Evaluation of fresh and aged clam processing wastes as agricultural liming agents for coastal vegetable production fields

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Abstract:
Clam processing in Atlantic Canada generates 4000 metric tons of clamshell wastes annually. Twenty-year stockpiles of shells must now be remediated to satisfy environmental regulations. This study examined fresh and aged clamshells as agricultural liming agents for sandy, acidic, coastal vegetable production soils. Clamshell wastes fresh from processing and aged stockpiled shells were analysed for coliform bacteria, plant nutrients, calcium carbonate equivalent, and organic matter. The shells met New Brunswick's guidelines for wastes as soil additives. Clamshells were ground to three size fractions (<0.250 mm, 0.250 to 1.00 mm, 1.00 to 2.00 mm). These were mixed with two soils at four rates, and placed in a control-plus-factorial (commercial agricultural lime as control) pots experiment. During an eight-week incubation, soil water pH and electrical conductivity (EC) were monitored biweekly. At four and eight weeks, a soil extract germination test was conducted using watercress (*Lepidium sativum* L.), a species sensitive to water quality, as an indicator plant. The pH and EC data were used to develop prediction graphs of the soil reactions which can be used as a basis for guidelines for rates of land application for liming. Clamshell amendment did not negatively affect germination of watercress seeds.

Materials and methods

Fresh and aged clam shell wastes
Fresh clam shells were collected from the processing line at Mills Sea Food Ltd. (Fig. 1a). Aged clam shell wastes were collected from the company's land fill (Fig. 1b) and were estimated to be 1.5 to 2 years old. Three composite fresh samples were collected and 12 composite aged samples were collected: three at each of four depths within the land fill.

Chemical and microbial analysis
Analyses of the various clamshell samples were carried out by a commercial laboratory (RPC, Fredericton NB). Microbiological analyses included total coliforms, faecal coliforms and *E. coli*. Organic matter was analysed using the loss on ignition method at 550ºC. Plant nutrients were measured using Mehlich III extractions. Metals were analysed by first digesting samples using EPA method 3050, followed by ICP-MS and ICP-ES. Mercury was analysed using Cold Vapour AAS. Chemical and microbial profiles were tabulated and compared with New Brunswick's Provincial *Guidelines for issuing certificates of approval for the utilization of wastes as soil additives.*

Soil reaction
The reaction of two soils, a loamy sand and a loam, to the addition of clamshell wastes was examined in a pots experiment. The soils were collected from local fields, screened and placed in pots. Treatments consisted of different liming materials (aged clamshells, fresh clamshells or commercial lime) at different rates, and in the case of shells, different finenesses. Standard industry recommended quantity of lime to bring pH to 6.5 in each soil was used as the base rate (1x) and doubled or tripled for the other rates (2x, 3x). These same rates were also used for shell amendments. In addition, pots with no amendments (0x) were included as a check. The size fractions of the shells were less than 0.250 mm, 0.250 mm to 1.00 mm, and 1.00 mm to 2.00 mm for the fine particles, medium particles and coarse particles, respectively (Figure 1c). The experiment was a control-plus-factorial, with rates, finenesses, and age of shells factorially combined within each soil type. The control was no liming amendment (0x). Lime, fresh fine shells, fresh medium shells, fresh coarse shells, aged fine shells, aged medium shells and aged coarse shells were combined with three rates (3 $t{\cdot}ha^{-1}$, 6 $t{\cdot}ha^{-1}$, 9 $t{\cdot}ha^{-1}$ for loamy sand, and 6 $t{\cdot}ha^{-1}$, 12 $t{\cdot}ha^{-1}$, 18 $t{\cdot}ha^{-1}$ for loam). The treatments were replicated twice and arranged in a two-way blocking pattern in an incubation chamber to account for any temperature gradients in the room. Soil water pH and electrical conductivity were measured biweekly for the eight-week duration of the experiment. Aqueous extracts from the treatments were prepared at week four and at week eight, and these were used in germination tests using watercress (*Lepidium sativum* L.) to establish whether extracts had phytotoxic effects. Germination index was calculated as:

$$\text{Germination Index} = \frac{\text{number of seeds germinated in treatment solution}}{\text{No. of seeds germinated in control solution}} \times \frac{\text{Mean root length in treatment solution}}{\text{Mean root length in control solution}} \times 100$$

