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Original Article

Development of Sustainable *Ulva Lactuca* Genus Algae and Hemp Based Composites for Agrotextiles Application

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Abstract

As the global population grows, there is an increasing demand for food, requiring sustainable farming methods to increase agricultural productivity. Soil covers and mulches used in agriculture are mostly made of synthetic materials derived from petrochemicals, which pose various problems such as soil contamination and long-term insolubility. This study aims to use *Ulva Lactuca* algae as a sustainable raw material for soil covers, as it contains vitamins and minerals that the soil needs. As seawater acidity increases, the population of this algae is also increasing, creating the opportunity to use it in agriculture. The product is expected to retain moisture and reduce water consumption and high temperatures. In addition, hurds obtained from industrial hemp waste are used due to their high-water retention potential. The study combined *Ulva lactuca* algae from the Marmara region and hemp strings from Narlı and Vezir seeds to create various composites with different structures. Basic tests were conducted to determine the mechanical and physical properties of the products. The goal is to increase soil organic matter by using these materials as fertilizer after their use as soil covers.

Keywords: Ulva Lactuca, Algae, Hemp, Biodegradable Agrotextiles, Sustainability

1. INTRODUCTION

Soil is one of our most significant natural resources that all living creatures share and ensure the continuance of life. While the world population is expected to be 9.7 billion in 2050, in order to meet the food needs of the future, it is necessary to focus on studies in this branch quickly compared to today. Today, while arable land is decreasing day by day due to ecological reasons, the quality of the soil is deteriorating [1]. One of the main indicators of this deterioration is the decrease in the organic matter content, which is the most important element of the soil. It is known that organic matter loss is caused by incorrect agricultural practices [2, 3]. Economic and sustainable practices that evaluate organic wastes that can be used to improve the quality of the soil are of great importance [4].

Soil organic matter (SOM) is a crucial component of soil quality that plays a significant role in providing nutrients to plants, maintaining water retention capacity, and regulating climate. As a result, organic matter is not only important for agricultural productivity but also for environmental resilience. The balance of soil organic matter is essential to maintain these functions [5, 6]. Microorganisms in the soil require energy and nutrients to carry out their functions, and organic matter provides them with this. When there is a higher amount of organic matter in the soil, microorganisms become more active, and plant nutrients become more available and easier to absorb [7, 8]. Soil organic matter (SOM) is reduced through common farming

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practices such as intensive tillage, erosion, monoculture farming, and the use of chemical fertilizers and pesticides. These practices can have a negative impact on soil quality and reduce the amount of organic matter available in the soil [9]. The rising usage of chemical fertilizers has a negative impact on the soil, environment, and human health [10]. Using chemical fertilizers can result in various negative effects on the soil, environment, and human health. The properties of the soil, including its physical and chemical properties, can be altered by using chemical fertilizers. The soil pH may exceed the plant's optimal range, which can lead to the formation of ionic toxicity, causing a salt effect on the plants. This can result in a decrease in soil biodiversity and resistance to diseases and pests, as well as a disruption of the nutrient balance in products. Moreover, chemical fertilizers can pollute water and cause heavy metals to accumulate in the soil, leading to heavy metal contamination [11, 12]. Sustainable agricultural practices are centered on techniques that safeguard and enhance the quantity of soil organic matter (SOM) and microorganisms in the soil.

Plastic mulch films are commonly utilized in agricultural crop production to boost yields [13, 14]. Using agricultural plastic mulch films can enhance crop yields by altering soil temperatures, preserving soil moisture, and minimizing the emergence of weeds [15, 16]. Mulching is also a technique for conserving water, as it helps the soil to retain more moisture and reduces erosion [17]. Plastic mulch made of low-density polyethylene (PE) is popularly used due to its affordability, ease of production, and ability to possess the required characteristics such as durability and flexibility [18]. The extensive utilization of non-biodegradable polyethylene has led to significant environmental harm, as it remains a residue in the soil for numerous years [19, 20]. Besides its environmental impact, removing plastic mulch films from the land after their use is inconvenient regarding both time and resources [21]. Biodegradable mulches serve as an eco-friendly substitute for conventional petrochemical-based polyethylene (PE) mulches, which are extensively utilized in agriculture. Biodegradable mulches can be produced from bio-based polymers from plants or microbes, or from fossil-based materials. Bio based polymers commonly employed in biodegradable mulches include polylactic acid (PLA), starch, cellulose, and polyhydroxyalkanoates (PHA) [22]. Biodegradable mulches can also be made from fossil-derived materials, such as polyesters like polybutylene succinate (PBS), polybutylene succinate-co-adipate (PBSA), and polybutylene-adipate-co-terephthalate (PBAT) [23].

