

OPTIMIZATION OF THE EXTRACTION YIELD OF POLYSACCHARIDE BASES MUCILAGE FROM LIPIDIUM SATIVUM SEEDS

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Abstract

Garden cress (*Lipidium sativum*) seeds are a plentiful source of natural polysaccharide-based mucilage with superior thickening, stabilising, emulsifying, and film-forming qualities, making them appealing for use in food, medicine, biomedicine, and environmental applications. To optimize yield while maintaining its functional properties, this mucilage must be extracted effectively. The goal of the current research is to optimize the yield of polysaccharide-based mucilage extracted from *L. sativum* seeds by assessing the effects of important extraction factors, such as temperature, time, pH, seed-to-water ratio, and agitation conditions. To determine the ideal extraction conditions that maximize polysaccharide recovery, the impacts of these factors on mucilage yield were methodically examined. While preserving the extracted mucilage's physicochemical integrity, the optimized procedure greatly increased extraction efficiency. The increased yield shows that *L. sativum* seeds have the potential to be a cost-effective and sustainable source of natural hydrocolloids for industrial uses. Additionally, optimization reduces processing time, energy consumption, and solvent use, all of which support ecologically beneficial extraction techniques. The results support the use of mucilage as a renewable biopolymer in the creation of biodegradable materials, controlled drug delivery systems, food additives, and environmentally friendly adsorbents for wastewater treatment. They also provide important insights for the large-scale manufacture of high-quality mucilage.

1 Introduction

Natural polysaccharides have garnered significant interest as renewable, biodegradable, and eco-friendly biomaterials due to their superior biocompatibility, lack of toxicity, and diverse functional characteristics. Plant-derived polysaccharides may be used in culinary, pharmaceutical, cosmetic, biological, and environmental applications since they are sourced from renewable resources and have an abundance of hydroxyl and carboxyl groups, unlike

manufactured polymers [1, 2]. Due to its remarkable water-holding capacity, viscosity increase, gel-forming ability, emulsifying qualities, and film-forming features, seed mucilage has become a potential hydrocolloid among these natural biopolymers [3].

A popular annual plant in Asia, the Middle East, and Africa, *L. sativum* (garden cress) is a member of the Brassicaceae family and grows quickly. The seeds are beneficial for both industrial and nutritional uses since they are high in proteins,

carbs, dietary fibre, minerals, and bioactive phytochemicals [4]. A very hydrophilic mucilage found in the outer seed coat is quickly released when the seed is hydrated. The complex polysaccharides that make up this mucilage, which include arabinose, xylose, galactose, rhamnose, glucose, and uronic acids, are what give it its exceptional swelling behaviour, viscosity, and gel-forming qualities [5].

L. sativum seed mucilage has drawn more attention from scientists as a natural substitute for synthetic polymers because of these special structural and physicochemical traits. It has been investigated as a matrix-forming polymer in medicinal dosage forms and as a thickening, stabilising, emulsifying, and binding agent in food formulations. Furthermore, it is a good option for controlled drug administration, wound healing, tissue engineering, edible coatings, biodegradable packaging, and wastewater treatment applications due to its biodegradability, biocompatibility, and non-toxic nature [6].

Plant-derived mucilage output and quality are mostly determined by the extraction technique. Seed hydration, polysaccharide dissolution, diffusion into the extraction medium, and the physicochemical integrity of the extracted mucilage are all strongly impacted by a number of operational factors, including extraction temperature, extraction time, pH, seed-to-water ratio, agitation speed, and extraction medium [7-12]. While inadequate extraction conditions often result in incomplete recovery and reduced extraction efficiency, excessive extraction temperatures or extended extraction times may cause partial polysaccharide chain breakdown [13-22]. To maximise mucilage yield while maintaining its structural and functional qualities, extraction parameters must be optimized [23-26]. Seed mucilage may be recovered using a variety of extraction methods, including as traditional hot-water extraction, microwave-assisted extraction, ultrasound-assisted extraction, and enzyme-assisted extraction. Because of its ease of use, cheap operating costs, low chemical needs, and ease of scaling up for commercial production, traditional hot-water extraction is still the most

popular of these techniques. However, optimising the extraction factors to achieve maximal polysaccharide recovery with low degradation is crucial to this method's effectiveness. Using statistical experimental methods, a number of studies have looked at the optimisation of *L. sativum* mucilage extraction [27-35].

