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Swelling Index and Physicochemical Properties of Natural Polysaccharides from Selected Plant Seeds: A Review

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Abstract: *When some seeds are kept in water they become slimy. The slimy material is called mucilage. It is made of polysaccharides that can hold a lot of water, so it is used in medicines as a binder, disintegrant, suspending agent and thickener. Many people are now studying plant gums and mucilages as replacements for some synthetic excipients, because they are renewable, easy to get and mostly biodegradable.*

In this review we look at ten seeds: sabja, javas, methi, aliv, isabgol, chia, shevga, chinch, gavar and bhendi. We describe each seed in short and explain how swelling index and other properties are tested. The results given in different papers are not easy to compare, because the samples and the methods are not the same. So we suggest that all ten seeds should be tested together by one common method, and we give the plan for this.

Keywords: swelling index; mucilage; natural polysaccharides; seed gum; excipients.

I. INTRODUCTION

Every tablet or syrup has two kinds of ingredients. One is the drug, which gives the effect. The other is the excipient, which helps to make the dosage form. Excipients hold the tablet together, help it break in the stomach, keep a suspension from settling, or make a liquid thick enough to pour and measure. Many excipients used today are made in factories, but some come from plants. Natural polysaccharides are one such group. They are found in plants, animals and microbes, they hold water, and they are usually biodegradable [1,2].

Plant gums and mucilages are being tried in place of some synthetic excipients. They are renewable and can be cheap and easy to get. But we cannot use a natural material only because it comes from a plant. It must be pure, its chemical make-up must be known, it must be free from germs, and one batch must be like the next batch [1,3]. A synthetic excipient is made to a fixed standard. A plant material changes with the plant, the place where it grew and the way it was processed. So it has to be tested before it can be trusted.

Seeds are a good source of mucilage, and most of it sits in the seed coat. When a seed is put in water, the outer layer takes up water and swells. In many seeds a soft gel-like layer forms around the seed. How much the seed swells depends on the structure of the polysaccharide, the particle size, the temperature, the pH and the time given for the seed to take up water [3,4]. Because of this, swelling index is one of the first tests done on a seed material. It is simple, it needs very little equipment, and it gives a first idea of how the material will behave in a formulation.

This review is about ten seeds that are well known in India: sabja, javas, methi, aliv, isabgol, chia, shevga, chinch, gavar and bhendi. Our aims are:

- to explain what seed mucilage is and what changes the way it swells;
- to explain how swelling index and the other physicochemical tests are done;
- to write briefly about each of the ten seeds from the papers we read;

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- to show why the published values cannot be compared directly; and
- to suggest one common method for testing all ten seeds side by side.

Aim and objectives

The main aim of our project is a comparative study of the swelling index and physicochemical properties of natural polysaccharides obtained from these ten plant sources. For each seed we want to extract the mucilage or gum and calculate the yield, measure the swelling index, and test the pH, viscosity, solubility and powder flow. For isabgol we also want to measure swelling in buffers of pH 1.2, 6.8 and 7.4. Isabgol and guar gum will be used as reference materials. For chia, shevga, chinch, gavar and bhendi we also want to look at uses such as suspending, binding, thickening, emulsifying and film forming, depending on what each material shows.

II. NATURAL POLYSACCHARIDES AND SEED MUCILAGE

Polysaccharides are long chains made of many sugar units joined together. Starch, cellulose, pectin and gums are all polysaccharides. Natural polysaccharides are used in medicines, food, cosmetics and other products because they hold water and have useful properties of their own [1,2]. In pharmacy they are used as binders, disintegrants, suspending agents, thickening agents, gelling agents and in some cases to control the release of a drug from a tablet.

Mucilage is a water-loving material found in the seed coat or other parts of many plants. When it meets water, the chains take up water and spread out. The result is a thick liquid or a soft gel. In sabja and chia this can be seen with the eye. The dry seed looks hard and dark, but within a short time in water it is covered with a clear jelly-like coat [4,5].

2.1 Different seeds, different polysaccharides

The ten seeds do not all contain the same kind of polysaccharide. From the papers we read, the main types are these.