Biodegradable mulches have an advantage over traditional PE films because they can decompose naturally in the soil after use, eliminating the need for collection [24]. While biodegradable mulches have the advantage of being able to degrade naturally in the soil after use, there are still concerns and uncertainties about their potential long-term impacts on soil ecosystems [25]. Biodegradable mulches have two different potential effects on soil ecosystems. The first effect occurs when the mulch is on the soil surface, acting as a barrier and affecting the soil atmosphere before it is mixed into the soil. The second effect occurs when the physical particles of the mulch are directly mixed into the soil. Using biodegradable mulches can enhance microbial activity and increase the presence of certain types of fungi [26]. Choosing appropriate soluble ingredients for biodegradable mulches is important as they can affect soil organic matter dynamics and stimulate microbial activity. Natural ingredients that meet the desired properties are preferred. The use of chemical fertilizers should be minimized due to their negative impacts on soil, environment, and human health. Increasing soil organic matter through natural raw materials can support sustainable organic agriculture [23].

Seaweed is an organic fertilizer commonly used and can be a great choice for improving soil organic matter when mixed with the soil after plastic film application [27, 23, 28]. *Ulva lactuca* is a type of flat green algae from the Ulvaceae family that is present all around the globe. It is highly valued due to its various applications in different fields, such as food, agriculture, medicine, and pharmacology. *Ulva lactuca* can be found in coastal and subtidal waters, typically at depths of up to 75 meters. However, it requires a significant amount of sunlight to grow successfully [29]. This species is perennial that continues to grow throughout the year but mostly blooms in summer. Its growth has been rapidly increasing due to the rise in acidity and the presence of nitrogen and phosphorus in our oceans. Additionally, it has a high sodium, potassium, magnesium, iodine, aluminum, manganese, and nickel content. It also contains various nutrients such as Vitamin A, Vitamin B1, Vitamin C, calcium, soluble nitrogen, phosphorus, and many other trace elements [30, 31].

There is a growing interest in hemp globally, which is also increasing in our country. Hemp is an annual plant that has the potential to fill the gap in sustainable textile products as it grows quickly and efficiently with minimal water usage. Industrial studies on hemp are gaining momentum [32]. The waste product known as hurds is obtained after separating the stem fibers from the stem. These lignocellulose-based particles are produced as a byproduct [33]. The hurds possess good moisture retention capacity due to their physical structure [34]. Hemp hurds will be utilized to retain the moisture lost from the soil due to rising temperatures by creating a material with their physical properties.

The level of organic matter in agricultural soils is extremely low, and it is necessary to have a minimum of 3% organic matter in the soil weight to achieve the desired physical, chemical, and biological properties and yield potential of the soil [35]. To increase the organic matter content of agricultural soils, it is important to consider sources of organic matter. The use of vegetable waste has shown promising results in increasing organic matter. The project also focuses on recovering phosphate using seaweed (*Ulva lactuca*) as an organic fertilizer. The goal is to create a multipurpose material by making hemp residues and algae suitable for mulching before being used as fertilizer.

The goal is to find a sustainable solution for traditional mulch disposal in agriculture by choosing renewable and biodegradable materials derived from natural sources with diverse content. Combining *Ulva Lactuca* algae, which is rich in organic matter and immediately usable minerals for plants, with moisture-retaining and sustainable hemp, a novel product can be created with potential benefits for agriculture. This combination has not been studied in literature before and could be groundbreaking.

2. MATERIALS AND METHOD

2.1 Hemp (*Cannabis Sativa* L.)

The hurds used in the study were obtained from the crops of Narlı and Vezir seeds. Hemp Hurd was obtained as a side material in the fiber extraction process. In the study, it was used in the form shown in Figure 1, in 2 different sizes. In the form of finely ground Hurd, the fibers on the hurds are also fully exposed and become softer.

Figure 1. Hemp hurd

2.2 Seaweed (*Ulva Lactuca*)

The *Ulva Lactuca* algae used in the study were collected by us in Marmara Ereğlisi (40.9686885, 27.9284249). As shown in Figure 2, different types of algae are collected in the bay area. Ulva Lactuca algae were tainted and collected by us.

