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Muge Burcu Ozdemir, Recep Karadag

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Anatolian Acorn Oak's Economic Potential in the Application to the Textile and Leather Industries

Muge Burcu OZDEMIR[1*], Recep KARADAG[2,3]

[1]Department of International Trade and Finance, Istanbul Aydin University, Istanbul, Turkey

[2]Department of Fashion and Textile Design, Istanbul Aydin University, Istanbul, Turkey

[3]TCF Cultural Heritage Preservation and Natural Dye Laboratory, Istanbul, Turkey

*mugeozdemir@aydin.edu.tr

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ABSTRACT

The Anatolian acorn (Quercus ithaburensis Decne) is a promising resource for a variety of industries in Turkey and the world. It has the potential to serve as a bio-mordant, natural dye for textiles and leather, providing an eco-friendly alternative to synthetic dyes and reducing dependence on chemicals and petrochemicals. The commercial viability of the acorn and its export potential make it a valuable resource for supporting regional trade and boosting the local economy, with the potential to create new job opportunities. In addition, the acorn has a unique colour range, fastness, and antimicrobial properties, making it a desirable choice for manufacturers looking for a sustainable alternative. Overall, the Anatolian acorn holds great potential as a natural dye and a valuable resource for supporting regional trade and sustainability goals. The development and commercialization of this resource could play a significant role in the future of sustainable development in Turkey and the world.

KEYWORDS

Anatolian acorn, economic potential, bio-mordant, natural dye, textile, leather, sustainability

INTRODUCTION

The utilization of sustainable natural products has gained significant importance in the dyeing of textiles and textile products, as well as in various other industries. With the growing emphasis on natural alternatives, the significance of forest ecosystems has become increasingly recognized. This is because forest ecosystems serve as the primary source of essential natural products, contributing to economic growth and societal well-being [1]. Acorn, one of the main products of forest ecosystems, is a significant raw material in textile colouring and the leather industry. It also plays a vital role in supporting regional trade [2] and advancing sustainability and zero discharge of hazardous chemicals (ZDHC) goals [3,4].

Acorns naturally grow in Mediterranean coastal regions, from Italy to Israel, as well as in Turkey's Aegean and Mediterranean regions [2]. Acorn caps, a primary product of forest ecosystems, hold importance not only as a raw material in the leather and textile industry but also as a popular animal food in many parts of the world, especially in the Mediterranean region. The objective of this study is

to explore the economic aspect of acorn oak (*Quercus ithaburensis*) by analyzing its potential for export. Specifically, the study aims to investigate its role in achieving sustainable development goals and its contribution to regional development within the context of textile dyeing. Acorn caps include tannen colouring compounds. Ellagic and gallic acids and their derivatives are the main colouring compounds of acorn caps. The colouring compounds are used in the dyeings (in the textile and leather) and used as a bio-mordant material textil dyeings and vegetable tanning of leather. Despite a long history of deforestation, pure oak forests in Turkey still account for 25% of the total forested area. Acorns, which are the fruit of oak trees, are produced by several oak species, with the most commonly found ones in Turkey being *Quercus cerris* L. (Turkish oak), *Quercus ithaburensis* Decne subsp. macrolepis (Kotschy) Hedge-Yalt (Acorn oak), and *Quercus robur* L. (Handled oak). These species hold significant economic value due to the utilization of their acorns for various purposes [1].

POTENTIAL

It is estimated that about 220 t of acorn oak caps can be harvested from one hectare. In Turkey, acorn oak covers an area of 142,293 ha and its caps have an estimated potential yield of 3,304,460 t per year [1]. Acorn oak is used in the textile dyeing process as well. In light-colour dyeings, 10% of acorn caps are used for beige and light brown colours [5]. Based on several studies, the estimated dyeing capacity for light colours, such as beige and light brown, is approximately 313,044,600 t of fabric per year. However, when it comes to dark colours, such as dark brown, grey, and black, the use of acorn oak is limited to a maximum of 50%, which may allow for an average of 62,608,920 t/year of fabric or textile goods to be dyed.

It is important to note that the dyeing capacity may vary depending on various factors such as the type of fabric, textile, leather or leather goods, the concentration and quality of the dye, the dyeing method, and the environmental conditions during the dyeing process. Therefore, further research and testing may be required to accurately determine the dyeing capacity for different colours and materials.