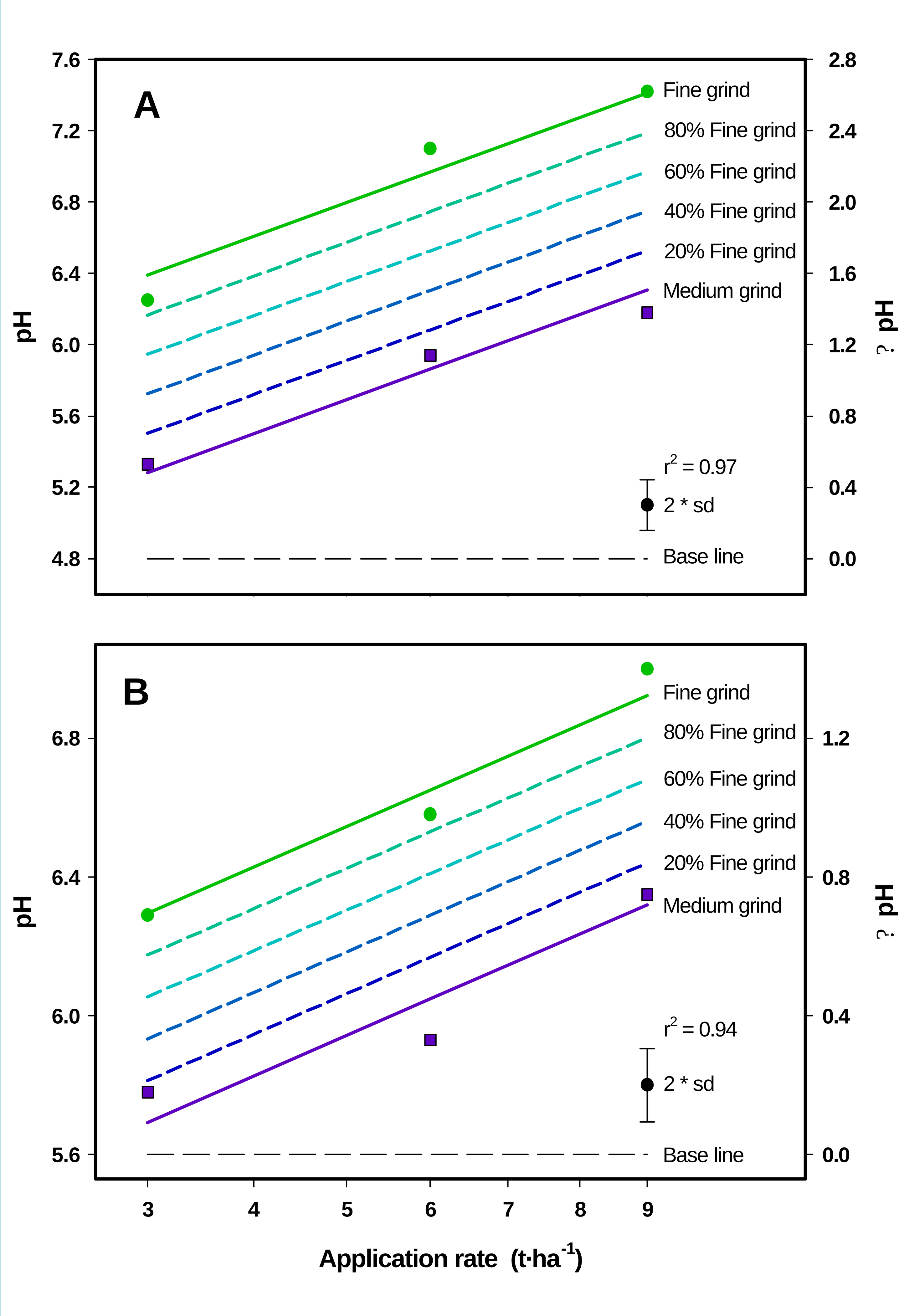

Figure 3: pH and expected change in pH (? pH) of loamy sand (A) or loam (B) amended with aged clamshells in different proportions of mixed fine and medium fragments.

