Annals of West University of Timişoara, ser. Biology, 2025, vol. 28 (2), pp.223-232

PRELIMINARY INVESTIGATION ON SOME VEGETAL HYDROGELS INDICES

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Received 28 November 2025; accepted 29 December 2025

ABSTRACT

The reuse of vegetal residues is a well-known bioeconomical practice and provides materials which are advantageous in various domains, such as agriculture, biotechnology or wastewater treatment and purification. In agriculture it can be noticed that innovative technologies are developed to enrich soils and to enhance productivity. There is a growing interest in studies on hydrogels, especially on those which are obtained from environmentally friendly sources, as residues or organs of some common plants. In this context, the main objective of this study was to gravimetrically characterize some hydrogels obtained from quince, psyllium, chia and flax seeds. The analyzed indices were gel initial weight, gel moisture content and dry content. Different protocols for hydrogels preparation were utilized, and various results were obtained, highlighting their potential use in agriculture and biotechnologies.

KEY WORDS: *chia, flaxseed, quince, psyllium, hydrogels.*

INTRODUCTION

Research on hydrogels has been rapidly increased, given their properties and many possible utilities, such as industrial applications, agricultural applications, tissue engineering applications, wastewater treatment and purification, medical and biomedical applications (Oyen, 2014; Sayed, 2023; Ali et al. 2024). In fact, using hydrogel in actual urban agriculture was mentioned to come with numerous benefits (Alonso-Cuevas et al. 2025) including improving seed germination (Azahari et al. 2023), but also plants growing in arid environments (Kabir et al. 2018). Moreover, these assure enough water due to their potential to be water-holding reservoirs (Sarmah and Karak, 2020). Hydrogels are characterized by their three-dimensional network of hydrophilic polymer chains that have the capacity to absorb water up to thousands of times their dry weight (Sapuła et al. 2023). Because of their biocompatibility, bioactive characteristics, biodegradability, low cost, biofunctionality of their derivative products, and the lack of negative impact on the environment, natural polymers are frequently used (Sayed, 2023; Sapuła et al. 2023).

Uses of plant-based polysaccharides have expanded, as they are a source of hydrogel production. Alginate and pectin show an impressive gel-forming capacity, and a high biocompatibility (Sapuła et al. 2023; Segneanu et al. 2025).

Several seeds, originally thought to have a minimal role in science fields and environment, have been reported to show hydrogel forming properties (Mandal et al. 2024; Zahid et al. 2021). This category includes chia, quince, psyllium and flax seeds, representing a form of natural hydrogel-forming materials, as they can be obtained from agricultural by-products and are biodegradable, renewable, and can reduce waste streams (Khatoon et al. 2024; Guzelgulgen et al. 2021; Yildirim et al. 2025; Mehta & Singhal, 2025).

Chia (*Salvia hispanica*, Lamiaceae) seeds are widely used in foods, such as cookies, cereals, and drinks (Khatoon et al. 2024; Tomić et al. 2022). Their mucilage indicates super-porous, highly absorbent, and pH-sensitive properties, which make them a smart material for hydrogel formation with uses in fat replacement, water purification, and controlled release. These properties are relevant for circular economy strategies, as chia mucilage is non-toxic, biodegradable and can replace non-renewable synthetic polymers (Khatoon et al. 2024; Tomić et al. 2022; Shehzad et al. 2025). These seeds contain valuable biologically active compounds, such as proteins, antioxidants, polyunsaturated fatty acids, minerals, and vitamins (Tomić et al. 2022). However, their hydrogel-forming properties arise mainly from their polysaccharides, particularly glucuronic acid, xylose and units of α-D-glucoronopyranosyl, β-D-xylopyranosyl (Khatoon et al. 2024).

Psyllium (*Plantago ovata*, Plantaginaceae) seeds have been utilized in the food, pharmaceutical, and cosmetic industries as thickeners. However, their low cost, water-soluble and gel forming polysaccharides, have recently gained attention in biomedical and engineering applications (Yildirim et al. 2025). Their gel-forming properties are mainly due to polysaccharides such as arabinose, xylose, glucuronic acid, galacturonic acid, rhamnose, galactose, and glucose (Lima et al. 2026). Psyllium also supports circular economic principles through its biocompatibility and biodegradability, especially in the development of sustainable materials for packaging, medicine and other sectors (Lima et al. 2026; Yildirim et al. 2025).

Quince (*Cydonia oblonga*, Rosaceae) seeds are mostly discarded as by-products during juice or jam processing, which make them an excellent circular-economy resource due to their high mucilage content (Romero et al. 2024; Fatima et al. 2024). Their water-soluble polysaccharides, mainly rich in glucuronic acid, form stable, viscoelastic hydrogels, with reported uses in edible films, tissue engineering, and water purification (Fatima et al. 2024).

Flaxseed (*Linum usitatissimum,* Linaceae) is cultivated for oil, fiber and medicinal compounds. Its mucilage proved to be used in biomedical research, because of its non-carcinogenic, non-cytotoxic and low hemostatic features (Radinekiyan et al. 2023). Its main polysaccharides consist of arabinose, galactose, rhamnose, fucose, galacturonic acid, glucose, and xylose, which facilitate water binding formation. Its hydrogel properties make it suitable for biodegradable materials, contributing to bioresource valorization (Kučka et al. 2024; Radinekiyan et al. 2023; Mehta & Singhal, 2025).