The acorn oak tree is utilized for various purposes. Its wood, bark, and acorn are all used. In addition, its fruits and caps are also utilized. The caps contain 10-15% water and fruits contain sugar (glucose) apart from the grain [1].

The acorn oak tree has many uses in various industries. The portion of sugar in the fruits is 9% in the flesh and 2.7% in the caps. Acorn caps and nails are used in the leather industry in the form of powder or extract, either alone or mixed with other tanning materials. It is also used in the textile industry for dyeing silk, wool, cotton, etc. fabrics, or garments in black. The extract obtained by treating the caps and nails with water after pulverizing is also used in the production of syrups, which are used as a remedy for diarrhoea in children and can be sweetened with honey, sugar, or other sweeteners [1].

Acorn extract contains 70% tanning agents, 4% glucose, 1.5% sucrose, and 7.5% water. The world leather industry relies heavily on vegetable tanning materials to meet its annual tanning needs, with a significant portion of this demand being met by acorn extract. The fruits of the acorn oak tree are also used as medicine, specifically to treat diarrhoea effectively. The extract and powder obtained from the goblets and nails are also used to cure stomach and diarrhoea. An understanding of the characteristics of acorn powder can provide insights into the significant economic value of acorns [1].

GENERAL USES

When evaluated in its historical process, it is clear that the Anatolian acorn oak tree has always been a valuable resource. The ancient Greeks and Sumerians used it as a tanning agent and a dye plant. Its cupulas, in particular, are multi-functional and contain high levels of tannins [6]. Tannins can be extracted from various parts of plants, such as the roots, bark, wood, fruit, fruit peels, leaves, and plant glands, using an extraction method [7].

This section aims to explore the various applications of Anatolian acorn oak. One of its primary uses is as animal feed. Acorns are widely employed as a food source for small livestock in numerous regions across the globe.

Biochemical analyses were conducted to explore the diverse nutritional attributes of distinct types of acorns. According to Sarıçiçek et al., the acorns of the oak species used in the study were found to contain the necessary protein for the daily nutrition of animals, making it a suitable feed for small cattle. The study also found that both shelled and unshelled acorns are rich in carbohydrate content [8]. The most significant use of acorn oak is its ability to tan leather. The tanning process improves the durability of raw hides when exposed to conditions such as heat, abrasion, water, and bacteria [9]. The caps and nails of acorns contain a high level of tannins. These tannins are widely used in the leather industry due to their high-level tanning properties. Approximately 90% of the herbal tannin extracts produced worldwide are used in the leather industry [10].

The acorn oak tree holds significant technical and economic value due to its abundance of tannins, which serve as a valuable source of raw materials. In Turkey, tannins are extracted from the acorn oak tree and utilized in various industries. Furthermore, scientific research has confirmed the anti-cancer properties of the acorn oak tree.

In a study titled "Anticancer, Antiproliferative and Lactate Dehydrogenase Enzyme Activities of Different Parts of Acorn (*Quercus coccifera* L.) Against A549, MCF-7, and HeLa Human Cancer Cells", the anti-cancer properties of the extracts obtained from the outer shell, cone, and inner part of the acorn were investigated against cancer cells and healthy cells [11]. The results of the analysis showed that the extracts had anticancer activity and that the acorn has a feature that prevents the

development of cancer. Another of the health-related properties of acorn oak is its ability to act as an antioxidant in type 2 diabetes. Oxidative stress, which develops due to increased blood glucose and lipid levels, can cause complications in diabetes. *Quercus ithaburensis* Decne can reduce oxidative stress by decreasing elevated blood glucose and lipid levels and acting on antioxidant enzyme systems. As a result of Özmen's study, it was found that the plant extract of *Quercus ithaburensis* Dence had antihyperglycemic, antihyperlipidemic, and antioxidant effects in rats with induced type 2 diabetes. The study also concluded that it has a protective and/or preventive effect against oxidative stress [12]. Therefore, it could be beneficial to use it as a treatment or supportive agent for diabetes. Acorn extract also offers health benefits by providing protection to the liver and pancreas. A study conducted in a controlled laboratory environment revealed that acorn extract has a protective effect against liver and pancreas damage in diabetes. This finding highlights the potential therapeutic properties of acorn extract in safeguarding these vital organs [13]. In addition to its medicinal properties, the extract obtained by treating the Anatolian acorn oak with water after grinding the caps and nails into powder is used in the manufacture of syrups, which are used with honey, sugar, or other sweeteners to prevent diarrhoea in children [1].

