architecture with its simplicity in the harim, the engravings of the mosque and the stained glass windows in the dome of the mosque slightly break the simplicity of the mosque (Photograph 28). The most spectacular part of the mosque is the north facade and the sentence door. The mihrab and minbar of the mosque are simple and made of marble.

The narthex of the mosque has two porticos much like the Üsküdar Mihrimah, Atik Valide and Eminönü Rüstem Paşa, Tekirdag Rüstem Pasha, Pertev Pasha, Behram Pasha Mosques which are other structures by Sinan (Figure 58). The southern section of the narthex is covered by five domes with pendentives supported by six marble columns and sharp arches on the northern wall (Drawing 26). The dome at the entrance axis is larger than the other domes. The sides of this section of the narthex are open. The southern section of the narthex has been encompassed in a U shape by the second narthex. This portico made by sharp arches on 24 columns is covered by a hipped roof resembling a lean-to (Figure 59).

There is one mihrab each on the outer facade of the northern wall of the mosque with one to the east and the other to the west.

The crown gate of the mosque made of marble has five lines of muqarnas. Two pillars have been placed to the eastern and western facades within the width of the supporting arches carrying the dome in the harim space after which they were connected via lancet arches thus making a gallery surrounding the interior space at all three facades excluding kiblah. The rear side of the crown gate has been protruded inside like two props for supporting these galleries (Figure 59). The transition between the galleries was provided through pendentives that carried the dome from the northwest and northeast corners. There are pointed arched iwan shaped spaces at the bottom of the galleries that surround the harim walls from 3 directions. There are these spaces in the form of iwan, which are two on the north and south facades and three on the east and west facades. Similar iwan arrangements were applied in Behram Pasha, Bali Pasha and Pertev Pasha Mosque of Mimar Sinan. Access to the mahfil is provided by the arched opening on the northeastern part of the last congregation place. On the southern facades of the eastern and western facades of the mahfil, there are a mihrab carved into the wall (Figure 60, 61).

There are two windows each at the lower sections of the southern and northern walls and three windows each on the eastern and western walls (Figure 61, 62, 63). These windows have a rectangular form with lancet arch pediments. There are six more windows at the upper section of the southern wall. The same arrangement can be seen on the eastern, western and northern walls. All upper windows are leaded. The eastern and western facades have the same appearance but a different application was made on the southern facade. There are buttresses that are not used in other fronts, raised up to the level of eaves in the east and west directions. There are nine windows in different forms and sizes on the facades. The minaret base in the northwest corner of the mosque continues to the top cover of the last congregation place (Figure 65)

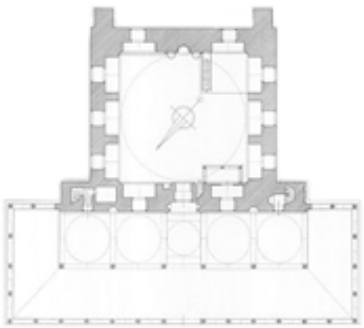


Figure 49. Kursunlu Mosque Ground Floor Plan (Ülgen, 1989)

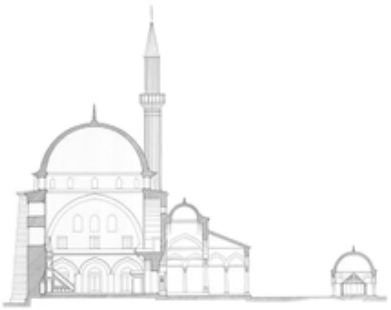


Figure 50. Kursunlu Mosque Section (Ülgen, 1989)

Figure 51. Kurşunlu Mosque Quad (Hasözhan, 2016)

Figure 52. Kurşunlu Mosque Interior (Hasözhan, 2016)

Figure 53. Kurşunlu Mosque Southern Façade (Hasözhan, 2016)

Figure 54. Kurşunlu Mosque Garden Wall and Enterance (Çopuroğlu, 2016)

Figure 55. Kurşunlu Mosque Northern Façade (Çopuroğlu, 2016)

Figure 56. Kurşunlu Mosque Interior (Kayseri Vakıflar Genel Müdürlüğü Arşivi, 2019)

Figure 57. Kurşunlu Mosque Dome (Kayseri Vakıflar Genel Müdürlüğü Arşivi, 2019)

Figure 58. Kurşunlu Mosque Northern Façade (Hasözhan, 2016)

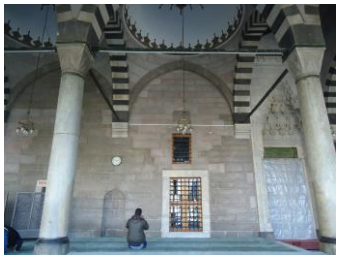


Figure 59. Kurşunlu Mosque Northern Façade (Hasözhan, 2016)

Figure 60. Kurşunlu Mosque Interior (Kayseri Vakıflar Genel Müdürlüğü Arşivi, 2019)

Figure 61. Kurşunlu Mosque Interior (Kayseri Vakıflar Genel Müdürlüğü Arşivi, 2019)

Figure 62. Kurşunlu Mosque Western Façade (Çopuroğlu, 2016)

Figure 63. Kurşunlu Mosque Eastern Façade (Çopuroğlu, 2016)

Figure 64. Detail from Kurşunlu Mosque Façade (Çopuroğlu, 2016)

