DEVELOPMENT AND APPLICATION OF BIODEGRADABLE WHEAT STRAW AND CARRAGEENAN COMPOSITE IN AGRICULTURE

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Abstract. Environmental concerns in the long run have led the public to develop alternative materials that could be used in agriculture. The development and application of carrageenan and wheat straw biodegradable composite in agriculture is the main focus of this study. This composite is crafted to tackle the environmental repercussions linked with traditional agricultural materials. The manufacturing procedure encompasses the extraction and treatment of wheat straw fibres, which are then merged with carrageenan, a naturally occurring polysaccharide sourced from red seaweed Furcellaria Lumbricalis. The resultant bio composite displays encouraging mechanical traits, rendering it suitable for a variety of agricultural applications. The employment of wheat straw not only offers an environmentally conscious substitute but also addresses the predicament of disposing of agricultural waste. Regarding its application, the biodegradable composite can serve as a material for seedling trays. Due to the composite natural propensity to break down over time, long-term environmental pollution is prevented. Additionally, the material biodegradability is improved by its contact with soil microbes, enhancing the overall sustainability of agricultural methods. The outcomes of this study underscore the potential of the biodegradable wheat straw and carrageenan composite as a sustainable substitute for diverse agricultural applications. The development and assimilation of such environmentally friendly materials contribute to the ongoing endeavours to promote sustainable practices in agriculture, addressing both ecological apprehensions and the necessity for pioneering solutions in the field.

Keywords: wheat, materials, biodegradable, carrageenan.

Introduction

Seedling production commonly involves the cultivation of agricultural, decorative, and forestry plants in single plastic pots, predominantly composed of polyethylene and polypropylene materials [1; 2]. The key advantages of these pots lie in their superior mechanical features, which include a lightweight nature, chemical resistance, durability, and affordability.

Additionally, plants may be delivered and placed in plastic containers via automated equipment [3]. In addition, even in wet conditions, the material durability remains intact since moisture has no influence on it. In addition, plastic pots exhibit resistance to corrosion and mould, as well as resistance to algae growth. In addition to these advantages, a large range of plastic pots with various sizes, colours, and shapes are readily available due to their vast manufacturing [2].

Carrageenan, wheat straw and paper pulp are materials used to make seed trays [4; 5]. These types of materials are better than conventional materials like plastic because they are environmentally friendly. Wheat straw is a natural and degrading material. With its high nutritional value, wheat straw is plant-beneficial because it provides a great substrate for plants [6]. Plant pots may be shielded from extreme temperature swings by using wheat straw, which has high thermal insulation qualities [7; 8]. Seedling pots made from wheat can be conveniently added to the soil once seedling is grown, since it breaks down organically. In 2022, wheat grain production in Latvia reached 2 539 000.4 tons. The use of organic fertilizers, such as wheat straws (post-harvest residues), amounted to 641 000 tons. The sown area of wheat crops was 448 000 hectares [9]. Wheat straws had many positive characteristics that make them a great material for seedling pots. Wheat straws break down naturally, making them a good choice for use in agriculture that does not harm the earth [10]. Consequently, after the seedlings have reached a satisfactory growth stage, the trays can be conveniently decomposed, thereby minimising waste and mitigating the negative environmental effects. Furthermore, the inherent biodegradability of wheat straws guarantees their non-exacerbation of plastic pollution, a prominent issue in modern agricultural practices.

Furthermore, wheat straws exhibit sufficient strength and durability to provide enough support for new seedlings throughout their initial stages of growth. The straws possess a high degree of structural integrity, which furnishes substantial support to the soil and the developing roots, so contributing to the preservation of stability inside the seedling tray. The presence of steady conditions is of utmost importance for seedlings, as it is essential for facilitating optimal root development and overall growth.

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Proper air circulation and moisture play the main role in promoting the best growth of seedlings, as they contribute to the growth of strong root systems and reduce the risk of root rot. It is important to note that wheat straws exhibit a high degree of porosity, hence enabling good aeration and improved moisture retention in the seedling pots. The inherent fibrous composition of wheat straws promotes this equilibrium, establishing an ideal microenvironment for optimal seedling growth [11].

In addition, wheat straws are easily obtainable and economically viable, rendering them a viable choice for individuals engaged in small-scale farming and horticulture.

As a binding material for seedling pots carrageenan is used. Carrageenan is a natural and sustainable type of polymer that is environmentally friendly, and material degrades in soil. Carrageenan enhances moisture absorption. Carrageenan capacity to hold onto moisture promotes healthy seed germination and growth. Carrageenan can provide plant pots a sturdy framework that will help them hold their form and hold seeds with substrate [5].

The section that follows will provide an overview of the corresponding quantities of the components used in the production procedure of seedling pots, and the research methodologies employed.