Figure 2. The region where algae used in the study

According to Figure 3, the sea algae known as *Ulva Lactuca* were dried naturally for two days without additional materials. After that, the dried pieces were ground and separated into smaller sizes.

Figure 3. Drying and decomposition steps of collected ulva lactuca algae

The study focused on constructing designs with varying degrees of fineness and content, using four different methods that cater to different usage areas. Sample codes created according to specific details, are listed in Table 1.

Table 1. Production methods and samples

Method	Samples obtained in the production method
1	101 / 102
2	201 / 202 / 203
3	301 / 302 / 303 / 304
4	401 / 402 / 403

The study conducted seven content analyses to measure the differences between freshly collected and dried algae, the adhesion of thin and thick stalks to the structure, and their chemical resistance. The various contents designed for this purpose are listed in Table 2. It is also important that the developed structures contain vinegar as it has a number of benefits to used areas such as natural herbicide for weed control (especially in organic farming practices), pest and fungal control in agricultural crops, increasing the acidic nature of soil or balance alkaline soils, compost decompose and break down quickly. Vinegar can also assist in controlling odors and repelling insects in the composting process.

Table 2. Sample contents table

Content Name	Contents	Worked Samples Conforming to Content
A	Dried Seaweed + Corn Starch + Grape Vinegar + Water	101 / 203 / 301/
B	Dried Seaweed + Corn Starch + Grape Vinegar + Water + small particle Hurd	102 / 302 / 303
C	(Fresh Seaweed + Corn Starch) + Corn Starch + Grape Vinegar + Water	201
D	(Fresh Seaweed + Corn Starch) + Corn Starch + Water	202
E	Dried Seaweed + Corn Starch + Grape Vinegar + Water + medium particle hurd	401 / 304
F	Dried Seaweed + Corn Starch + Grape Vinegar + Water+ small particle hurd	402
G	(Fresh Seaweed + Corn Starch) + Corn Starch + Grape Vinegar + Water	403

2.3 Production Methods

Samples labeled 101-A and 102-B were created using production method number 1, which involves a thin design. These samples were prepared with A and B contents and involved pouring and pressing a mixture between oiled paper under a 20-kilogram pressure, then allowing them to dry.

Figure 4. Fine samples in series #1 (101/102)

Samples with codes 201-C, 202-D, and 203-A, which have a thickness range of 0.5-0.7 mm, were produced according to specified contents using production method number 2. The mixture was then poured into a mold to achieve the desired thickness and left to dry. The effect of vinegar on samples 201 and 202 was observed during production. As shown in Figure 5 and Figure 6, the color of the samples became darker due to the acidic nature of vinegar reacting with the dye pigments, resulting in a difference in tone. Vinegar was included in the content because of its protective properties, which help to delay decomposition.

Figure 5. Sample production with code 201

Figure 6. Sample production with code 202

The aim was to investigate the impact of fresh algae structure on the samples labeled 201 and 203. The observations revealed that the color of the freshly applied 201 sample was just as dark as that of the 203 sample.

Figure 7. Sample production with code 203

For production method number 3, mold work was carried out beforehand to facilitate strength and related tests. Samples with codes 301-A, 302-A, 303-A, and 304-B were created with specified contents by pouring the mixture into the molds and letting it dry. The A content was chosen to examine the properties of the hurd and its fineness in the samples. During the production of the 301 and 302 coded samples, the hurds were first spread inside the mold, and then the mixture was poured on top, smoothed out, and left to dry.

Figure 8. Prepared samples in series 3 (301 / 302 / 303 / 304)

Figure 9. Production of 303 and 304 coded samples

Production method number 4 involved creating samples coded 401-E, 402-F, and 403-G with a size range of 4-5 cm and specified contents. Hurds of varying thickness were placed beneath the molds, and the prepared mixtures were poured on top and allowed to dry.