Methi and gavar contain galactomannan, which is made mostly of mannose and galactose units [9,23,24]. Chinch gives tamarind seed polysaccharide, which is rich in xyloglucan [19,20]. Isabgol mucilage is rich in arabinoxylan [13,14]. Bhendi (okra) gives a pectic polysaccharide [25,28]. Sabja, javas, aliv, chia and shevga are described in the papers mostly as seed-coat mucilages or gums [4,5,6,7,16,18].

Since the chemistry is different, the same weight of two different seeds can act very differently in water. Guar gum, a galactomannan, makes a thick dispersion [23,24]. Isabgol, with arabinoxylan, swells into a thick mass [13,14]. This is the first reason why swelling values of different seeds should not be expected to be the same.

2.2 What changes the swelling

Swelling is not a fixed number for a seed. Papers show that it depends on several things [3,4,13,14].

The first is the polysaccharide itself, meaning its type and how branched it is. The second is particle size. A fine powder takes up water faster, but it may form lumps, and a whole seed behaves differently from a ground one. The third is temperature, which changes how fast the material hydrates and also how much mucilage comes out during extraction. The fourth is pH and the salts present. For example, the viscosity of isabgol is reported to change with pH and salts [13,14]. The fifth is time. Swelling goes on for some time, so a reading taken after one hour is not the same as a reading taken after twenty-four hours. The last is the form of the material. Whole seed, husk, kernel powder, crude mucilage and purified gum are all different materials [21,22].

2.3 Why it matters for medicines

A material that swells fast and a lot may work as a disintegrant and help a tablet break up in the stomach or intestine. A material that makes a thick gel may work as a binder, a suspending agent or a matrix that releases the drug slowly [1,13,18,24]. Some mucilages, such as fenugreek and garden cress, have been studied as mucoadhesive materials, which means they stick to a moist surface in the body [7,10]. So what a material can do in a formulation depends on how it takes up water. Swelling index is the usual first test of this.

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III. PHYSICOCHEMICAL PROPERTIES

Before a seed material is used in a formulation, it is checked by a number of tests. The common ones are organoleptic properties, swelling index, mucilage yield, pH, moisture content, water absorption capacity and viscosity [3,8]. If the mucilage is dried and powdered, its bulk density, tapped density, Carr's index, Hausner ratio and angle of repose are also measured.

Test	What it tells us
Organoleptic properties	Colour, smell, taste and look of the sample. Important for how the patient accepts the medicine (for example, methi gum has a bitter taste and a smell [9,10])
Swelling index	How much the material swells in water or another liquid
Mucilage yield	How much dry mucilage we get from a known weight of seed
pH	Whether the dispersion is acidic or alkaline; matters for the drug and for the route of use
Moisture content	How much water the sample already has; affects storage
Water absorption capacity	How much water a fixed weight of material can take up and hold
Viscosity	How thick the dispersion is; matters for thickening and suspending
Bulk and tapped density, Carr's index, Hausner ratio, angle of repose	How well the dried powder flows, which matters for making tablets

3.1 Swelling index

In the usual method, a known weight of the material is put in a graduated measuring cylinder and water is added. After a fixed time we read the volume taken by the swollen material [3]. The result can be written in different ways, such as mL per gram, percent swelling or number of times the volume has increased. These are not the same thing and one cannot be changed into the other [3]. A value of 20 in one paper can mean something quite different from a value of 20 in another paper, unless we know the unit, the starting weight and the time.

So along with the swelling value, the paper should say what form of material was used (seed, husk, powder or isolated mucilage), how much was taken, how much water or buffer was added, the temperature, the pH, the time allowed, whether the cylinder was shaken or left alone, and the unit used. Many papers leave out some of these.

3.2 Mucilage yield

Yield tells us how much dry mucilage we get from the seed after extraction. It depends a lot on the method, such as the ratio of water to seed, the temperature, the time, and how the mucilage is separated and dried [6,7]. In chia, separating the mucilage from the seed is said to be difficult [4,16]. In flax, the oil in the seed makes the isolation harder [6,12]. So yields from two different methods should not be compared as if the process was the same.

3.3 pH, moisture and water absorption

The pH of the mucilage dispersion is measured with a pH meter. It is important because the excipient must suit the drug and the dosage form. Moisture content is found by loss on drying. It matters for natural materials because moisture can affect stability and help germs to grow [3,8]. Water absorption capacity tells how much water the material can take up. It is related to swelling index, but it is not the same thing.