Effective extraction of *L. sativum* seed mucilage has grown in significance due to the rising need for sustainable hydrocolloids and bio-based products. Optimisation improves the economic viability of industrial-scale manufacturing by increasing polysaccharide recovery while lowering processing time, energy consumption, and production costs. Therefore, by methodically assessing the impact of crucial extraction factors, the current work seeks to maximise the extraction yield of polysaccharide-based mucilage from *L. sativum* seeds. It is anticipated that the optimised extraction technique would provide a dependable and effective way to produce high-quality mucilage for use in culinary, pharmaceutical, biomedical, packaging, and environmental applications.

2 Materials and methods

2.1 Materials

The *L. sativum* seeds were bought at the local market. All of the chemicals used were analytical grade and came from Riedel-de Hañ (Germany), with the exception of ethanol, which was purchased from the local supermarket. Microcrystalline cellulose was supplied by Merck (Germany), while magnesium stearate was supplied by BDH (Bristol, England). The tragacanth gum was purchased from Sigma-Aldrich in the United States. Aceclofenac of European Pharmacopoeia (EP) grade was the medication used in the model. Simulated intestinal and stomach fluids were made using the procedure described in USP. Every experiment was conducted using deionised water.

2.2 LSH isolation

The collected *L. sativum* seeds were washed to get rid of dust and other contaminants. After being cleansed, the seeds were kept for a whole day in 800 millilitres of deionised water. To release

mucilage, the soaked seeds were submerged in water and heated to 60°C for 30 minutes after hydration. Nylon mesh was used to carefully remove the hydrogel/mucilage away from the seed coat. Following many rounds of deionised water cleaning, the isolated material was cleaned using the lipophilic (wax) solvent n-hexane. The pure hydrogel was ground into a fine powder, vacuum-dried at 60°C for 48 hours, sieved thru a 60-mesh screen, and stored in a desiccator until needed. The hydrogel's total extraction yield was determined to be 13.68 (w/w)

2.3 Optimization of hydrogel extraction

The extraction procedure was refined and modified from a previously published approach. For two and a half hours at room temperature, the *L. sativum* seeds were submerged in 1:25 (w/v) deionised water. To encourage mucilage extrusion, the seeds were first soaked and then heated to 50°C for 30 minutes. The released mucilage was carefully collected using a spatula and placed on a clean cotton garment. To improve the purity of the extracted mucilage, the isolated mucilage was washed three times with n-hexane to remove non-polar impurities, and then it was repeatedly washed with deionised water to remove polar impurities. In order to remove the mucilage from the sediment, the purified hydrogel was uniformly put onto a stainless steel tray and centrifuged at 4000 rpm for one hour. After being dried at 60°C in a vacuum oven, the recovered

hydrogel was ground into a fine powder using a 60-mesh filter and kept in a desiccator for further analysis and experimentation.

3 Results and discussion

3.1 Effect of pH

A crucial factor in the recovery of LSH is the extraction medium's pH, which affects the swelling behaviour and solubility of the polysaccharide. In order to achieve this, extraction experiments were conducted at different pH levels using the following extraction parameters: 1:40 (w/v) seed to water ratio; 65°C extraction temperature; and 4 hours of extraction time. As shown in Figure (1), it was discovered that the extraction yield increased gradually throughout the pH range between pH 4 and neutrality. The highest yield was obtained at pH 7, indicating that neutral conditions were ideal for mucilage swelling and release from the seed coat. At pH levels below 4, extraction efficiency was determined to be insignificant (less than 1%), hence they were not the topic of further optimisation research. It was discovered that the extraction yield decreased when the pH rose over the neutral level. At pH 10, the recovery decreased. The drop in the proportion of recoverable hydrogel at alkaline conditions may be explained by the partial dissolution and hydrolysis of insoluble polysaccharide components to retrieve water-soluble fractions. The relationship between pH and *L. sativum* hydrogel extraction yield.