The acorn oak tree has the widest distribution in Turkey, and due to the gallic tannin it contains (6-10% in the flesh, 27.5% in the caps, 34-50% in the nails) it is used in the production of tannin which is used in the tanning of raw hides. The acorn oak tree contains a hydrolyzable tannin, a type of tanning agent, and the content of this substance varies in the different parts of the tree, the flesh contains 6-10%, the caps 27.5%, and the nails 34-50% gallic tannin [1].

Cochineal, weld, and some biological natural dye resources were used in the industrial mass production of textile dyeing in the last years). Anatolian acorn oaks can be used in mass production dyeing for beige, grey, and brown colours [4].

ANATOLIAN ACORN (*QUERCUS ITHABURENSIS* DECNE) AS DYESTUFF

Anatolian acorn oak has a long-standing history of being utilized in the leather industry for tanning and dyeing purposes, primarily due to its rich tannin content. Presently, it continues to be employed as a vegetable tanning agent and a natural dyestuff, highlighting its ongoing significance in these applications. In addition to being used as a dyestuff in the dyeing of protein and cellulose-based fibres, it is also used as a bio-mordant agent. It is the most widely used source of dyestuff for black [14] and brown [15] dyeing in the analysis of historical textiles [16,17]. It has also been used in dyeing other colours, in combination with other natural dyestuffs derived from plants and insects [16].

In the analysis of historical textiles, it has been determined that acorn oak was used in bio-mordant with madder and insect dyes to achieve red dyeing [16]. The utilization of Anatolian acorn oak in

combination with other natural dye sources for textile dyeing enhances the colour fastness properties, including lightfastness, wash fastness, and rubbing fastness. This combination results in improved durability and resistance of the dyed textiles to fading, washing, and rubbing. It has been observed that fabrics and products dyed with the Anatolian acorn oak comply with the ZDHC (Zero Discharge of Hazardous Chemicals) and NODS (Natural Organic Dye Standard) criteria [18]. Furthermore, due to its antimicrobial and antifungal properties, using Anatolian acorn oak in dyeing imparts natural antimicrobial and antifungal properties to the dyed products or fibres [19].

The direct dyeing method is used for beige and brown dyeing of protein and cellulose-based fabrics using Anatolian acorn oak. The $FeSO_4$ post-mordanting method is used for dyeing grey and black colours. Traditional dyeing methods use a high amount of dyestuff resources, have low sustainability, and have high costs. In traditional methods, plants are used at a rate of 50-100% of the weight of the dyed fabric or textile goods, whereas in industrial methods this rate is between 5 and 10%. Given the annual availability of the Anatolian acorn oak, it can be seen that it is an ideal sustainable natural dye source for protein and cellulose-based textile fabrics and products in the beige-brown and grey-black colour ranges [5].

COMMERCIAL VALUE AND EXPORT

In terms of commercial value and export potential, the cups and husks of acorns contain high levels of tannins, which possess excellent tanning properties. The tannins derived from acorns serve as a non-wood forest product that finds application as an adhesive and dyestuff, particularly in the leather and textile industry. Acorn caps (*Quercus ithaburensis*), which have a natural range in Turkey, have large quantities of raw materials suitable for the production of valex (powder extract), which is acorn extract. Additionally, facilities that process this raw material are located in Turkey. Valex is a natural, environmentally friendly, and sustainable product and thus it has strategic importance. Annual valex production in Turkey ranges from 1,300 to 1,500 t, the majority of which is exported. The contribution of valex production to the Turkish economy is approximately 3 million dollars per year [1].

Acorns are exported under three distinct customs tariff classifications, namely acorn nails, fruits, and tanning substances used in dyeing. These exports, primarily in the form of processed or semi-processed extracts and powders, are sent to various countries, with a notable emphasis on Germany and England. Significant quantities of these acorn-derived products are shipped to meet the demand in international markets [1]. Acorns, particularly oak acorns, play an important role in the global leather industry as a source of vegetable tanning materials, with 30% of the annual tanning needs of the industry being met by this type of tanning material. Oak acorn extract and powder are significant contributors to this demand. As a non-wood forest product (NWFP), oak acorns have a high economic significance.