Materials and methods

Simple materials and methods were selected for evaluating the wheat straw seedling pots. There were four distinct categories of wheat straw seedling pot batch samples that were prepared, with each batch including 24 seedling pots. In the environmental chemistry laboratory of the Riga Technical University Liepaja Academy, the production of seedling pots was carried out. The materials utilised in the manufacturing of seedling pots are displayed in Figure 1, 2 and 3.

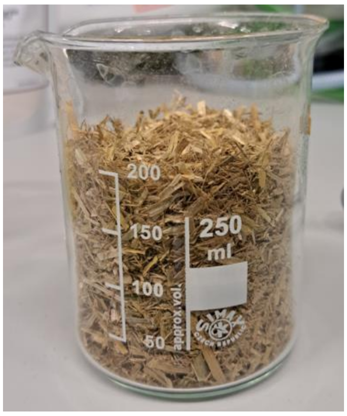

Fig. 1. **Shredded wheat straws, 2-5 mm long**

Fig. 2. **EstAgar, EstGel1000TM mixed with water**

Fig. 3. **Shredded paper, 4x3 mm particles**

In the production of all four batches of seedling pots, the Estonian company *EstAgar*, *EstGel1000*^{TM} unique texturizing carrageenan agent with variable properties, was used. Each batch contains 29 g of powder. The powder acts as a natural colloid, gelling agent, bonding agent, and viscosity control agent. The product is characterised by its plant-based, vegan, natural, organic composition, making it a beneficial inclusion in several industries [12].

The powder exhibits a pale-yellow hue and possesses a neutral scent. The powder moisture content 8.35%, pH 1% aqueous solution at 25 ºC – 7.6. Water gel strength, 2.5% gel of a 100% dry *Furcellaran*, trigger 4.5 g, deformation 15 mm, speed 0.4 $mm \cdot s^{-1}$ (LM 303) – 972.5 g. Temperature of gelation on cooling, 1.25 g absolute dry *Furcellaran* and 70% sugar solution – 57 ºC. Total salt –27%. Heavy metal saturation in the powder is in acceptable amounts, Arsenic – 0.150 $mg \cdot kg^{-1}$, Lead – 0.340 $mg \cdot kg^{-1}$. Sulphur dioxide in EstGel1000^{TM} is higher as the norm – 14 $mg \cdot kg^{-1}$ (norm 10 $mg \cdot kg^{-1}$).

The seedling pot primary structural element is wheat straws, specifically *Triticum aestivum*.

Wheat straws are gathered from local farmers in Dienvidkurzeme. Wheat straw dry matter – 89%, protein – 3%, cellulose – 40%, hemicellulose – 26%, lignin – 22.9%, ash – 9%, calcium – 0.17% and phosphorus – 0.04%. The *Sirman C-Tronic 40780958S C9 PLUS* food processor is used to process wheat straws into bits that are typically 2-5 mm long.

The paper recycling laboratory at the Riga Technical University Liepaja academy is responsible for the preparation of paper pulp. The pulp utilised in this study is derived from recycled office paper that has been gathered from the campuses. In the preliminary stage of processing, the paper undergoes shredding using a paper shredder and is thereafter stored in carton boxes for future utilisation. The paper pulp production process necessitates the use of shredded paper in 4x3 mm particles with the *Fellowes Powershred 53C* paper shredder. Only two types of seedling pots were supplemented with paper to further investigate its potential application as a constituent.

Two types of pots were treated with 10 g potassium metabisulfite as a preservative to prevent mould growth during the experiment, given the susceptibility of the straw material to mould and fungi [13]. The material composition for 24 pieces per each batch of seedling pots is displayed in Table 1.

Table 1

Material composition for 24 pieces per batch of seedling pots

Batch type	Materials used						
	EstGel1000TM Hybrid k/ß-carrageen complex, g	**Destilled water, ml**	**Wheat straws (*Triticum aestivum*), g**	**Shreded paper, g**	**Potassium metabisulfite, $K_2S_2O_5$, g**	**Drying temperature, ºC**	**Drying time, h**
B1	29	1000	300	-	-	50	10
B2	29	1200	300	250	-	60	13
B3	29	1000	300	-	10	50	10
B4	29	1200	300	250	10	60	13

Each batch consists of fixed components – wheat straws and carrageenan. The added paper in B2 and B4 batches was soaked in water for 30 minutes before being added to the batch mass and then ground into a homogeneous mixture. During the manufacturing process of seedling pots, the initial ingredients incorporated consist of finely powdered wheat straws combined with carrageenan. Prior to use, carrageenan is dissolved in distilled water. Next, the quantity of paper mass is determined based on the specific batch type. Lastly, the addition of potassium metabisulfite is contingent upon the specific batch type. Subsequently, the mixture is transferred into moulds and subjected to a drying process within a desiccator, with the duration and temperature of the drying process contingent upon the specific batch category. The moulding process utilised plastic moulds measuring 40 mm in width, 50 mm in height, and 40 mm in length. Figure 4 depicts the drying process and the final seedling pots.