Figure 10. Sample production in thick structure form

Table 3. Dried samples ready for testing

102

201

202

203

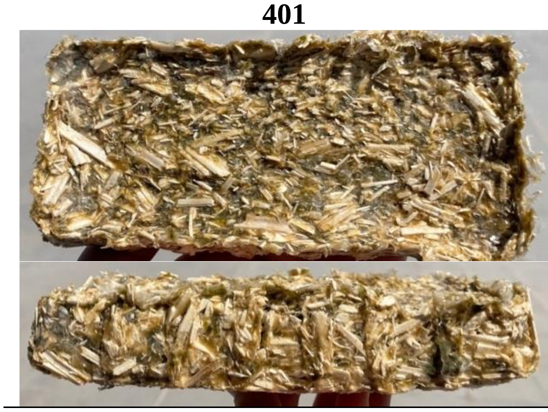
301

302

303

304

401



402

403

3. RESULTS AND DISCUSSION

The tests were conducted under standard atmospheric conditions, starting at (20 ± 2) °C and (65 ± 4) % relative humidity. The test methods used in this study were based on the standards applied to conventional textile-based structures. Technical textiles are generally tested regarding to conventional textiles. The most appropriate test methods were used in this study to determine the basic properties of the developed structures.

3.1 Areal Density and Thickness

Weight and fineness were determined by using a precision digital micrometer (Mitutoyo, Kanagawa, Japan). Ten measurements were taken at random points for each sample, and the mean values were determined. Film thickness was a critical property that needed to be measured, as it influenced the mechanical strength and water barrier properties of the samples. For agricultural purposes, a film thickness as low as 5 µm was adequate for controlling weed growth in the field [1]. Samples containing tortillas showed an increase in deviations in average values, particularly in thin samples such as 303 and 304 and thick samples such as 402 and 403, which were formed with hurds on one surface.

Table 4. The average thickness and weight values of the produced samples

Sample Codes	Average Thinness Values (mm)	Weight Values (g/cm^2)
101	0.5680	0.0393
102	1.3387	0.0450
201	0.7529	0.1417
202	0.4465	0.1662
203	0.7075	0.2479
301	0.5083	0.0405
302	1.235	0.1692
303	1.367	0.1456
304	1.692	0.2110
401	5.4187	2.686
402	4.8825	1.468
403	4.1020	1.352

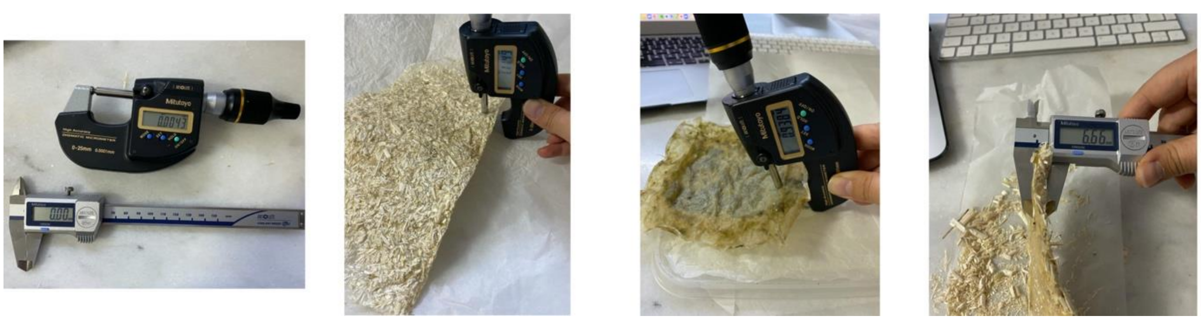


Figure 11. Thickness values measurement

3.2 Tensile Strength Test

All samples were tested for their mechanical properties using a Shimadzu EZ-X device at a speed of 5 mm/min and following the standard test method ASTM D1682-64 under standard atmospheric conditions. The mechanical properties are as important as the water barrier properties to determine the film's performance, especially in packaging and plastic culture. The mulch film must have sufficient strength as it is usually laid on the ground by machines, and the poor mechanical properties shouldn't deform during processing and fixing of the films to the ground. The results show a decrease in strength due to the moss and starch mixture not fully bonding with the hurd pieces, which is a common problem in composite construction. Additionally, a decrease in tensile strength was observed as the thickness of the samples increased, which is likely due to the evaporation rate and strength being dependent on the fineness during the drying process.