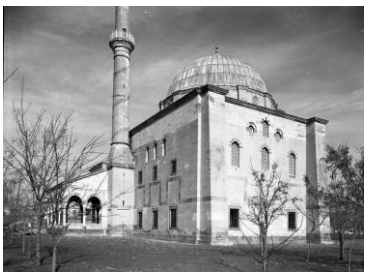


Figure 65. Kurşunlu Mosque Façade (Kayseri Vakıflar Genel Müdürlüğü Arşivi, 2019)

Figure 66. Kurşunlu Mosque Eastern Façade (Kayseri Vakıflar Genel Müdürlüğü Arşivi, 2019)

3. RESULTS

The study was carried out in ten mosques that Mimar Sinan built on different periods. Through these mosques, Sinan shows the developments in his architectural approach stage by stage. The changes are not observed just in the plan schema, but all of his new works strive to surpass his previous one from a structural point of view. This progress can be felt from what he called his apprenticeship period piece Şehzadebaşı, qualification period piece Süleymaniye and master period piece Selimiye Mosque. The attention and diligence he paid to the selatin (built for sultans) mosques is possible to observe in his smaller work. Each one of his works have been a small scale trial piece for him to test his new ideas for his next selatin mosque.

The plans, sections and views of the selatin and provincial mosques discussed within the scope of the article were reached and turned into Table 1. In the table, floor plans, sections and facades are arranged for each building. Thus, different data obtained from 10 mosques have been overlapped and made comparable. When Selatin and provincial mosques are compared among themselves; It is observed that the dimensions and fiction of the space in the plan plane, the height in the space dimensions in the cross-section plane, and the vacancy rates in the facades are similar in appearance. It is seen that the dimensions and positions of the bearing elements are similar in all three planes.

Şehzade Mosque has a main space with a half done that sits on four large feet completed by four quarter domes around this half dome. The two main carrier walls next to the mihrab wall is supported by elegant columns. The porticos that surround the mosque courtyard and the narthex is covered by small half domes. Süleymeniye, which follows Şehzade mosque and is a selatin mosque, is a higher design of Şehzade mosque with a very large space. It is a larger scale application of what's been learned in Şehzade. Sinan also put a great half dome on top of four great carrier feet supports this dome with two quarter domes in this work. By managing to cover a larger rea with a lesser number of carriers, he manages to surpass Şehzade. Here, again the two carrier walls are supported by elegant columns. But the column sections of Şehzade have been applied with elegance and in twos in Süleymaniye. He also got rid of the thick carrier walls of Şehzade Mosque by putting window openings created on the walls in the Süleymaniye mosque. Larger spaces have been passed by using lesser and more elegant carriers.

Although Selimiye Mosque is a selatin mosque built outside of Istanbul, it is grander than the selatin mosques in Istanbul. Using the teachings from the Süleymaniye Mosque, the carriers in Selimiye Mosque have smaller sections and can cross larger spaces. In Selimiye, now a single large half dome covers the entire space and eight feet with smaller sections carry this great dome. Now also the main carrier walls are thinner in sections and are lighter with the opened window spaces.

Bali Pasha Mosque which is chronologically in between Şehzade and Süleymaniye and the Hadım Pasha Mosque which is chronologically in between Süleymaniye and Selimiye have similar plan schemes and section creations. The main space, which is covered by a single half dome, has main carrier walls are made of think stones. The tranquality and simplicity of the space is striking. The efforts to make the carrier main wall sections thinner are visible in both mosques. This is a small trial for Selimiye as well. Subsequently constructed Rüstem Pasha Mosque again was created by covering a single space with a half dome. But what sets is apart from Bali Pasha and Hadım İbrahim Pasha is that the existence of four delicate columns that help carry the dome. Again, it can be seen as a sub-scale of the Selimiye Mosque plan scheme. In fact this is a proof of how the schemes develop as well as Sinan giving the same attention and diligence to his other work as he does to his selatin mosques.

Close to the time of his death, Mimar Sinan also constructed a piece in his hometown Kayseri. Kurşunlu Mosque is among Sinan's farthest work from Istanbul, the capital of Ottoman Empire. The planning scheme of Kurşunlu Mosque is the same with Bali Pasha, Hadım İbrahim Pasha Tekirdağ Rüstem Pasha and Rüstem Pasha Mosques. Even more, it is identical to the plan typology and carrier system of Tekirdağ Rüstem Pasha Mosque. In both Tekirdağ Rüstem Pasha and Kurşunlu Mosques, it can be seen that a single space is covered by a single dome. The carrier main walls were attempted to thin down and lighten up by using window spaces on the interior. The most significant difference between Tekirdağ

Rüstem Pasha and Kurşunlu Mosque from other similar work is the portico sections added to the narthex. Tekirdağ Rüstem Pasha and Kayseri Kurşunlu Mosques are their twins in every way. Tekirdağ Rüstem Pasha Mosque is placed as an example close to the capital city. On the other hand, Kurşunlu Mosque is among the rare examples in the rural parts of the Ottoman Empire. As a great architect in his master years, Mimar Sinan's humble approach in the Kurşunlu Mosque is a proof that the architect did not only develop himself in the architectural schemes but also as a person too.

As an architect who exceeds himself in every one of his mosque, Mimar Sinan's approach in Kurşunlu Mosque greets us as a humble example of classical Sinan schemes in a faraway land of the Ottoman Empire.

