Soy–Based Biodegradable Super-Absorbents for Personal Care and Agricultural Products.

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Objectives of the research

In this project, we are developing a new soy-based super-absorbent polymer (SAP) from soybean oil and soy protein/soy meal. The new biodegradable soy-based material will have the ability to absorb large quantities of water and can find an application in personal care, animal care, and agricultural products. The new soy-based SAP will compete with existing polyacrylic acid-based SAPs and being biodegradable, will sufficiently lower its negative environmental impact.

Completed work:

- Synthesis and optimization of water-based dispersions from soybean oil and soymeal
- Preparation of soy-based solid absorbents by air drying and thermal crosslinking
- Studied water uptake of different synthesized SAP samples
- Studied biodegradability in soil
- Explored a possible application of SAP for seed coatings

Preliminary results

Progress of Work and Results to Date

In the reporting period, water dispersions were synthesized from modified soybean oil (SBO), acrylic acid, and powdered soy meal. Soymeal was dried, finely ground, and sieved through 140 mesh sieves to obtain the soy meal powder (SMP) with a particle size of <105 microns (µm).
SBO was initially modified with carboxylic acids or carboxylic acid anhydrides. The acids used for SBO modification were itaconic and citric acids, and the anhydrides used for SBO modification were maleic and itaconic anhydrides. As a result of the modification, we obtained SBO with

grafted carboxylic groups which can be emulsified in water and co-polymerized with acrylic acid in radical emulsion polymerization.

The soy-based water dispersions were synthesized by radical copolymerization of modified SBO with acrylic acid in water emulsion with the addition of SMP as a viscosity modifier. The soy-based dispersions which are viscous glue-like latexes, were used to cast polymer films by pouring the latex on Teflon-coated glass panels. The dried polymer films were thermally crosslinked at 120°C for 1 h, neutralized with 0.5N solution of NaOH to pH=7, and tested for water uptake capacity (WUC).

Table 1. Optimized composition for synthesis of superabsorbent polymer in water dispersion

Component	Weight parts (phr)	Wt.% in dry polymer film
Oil (SBO modified with itaconic acid)	24	46%
Soy meal powder	8	15.5%
Water with 3% of SDS emulsifier	80	
Acrylic acid	20	38.5%
Initiator PSA	1	

The composition of soy-based water dispersions was optimized to achieve maximum WUC and higher latex stability. The optimum composition for water dispersion is given in Table 1. With this optimized composition, the latex is stable for 4+ weeks and can be successfully re-dispersed if phase-separated after longer storage times. The cured neutralized polymer film obtained from this latex demonstrated

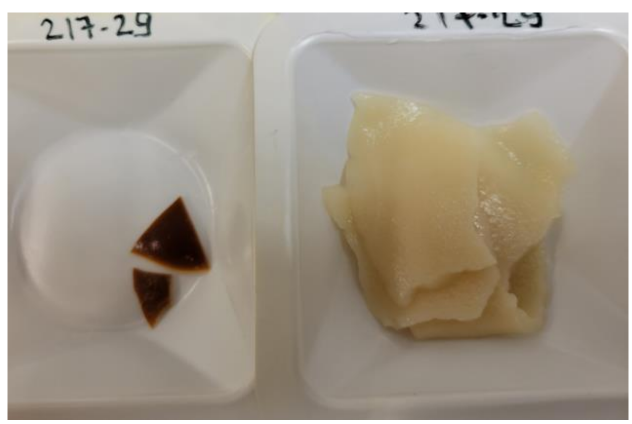

Figure 1. Dry crosslinked sample of soy polymer obtained from the latex with composition listed in Table 1 (left) and same polymer sample swollen in water (right).

a WUC of up to 70g water per gram of polymer.

The image in Figure 1 shows the sample of cured soy polymer obtained from the latex with the composition listed in Table 1, and the same polymer sample swelled in water at pH=8. The WUC for this sample was measured as 46 g/g.

Biodegradability.

One sample of cured polymer film with the composition given in Table 1 is currently being tested for biodegradability in soil following ASTM 5988. The sample is tested in two parallel runs, one is for the cured polymer, and the second test is for the same cured polymer but neutralized with NaOH solution and with increased pH=8. The reference sample is a sample of corn starch also being tested. The results of 7 weeks of testing are given in Figure 2 which presents the percentage of organic carbon in the testing sample reacted to form CO_2 over time. It can be seen from Fig. 2 that the neutralized crosslinked soy-based polymer has a similar biodegradation rate as corn starch while the acidic polymer sample shows a slower biodegradation rate.