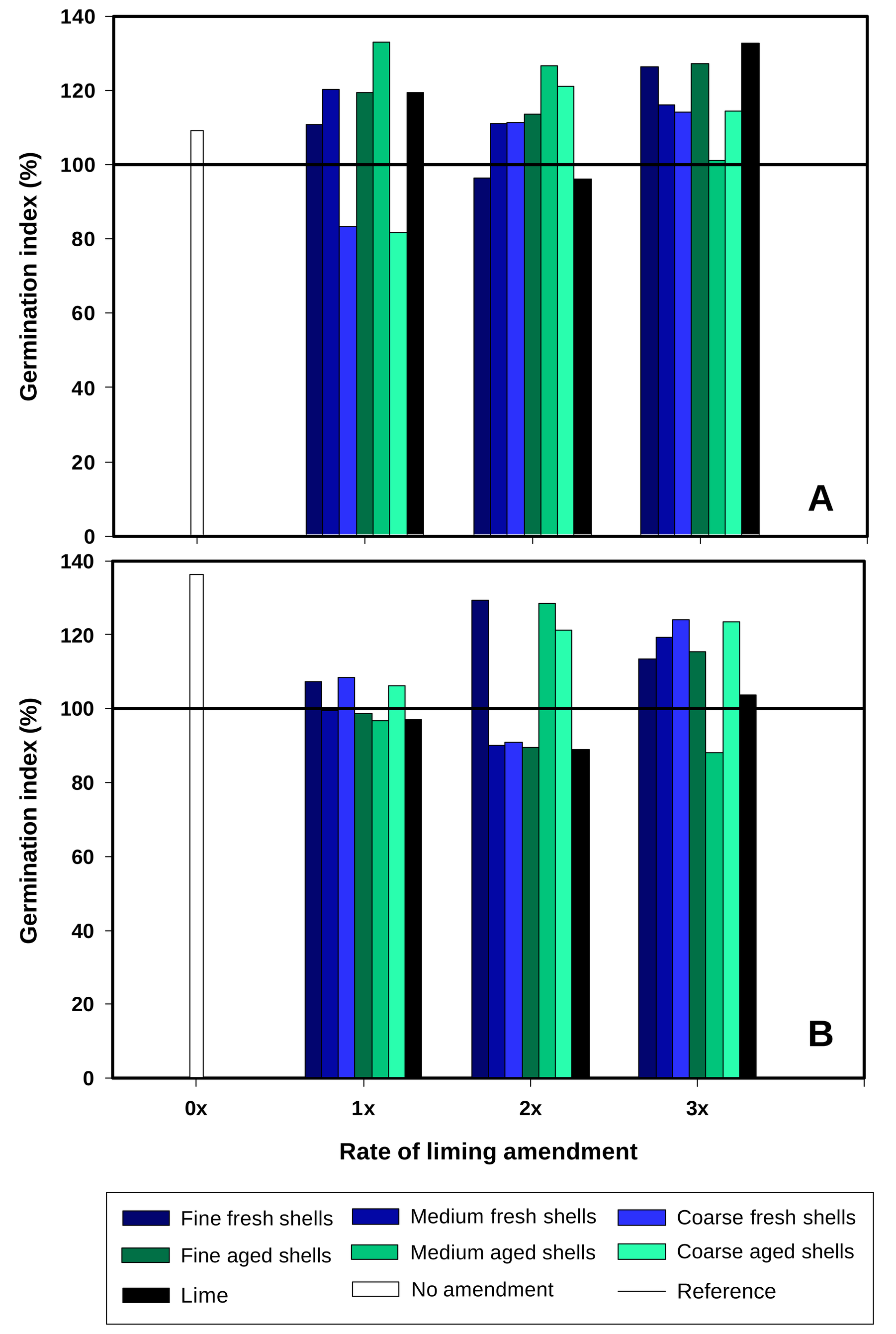

Figure 2: Germination index of watercress seeds in aqueous extracts from pots of loamy sand (A) or loam (B) incubated for eight weeks with combinations of three rates of lime or clamshell (fine, medium, coarse fragments and fresh or aged).