Table 1. Chronological Analysis Table of Mimar Sinan Mosques

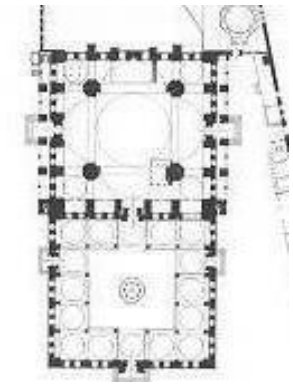
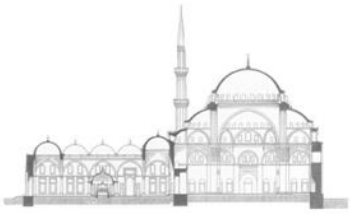
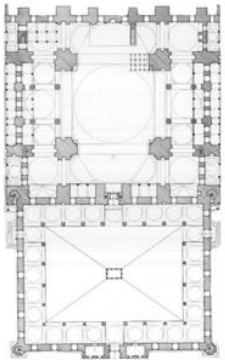
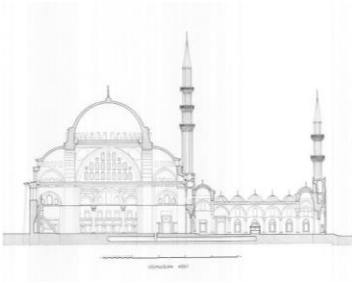
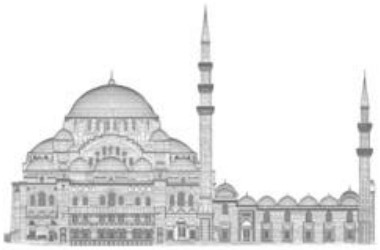
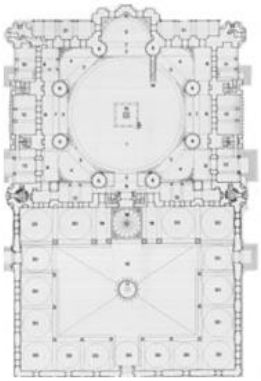
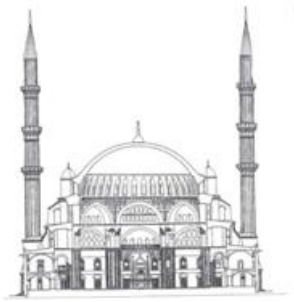
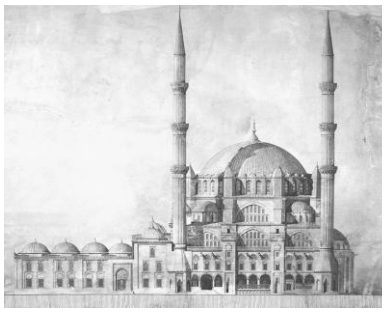
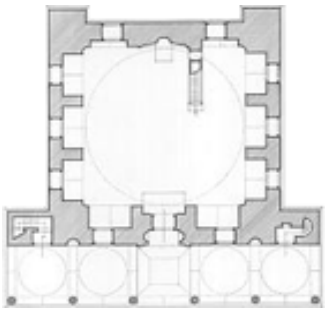
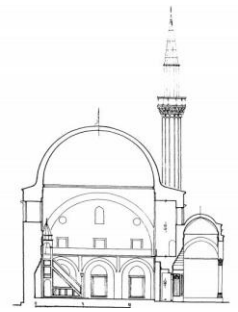
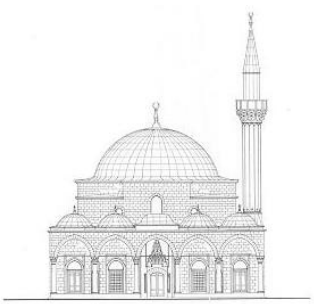
NAME	DATE	PLAN	SECTION	FACADE
Şehzade	1543			
Süleymaniye	1550			
Selimiye	1568			
Bali Pasha	1548			