3.4 Viscosity

Viscosity is measured with a viscometer. It depends on the concentration, the temperature, the speed of stirring, the pH and the salts in the liquid. Isabgol is a good example, because its viscosity is reported to change with pH and salts [13,14]. A viscosity value has no meaning unless the concentration and the conditions of the test are given.

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3.5 Powder flow

If the mucilage is dried and ground to make tablets, the powder must flow well. Bulk density and tapped density are measured in a cylinder. Carr's index and Hausner ratio are worked out from these two values. The angle of repose is measured from the heap that forms when the powder falls through a funnel [8]. These values show whether the powder can be used directly in a tablet machine or whether it needs a glidant or granulation.

IV. THE TEN SEEDS

The details below are taken from the papers listed at the end. For every seed we give the botanical source, the part used, what it contains, and what has been reported about its use.

4.1 Sabja (basil seeds)

Sabja seeds come from Ocimum basilicum L., family Lamiaceae. They are also called basil seeds or sweet basil seeds [5]. The seeds are small and dark. They contain mucilage polysaccharides, dietary fibre, protein and fixed oil. When put in water, a clear jelly coat forms around each seed and the seed looks larger [5]. Basil seed mucilage has been studied as a thickening and gelling material, and one study looked at how well it can trap lipids [5]. Before it is used in a formulation it needs to be purified and preserved well, and the use has to be checked for each formulation [3,5].

4.2 Javas (flax seeds)

Javas, also called alsi, flaxseed or linseed, is the seed of Linum usitatissimum L., family Linaceae [6]. The seeds are brown or golden, smooth, flat and oval. Besides mucilage they contain a good amount of oil, protein, fibre and lignans [6]. Flax mucilage has been used to make hydrogels for slow release of drugs by mouth, and it has also been tested as a binder for granulation [6,12]. The oil makes it more difficult to isolate the mucilage, and the properties of the mucilage change with the method used, so values from different papers are hard to compare [6,12].

4.3 Methi (fenugreek seeds)

Methi is the seed of Trigonella foenum-graecum L., family Fabaceae [9]. The seeds are small, hard, angular and yellowish-brown. They contain a gum rich in galactomannan, along with protein, oil, saponins and fibre [9]. The gum gives a thick material when the seeds are soaked or extracted. It has been tried as a mucoadhesive agent in a nasal gel [10]. The bitter taste, smell and colour can be a problem for use in medicines [9,10]. Also, results on the isolated gum cannot be taken as true for the whole seed [10].

4.4 Aliv (garden cress seeds)

Aliv, also called halim, is the seed of Lepidium sativum L., family Brassicaceae [7]. The seeds are small and reddish-brown. The seed coat has mucilage which swells in water and forms a gel-like layer around each seed [7,11]. Garden cress mucilage has been studied as a mucoadhesive polymer and as a granulation binder [7,12]. Compared to isabgol, less standard data is available for aliv, so its properties are not so well settled. How it performs in an actual tablet still has to be tested [7,11].

4.5 Isabgol (psyllium)

Isabgol, or ispaghula, comes from Plantago ovata Forssk., family Plantaginaceae [13]. In this case the husk of the seed is used, as it is rich in mucilage. The husk is light in colour and fibrous. It contains arabinoxylan-rich mucilage and dietary fibre, and in water it swells into a thick mass [13,14]. It has been tested as a tablet binder, and its viscosity changes with pH and salts [13,14]. Because it is well known, isabgol is a useful reference material when other seeds are compared. We should remember that a husk is not the same thing as a whole seed.

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4.6 Chia seeds

Chia seeds are from Salvia hispanica L., family Lamiaceae [4]. They are small, oval and flat, and may be black, grey, white or spotted. They contain fibre, mucilage, protein, oil that is rich in alpha-linolenic acid, minerals and phenolic compounds. The sugars reported in the mucilage include xylose, glucose, arabinose and uronic acids [4,15,16]. The seed coat gives out its mucilage very quickly in water [4]. Chia gum is studied as a thickener and hydrocolloid [16]. The difficult part is separating the mucilage from the seed, and the composition depends on how it is extracted and purified [4,16].

