

Research Article

# Investigation of Dandelion (*Taraxacum officinale* G.) Plant as an Alternative Source for a Natural Rubber Production

Gülsemin Savaş Tuna<sup>1,\*</sup> , Damla Demirbilek<sup>2</sup> , Salim Efe Zeybek<sup>3</sup> 

<sup>1</sup>Tekirdag Vocational and Technical Anatolian High School, Tekirdag, Türkiye

<sup>2</sup>Faculty of Engineering and Natural Sciences, Computer Engineering, Uskudar University, Istanbul, Türkiye

<sup>3</sup>Faculty of Civil Engineering, Civil Engineering, Istanbul Technical University, Istanbul, Türkiye

## Abstract

Rubber that is one of the most important polymers naturally produced by plants is a strategic raw material. Since rubber is used in a wide variety of areas and natural rubber resources are heavily destroyed, synthetic rubbers are produced, especially using petroleum-based polymers. In this study, it was aimed to find a natural alternative to the rubber trees that are endangered and to the synthetic rubbers that are difficult to recycle and expensive. The *T. officinale* samples used as material in the study were collected from natural areas. The roots of the collected plants were broken into small pieces, they were kept in different solvents for 24 hours. After they filtered and formic acid was added, the prepared samples were kept for 24 hours. The part sinking to the bottom was taken and dried in a fume hood. The test paste was prepared by using 100 g of the produced rubber, 1% sulfur and 2% extender material. After the paste had reached the desired consistence, it was taken into hot press machine and the vulcanization process was completed (at 140 °C, for 7 minutes). Rheometer was used for vulcanization curve testing. The graph obtained in the rheometer was compared with the rubber graph prepared to obtain a product by adding various substances. As a result of the study, it was determined that by adding some substances to the structure of the produced rubber during the vulcanization according to the desired purpose, it can be used in various fields, and thus, *T. officinale* can be an alternative natural rubber source.

## Keywords

*Taraxacum officinale*, Natural Rubber, Synthetic Rubber, Recyclin

## 1. Introduction

The natural rubber (cis-1, 4-polyisoprene), which is one of the most important polymers naturally produced by plants, is a strategic raw material. It is used as a raw material in is applied in over 50,000 products [1] including more than 400 medicinal products [2]. The natural rubber, which is used in automobile parts, automobile tires and many tools and equipment in daily life, is an indispensable engineering material of the modern life

[3]. Rubber was first used by Meso-Americans in the 1600s and was produced from Panama Rubber tree (*Castilla elastica* Sesse). The produced material was named as “cauchu” (weeping wood) by Meso-Americans [4]. Then, Aztecs, Mayans and Mexicans used rubber in the production of waterproof clothes, footwear and coating [5]. While the rubber was used in ball production by the Spanish and in the production of water-

\*Corresponding author: glsvs@yahoo.com (Gülsemin Savaş Tuna)

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proof tire fabric, hose, car bumper, tire, etc. by British, some problems (softening or hardening according to ambient temperature) were experienced. However, these problems were eliminated by the development of the vulcanization method found by Goodyear [6].

The source of the rubber, which is the only commercial natural resource, is *Hevea brasiliensis*, an endemic species (Brazilian rubber tree). The rubber obtained from this plant has high performance in terms of flexibility, elasticity, wear resistance, heat distribution and impact resistance properties [2]. Due to these features and high usage areas, the demand for rubber increases day by day and millions of hectares of tropical forests having biological diversity are destroyed in order for meeting with these demands [7]. Also, it should not be forgotten that trusting in a single plant species has some disadvantages and potential dangers. The most of plants grown consist of cloned individuals. This situation affects the genetic diversity negatively and increases the susceptibility to pathogens [6]. For example, cultivated trees in South America have been greatly damaged due to the leaf blight [8].