Table 1. Chronological Analysis Table of Mimar Sinan Mosques

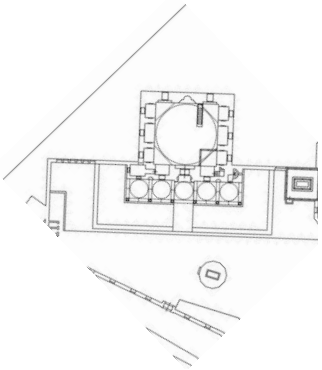
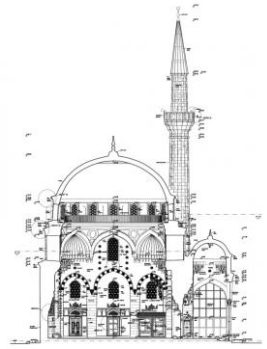
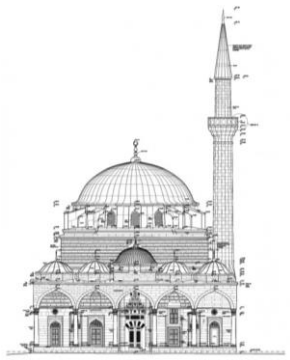
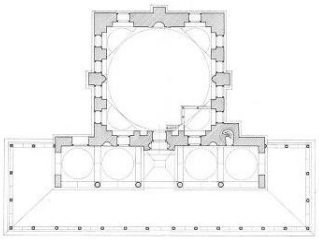
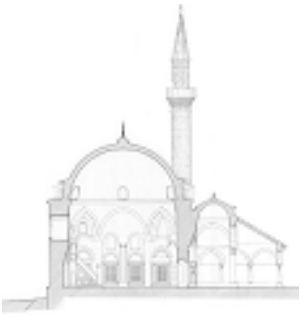
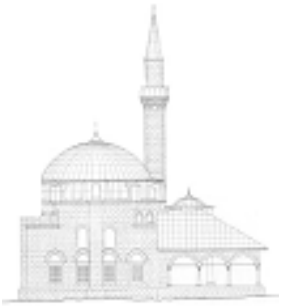
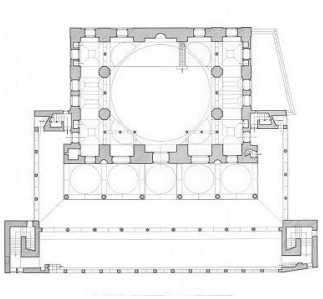
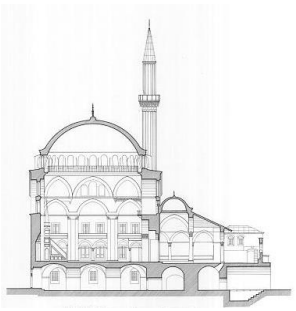
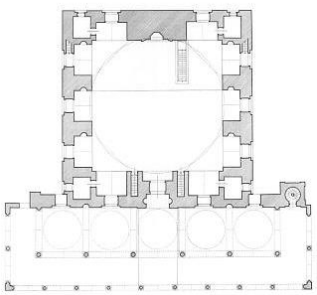
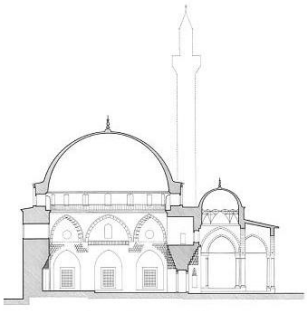
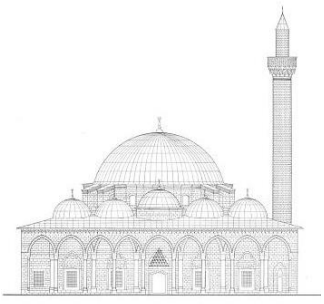
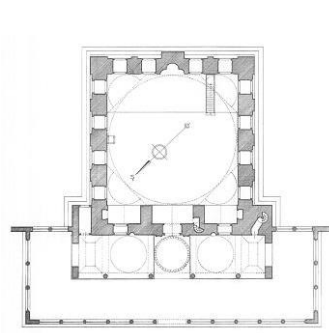
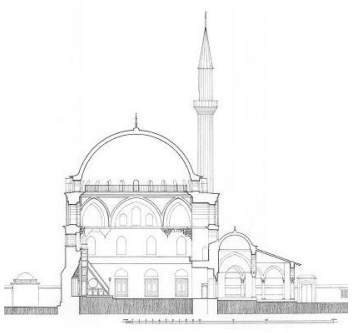
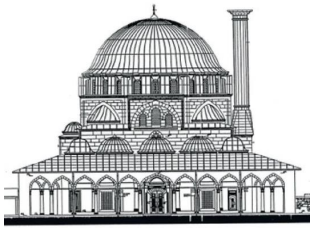
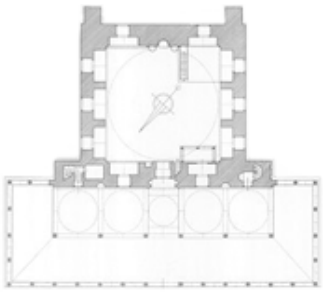
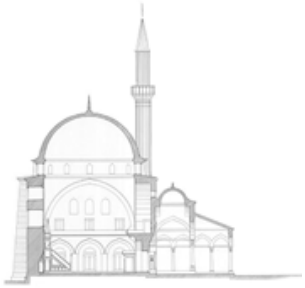
NAME	DATE	PLAN	SECTION	FACADE
Hadım İbrahim Pasha	1551			
Tekirdağ Rüstem Pasha	1552-1553			
Rüstem Pasha	1561			
Behram Pasha	1572			

Table 1. Chronological Analysis Table of Mimar Sinan Mosques

NAME	DATE	PLAN	SECTION	FACADE
Pertev Pasha	1579			
Kurşunlu	1586			

4. DISCUSSION AND CONCLUSION

In many monumental structures across the Ottoman Empire, such as mosques, manufacturing facilities, bridges, dams and more, Mimar Sinan acted in various capacities, such as designer, builder, design/builder. It was also observed that in constructions that he was not directly present, he managed to leave his mark through his approvals and interventions or by the education he provided to the architects that learned from him. In fact, Mimar Sinan's influence on his pupils was so great that some of the works done by his pupils are attributed to Mimar Sinan as well. The largest discussion about this subject is on how it was possible to see Mimar Sinan's mosques across the incredibly vast domains of the Ottoman Empire. During his period, Mimar Sinan designed and personally attended most of the works. But it is also known that in projects that were on the far ends of the Empire, the design of the piece was created in a single center by Mimar Sinan and was managed by architects guided by Sinan. This is understood from the official records of the period.