According to a study of Turkey's export and import data for forest products from 1990-2009, the export income of non-wood forest products (NWFPs) such as oak acorns was found to be significantly higher than that of roundwood. However, the opposite was true for imports. The production of NWFPs for industrial purposes varies depending on domestic and foreign market demands. It was found that foreign market demands for these products are typically higher than domestic demands, making oak acorns a product with high export potential [20].

It is reported that 347 Non-Wood Forest Products (NWFPs) are traded domestically and internationally in Turkey, and around 30% of these are exported [20]. Anatolian acorn oak is one of Turkey's Non-Wood Forest Products (NWFPs) with the highest potential for foreign trade among these products.

ROLE IN SUPPORTING REGIONAL TRADE

Primary forest products encompass various items such as logs, wooden poles, industrial wood, and pulpwood that are derived from trees, shrubs, and bushes. Conversely, non-wood forest products encompass a wide range of materials including seeds, bark, fruits, flowers, leaves, young branches, green shoots, roots, tubers, and bulbs, as well as various balsam oils, natural resins, galls, mushrooms, diverse vegetation, and other associated materials [21].

The importance of non-wood forest products (NWFPs) production in the economy is increasingly being recognized, leading to various studies and research on the topic. Most of these studies focus on the introduction of certain NWFPs, their areas of use, inventory, harvest, processing, economy, and marketing of the harvested products. The first harvest data on NWFPs was collected by the Non-Wood Products and Services Department of the General Directorate of Forestry between 1989-2016. According to these data, 9000 kg of NWFPs were harvested in the Aegean Region of Turkey in 1989, and in 1990, 1000 kg of acorn caps were harvested in the Mediterranean Region of Turkey. Data on oak leaves and bark were also collected from various Regional Directorates of Forestry in Turkey. The evaluation of these data showed that the Regional Directorate of Forestry with the highest harvest data in Turkey was Isparta (Mediterranean Region of Turkey) with 746,000 kg, while the Regional Directorate of Forestry with the least harvest data was Bursa (Marmara Region of Turkey) with 500 kg [22].

It is evident that non-wood forest products (NWFPs) significantly contribute to regional economies, notably by providing alternative income opportunities for local communities. To maximize the export potential of NWFPs like acorns, one viable approach would be to focus on developing the domestic market. By fostering domestic demand and promoting the utilization of NWFPs within the country, opportunities for economic growth and sustainable development can be enhanced. Additionally, it is also important to note that NWFPs have significant socio-economic importance globally, as they

provide livelihoods for the rural population and contribute to local economic development in some countries. It is reported that 80% of the world's population relies on NWFPs for their health and food needs. This emphasizes the importance of these products for socioeconomic development [23].

In recent years, the General Directorate of Forestry of Turkey has done a lot of studies on non-wood forest products. According to the 2010 balance sheet of the General Directorate of Forestry of Turkey, 131 t of non-wood forest products were produced. 64,000 kg of the produced products were exported and the rest was consumed in the domestic market. Thus, income was provided and contribution was made both to forest villagers and to the increase of production [24]. In Turkey, in 2021, a total of 928,000 t of non-wood forest products were collected from nature and produced [25].

CONTRIBUTION TO SUSTAINABILITY GOALS

From an ecological perspective, acorn oak (*Quercus ithaburensis*) forests provide important ecosystem services such as carbon sequestration, soil conservation, and habitat for a variety of plant and animal species. These forests also play a critical role in maintaining water cycles and preventing soil erosion [1]. Acorn oak (*Quercus ithaburensis*) is an important non-wood forest product (NWFP), providing a wide range of products such as acorns, bark, tannins, and honey that are used for food, medicine, and industry. The sustainable management of these resources is crucial for the long-term conservation of the species and the well-being of local communities that depend on them [23]. However, acorn oak (*Quercus ithaburensis*) forests have been facing several threats like over-grazing, illegal logging, fire, and urbanization. Therefore, sustainable management practices and conservation measures are required to protect and conserve these forests and the services they provide [1]. Overall, the sustainable management of acorn oak (*Quercus ithaburensis*) forests is necessary to maintain the ecological and socio-economic benefits that they provide.

Currently, basic chromium sulfate salts are extensively employed in the leather industry as tanning agents. However, their usage poses adverse effects on soil, water, and living organisms. Consequently, there is a growing inclination towards the utilization of vegetable tannins and metal-free tanning systems, particularly in the leather industry. These natural tanning materials are also increasingly used as colouring compounds in traditional and industrial textiles for dyeing purposes. This shift towards eco-friendly alternatives aims to minimize environmental impact and promote sustainable practices in the textile and leather sectors [5].