Synthetic rubbers are produced using various polymers (styrene-butadiene, etc.) in order to meet the need and prevent damage. Most of the rubber products used today are petroleum based. But, compared to the natural rubber, the produced synthetic rubber does not have high performance in terms of various properties (flexibility, impact resistance, etc.) [1]. Various chemicals are used to improve the performance and synthetic products are not recyclable. Performance is very important especially for medical materials and aircrafts [6]. Therefore, natural rubber-producing sources need to be protected and developed or potential alternative rubber sources should be found [9]. *Asclepias* spp. (buttercup, verbena, milkweed), *Castilla* spp. (rubber plant), *Euphorbia* spp. (spurge), *Ficus* spp. (rubber tree), *Landolphia* spp., *Solidago* spp. (goldenrod), *Taraxacum* spp. (dandelion), *Parthenium* spp. (guayule) etc. plants are proposed as natural sources for rubber production [2, 6]. Among them, *Parthenium argentatum* (guayule) and *Taraxacum kok-saghyz* (Kazakh dandelion = Russian dandelion) come to the fore in terms of rubber yield [9, 10]. It was also recently proposed for the production of natural rubber in *Taraxacum brevicorniculatum* Korol. and *Taraxacum bicornis* Dahlst. [11-14]. In some studies, *Taraxacum kok-saghyz* and *Taraxacum brevicorniculatum* were investigated together, their chemical structures were compared and various suggestions were made [1, 14].

*T. kok-saghyz*, a single-year plant, was defined as a latex producer in the 1930s [15]. It produces latex in plant roots. Numerous studies related to this plant have been carried out and it has been determined that latex production of the plant is better than the other species but its competitiveness with weeds is weak. Therefore, studies such as gene transfer, cloning [16, 17] and hybridization with *T. officinale* are going on [9]. *Taraxacum kok-saghyz* is not a species that grows naturally in our country (Turkey); therefore, its culture must be done. On the other side, *T. officinale* is a common species

that grows naturally in our country. *T. officinale*, which is multi-year, is known for its pharmacological effect and the conducted studies are generally for this purpose. The plant has antioxidant, antifertility, hepatoprotective, anti-inflammatory, antitumor, choleric, diuretic and antirheumatic effects [18-20]. It is used by the public for fever, stomachache and headache [21]. Also, its racemes, leaves and roots are used as food, its roots are dried and consumed as coffee and used as a flavoring agent in various desserts, beverages and pastries [22]. The studies done with this plant are quite limited in our country. [3] gave place to this plant while giving information about rubber materials in his study. [23] investigated the development of individuals under heat stress by adding plant extract to forage. [24] used it in the production of tincture. However, no study has been found on obtaining rubber from *T. officinale*. In this study, it is aimed to obtain rubber from *T. officinale* plant and contribute to the production of natural rubber, which has become a global problem and various alternatives are searched for it, and to produce healthy and natural substances instead of non-recycled synthetic products.

## 2. Material and Method

### 2.1. Collecting of the Plant Material

In the study, *T. officinale* plants collected from natural area in Namık Kemal University Campus, Tekirdag- Türkiye (latitude: 40°9'08.2", longitude: 40°9'08.2", altitude: 29 m) was used as material.

### 2.2. Obtaining Rubber from the Plant

The roots of the collected plants were washed thoroughly and then the roots were cut into small pieces by means of knife and scalpel. Because the root parts were hard, pestle and blender were used to minimizing the parts better (to increase the surface). The crushed pieces were weighed and taken into 3 different glass flasks (500 g for each glass). Ethyl alcohol was added to the first glass flask, chloroform was added to the second glass flask, and acetone was added to the third glass flask (up to 1000 ml). The flasks were covered with aluminum foil and kept waiting at room temperature for 24 hours. After the samples were filtered, formic acid (50 ml) was added to them. The glass flasks, whose mouths were closed, were waited for 12 hours in a fume hood. It was checked whether the rubber sank or not by looking at the bottom of the flask. The excess amount of the solvent and formic acid in the glass flasks was collected and the material accumulated at the bottom was taken into the petri dishes. In order to remove the liquid in the samples, the petri dishes were kept waiting in the fume hood.