One of Mimar Sinan's mosques is the Kurşunlu Mosque in Kayseri. The distance of Kayseri and the capitol Istanbul, the fact that it was built during Mimar Sinan's master years and still having a very humble layout makes Kurşunlu even more significant. Mimar Sinan is from Kayseri and his work he left in his hometown is the Kurşunlu Mosque. The reason to why Kurşunlu Mosque is ranked high among Sinan's mosque is understood following a comparison with his previous work.

The comparison shows that his apprentice, qualified and master period works are monumental structures that are improved versions of each other. It was observed that Şehzade Mosque guided Süleymeniye Mosque and in return, Süleymaniye Mosque guided Selimiye Mosque. Within this period, four

mosques of Sinan that rank among his more humble pieces have interesting attributes. These are the Bali Pasha, Hadım İbrahim Pasha, Tekirdağ Rüştem Pasha and Rüstem Pasha Mosques. Looking at their plan schemes, it can be seen that the main walls that define the single main space and carry the dome transform into narrower and more elegant carriers. Another common attribute of these four mosques is to have a narthex covered by 5 small domes right in front of the main space. It is possible to see a similar plan scheme in Kurşunlu Mosque that resembles these four. But it is clearly visible that Kurşunlu has exactly the same scheme with Tekirdağ Rüstem Pasha Mosque. Similar to the Tekirdağ Rüstem Pasha Mosque, Kurşunlu Mosque has a portico instead of the narthex.

The studied selatin and provincial mosques are generally in the sense of classical Ottoman architectural plan with the application of courtyards, fountains and last narthex. On the other hand, when the structures of the mosques designed at different scales on the plan plane are examined, it is seen that they are constructed differently. While the Bali Pasha, Hadım İbrahim Pasha, Tekirdağ Rüştem Pasha, Behram Pasha, Pertev Pasha and Kurşunlu mosques, which are handled in the provincial mosques, rise with their body walls, it is seen that the Rüştem Pasha mosque rises with carrier columns in the main space. The factor that caused this difference; While the main walls in the rectangular plan scheme close to the square are in the beaerer state, the columns in the Rüştem Pasha mosque with the rectangular plan scheme are also added as the bearer. When the samples of Selatin mosque are examined, it is seen that the main space proportional to the scale of the building has also grown. Therefore, in addition to the body walls, large-scale carrier columns stand out in the main space. Depending on Sinan's mosque design setup, it is also seen that column sizes, forms and positions within the building vary.

It is seen that the examples of the classical Ottoman period provincial mosques, which are considered in the study, have a rectangular plan of nearly square. When the plan types of the mosques of Sinan, which can be defined as small scale, are examined, the four facades rise with their main walls, and the narthex is attached to the main wall on the entrance facade. At the same time, it is observed that the narthex, which was gradually placed on the facades of the mosques, formed a corridor on the door axis with this rise.

The mosques built in accordance with the determined Classical Ottoman architectural style were examined comparatively on their structural, formal and technical features. Selatin mosques of Sinan, which are among the mosques studied, are known more than other mosques, and the provincial mosques have become an important part of the city with their modest identities. Within the scope of this study, Kurşunlu Mosque, which has not been worked on even though Sinan was located in the city where he was born, was brought to the fore by addressing the provincial mosques of Sinan. Among these mosques, the distance of Kayseri from Istanbul, which is a dignitary, and the fact that the building was so modest despite the period of mastership of Mimar Sinan increases the importance of Kursunlu.

It is clear that Kurşunlu Mosque, located in a small town in a remote part of the Ottoman Empire with the classic Sinan attributes of the time, has an important place among Sinan’s mosque.

This study determines that Sinan 's simpler and smaller works are related to each other in terms of scale and structure. It also aims to increase awareness by bringing these features to the fore. It is hoped that the study will contribute to future studies to be done on this subject.

5. ACKNOWLEDGMENT

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6. REFERENCES

Aslan A. (2016). Süleymaniye Cami'nin Yerel Zemin Koşullarına Bağlı Deprem Performansının Değerlendirilmesi. Yıldız Teknik Üniversitesi, Fen Bilimleri Enstitüsü, Yüksek Lisans Tezi, 26s, İstanbul

Bali Paşa Cami. (2017). www.mimarsinan.gen.tr (14-02-2017)

Bali Paşa Cami. (2017). www.istanbulkulturturizm.gov.tr (14-02-2017)

Bali Paşa Cami. (2017). Vikipedi, (14-02-2017)

Bali Paşa Câmi. (2020). www.fatih.gov.tr/balipasa-camii (23.01.2020)

Bali Paşa Câmi. (2020). http://www.fatih.gov.tr/balipasa-camii, bali paşa cami (25-01-2020)

Behram Paşa Câmi. (2020). https://islamansiklopedisi.org.tr/behram-pasa-camii (25-01-2020)

Benian, E. (2011). TUBİTAK Bilim Teknik Dergisi",Mimar Sinan ve Osmanlı Cami Mimarisinin Gelişimindeki Rolü, Baskı İhlas Gazetecilik Anonim Şirket, Ankara, ISSN 977-1300-33-80 Yıl 44 Sayı 518, Sayfa 41-47

Cambaz, M.(2014). Tekirdağ Rüstem Paşa Cami Fotoğraf Albümü, Tekirdağ

Cami. (2016). Vikipedia, https://tr.wikipedia.org/wiki/Cami (18-11-2016)