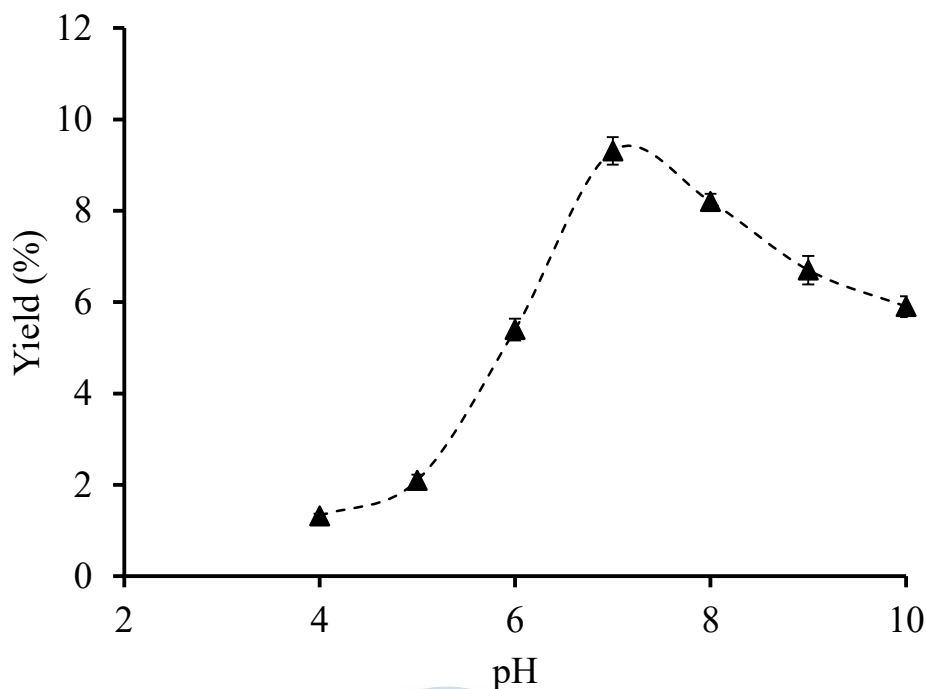


Figure 1. Effect of pH

3.2 Temperature effects

The extraction temperature has a significant impact on the absorption of polysaccharides from the plant tissues to the extraction media. While the pH, seed-to-water ratio (SWR), and extraction time were kept at 7, 1:4 (w/v), and 4 hours, respectively, the effect of temperature, within the range of 25–75°C, was evaluated for LSH yield. The findings (Figure (2)) showed that the yield of hydrogel varied increased from 4.2% to 9.2% when the extraction temperature was raised from 25°C to 65°C. This enhancement may be explained by the improved diffusion and enhanced solubility of polysaccharides at high

temperatures, which enable effective migration of mucilage into the aqueous phase. At 65°, the highest extraction yield (9.2%) was obtained. Nevertheless, the yield decreased as the temperature rose, reaching around 7.5% at 75°C. This is most likely the result of polysaccharide breakdown at higher temperatures, which may be caused by either thermal degradation or structural alteration. Additionally, it has been found that seeds become less sticky when heated to around 65°C and that mucilage release is effective. Thus, 65°C was determined to be the optimal extraction temperature. LSH yield and the effect of extraction temperature.