### 2.3. Vulcanization

At this stage, it is first necessary to give information about

vulcanization. All rubber types, whether natural or artificial, are a part of the general polymer class named elastomer. The polymeric (macromolecules) materials, which can be extended to at least two times the original length at the room temperature and which are able to return to the original state when the force that provides this elongation is removed, are called as the elastomer. The elastomers have dual bonds that provide flexibility. Properties of the elastomers are not suitable for commercial use in the raw state, that is, before any chemical treatment or vulcanization. Therefore, elastomers are generally vulcanized by using various chemicals. Through this way, the undesirable properties of the elastomers are eliminated and they were turned into a very suitable material for commercial use [25-27]. Vulcanization is chemically called as cross-linking.

In this study, sulfur, which was the first and most important vulcanization agent used in vulcanization, was used. Generally, 0.25-5 PHR (Part per hundred rubber) sulfur is used in soft rubbers and 25-40 PHR is used in hard rubbers [25]. The test paste for vulcanization was prepared by using 100 g of the produced rubber, 1% sulfur and 2% extender material. Molding method was used in vulcanization [28]. Firstly, produced rubber was placed in the machine and it was ensured to become flat shape by heating via friction. In order for a good mixture in the paste, sulfur and extender material were added to the produced rubber step by step and the process at the machine was continued until the paste reached the desired consistency.

After the paste reached the desired consistence, it was taken into hot press machine and vulcanization was performed in the press die (140 °C, 7 minutes) [25, 26]. The produced rubber was molded by pouring it into several different molds and given simple shapes (Figure 1). If a product is to be produced, various materials can be added at this stage or thereafter to give the desired shapes according to the area of use.



**Figure 1.** A: Sample of rubber produced from *T. officinale*, B: The state of the produced rubber after vulcanization C: Rubber samples after molding.

## 2.4. Analysis

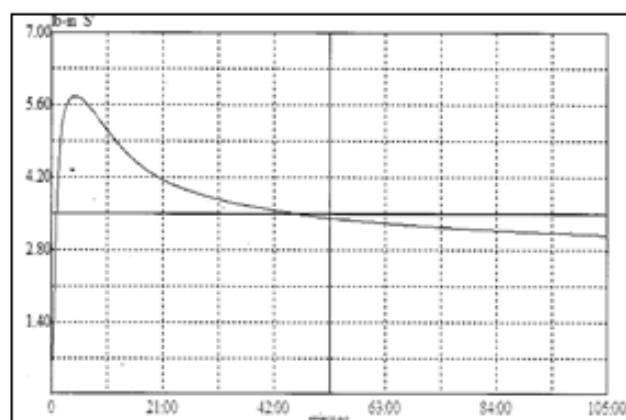
Vulcanization values, wearing, tensile-rupture strength, ash determination, aging determination etc. tests are applied to the rubbers produced for specific purposes. Information about these tests was obtained from the R & D Laboratory of a factory and the test procedures were carried out there. In the

study, only the vulcanization values test (vulcanization curve test) was performed since much additional material (enhancing strength-flexibility, more extender, accelerator, anti-aging material etc.) were not added. At this stage, rheometer device was used and the vulcanization curve was followed on the screen [29]. A vulcanization curve test was also carried out for rubber prepared for a factory-produced product and to which various substances were added, and the results were compared.

## 3. Results and Discussion

While collecting the samples used as material in the study, it was observed that if the root part of the plant was damaged, the latex flowed immediately. For this reason, great care was taken when removing the plants from the soil. Plants were collected several times during the study. The samples we collected one day after raining were observed to be more developed, soft and latex rich. Here, another important point is the collection time of the plant. The plants were collected at the end of the summer, beginning autumn. If the collection process is carried out in the spring, the amount of obtained rubber, that is amount of the product, can be increased. The reason of this is that the rubber is a secondary metabolite for the plant. The amount of secondary metabolite, the included substances, and the plant parts can vary depending on many factors such as the harvesting season, used methods and techniques, plant development stage and geographical area [30].