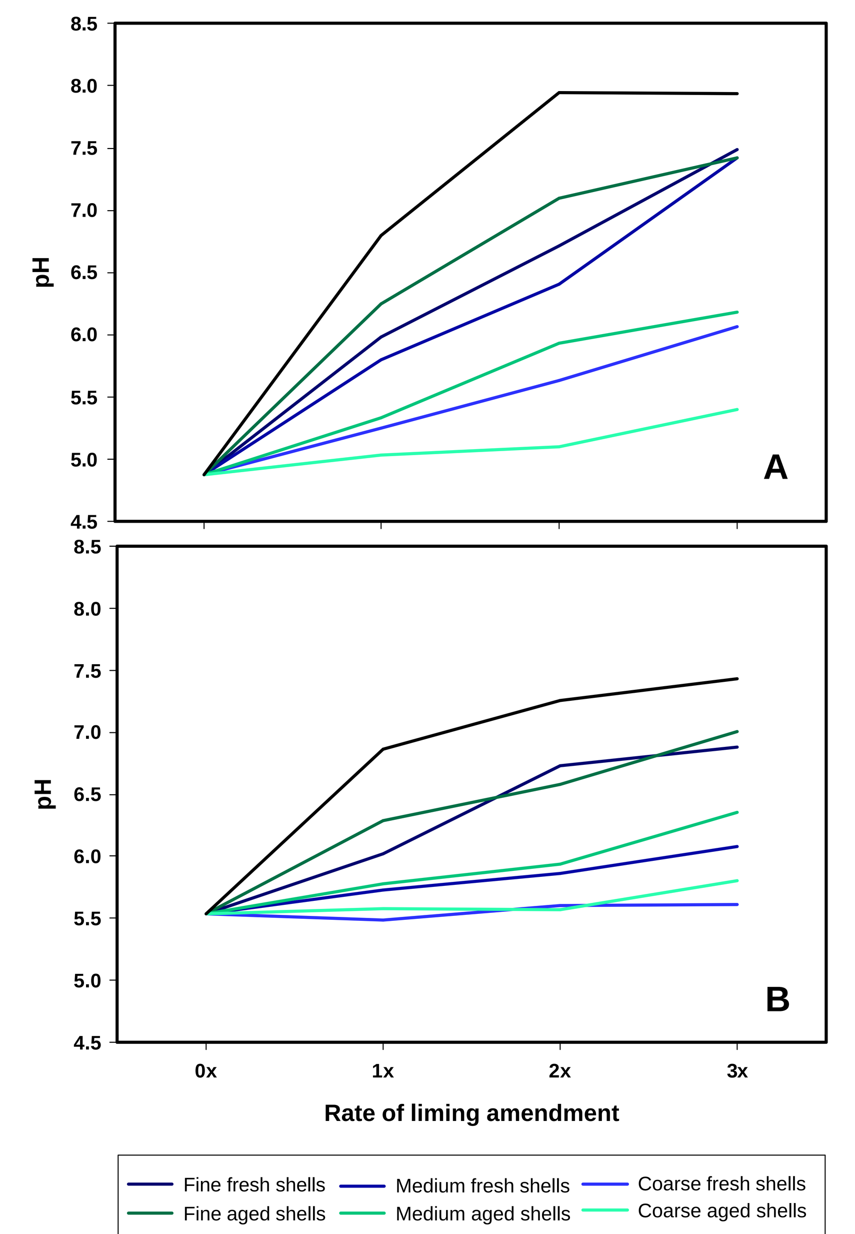

Figure 4: pH of aqueous extracts from pots of loamy sand (A) or loam (B) incubated for eight weeks with combinations of three rates of lime or clamshell (fine, medium, coarse fragments and fresh or aged).