Table 5. Tensile strength values of produced samples

Samples	**Tensile Strength (N)**
101	12,8627
102	13,9495
201	9,8345
202	9,1635
203	8,1367
301	7,7691
302	1,2107
303	0,9203
304	0,7503
401	0,5476
402	0,5286
403	0,4983

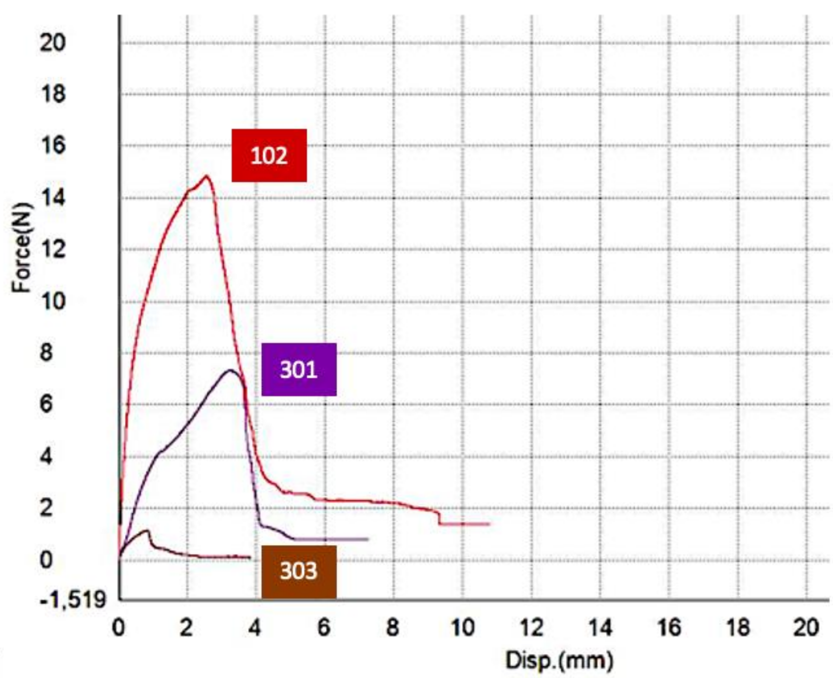


Figure 12. Tensile strength values

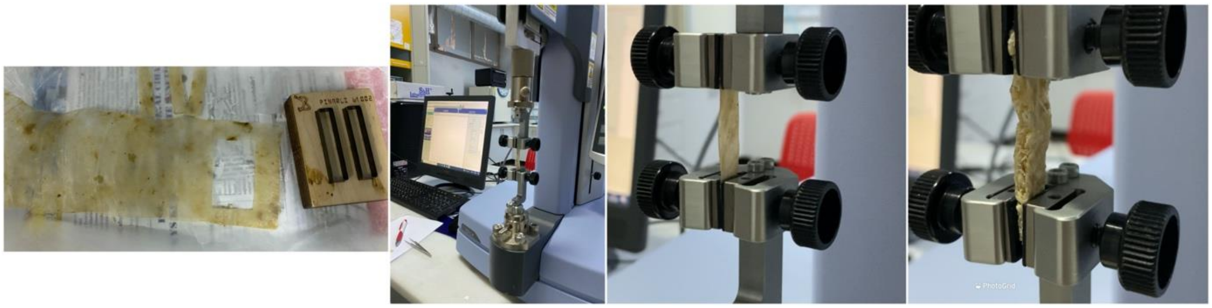


Figure 13. Tensile strength values measurement

3.3 Air Permeability Test

The test for air permeability was performed in compliance with the TS 391 ISO 9237 standard, under standard atmospheric conditions (20 ± 2) °C and (65 ± 4) % relative humidity. Air permeability is a crucial factor for protectingof the material against moisture. The film layer containing algae and starch, which was created, is impermeable to air. It was found that this film will protect against moisture during the growing season of seasonal plants when used as a ground cover.

3.4 Water Absorption Capacity Test

The test for water absorption capacity was performed according to the TS 866 standard. Each sample was measured ten times, and the mean value was calculated. For this test, five test samples were prepared from each original sample and weighed to get the dry weight. The samples were then placed in water at room temperature for one minute and then hung for three minutes to remove excess water. The weight of the wet samples was measured and recorded, and the water absorption capacity was calculated as a percentage.

Table 6. Water absorption capacity values of produced samples

Samples	Dry Weight (g)	Age Weight (g)	Water Absorption Capacity (%)
101	0.810	0.912	12.59
102	2.924	3.419	16.92
201	3.531	4.214	19.34
202	3.731	4.249	13.88
203	3.412	4.317	26.524
301	1.620	1.940	19.75
302	4.784	6.873	43.66
303	3.823	6.054	58.35
304	3.589	6.019	67.71
401	24.176	31.202	29.06
402	13.216	17.046	29.18
403	7.082	8.404	18.67

3.5 Light Transmittance Test

The light transmittance test is a custom-made test designed to measure the ability of the samples to transmit light under daylight conditions. The test setup, shown in Figure 15, uses D65 and D5000 daylight lighting sources to mimic outdoor lighting in a light-proof box. The amount of light that passes through the samples and reflects on a black plate is observed. The samples that contain hurd have lower permeability, and the opacity increases, and the amount of transmitted light decreases as the thickness increases in samples that do not contain tortillas. The reflection of light affects plant growth, plant response, and insect development.