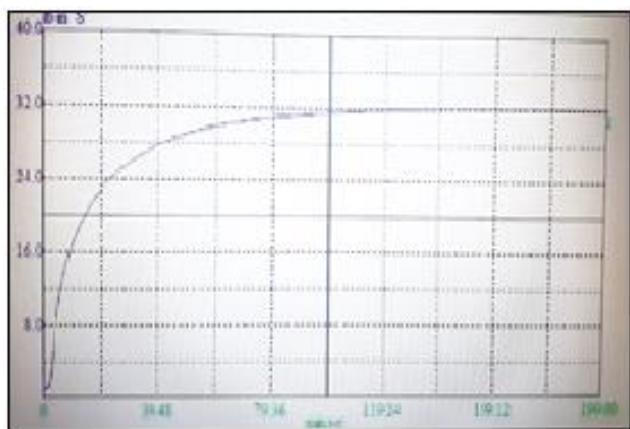
Compared to the results of three different solvents used in the study; it was determined that in the samples obtained in acetone from the same amount of material, there was no precipitation when formic acid was added and there was more precipitation (rubber) when ethyl alcohol was used than chloroform usage. For this reason, it is recommended to use ethyl alcohol as a solvent in studies similar to ours.



**Figure 2.** Vulcanization curve test results of natural rubber produced from *T. officinale*.

The rubber obtained from *T. officinale* was tested with a

rheometer after the vulcanization process required for use (Figure 2). The same test was applied to the rubber used in product production at the factory (Figure 3).



**Figure 3.** Vulcanization curve test results of rubber added with various additives.

Graphs of vulcanization curve test results are interpreted according to the following principles; If the curve is increasing, it means that it is vulcanized. When the curve starts to decrease, it means that the sample is deteriorated [29]. When the graphics are compared; It was observed that natural rubber produced from *T. officinale* started to deteriorate immediately after vulcanization, while rubber prepared to produce a product in the factory did not deteriorate. While adding too little of a single type of additive to the structure of the rubber produced during the vulcanization process caused it to deteriorate quickly, adding a large number of additives to the structure of the rubber in the factory prevented its deterioration and made it more durable. Because, in order to produce rubber with the desired properties, the properties are determined in advance and according to these properties, the amount of material to be added is calculated, that is, a recipe is prepared [27, 28]. The recipe includes rubber, fillers, softeners, process facilitators, anti-aging, activators, accelerators, extenders, cookers, retarders and other additives. When these additives are used in vulcanization, the duration of the vulcanization process is shortened and the quality of the rubber to be produced increases [28]. Three of these additives are very important. These are the additives that shorten the vulcanization time [inorganic accelerators (lead oxide, magnesium, calcium), organic accelerators, ultra-accelerators], antioxidants which increase the strength and carbon black which increases the tearing-friction resistance [3]. For example, in a study, it was determined that thiuram and dithiocarbamate groups increased the hardness and tensile strength properties of rubber by increasing the number of cross-links, and also increased the elongation properties of dithiocarbamates forming polysulfide bonds [27]. Additionally, the amount of sulfur added during vulcanization (0.5-50%) also affects the

properties of the rubber produced; When the amount of sulfur increases, the rubber hardens. For example, rigid rubber is obtained by performing vulcanization with 30-50% sulfur [31]. In this study, only 1% sulfur and 2% extender material were added during vulcanization. Therefore, as a result of the vulcanization curve test, it has been observed that the obtained rubber began to deteriorate in a short time. This result was also evaluated by the authorities in the R & D department. It was determined that the rubber obtained by increasing the amount of extender material and sulfur with adding other materials can be used in various areas.