THE USAGE OF ACORN OAK AS A NATURAL DYE AND ITS EXPORT SIZE

In Turkey, approximately 31,304,460,000 kg of acorn caps are produced annually [1]. Acorn caps have the potential to dye 312,044,600 t/year of light fabric and 62,608,920 t/year of fabric in dark colours.

It has an average of 187,326,760 t/year of fabric dyeing potential. The approximate value of acorn caps is 1.80 $ during the period of 2012-2022. The total annual value of acorn oak caps is 56,348,028,000 $. The figures for the quantity exported, unevaluated amounts, dollar-based revenue obtained, and unevaluated amounts and dollar-based unachievable value for the period 2012-2022 are shown in Figures 1-3.

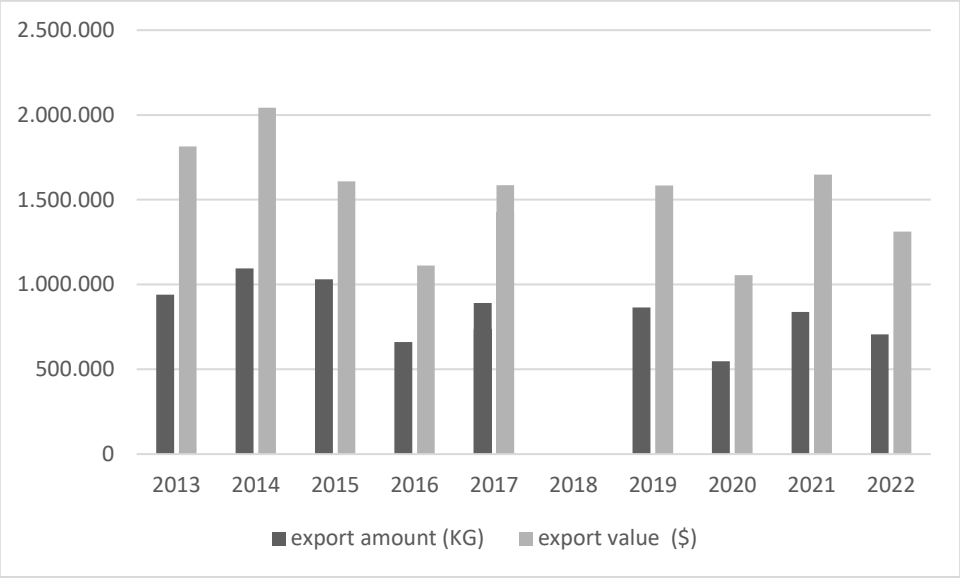

Figure 1. Export Amount And Value Of Acorn Caps in Turkey

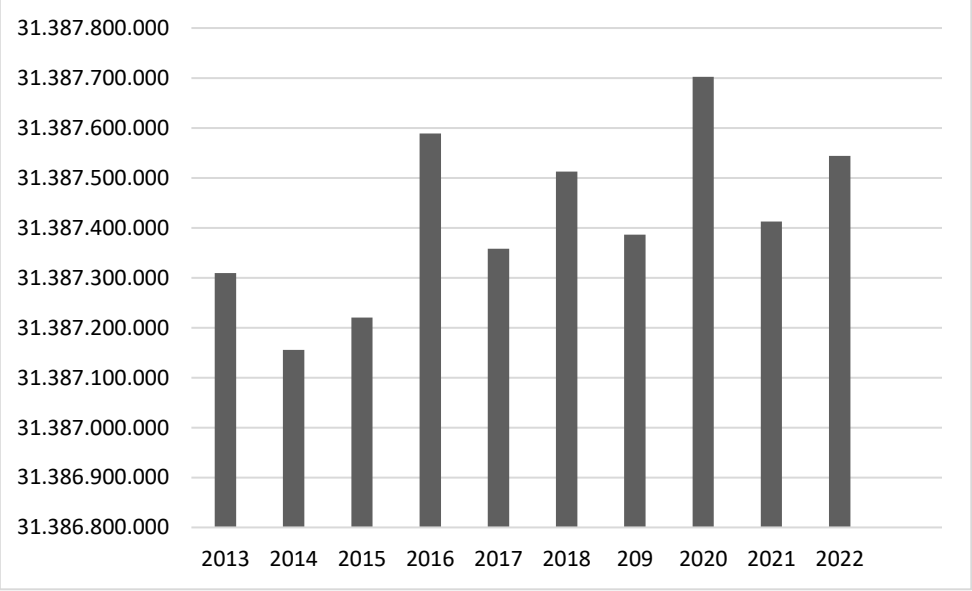

Figure 2. Avarage Amounts Of Acorn Caps Wasted in Production (Kg)