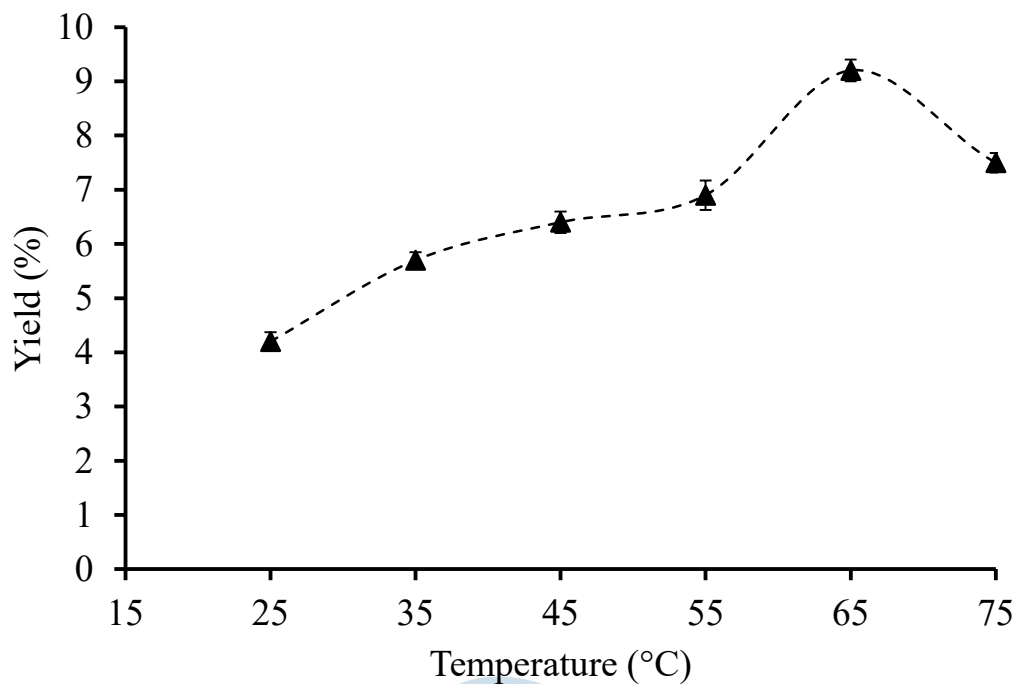


Figure 2. Effect of temperature

3.3 The seed/water ratio's impact

The effect of the solvent volume on the hydrogels' recovery was examined by changing the seed to water ratio from 1:10 to 1:70 (w/v) while keeping the extraction length at 4 hours, the extraction temperature at 65°C, and the pH at 7. Figure (3) illustrates how increasing the amount of the extraction medium greatly improved the recovery of hydrogels. The extraction yield rose as the seed to water ratio grew, with the highest yield value

being reached at 1:40 (w/v). The increased yield may be due to the increased availability of water molecules, which enhances seed coat hydration and promotes mucilage extrusion. Equilibrium was attained since no appreciable improvement in extraction efficiency was seen at ratios above the optimum. Since they offered no further advantages, solvent levels higher than the 1:40 ratio were not looked into.

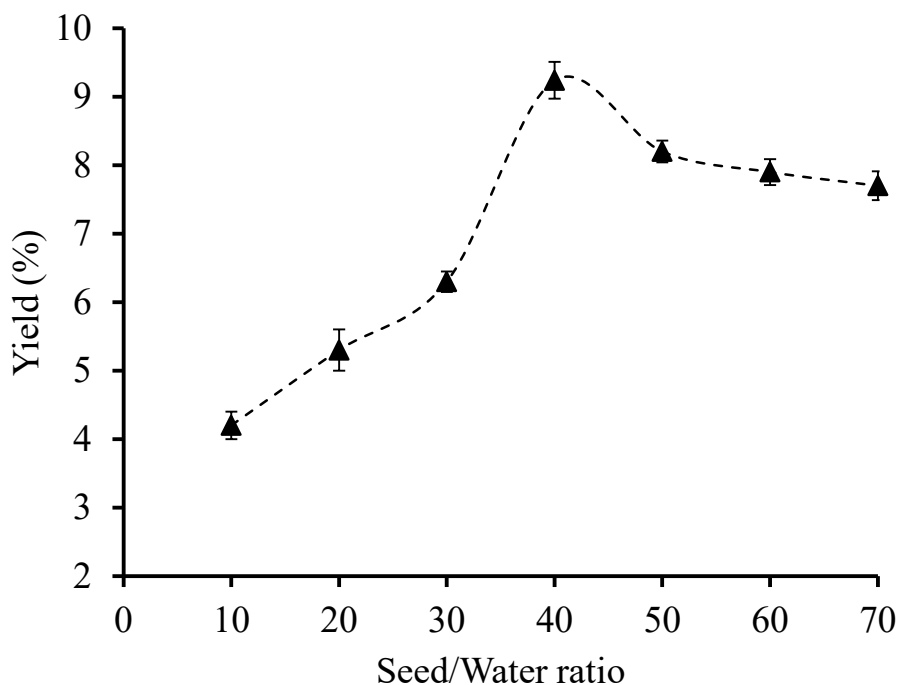


Figure 3. Effect of seed/water ratio

3.4 Impact of water-seed contact time

The length was varied between one and four hours to determine the effect of seed-water contact time. The pre-optimized extraction temperature of 65°C, pH of 7, and a seed/water ratio of 1:40 w/v were the other extraction parameters that were kept constant. The results demonstrated that when the initial seed-water contact time extended, the yield of LSH increased. The longer time it required for the water molecules to penetrate the seed coat and completely extrude the mucilage/hydrogel explained this. The highest LSH extraction yield of 9.16% was attained after 4 hours. The LSH extraction yield was maintained in a dynamic equilibrium state throughout this time (Figure (4)). The DW comes into contact with the *L. sativum* seeds and acts as a catalyst to remove