Further analysis of light contact and temperature reflection values will be conducted in the future as part of the study.

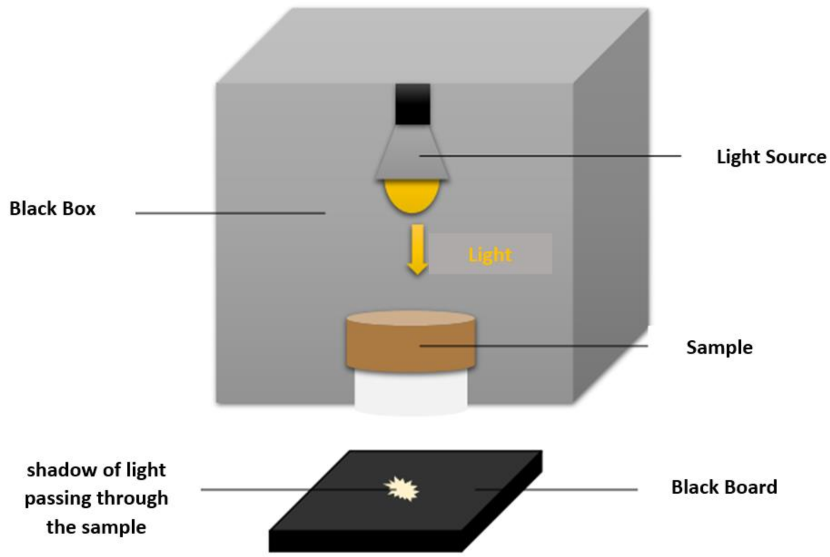


Figure 14. Experimental setup established to evaluate the light transmittance properties of the samples

3.6 Contact Angle Test

When the contact angle is less than 90°, wettability is considered high. Previous studies have shown that the contact angles of traditional mulch films are usually over 90 degrees. In this study, contact angle tests were performed on the samples, and the results showed that the hurd-free surfaces had higher contact angles due to their stronger hydrophobic properties. The bottom toppings in the 303 and 304 samples affected the thin film layer on the surface, leading to higher contact angles. In thin samples, the increase in the size of the hurd caused the angles to increase because it made the surfaces less homogeneous. The surfaces mixed with the hurd had wider spreading angles due to the water absorbing properties of the hurds.