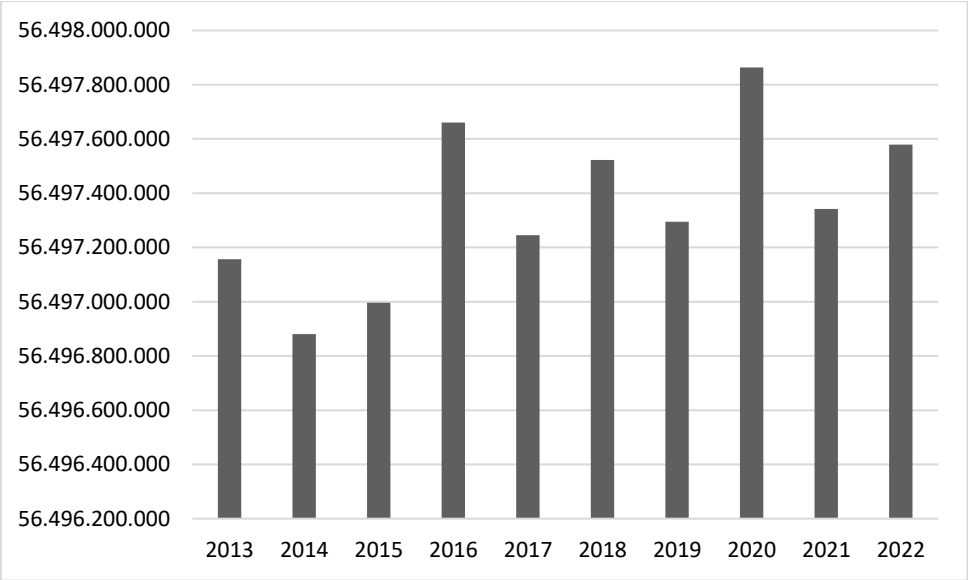

Figure 3. Average waste of export value caused by unused acorn caps

Figure 3 shows the amount of waste during the production of acorn oak wood in Turkey between 2012 and 2024.

In accordance with this, substantial quantities are discarded without being properly utilized during production, resulting in a significant economic cost. Furthermore, a considerable potential remains untapped, failing to be converted into income from an economic standpoint. Acorn oak is an important resource with both natural and economic value. It is rich in natural dye sources and a more sustainable alternative than industrial dyeing methods. Its antimicrobial and antifungal properties give natural antimicrobial and antifungal properties to the dyed product or fibers. It is also special because of its cancer-preventing properties and high feed value in animal feeding. It can be used in the leather industry because of its high content of tannin and provides economic contributions. Therefore, acorn oak has great potential as a non-wood forest product and should be brought to the country's economy. The export price of acorn caps is approximately 1.80 $ per kg. In the textile dyeing industry, 10% of the fabric weight is used for dyeing light colors (0.1 kg of acorn caps per 1 kg of fabric). The average cost of the dye for 1 kg of fabric is approximately 0.18 $. For dark colors, up to 50% of the fabric weight can be used for dyeing. The cost of dyeing 1 kg of fabric for dark colors is around 0.90 $. The average cost of reactive dye for 1 kg of fabric for light colors is around 0.30 $, whereas for dark colors it is around 0.90 $. The average cost of the acorn caps and reactive dye for 1 kg of fabric is approximately 0.54 $ and 0.60 $ respectively.

Consumptions of electricity, water, steam, and dyeing time were compared between conventional dyings with the natural dyeing in industrial-scale dyeing. Natural dyeing is more sustainable than conventional dyeing. Efficiency and ratios between conventional dyeing and natural dyeing was given in Figure 4. The figures have been given proportionally.