the mucilage from the seeds' pericarp. The 4 hour increase in LSH production is caused by the increased exposure of *L. sativum* seeds in an aqueous media. *L. sativum*-seeds: the best LSH extraction was obtained with water at contact length of 4 hours, which was the maximum DW penetration into seeds. The extraction yield of LSH from *L. sativum* seeds is significantly influenced by the pH, extraction temperature, seed to water ratio, and seed to water contact length, according to the previously mentioned preliminary study. The best extraction conditions for the maximum amount of LSH were found to be pH = 7, 65°C, a seed/water ratio of 1:40 w/v, and a seed-water contact time of 4 hours, yielding 9.2% (or 9.2 g/100 g).

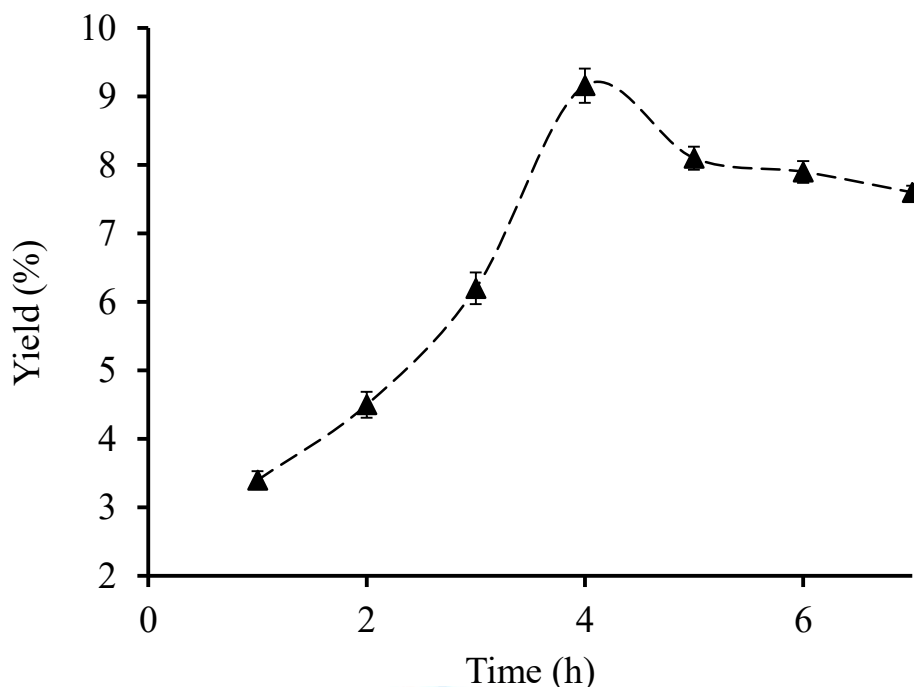


Figure 4. Interaction of seed/water time

4 Conclusion

L. sativum seed polysaccharide-based mucilage extraction optimisation highlights the need of regulating extraction conditions to optimise recovery while preserving the quality of the recovered biopolymer. Because they control seed hydration, polysaccharide diffusion, and the stability of polymeric chains, extraction factors including temperature, extraction duration, pH, seed-to-water ratio, and agitation have a substantial impact on mucilage production. Finding the best extraction conditions led to increased extraction efficiency, better process repeatability, and lower material and energy losses. A practical and affordable method for getting high-quality mucilage appropriate for industrial-scale manufacturing is provided by the optimised extraction technique. The extracted mucilage is a renewable, biodegradable, and sustainable natural polysaccharide with potential uses in biomedical materials, culinary technology, pharmaceutical formulations, biodegradable packaging, and environmental remediation. Effective extraction promotes the creation of environmentally benign substitutes for synthetic polymers in addition to making the use of *L. sativum* seeds more

economically viable. To further increase yield, purity, and commercial applicability, future research should concentrate on thorough physicochemical characterisation, rheological behaviour, structural analysis, and functional performance of the optimised mucilage, as well as scale-up studies and cutting-edge extraction technologies. Overall, *L. sativum* seed mucilage is a versatile natural biopolymer that may be used sustainably thanks to the optimised extraction procedure.

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