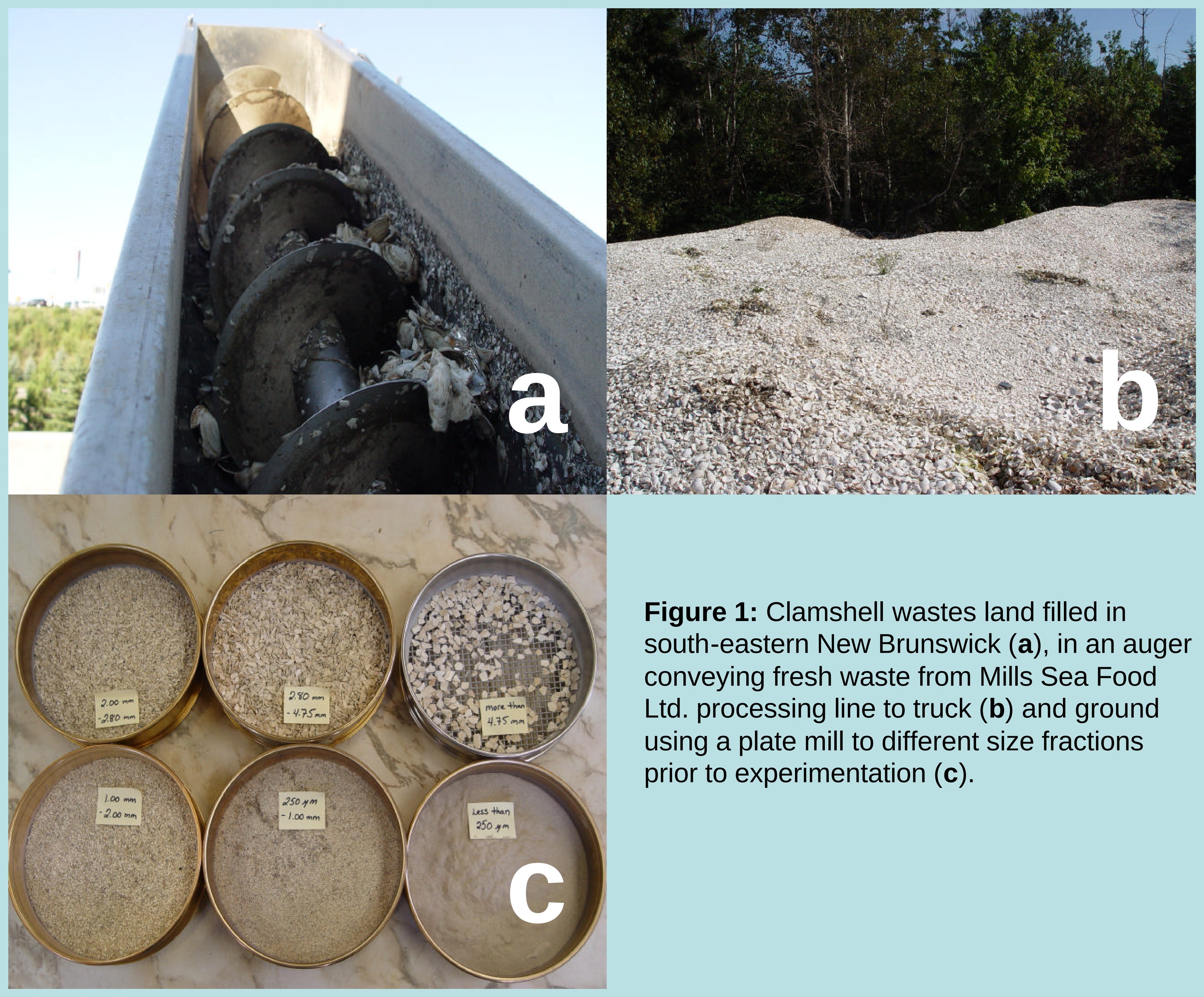

Figure 1: Clamshell wastes land filled in south-eastern New Brunswick (**a**), in an auger conveying fresh waste from Mills Sea Food Ltd. processing line to truck (**b**) and ground using a plate mill to different size fractions prior to experimentation (**c**).

Conclusions

Minerals, organic matter and coliform bacteria
Fresh and aged clamshell waste was characterized in the first phase of the research, and found to have potential as a liming agent due to its high calcium carbonate equivalent. The product generally met the criteria laid forth in the New Brunswick *Guidelines for issuing certificates of approval for the utilization of wastes as soil additives*. Few *E. coli* bacteria were found and these levels were much lower than what might naturally arise in an agricultural soil. The shells contained up to 13.4 % organic matter when fresh material was ground to <0.250 mm.

pH
While shells did not raise pH as effectively as lime did, shells, particularly when finely ground, did raise pH significantly, and appears to be a good alternative to lime (Fig. 2). The greatest efficiency of shells was obtained on the loamy sand. Regression analysis was used to predict a range of rates, presented in graphical form, which could be used as guidelines for shell amendment to fields with soils similar to those studied (Fig. 3a and b). These figures recommend rates of shell wastes in different mixes of fine particles and medium particles required to affect a given change in pH. Grinding method in a commercial situation would lead to a mixture of particle sizes. Grinding to achieve higher proportions of fine particles would likely result in higher energy costs, which in turn could affect the economic feasibility of producing liming material from shell wastes.

Electrical conductivity
The electrical conductivity (EC) of soils amended with shells was studied. EC stayed well within the range of EC associated with vegetable crop production soils. Where lime caused EC to increase sharply immediately following amendment, the effect of shells on EC was less immediate.

Germination tests
Germination tests on soils following amendment demonstrated that in general, the shells did not depress germination index more than lime, the current industrial standard, did (Figure 4).

Recommendation as a liming agent
This project shows that clamshell wastes originating from the Mills Sea Food Ltd. Processing plant have an excellent potential as a liming agent for the light-textured soils of the coastal vegetable production fields of south-eastern New Brunswick.

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