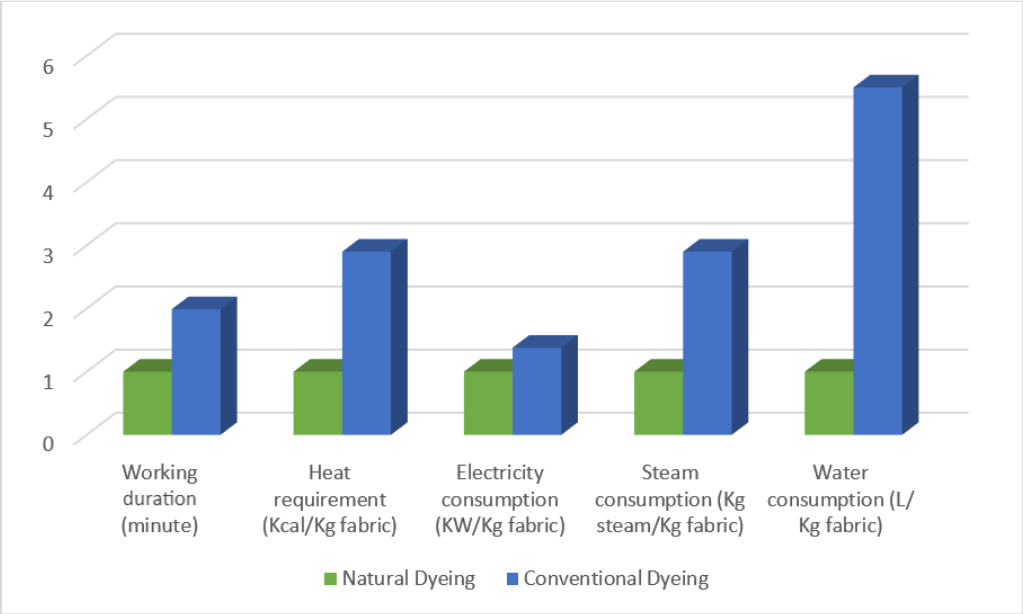

Figure 4. Ratio of conventional dyeing/natural dyeing

CONCLUSION

The utilization of acorn oak caps in the textile dyeing industry is a step towards sustainability and cost-effectiveness. The use of these natural dyes has been shown to produce a range of colors including beige, brown, and gray tones, which are in high demand in the textile industry. The use of acorn caps is considered sustainable as it meets the criteria set forth by the Zero Discharge of Hazardous Chemicals (ZDHC) program, making it a more environmentally friendly alternative to synthetic dyes. The usage of acorn oak also complies with NODS criteria [18]. Moreover, using acorn caps as a dye source not only helps reduce waste but also offers a cost-competitive alternative to synthetic dyes. The acorn oak caps are a waste material that would otherwise be discarded, but instead, they are transformed into a valuable resource that contributes to sustainable development. This shift towards using natural resources and reducing waste is an important step towards a more sustainable future for the textile industry.

The use of acorn caps as a dye source in the textile industry has the potential to bring about significant benefits for both the environment and the industry itself. By embracing sustainable practices, the textile industry can continue to grow and evolve while reducing its impact on the environment. Additionally, acorn oak, which has great export potential, will be a significant source of income from an economic perspective. Acorn oak is a more sustainable natural dye than other natural dyes in terms of energy, water, dyeing time, steam consumption, and low cost.

There are many laboratory studies that have been done on acorn caps dyeings. The dyeing properties of protein and cellulose-based fabrics dyed with *Quercus ithaburansis* have been published in many journals. *Quercus ithaburansis* has been used for dyeing alone as well as in combination with other

natural dyes [26,27]. However, their application to the industry has unfortunately not been possible. The reason for this is thought to be due to the lack of clear information on the sustainability of the dyeings with acorn caps. This study will eliminate these negativities.

Acorn oak caps are rarely used in animal feed, medicine, cosmetics, textile, leather, etc. Industries nowadays. However, it is revealed in this study that it has a great natural dye resource material for textile and leather dyeing industries. Solid woody waste leftover from the acorn caps used for dyeing can be converted into compost fertilizer, biocomposite material, or energy.

Author Contributions

Conceptualization – Ozdemir MB and Karadag R; methodology – Ozdemir MB and Karadag R; formal analysis – Ozdemir MB and Karadag R; investigation – Ozdemir MB and Karadag R; resources – Ozdemir MB and Karadag R; writing-original draft preparation – Ozdemir MB and Karadag R; writing-review and editing – Ozdemir MB and Karadag R; visualization – Ozdemir MB and Karadag R; supervision – Ozdemir MB and Karadag R. Both authors contributed to the article equally. The authors have read and agreed to the published version of the manuscript.

Conflicts of Interest

The authors declare no conflict of interest.

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