Çetintaş, S. (1935). Sencer Erkman Kişisel Arşivi, (20.03.1935)

Çobanoğlu, A., D. (2019) "Silivrikapı Hadım İbrahim Paşa Camii'nin Plan Özellikleri ve Klasik Dönem Osmanlı Mimarlığı İçinde Benzer Örnekler Üzerine Bir Değerlendirme", Art-Sanat Dergisi, İstanbul üniversitesi yayınevi, İstanbul,(2019)

Çobanoğlu, A., D. (2019). "Silivrikapı Hadım İbrahim Paşa Camii'nin Plan Özellikleri ve Klasik Dönem Osmanlı Mimarlığı İçinde Benzer Örnekler Üzerine Bir Değerlendirme", Art-Sanat Dergisi, İstanbul üniversitesi yayınevi, İstanbul.

Çopuroğlu, H. (2016). "Kurşunlu Cami kişisel fotoğraf albümü", Kayseri

Ekinci, Y. (2009).Tarihi Çevre Korumanın Yönetsel Boyutu Ve Yerel Yönetimlerin Sorumlulukları: Selimiye Camii Alan Yönetimi Örneği. Trakya Üniversitesi, Sosyal Bilimler Enstitüsü, Yüksek Lisans Tezi, 111-115s, Edirne

Eminönü Rüstem Paşa Cami. (2017). www.tas-istanbul.com (14-02-2017)

Erçağ, B. (1987). Rüstem Paşa Camii V. Vakıf Haftası: 7-13 Aralık 1987, s. 85-86

Eruyar, S. (2016). Süleymaniye Külliyesi'nin Tarihsel Süreçtek Değişimi,

www.kulturturizm.gov.tr/Eklenti/31198,secileruyarpdf.pdf, Mart 2016.

Gurlitt, G. (1912). Sehzade Mosque, Die Baukunst Konstantinopels Kitabı, https://dome.mit.edu/handle/1721.3/65891 (20-11-2016)

Gündoğdu, H.,Işık, R. (2017). İzmit Pertev Paşa Külliyesi'nin Klasik Osmanlı Mimarisindeki Yeri Ve Önemi, Gazi Akçakoca Sempozyumu, s. 1587-1607, Kocaeli.

Hadım İbrahim Paşa Cami. (2017). www.fatihmuftulugu.gov.tr (12-02-2017)

Hadım İbrahim Paşa Cami. (2017). Rölöve, Restitüsyon ve Restorasyon Projeleri, www.mptasarim.net (12-02-2017)

Hasözhan, M. (2016). "Kurşunlu Cami kişisel fotoğraf albümü", Kayseri

İstanbul Rüstem Paşa Cami. (2017). www.mimarsinaneserleri.com (14-02-2017)

İrfan Yıldız. (2011). Medeniyetler Mirası Diyarbakır Mimarisi, Diyarbakır Valiliği Kültür Ve Sanat Yayınları-3, Diyarbakır.

Kayseri Vakıflar Genel Müdürlüğü Arşivi (25-10-2019)

Kishalı, E., Türkmenoğlu, N., Şener, M. (2019). Kocaeli Tarihi Cami Örnekleri Üzerinden Planlı

Kocamustafa Hadım İbrahim Paşa Cami. (2017). www.tas-istanbul.com (12-02-2017)

Koruma Kapsamında Hasarsız Test Uygulamaları: Çoban Mustafa Paşa Camii, Fevziye Camii ve Pertev Paşa Camii (1), METU JFA, Ankara.

Köse, A. (2013).Edirne Selimiye Camii'nde Yazının Süsleme Unsuru Olarak Kullanımı. Trakya Üniversitesi, Sosyal Bilimler Enstitüsü, Yüksek Lisans Tezi, Edirne

Kurşunlu Cami. (2017). www.mimarsinaneserleri.com (14-02-2017)

Melek, A., Demir, A. (2009). "Dini Değerleri İle Diyarbakır", Diyarbakır İl Müftülüğü Yayınları, Diyarbakır.

Mimar Sinan-Eserleri. (2016). Vikipedia, https://tr.wikipedia.org/wiki/Mimar_Sinan%27%C4%B1n_eserleri_listesi (27-10-2016)

Mimar Sinan'ın Eserleri. (2017). http://www.mimarsinan.gen.tr/mimar-sinan-resimleri/ (25-03-2016)

Necipoglu, G.(2005). The Age of Sinan: Architectural Culture in the Ottoman Kitabı, London

Orbeyi, N. (2016). Çift Revaklı Sinan Camilerinde Modüler Sistem, Metu Jfa, Ankara.

Özdemir, B. (2017). Some Vıews on The Productıon Places of Eminönü Rüstem Paşa Mosque Tıles. Eurasian Academy of Sciences Social Sciences Journal, 15(2017), 76-105.