Fig. 4. **Drying process and the final seedling pots:** 1 – seedling pots in dryer; 2 – B1; 3 – B3; 4 – B4; 5 – B2

Multiple batch seed germination experiments were conducted for 45 days, with each batch containing 24 seedling pots. Every seedling pot is planted with 10 *Kurzemes sēklas Hanging petunia* seeds, the germination rate showed on the package - 65%. The experiment utilised Biolan universal peat substrate.

Results and discussion

The experimental data were documented and collated after a period of 45 days.

Table 2 presented below provides a summary of the average number of germinated seeds per pot, percentage of germination, standard deviation and error for each batch.

Table 2

Average number of germinated seeds per pot, percentage of germination, and standard deviation for each batch

Batch type	Average germinated seeds per pot	Percentage of germination	Standard deviation	Sample size (seeds)	Standard error
B1	4 (3.83) seeds	38.33%	2.79	240	0.176
B2	6 (6.21) seeds	62.08%	3.14	240	0.203
B3	6 (6.25) seeds	62.50%	2.52	240	0.163
B4	6 (6.33) seeds	63.33%	2.60	240	0.168

The data points after calculation in B1 have a standard deviation of 2.79 from the mean of 3.83. This relates to the number of seedlings that germinated per seedling pot. It seems that there is some variation in the results of the germinated seedlings in this batch, with values spread out around the average. Some pots displayed a significant decrease in the number of germinated seeds compared to the average, while others showed an increase. The data in B2 after calculation shows a wider range compared to B1, as shown by the larger standard deviation. The data shows that, on average, there is a deviation of 3.14 units from the mean of 6.21 (~6 seeds). This observation implies that there is a greater degree of variety in the outcomes of the germinated seeds within this batch. There was a wider data set dispersion since certain containers had a substantial variance in germinated seeds.

The variable B3 standard deviation of 2.52 indicates that data points range by 2.52 units from the mean value of 6.25. This observation indicates that the outcomes of germinated seeds in B 3 exhibit a rather high degree of proximity to the average value. The variability in this batch is smaller than that of B2, suggesting that most pots had a comparable number of germinated seeds.

The data points in B4 have a standard deviation of 2.60, indicating that, on average, they deviate by 2.60 units from the mean of 6.33. Analogous to B 3, this observation suggests that the outcomes of the germinated seeds exhibit a rather high degree of clustering around the mean. B2 has lower variability, while B3 displays somewhat more variability.

In the present scenario, it was seen that B2 exhibited the highest standard deviation, signifying the most pronounced dispersion in the outcomes of germinated seeds. Conversely, B3 and B4 had smaller standard deviations, implying a greater degree of consistency in the findings.

From the comparison of germination rates, it was found that B4 had the greatest percentage of germination (63.33%) and the highest average number of seeds that germinated per pot (~ 6 seeds). This finding indicates that the utilisation of carrageen, wheat straws, shredded paper, and potassium metabisulfite resulted in the most favourable circumstances for the process of seed germination. The use of wheat straws and potassium metabisulfite in B3 demonstrated positive outcomes. The germination rate 62.50% The inclusion of potassium metabisulfite was shown to be responsible for the positive germination findings in both B4 and B3. Fungus development was observed in two batches, namely B1 and B2, over the course of the experiment. The observed fungal growth is visible in Figure 5.

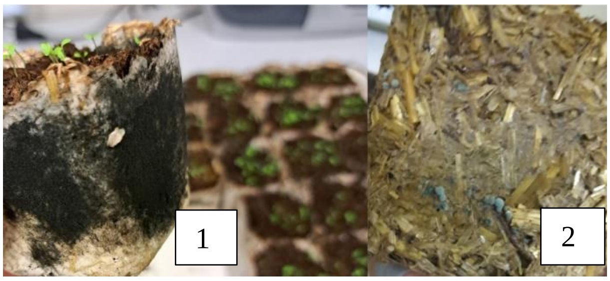

Fig. 5. **Observed fungal growth:** 1-B2; 2-B1

Conclusions

1. The study introduces a biodegradable composite material made from wheat straw and carrageenan, which may be used as a sustainable substitute for agricultural seedling containers.
2. The germination rates and percentage of the B4 batch (EstGel1000TM with shredded paper, wheat straws, and potassium metabisulfite) were found to be the greatest.
3. The presence of fungal growth in batches B1 and B2 suggests the necessity of employing a sterilisation agent.
4. The composite material has environmental advantages, including the reduction of waste and the conservation of moisture, so helping the promotion of sustainable agriculture methods.

Author contributions

Conceptualization, U.Z.; methodology, S.O. and U.Z.; software, A.K.; validation, U.Z. and S.O; formal analysis, S.O writing – original draft preparation, S.O.; writing – review and editing, U.Z. and A.K.; visualization, S.O.; project administration, U.Z. All authors have read and agreed to the published version of the manuscript.

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