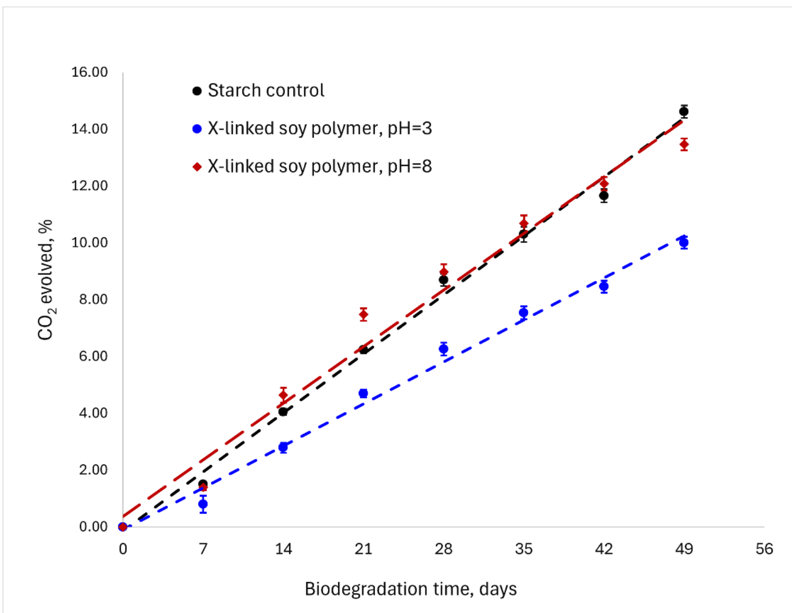

Figure 2. CO_2 evolved of corn starch and cross-linked soy polymer film at pH values 3 and 8.

Seed coating.

Soy-based latex was tested for seed coating application as a water-dispersible polymer adhesive. The common adhesives for seed coating applications are based on starch, cellulose, acacia gum, and synthetic polymers such as polyethylene glycol and polyvinyl acetate.

Two samples of coated corn seeds were prepared. The first sample of film-coated corn seeds was formulated with soy-based latex neutralized with potassium hydroxide (KOH) and ammonium hydroxide (NH_4OH), and the dry polymer coat was enriched with N and K elements. The second sample was prepared by encrusting corn seed with eggshell powder and soy-based latex adhesive. The latex was partially neutralized with NH_4OH solution, and then the eggshell powder was added as a second neutralizing agent and filler. Eggshell powder consists of 96% of calcium carbonate which reacts with carboxylic groups in soy polymer releasing CO_2 gas and creating a porous crust. Such crust quickly decomposes in wet soil while the polymer adhesive absorbs water from the soil and supplies extra moisture for the seed. The composition of each sample of coated corn seeds is given in Table 2 and the photograph of dried coated seeds is presented in Figure 3.

Table 2. Composition of seed coatings

	Sample 1. Film-coated	Sample 2. Encrusted
Weight of 100 dry corn seeds	33.5±0.2	33.8±0.2
Weight of 100 coated corn seeds	34.6±0.3	48.6±0.6
Coating, Wt. %	3.3%	44%
Coating composition, per 200 seeds		
Soy-based latex, 40% solids	8 g	8 g
Water		2 g
KOH solution, 0.5N	10 ml	
NH_4OH solution, 7N	2.5 ml	2 ml
Eggshell powder		30 g

Figure 2. Corn seed film coated with soy-based polymer (sample 1, left) and encrusted with soy polymer and eggshell powder (sample 2, right).

For the coating, the liquid components were mixed to neutralize the carboxylic groups of the latex and added to the glass flask filled with weighed dry corn seeds and eggshell powder for sample 2. The glass flask was placed on a rotary device and allowed to rotate until all polymer was adhered to the seeds and the glass walls became clear. Coated seeds were allowed to dry at room temperature for 2 days and coating weight was determined gravimetrically.

Both samples of corn seed will be tested for germination. If the germination is satisfactory, the next step will be to create pesticide-containing seed coat formulations and crust coat formulations for smaller seeds to increase their weight.

<u>Work to be completed:</u>

Biodegradability testing of soy polymer.

Compare the biodegradability of soy polymers containing SBO modified with different modifiers (maleic anhydride *vs* itaconic acid)

Germination test for coated corn seed samples

Writing of scientific paper.

<u>Other relevant information: potential barriers to achieving objectives, risk mitigation strategies, or breakthroughs.</u>

N/A

Summary

Stable polymer suspensions containing up to 60 wt.% of soy products, both soy oil and soy meal were synthesized. The composition of soy suspension was optimized. The dry product obtained from the suspension is a bio-based composite material that can absorb up to 70 g of water per gram at increased pH. The biodegradability test shows that neutralized soy absorbent polymer biodegrades with the same rate as corn starch control, while biodegradation of the same polymer at acidic pH is slower than control. Uncrosslinked soy polymer was successfully tested as an adhesive for corn seed coating.