Özbek, Y., Arslan, C. (2008). Kayseri Taşınmaz Kültür Varlıkları Envanteri, Kayseri Büyük Şehir Belediyesi Yayınları, Cilt-I, Baskı: Aydoğdu Ofset Matbaacılık ve Ambalaj Sanayi Tic. Ltd. Şti., Ankara, ISBN:978-975-8046-67-6, sayfa: 128-13

Pertev Paşa Külliyesi. (2020). https://islamansiklopedisi.org.tr/pertev-pasa-kulliyesi (28.01.2020)

Rüstem Paşa Cami. (2020). https://tr.wikipedia.org/wiki/R%C3%BCstem_Pa%C5%9Fa_Camii (25-01-2020)

Rüstem Paşa Külliyesi. (2017). www.islamansiklopedisi.info (20-03-2017)

Selatin Cami. (2017). Vikipedi b, https://tr.wikipedia.org/wiki/Selatin_camileri (20-03-2017)

Solak, S. (2013). Kayseri'deki Tek Kubbeli Camii ve Mescitler. Selçuk Üniversitesi, Sosyal Bilimler Enstitüsü, Yüksek Lisans Tezi, Konya.

Sönmez, N. Ü. (2010). Mimar Sinan Yapısı Menzil Külliyelerinden; İzmit Pertev Paşa Külliyesi. Sakarya Üniversitesi, Sosyal Bilimler Enstitüsü, Yayınlanmamış Yüksek Lisans Tezi, Sakarya

Süleymaniye Cami'nin Yapılış ve Özellikleri. (2016).www.suleymaniyecamii.org (27-10-2016)

Süleymaniye Cami, (2016). www.mimarsinaneserleri.com (30-12-2016)

Saraçhane Şehzade Mehmet Cami-Mimari Yapı. (2016). www.tas-istanbul.com, (23-11-2016)

Şehzade Cami. (2016). www.sehzade.gen.tr (23-11-2016)

Şehzade Cami. (2016). www.mimarsinaneserleri.com (23-11-2016)

Tekirdağ Rüstem Paşa Cami. (2017). www.mimarsinan.gen.tr (20.03.2017)

Tekirdağ Rüstem Paşa Cami İç Mekan Fotoğrafı. (2017). http://www.restorasyonforum.com (20-03-2017)

Ülgen, A., S. (1989). Mimar Sinan Yapıları, Ankara Türk Tarih Kurumu, ISBN 9751601649

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Book Review

Book Rewiew; Methods and Techniques in Ethnobiology and Ethnoecology

Albuquerque, U. P., da Cunha, L. V. F. C., De Lucena, R. F. P. and Alves, R. R. N. (Eds.) Springer New York, 2019. pp. 1537. 119.99 € (Softcover) ISBN 978-1-4939-5452-0, 199.99 € (Hardcover) ISBN 978-1-4614-8635-0, 96.29 € (eBook) ISBN 978-1-4614-8636-7.

BOOK REVIEW

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Ethnobiology, first coined by Edward Castetter in 1935 is the study of the biological knowledge of particular ethnic groups - cultural knowledge about plants and animals and their interrelationships (Anderson, 2011; D'Ambrosio, 2014). It is therefore was used to integrate two well established ethnoscience fields - ethnobotany and ethnozoology. Ethnobiology in general, and ethnobotany and ethnozoology, sometimes with ethnoecology, ethnoveterinary, ethnomedicine, ethnomicrobiology as related fields, in particular have recently been popular and a great deal of published data is available both online and printed. Although ethnobiological studies have initially been characterized by descriptive approaches and documentation related with the uses of plants and animals in daily life, it is currently considered to be in an interdisciplinary stage, where the cooperative approaches among researchers from different fields of biological and social areas is sought in order to handle more complex problems that can affect biological and cultural diversity (Sobral and Albuquerque, 2016).

Since its foundation, major advances occurred in ethnobiology but it is still a need for books that can serve as references for most popular and usual approaches as well as the methods of disciplines that interact with ethnobiology. Researchers interested in ethnobiology currently have the opportunity to reach a well-organized reference guide after the publish of the 2nd edition of "Methods and Techniques in Ethnobiology and Ethnoecology" edited by Albuquerque, U. P., da Cunha, L. V. F. C., De Lucena, R. F. P., & Alves, R. R. N. which was built on the 1st edition published in 2014 to fill some of the gaps not covered here. The editors say in their foreword that their intention was that "*each chapter should be a script that would allow the researcher to know each of the methods described in the literature as well as to make the best choices for their own research*".

The book was published to cover a total of 21 chapters organized in 4 parts as ***i)*** Methods and Qualitative Techniques, ***ii)*** Methods and Quantitative Techniques, ***iii)*** Methodological and Theoretical Challenges and ***iv)*** Methods and Techniques of Related Areas with contribution of 78 researchers mainly from Brazil. Brazil and Latin America in whole can be considered the lead in ethnobiological studies, at least in the comparison between Latin America and Asia reported by Sobral and Albuquerque (2016). The authors reports the numerical distribution of studies from 1960s to 2016 and the ratio of Brazil in Latin America studies is 41% with 289 studies, which is very close to the total number of studies in Asia (365 studies).

The first part of the book gives methods and techniques in qualitative research and starts

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with a chapter devoted to a brief discussion about qualitative research, an approach widely used in social sciences to understand the phenomena that involve humans. The rest of the first part continues with topics in designation, quality control and review of a research protocol among which the latter was given a special importance because review of a protocol helps the researcher in understanding if its protocol is appropriate to cover the entire phenomenon that is intended to study. The use of field journals, personal document consisting in recording observations, comments, and reflections for the researcher's individual use, audio and video recording techniques for ethnobiological research, qualitative data analysis and the method of organization and tabulation of qualitative data in ethnobiological research can also be found in this part.