4.7 Shevga (drumstick seeds)

Shevga seeds are from Moringa oleifera Lam., family Moringaceae [17]. The dry seeds are cream, pale grey or brownish, with a firm coat and a roughly triangular shape. They are rich in oil and protein, and also have fatty acids, carbohydrates and minerals [17]. Because of this, strong mucilage should not be taken for granted in these seeds [17]. Moringa gum has been tested as a tablet binder and as a material to slow down drug release [18]. Moringa seeds are also known for their use in clearing muddy water [27]. The papers deal with different materials (whole seed, defatted powder, isolated gum), so the findings should not be mixed up [17,18,27]. This is the seed for which direct testing is needed most.

4.8 Chinch (tamarind seeds)

Chinch is the seed of Tamarindus indica L., family Fabaceae [19]. The seeds are hard, smooth and brown to dark brown. The kernel inside is used to make tamarind kernel powder, from which tamarind seed polysaccharide (TSP) is obtained. TSP is rich in xyloglucan [19,20]. It has been studied as a binder, thickener, stabiliser and film former, and in drug release from tablets [21,22]. Whole seed and kernel powder do not behave in the same way, so the exact material should always be named [21,22].

4.9 Gavar (guar seeds)

Gavar, or cluster bean, is the seed of Cyamopsis tetragonoloba (L.) Taub., family Fabaceae [23,24]. Guar gum comes from the endosperm of the seed. It is a galactomannan made of mannose and galactose, and this is what gives guar its high viscosity [23,24]. Guar gum is a well-known excipient, used as a binder, thickener, suspending agent, stabiliser and also as a matrix for sustained release [23,24]. Like isabgol, it can be used as a reference when other gums are compared. Whole seed, seed powder and purified guar gum are different, so it should be said which one is used.

4.10 Bhendi (okra seeds)

Bhendi, also known as okra or lady's finger, is Abelmoschus esculentus, family Malvaceae. The seeds are small, round to oval and hard, grey-green or brownish in colour. Okra mucilage is a pectic polysaccharide [25,28]. It has been tested as a suspending agent and as a binder [26,29]. But most of the work has been done on the pods and not on the seeds, so there is not much information on seeds alone [25,28].

V. SUMMARY OF THE TEN SEEDS

The table below puts together what the papers report. No swelling numbers are given on purpose, because the numbers in different papers cannot be compared (see Section 6).

Seed	Family	Material used	Type of polysaccharide reported	Reported use	Problem
Sabja	Lamiaceae	Seed mucilage	Mucilage (gel coat)	Thickener, gelling agent [5]	Needs purifying and preserving
Javas	Linaceae	Seed mucilage	Mucilage	Slow-release hydrogel, binder [6,12]	Oil makes isolation harder

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Methi	Fabaceae	Seed gum	Galactomannan-rich	Mucoadhesive nasal gel [10]	Bitter taste, smell, colour
Aliv	Brassicaceae	Seed-coat mucilage	Mucilage (gel-like layer)	Mucoadhesive polymer, binder [7,12]	Less standard data
Isabgol	Plantaginaceae	Husk	Arabinoxylan-rich	Tablet binder [13,14]	Viscosity changes with pH and salts
Chia	Lamiaceae	Seed-coat mucilage	Mucilage / gum	Thickener, hydrocolloid [16]	Mucilage hard to separate
Shevga	Moringaceae	Seed gum	Gum (seed rich in oil and protein)	Tablet binder, release retardant [18]	Strong mucilage not to be assumed
Chinch	Fabaceae	Kernel	Xyloglucan-rich	Binder, thickener, drug delivery [21,22]	Kernel powder and whole seed differ
Gavar	Fabaceae	Endosperm	Galactomannan	Binder, thickener, sustained-release matrix [23,24]	Whole seed and gum differ
Bhendi	Malvaceae	Mucilage (mostly from pods)	Pectic polysaccharide	Suspending agent, binder [26,29]	Little work on seeds

Two things can be seen from this table. First, the ten sources are not the same kind of starting material. Husk, kernel, endosperm, seed coat and whole seed are all used. Second, isabgol and gavar are the best known excipients of the group [13,14,23,24], so they are the natural choice for reference materials.