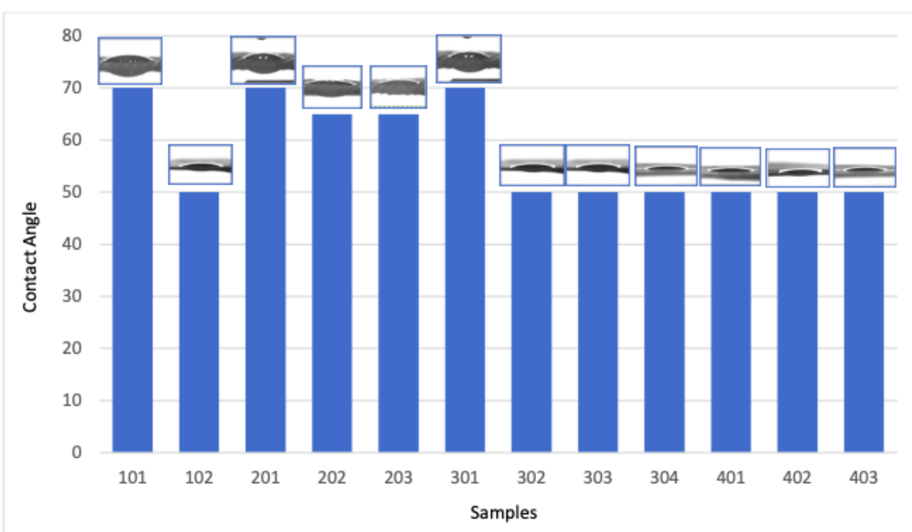


Figure 15. Contact angle test results and contact images

3.7 Thermal Properties (Far Infrared Radiation-FIR) – Flammability

The samples were tested to determine their thermal resistance and heat retention properties using a soot method [2, 3]. This is used as a kind of heat absorption test in the study. Thermal imaging was used to measure heat storage properties. The samples were warmed up for 4 minutes and the hottest point was determined using a thermal imaging camera. The heat source was then turned off and the cooling process was measured for 8 minutes. The heat retention values increased with weight ratios, and samples containing hurds had better heat retention properties due to their voluminous structure. The sample coded 401 had the highest heat retention weight and thickness, reaching 61.3°C in the 4th minute after heating. The sample coded 302 containing tortillas and hollow parts reached 41.7°C in the 4th minute and showed good heat retention properties. In the samples without hurds, slight folds were formed during heating but returned to their original state during the cooling process.

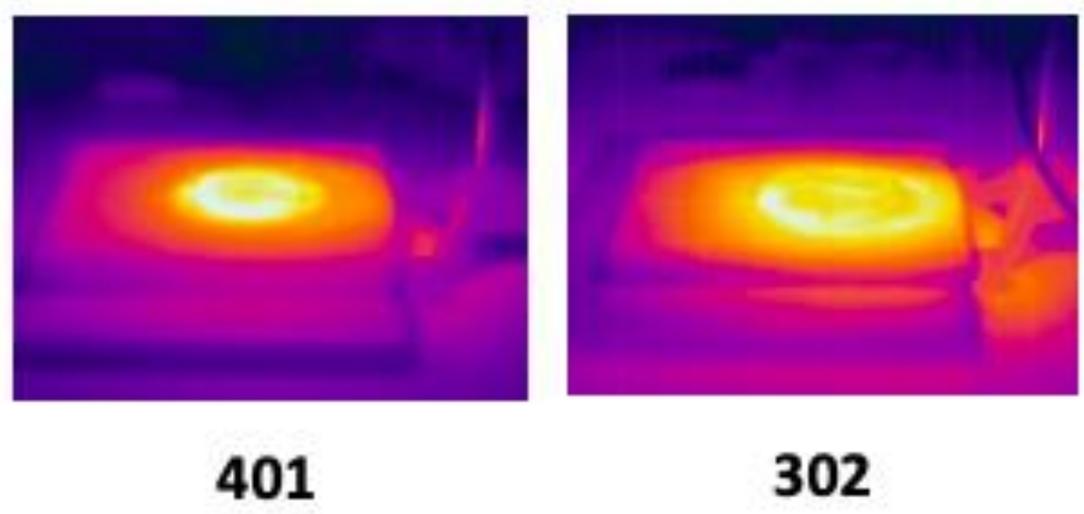


Figure 16. FIR test process applied to samples

Traditional greenhouse mulches do not protect to the soil or plants during a fire in the greenhouse. Results from the fire-fighting observation tests performed on the samples showed that improvements can be made based on the initial results. Previous research has indicated that the algae content used in this study is non-flammable [4, 5, 6]. The bond structures in the contents can be utilized for conducting studies to preserve this characteristic.

Figure 17. Flammability tested samples

4. CONCLUSION

The tests conducted on the samples created based on the project objectives have been analyzed, and the corresponding results have been presented in the findings section. The initial stage goals have been achieved by utilizing the obtained values. The long-term effects of the materials on plants, soil, and the environment should be further investigated. These materials can provide a natural and sustainable alternative to conventional PE products that are petrochemical-based in the agrotextile market. They possess a competitive advantage over other biodegradable products as they have a much more diverse composition. The thickness, weight, and content of the materials can be tailored to best suit the intended purpose. In future studies, various production methods will be tested to obtain samples, and research will continue. The goal is to maximize agricultural productivity using sustainable techniques based on the results of these studies.

The research has the potential to be expanded and advanced to gain more knowledge about *Ulva Lactuca* and hemp combination. It is seen that the hemp by-product and waste *Ulva Lactuca* has potential to develop different composite structures to be used in different agro and geo textile applications. The usability and processability of this composition are generally examined and successfully converted into one unique structure. It is also important to mention that different elements can be added to the structures to make extra benefit from the final product. Compared to nonwoven structures, hemp and Ulva have fibrillar structure, giving water absorption and slow-release properties to the product. Sustainable productions can be accomplished by aiming to achieve carbon-neutral products in all production processes.

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