The second part of the book is a detailed reference guide for researchers in Ethnobiology who will find a discussion of quantitative approaches on the use of hypothetico-deductive method (HDM) and univariate and multivariate statistical approaches in ethnobiology research. This part starts with a chapter built upon the idea that practice without theory is blind and unpredictable. The chapter is devoted to provide the way to combine the HDM with statistical thinking to create a diagram that links variables by causal links. The authors of the chapter underline the importance of this in improvement of the scientific method and statistical literacy. The following chapter on multidimensional analyses for testing ecological, ethnobiological, and conservation hypotheses encourages students and researchers to move from a description-based multidimensional analysis to an explicit hypothesis-testing framework that can greatly improve learning and research programs. The rest of this part deals with the use of multivariate tools in studies of traditional ecological knowledge and management systems, the spatiotemporal scale of Ethnobiology and collection and analysis of environmental risk perception data. Within the scope of multivariate tools, the readers can find details of constructing a matrix of ethnoecological data, types and principles of multivariate analyses with special attention to Principal Component Analysis (PCA), Correspondence Analysis (CA), Non-Metric Multidimensional Scaling (NMDS) and Principle Coordinate Analysis (PCoA). It is known that ethnobiological data study at different spatiotemporal scales allows researchers to define the social-ecological patterns and the variables that originate them. The chapter focused on the spatiotemporal scale of ethnobiology lists the newly emerged research perspectives as a result of the conceptual growth at different spatiotemporal scales of ethnobiology and details two of these new perspectives, the application of Meta-Analysis or Meta-Analytical Approach and the Macro-Ethnobiological approach. The second part lasts with collection and analysis of environmental risk perception data, a title which was considered a very useful tool in ethnobiological studies particularly in search for a better understanding of environmental problems perceived and faced locally.

The third part of the book convers chapters on methodological and theoretical challenges of ethnobiology. The first chapter describes the scientific study of relationships which are said to be complex between people and their environment and terms it biocultural ecology as a specific ecological domain. In addition to biocultural ecology, readers can find a discussion about presuppositions about ecology, ethnoecology and about the dissociation between nature and culture, the links between knowledge and actions. The following chapter written with the contribution of ethnobiologists, botanists, ecologists, and archaeologists from several institutions working in the Amazon basin integrates archaeology and ethnobiology. The guidelines and suggestions, and the given examples, for the application of ethnobotanical and ethnoecological methods in archaeological sites are absolutely interesting for all readers. The rest of this part continues with a discussion on methodological challenges

and difficulties in ethnozoological researches and points out suggestions that could be considered on minimization of such difficulties. Bioculture can be regarded as a component of biodiversity which should be paid special attention. The end of the third part starts with a chapter on biocultural collections by which one can document human–nature interactions through plant and animal-based artifacts, raw materials, herbarium voucher collections, and varied forms of documentation. The importance of such collections especially on biocultural conservation, preserving and enhancing traditional knowledge, livelihoods, and the environment is highlighted. The closing chapter is on protocols and ethical considerations in ethnobiological research development and provides an excellent insight about legal and ethical issues through international and national frameworks.

The latter part of the book provides readers a description of methods used in other disciplines such as phytochemistry, ecology, zoology, and conservation biology. Considering the fact that isolation and the study of bioactive natural products is an important interest area in pharmacological studies, the most recent and advanced techniques for extraction, isolation, and analysis of natural products from medicinal plants were given. Animals as zootherapeutic resources for ethnoveterinary practices are listed with related methodological details. The readers, in the rest of the last part, will have the opportunity to find the most appropriate methodology for their special objectives on extractive practices on exploited plant populations. Noninvasive sampling techniques for vertebrate fauna and techniques to evaluate hunting sustainability are the last topics of this part with which a brief summary on the main available noninvasive techniques for vertebrate sampling and the main protocols used in research for the evaluation of how hunting impacts on the populations of target animals was given.

In conclusion, the book "Methods and Techniques in Ethnobiology and Ethnoecology" provides an insightful understanding of ethnobiological methods described in literature by presenting various methods covered in each chapter in addition to the extensive bibliography that details the current literature available in the field. It is for sure that the book is useful for a wide range of readers including both students and scholars from different disciplines. It is a pleasure to read such a well-written book that successfully integrates different fields of science in ethnobiology as a junction point. As stated in Wolverton (2013), ethnobiology should be regarded a field of science where researchers can address biocultural conservation, environmental co-management, environmental ethics, respect for the intellectual property rights of indigenous and local peoples, and other relevant issues, such as climate change, to solve modern local, regional, and global environmental and cultural issues.

REFERENCES

Anderson E. N. (2011). Ethnobiology: overview of a growing field. In: Ethnobiology. Anderson, E. N., Pearsall, D.M., Hunn, E.S. and Turner, N.J. (eds), Wiley-Blackwell, 1-14.

D'Ambrosio U. (2014). Theoretical reflections on ethnobiology in the third millennium. *Contrib Sci*, 10, 49–64.

Sobral A., Albuquerque U. P. (2016). History of ethnobiology. In: Introduction to Ethnobiology. Albuquerque, U. P. and Alves, R. R. N. (eds), Springer, Cham., 9-14.

Wolverton S. (2013). Ethnobiology 5: interdisciplinarity in an era of rapid environmental change. *Ethnobiol Lett* 4, 21–25.

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