On the other hand, the obtained rubber from *T. officinale* is not a pure rubber. Other organic or inorganic substances in the structure of the plant may also have affected the vulcanization curve test. When the literature is examined, various methods have been applied to obtain pure rubber [6, 32]. However, in order to apply these methods, a wide variety of chemicals and laboratory environments are needed and experience is required in this field. Since the aim of this study is to obtain rubber from *T. officinale*, properties such as chemical structure and increasing durability can be investigated in other studies.

The unique properties of natural rubber, uncertainty regarding gas, coal and oil reserves, global warming due to the increase in greenhouse gases, the difficulty of recycling synthetic rubber and the production of synthetic rubber from oil, a non-renewable resource, etc. The combination of many factors has led to the necessity of diversifying the commercial sources of natural rubber [14, 31]. Damaging of the rubber trees due to the destruction of nature has also triggered the search [7]. Natural rubber resources have lost their former productivity as a result of this destruction. Therefore, this study is very important.

## 4. Conclusion

As a result of the study, it was determined that the rubber obtained could be used in various fields by adding some additives to its structure during vulcanization according to the desired purpose, thus *T. officinale* could be an alternative source of natural rubber. Based on this study, chemistry-biochemistry (for example: the chemical structure of rubber produced from *T. officinale* is comparable to other natural and synthetic rubbers), genetics (effect of polyploidy on the amount of rubber, gene transfer, etc.), agriculture (growing cultures, recommending to farmers, etc.), research can be done in industry and many other fields.

## Abbreviations

|                      |                             |
|----------------------|-----------------------------|
| <i>T. officinale</i> | <i>Taraxacum officinale</i> |
| PHR                  | Port Per Hundred Rubber     |
| R&D                  | Research and Development    |



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## Author Contributions

The authors contributed equally.

## Conflicts of Interest

The authors declare no conflicts of interest.