VI. WHY THE RESULTS ARE HARD TO COMPARE

If we read papers on these seeds one after another, we will find swelling values, yields and viscosities for each of them. But we cannot put them in one table and decide which seed is best. There are three main reasons.

The first reason is that the materials are different. Some studies use whole seed, some use husk, some use powder, and some use isolated gum [1,5,6,7]. A swelling value for isabgol husk and one for mucilage taken out of chia seeds are numbers for two different things.

The second reason is that the extraction methods are different. The conditions of extraction change both the yield and the properties of the mucilage [6,7]. Two samples from the same seed can behave differently if one was extracted with hot water and the other with cold water, or if one was purified and the other was not.

The third reason is that the swelling methods are different. One paper gives mL per gram and another gives percent. The temperature, the liquid, the pH and the time also change from paper to paper [3,5,13].

Because of this, a reader cannot rank the ten seeds by looking at published tables. Even for the same seed, the difference between two papers may be bigger than the difference between two seeds. A fair comparison needs all ten materials to be prepared and tested in the same way, in the same laboratory and at the same time.

VII. USES AND LIMITS

The ten seeds have been suggested for many jobs in formulations. Javas, aliv, isabgol, shevga, chinch, gavar and bhendi have been tried as binders. Javas, shevga, chinch and gavar have been tried to slow down the release of a drug. Methi and aliv have been studied for mucoadhesion, bhendi as a suspending agent, and sabja, chia, chinch and gavar as thickeners or gelling agents [5,6,7,10,12,16,18,22,24,26]. Natural excipients are renewable, easy to get and usually biodegradable [1,2].

There are also some limits that apply to all of them.

- Batch to batch change. Purity, composition and consistency decide if a natural material is suitable [1,3].
- Preservation. Mucilages need to be purified and kept well, as is said for sabja [3,5].
- Taste and smell. These can stop the use of a material, as with methi [9,10].
- Difficult isolation. The oil in javas and shevga and the way mucilage sticks to chia seed make extraction harder [4,6,16,17].
- Missing data. Aliv has less standard data than isabgol [7,12], and the work on bhendi is mostly on pods [26,29].

Also, a paper that reports a possible use does not prove that the material will work in a given dosage form, or that it is approved for use. That needs separate testing for each formulation [1,3].

VIII. PLAN FOR OUR STUDY

We plan to test all ten seeds by one method, so that differences in the result come from the seeds and not from the method. The work will go in the following order.

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1. Collection and checking. We will collect the seeds and have them identified by a botanist, keeping a voucher specimen. For isabgol we will use the husk, for chinch the kernel, and for gavar the endosperm or the seed, as decided.
2. Cleaning. The seeds will be cleaned to remove dirt and other matter, dried and stored in labelled airtight containers. Where oil is a problem, as in javas and shevga, the same step will be used for removing it from every seed.
3. Extraction. Mucilage will be taken out by soaking or boiling the seeds in distilled water, and squeezing through muslin cloth. The same water-to-seed ratio, temperature and time will be used for all.
4. Isolation and drying. The mucilage will be precipitated with acetone or ethanol, filtered, washed and dried in an oven. It will then be ground, sieved and kept airtight, and the percentage yield will be worked out.
5. Tests. Each mucilage will be tested in triplicate for identification (Molisch, ruthenium red, iodine, tannin and protein tests), physicochemical properties (yield, solubility, pH, loss on drying, ash value, viscosity), swelling and hydration (swelling index, water-holding capacity) and powder properties (bulk and tapped density, Carr's index, Hausner ratio, angle of repose).
6. Comparison. The mean and standard deviation will be tabulated, and the seeds will be compared and ranked on swelling index and the other values.
For isabgol the swelling index will also be measured in pH 1.2, 6.8 and 7.4 buffers, because swelling depends on pH and salts [13,14]. Isabgol and guar gum will be used as the reference materials.

IX. CONCLUSION

The mucilages and gums of these ten seeds look promising as natural excipients, and each one has some good points and some problems. Since the published results cannot be compared, one study is needed that tests all ten by the same method. Such a study will show which seed is suitable for which use.

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