The following table (Table 1) presents the seeds described, highlighting their main polysaccharide compounds, hydrogel-related properties, and the potential waste sources that can be valorized for gel-formation.

TABLE 1. Main polysaccharides of the described seeds, their hydrogel-related properties, and typical waste source

Seed	Main carbohydrates	Hydrogel-related properties	Typical waste source	References
Psyllium	Arabinoxylans	Water-binding, viscoelastic	Husk by-product	Lima et al. 2026; Akcicek et al. 2025; Qaisrani et al. 2016
Chia	Glucose, glucuronic acid	Rapid gel formation,	Chia seed by-products	Khatoon et al. 2024; Muñoz et al. 2021
Flax	Rhamnose, arabinoxylans	Stable gels, emulsifying	Milling residue	Kučka et al. 2024; František et al. 2024; Elsorady et al. 2024
Quince	Glucuronic acid, pectin-rich mucilage	Strong, viscoelastic gels	Seed waste from processing	Fatima et al. 2024; Romero et al. 2024; Yousuf & Maktedar, 2023

As shown in Table 1, all four seeds contain polysaccharides with hydrogel forming properties. While glucuronic acid-rich polysaccharides are major in Chia and Quince seeds, arabinoxylans dominate in Psyllium and Flax seeds. Various seed by-products can also be observed as a valuable resource of gel-forming mucilage, underlining their potential in circular economy. The properties of these seeds can be observed, they serve both a functional hydrogel use and a sustainable valorization of the by-products, thus reducing waste.

Although the seeds have been each individually studied (Khatoon et al. 2024; Lima et al. 2026; Kučka et al. 2024; Fatima et al. 2024), an analysis for the comparison of their hydrogel-forming potential and their current relevance in circular economy, especially potential utility in agriculture remains to be further analyzed. This study aims to investigate the hydrogel behavior of the summarized seeds, through quantitative gravimetric analyses, focusing on parameters such as initial weight, moisture, and dry mass content to characterize their hydrogel properties.

MATERIALS AND METHODS

The methodology included the use of four types of seeds (chia, quince, flax and psyllium), bought from a local store from Timisoara, Romania. The study was conducted during September and October 2025. Chia, psyllium and flax seeds were soaked in 15 ml of distilled water without any mechanical processing. For quince seeds, three experimental variants were tested: for the first gel whole seeds soaked in distilled water; for the second the seeds were sectioned using a blender and for the third variants the seeds were ground in a ceramic mortar. Subsequently, 15 ml distilled water was added for each probe. The gels were prepared in different dilutions, with distilled water, each in triplicate, as can be observed in Table 2.

TABLE 2. Hydrogels coding and dilutions

Seed	Chia			Quince			Flax			Psyllium		
Hydrogel	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
Dilution	1:10	1:20	1:30	1:5	1:5	1:5	1:10	1:20	1:30	1:10	1:20	1:30
Seed weight (g)	1,5	0,75	0,5	3	3	3	1,5	0,75	0,5	1,5	0,75	0,5

The obtained gels were heated at 60ºC for one hour, after which they were filtered through gauze to remove the remaining seed residues. The gels were thoroughly washed with distilled water to remove any polar impurities.

After washing, the gels were weighed to determine the initial weight (Wi). Then, the samples were placed in an oven at 100º for 6-10 hours. After this process, the dry weight (Wf) was obtained, being used for the determination of gel moisture content (GMC) and dry mass content (DMC).

$$Gel\ moisture\ content\ (\%) = \frac{(Wi - Wf)}{Wf \times 100} \quad (1)$$

$$Dry\ mass\ content\ (\%) = \frac{Wf}{Wi \times 100} \quad (2)$$

Statistical processing was accomplished using Microsoft Excel.

RESULTS AND DISCUSSIONS

Tables 3-5 presents the results obtained for initial weight, moisture and dry content of the probes. Gravimetric analysis performed on twelve hydrogels revealed differences between the types of gels, highlighting their natural composition.

TABLE 3. Initial weight (%) of the analyzed hydrogels

Wi	Min	Max	Mean
I	2,5230	3,9260	3,1257
II	5,2460	6,5390	5,8140
III	7,3340	7,7850	7,5595
IV	5,6590	5,9580	5,8577
V	5,8390	5,9500	5,8540
VI	5,5810	6,2610	5,9487
VII	10,4490	11,0950	10,7987
VIII	11,2650	11,5070	11,3483
IX	11,4100	11,6280	11,5407
X	2,3310	2,5420	2,4365
XI	4,8200	6,4440	5,8240
XII	7,3690	8,0260	7,6407

In Table 3 initial weight results are presented. The highest minimum, maximum and mean values correspond to gels VII-IX, representing the quince samples. This is likely due to their larger seed size. Comparatively, psyllium (X-XII) and chia (I-III) seeds show similar values, with psyllium showing the lowest average (2,4365%).