## References

- [1] Salehi, M., Cornish, K., Bahmankar, M., Naghavi, M. R. Natural rubber-producing sources, systems, and perspectives for breeding and biotechnology studies of *Taraxacum kok-saghyz*. *Industrial Crops and Products*. 2021, 170, 113667. <https://doi.org/10.1016/j.indcrop.2021.113667>
- [2] Mooibroek, H., Cornish, K. Alternative sources of natural rubber. *Applied Microbiology Biotechnology*. 2000, 53, 355-365. <https://doi.org/10.1007/s002530051627>
- [3] Vahapoğlu, V. Kauçuk Türü Malzemeler I. Doğal Kauçuk. *Celal Bayar Üniversitesi Fen Bilimleri Dergisi*. 2007, 3(1), 57-70.
- [4] Hosler, D., Burkett, S. L., Tarkanian, M. J. Prehistoric polymers: Rubber processing in ancient Mesoamerica. *Science*. 1999, 284(5422), 1988–1991. <https://doi.org/10.1126/science.284.5422.1988>
- [5] Evans, S. T. *Ancient Mexico & Central America: Archaeology and Culture History*. Thames & Hudson. 2008.
- [6] Bell, J. L. Biochemical and Genetic Characterization of Rubber Production in Prickly Lettuce (*Lactuca serriola* L. PhD Thesis). Washington State University/Molecular Plant Sciences Graduate Program. Washington, USA. 2013.
- [7] Warren-Thomas, E., Dolman, P. M., Edwards, D. P. Increasing demand for natural rubber necessitates a robust sustainability initiative to mitigate impacts on tropical biodiversity. *Conservation Letters*. 2015, 8(4), 230–241. <https://doi.org/10.1111/conl.12170>
- [8] Le Guen, V., Rodier-Goud, M., Troispoux, V., Xiong, T. C., Brottier, P., Billot, C., Seguin, M. Characterization of polymorphic microsatellite markers for *Microcyclus ulei*, causal agent of South American leaf blight of rubber trees. *Molecular Ecology Notes*. 2014, 4(1), 122–124. <https://doi.org/10.1111/j.1471-8286.2004.00589.x>
- [9] Iaffaldano, B., Cardina, J., Cornish, A. K. Hybridization potential between the rubber dandelion *Taraxacum kok-saghyz* and common dandelion *Taraxacum officinale*. *Ecosphere*. 2018, 9(2), 1-9. <https://doi.org/10.1002/ecs2.2115>
- [10] Ramirez-Cadavid, A. D., Cornish, K., Michel, C. F. *Taraxacum kok-saghyz* (TK): compositional analysis of a feedstock for natural rubber and other bioproducts. *Industrial Crops and Products*. 2017, 107, 624-640. <https://doi.org/10.1016/j.indcrop.2017.05.043>
- [11] Gronover, C. S., Wahler, D., Prüfer, D. Natural Rubber Biosynthesis and Physic-Chemical Studies on Plant Derived. *Biotechnology of Biopolymers*. 2011, 75-88.
- [12] Wahler, D., Colby, T., Kowalski, N. A., Harzen, A., Wotzka, S. Y., Hillebrand, A., Fischer, R., Helsper, J., Schmidt, J., Gronover, C. S., Prüfer, D. Proteomic analysis of latex from the rubber-producing plant *Taraxacum brevicorniculatum*. *Proteomics*. 2012, 12(6), 901-905. <https://doi.org/10.1002/pmic.201000778>
- [13] Zeisek, V., Kirschner, J., van Dijk, P.T., Stepanek, J., Cerny, T., Kotek, J., Urbanovsky, P. Analysis of wild *Taraxacum bicorne* Dahlst. (Compositae-Crepidinae) as a potential alternative natural rubber crop. *Genetic Resources and Crop Evolution*. 2019, 66, 1341-1361. <https://doi.org/10.1007/s10722-019-00788-4>
- [14] Piccolella, S., Sirignano, C., Pacifico, S., Fantini, E., Daddiego, L., Paolo Facella, P., Lopez, L., Scafati, O. T., Panara, F., Rigano, D. Beyond natural rubber: *Taraxacum kok-saghyz* and *Taraxacum brevicorniculatum* as sources of bioactive compounds. *Industrial Crops and Products*. 2023, 195, 116446. <https://doi.org/10.1016/j.indcrop.2023.116446>
- [15] Ulmann, M. Wertvolle kautschukpflanzen des gemässigten klimas: Dargestellt auf grund sowjetischer forschungsarbeiten. Akademie-Verlag. 1951.
- [16] Schmidt, T., Hillebrand, A., Wurbs, D., Wahler, D., Lenders, M., Gronover, C. S., Prüfer, D. Molecular cloning and characterization of rubber biosynthetic genes from *Taraxacum koksaghyz*. *Plant Molecular Biology Reporter*. 2010a, 28, 277–284. <https://doi.org/10.1007/s11105-009-0145-9>
- [17] Schmidt, T., Lenders, M., Hillebrand, A., Van Deenen, N., Munt, O. Reichelt, R., Eisenreich, W., Fischer, R., Prüfer, D., Gronover, C. S. Characterization of rubber particles and rubber chain elongation in *Taraxacum koksaghyz*. *BMC Biochemistry*. 2010b, 11, 11. <https://doi.org/10.1186/1471-2091-11-11>
- [18] Baba, K., Abe, S., Mizuno, D. Antitumor activity of hot water extract of dandelion, *Taraxacum officinale*: correlation between antitumor activity and timing of administration. *Yakugaku Asshi*. 1981, 101(6), 538-543. [https://doi.org/10.1248/yakushi1947.101.6\\_538](https://doi.org/10.1248/yakushi1947.101.6_538)
- [19] Jeon, H., Kang, H. J., Jung, H. J., Kang, Y. S., Lim, C. J., Kim, M. Y., Park, E. H. Anti-inflammatory activity of *Taraxacum officinale*. *Journal of Ethnopharmacology*. 2008, 115(1), 82-88. <https://doi.org/10.1016/j.jep.2007.09.006>
- [20] Tahtamouni, L. H., Alqurna, N. M., Al-Hudhud, M. Y., Al-Hajj, H. A. Dandelion (*Taraxacum officinale*) decreases male rat fertility *in vivo*. *Journal of Ethnopharmacology*. 2011, 135(1), 102-109. <https://doi.org/10.1016/j.jep.2011.02.027>