Flax (IV-VI) seeds display intermediate values. Despite the low initial measurements for chia, psyllium and flax seeds, their water-holding capacity facilitates stable gel formation. Overall, the table presents a variation in seed types and displays the potential of these seeds for hydrogel applications.

As shown in Table 4, most gels, including Chia (I-III), and Flax (VII-IX) presented very high humidity values, exceeding 99%, which indicate a high water-holding capacity and a high content of soluble polysaccharides. Psyllium gels (X-XII) exhibited more heterogeneous hydration, observed through the wider min-max range (81-99%), reflecting variability in gel formation. Among the samples, Quince gels (IV-VI) showed lower mean humidity (44-55%), which can be attributed to the presence of a considerable amount of insoluble material, represented by an internal woody component, which remains in suspension even after filtration and washing.

In Table 5, minimum, maximum and average values for the dry content (%) of the samples can be observed.

TABLE 4. Gel moisture content (%) of the analyzed seeds

GMC(%)	**Min**	**Max**	**Mean**
I	99,5219	99,5670	99,5510
II	99,7903	99,7706	99,7764
III	99,8500	99,8587	99,8545
IV	85,5608	44,9815	49,4964
V	44,0315	54,5210	54,9801
VI	49,3460	48,9007	47,5962
VII	99,5577	99,6459	99,5963
VIII	99,7692	99,8001	99,7884
IX	99,8360	99,8598	99,8499
X	68,2540	93,9418	81,0979
XI	99,4724	99,5228	99,4932
XII	99,6413	99,6761	99,6594

TABLE 5. Dry mass content (%) of the analyzed samples

DMC (%)	Min	Max	Mean
I	0,4330	0,4781	0,4490
II	0,2097	0,2294	0,2209
III	0,1413	0,1500	0,1456
IV	14,4392	55,0185	39,9871
V	45,0199	55,9685	48,8225
VI	50,6540	52,4038	51,3857
VII	0,3541	0,4423	0,4037
VIII	0,1999	0,2308	0,2116
IX	0,1402	0,1640	0,1501
X	6,0582	31,7460	18,9021
XI	0,4772	0,5276	0,5068
XII	0,3239	0,3587	0,3406

Chia (I-III) and Flax (VII-IX) gels displayed very low dry mass (<0.45%), confirming their particularly hydrated structure. Even after dilution, the gels retained high water content, compatible with their mucilage-rich composition. Psyllium gels (X-XII) displayed low dry content (<0.52%), confirming that hydrated gels are formed when conditions are optimal. Quince gels (IV-VI) showed considerably higher dry mass, reflecting the presence of insoluble material. Whole seeds (IV) had a mean DC of 39.99%, sectioned seeds (V) showed similar values, and ground seeds (VI) expressed the highest dry mass (51.39%), suggesting the possibility of grinded seeds to release more dense structural components, which remain as solids in the gels.

The combined analysis of gel moisture content (Table 4) and dry content (Table 5) underlines the influence of seed type and processing on gel formation. An inverse association is observed between water content and dry matter, with highly hydrated gels (Chia, Flax) displaying low solid content, and gels with more insoluble material (Quince) expressing lower water content and higher dry mass. These differences show that seed composition and processing can impact the hydrogel properties, providing an insight into their functional behavior.

These hydrogels have numerous applications, in various domains, including among others, agriculture, biology, biotechnology. Between actual agronomical practices and methods used hydrogels became a focal point (Ali et al. 2024). The application of these products to a planting medium increases the integrity of cell membrane, but also leaves water content (Ghobashy, 2020). Also, it reduces xylem and phloem obstruction during translocation. These products present cost-effectiveness, but also a capacity for increasing yield (Jat et al. 2018; Buitrago-Arias et al. 2025). In addition, there is a growing interest in multifunctional hydrogels, some with biomass source, as, for example, pine resins (Das & Ghosh, 2022). Hydrogels also are documented to be formed using agricultural waste (Perez et al. 2018) and further studies are necessary in this domain.

CONCLUSIONS

To summarize, this study provides a comparative gravimetric assessment of hydrogels derived from quince, psyllium, chia, and flax seeds, emphasizing their potential as sustainable, plant-based materials with relevance to agricultural applications. The analysis of initial gel weight, moisture content, and dry matter percentage revealed clear differences in hydration behavior and structural consistency across the hydrogels investigated. These variations reflect not only the intrinsic biochemical composition of the botanical sources but also the influence of the extraction and preparation protocols employed.

Overall, the findings highlight that specific plant residues can yield hydrogels with favorable physicochemical characteristics, supporting their integration into bioeconomic strategies aimed at soil enrichment, water retention, and improved agricultural productivity. Further research should explore the mechanistic basis of these differences, optimize extraction methodologies, and evaluate the performance of these hydrogels under real agronomic conditions. Such efforts will contribute to expanding the practical use of biodegradable, residue-derived hydrogels in sustainable agriculture.

ACKNOWLEDGEMENTS. We express our sincere gratitude to the Advanced Environmental Research Institute, Timisoara (AERI), for their valuable support in providing access to equipment and research facilities.

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