- [21] You, Y., Yoo, S., Yoon, H. G., Park, J., Lee, H. Y. Kim, S., Oh, K. T., Lee, J., Cho, H. Y., Jun, W. *In vitro* and *in vivo* hepatoprotective effects of the aqueous extract from *Taraxacum officinale* (dandelion) root against alcohol-induced oxidative stress. *Food and Chemical Toxicology*. 2010, 48(6), 1632-1637. <https://doi.org/10.1016/j.fct.2010.03.037>
- [22] Gürdal B (2015). Marmara bölgesinde yetişen *Taraxacum* türleri üzerinde farmasötik botanik araştırmalar. İstanbul Üniversitesi, Sağlık Bilimleri Enstitüsü, Doktora tezi, İstanbul-Türkiye.
- [23] Yıldırım, B. A. Sıcaklık stresi oluşturulan broylerlerde yeme ilave edilen *Taraxacum officinale* L. ve *Hypericum scabrum* L. bitki ekstraktlarının bazı biyokimyasal parametreler üzerine etkileri. Atatürk Üniversitesi Ziraat Fakültesi dergisi. 2016, 47(1), 65-70.
- [24] Kaplan, M., Yılmaz, M. M., Köprü, S., Gözelle, H., Muhderem, G., Uslu, R. Sıvı/Katı oranı ve etanol konsantrasyonuna göre karahindiba (*Taraxacum officinale*) tentürünün verim ve biyoaktivitesindeki değişimin incelenmesi. Türk Tarım ve Doğa Bilimleri Dergisi. 2018, 5(2), 163-174.
- [25] Hoffman, W. *Rubber Technology Handbook*, Carl Hanser Verlag, Munich- Germany. 1989.
- [26] Akiba, M., Hashim, A. S. Vulcanization and Crosslinking in Elastomers. *Progress in Polymer Science*. 1997, 22(3), 475-521. [https://doi.org/10.1016/S0079-6700\(96\)00015-9](https://doi.org/10.1016/S0079-6700(96)00015-9)
- [27] Öztürk, E. Farklı kauçuk karışımlarının vulkanizasyonuna hızlandırıcıların etkisi. Sakarya Üniversitesi, Fen Bilimleri Enstitüsü, Yüksek Lisans Tezi. Sakarya- Türkiye. 2008.
- [28] Savran, H. Ö. Elastomer Teknolojisi-1, Kauçuk Dergi Yayınları, İstanbul. 2001.
- [29] Rader, C. P. Vulcanization, Intermediate Correspondence Course, Rubber Division, ACS, Akron, OH. 1985.
- [30] Burt, S. Essential oils: Their antibacterial properties and potential applications in foods-A review. *International Journal of Food Microbiology*. 2004, 94(3), 223-253. <https://doi.org/10.1016/j.ijfoodmicro.2004.03.022>Getrightsandcontent
- [31] Hazar Yoruç, A. B. Uğraşkan, V. Yeşil Polimerler ve Uygulamaları. Afyon Kocatepe Üniversitesi Fen ve Mühendislik Bilimleri Dergisi. 2017, 17(1), 318-337. <https://doi.org/10.5578/fmbd.53940>
- [32] Bushman, B. S., Scholte, A. A., Cornish, K., Scott, D. J., Brichta, J. L., Vederas, J. C., Ochoa, O., Micheltore, R. W., Shintani, D. K., Knapp, S. J. Identification and comparison of natural rubber from two *Lactuca* species. *Phytochemistry*. 2006, 67, 2590-2596. <https://doi.org/10.1016/j.phytochem.2006.09.012>