Development of an Automated Grinding Unit for Finely Ground Soil and Plant Tissue Samples

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Abstract

An automated grinder capable of grinding a large number of plant, grain, and soil samples was designed. One of the main reasons for developing the device was to increase the number of samples being processed at one time for dry combustion analysis of total N and organic C that required a high level of fineness. The original prototype was developed at the University of Nebraska (J.S. Schepers) and was modified to increase the number of samples and overall structural security. The device consists of sequentially aligned horizontal rollers spaced 6.67cm apart that are driven simultaneously. French squares bottles (118.3ml)are then placed in the center of the horizontal rollers and by including round steel rods within the bottles (including grain, plant, and soil samples) grinding is accomplished via internal hammering. Before this device was engineered, samples were ground one by one utilizing mortar and pestle techniques that are costly, time consuming and prone to errors. This apparatus will grind approximately 140 samples overnight, at >100 mesh fineness. Using this procedure, samples are contained in sealed bottles where no cross-contamination can take place.

Introduction

Grinding procedures for dry combustion analysis require sample fineness (100 mesh) that generally employ manual use of mortar and pestle techniques. This work was initiated to construct an automated grinding unit that could process > 140 samples simultaneously. Previous work at the University of Nebraska has employed a similar piece of equipment utilizing metal bar hammering within glass containers. The equipment developed at the University of Nebraska was extremely useful in terms of obtaining homogenous samples of high fineness from larger sample sizes (>30g). Errors associated with the use of mortar and pestle techniques can be 20% larger than with other automated units. Larger errors are due to sample fineness which is variable depending on the individual and the time/pressure employed. Sample contamination is also a problem using mortar and pestle techniques, since acid washing and drying is required before processing each individual sample. Because of the problems associated with mortar and pestle techniques, the grinding process becomes extremely time consuming, costly, and can increase experimental

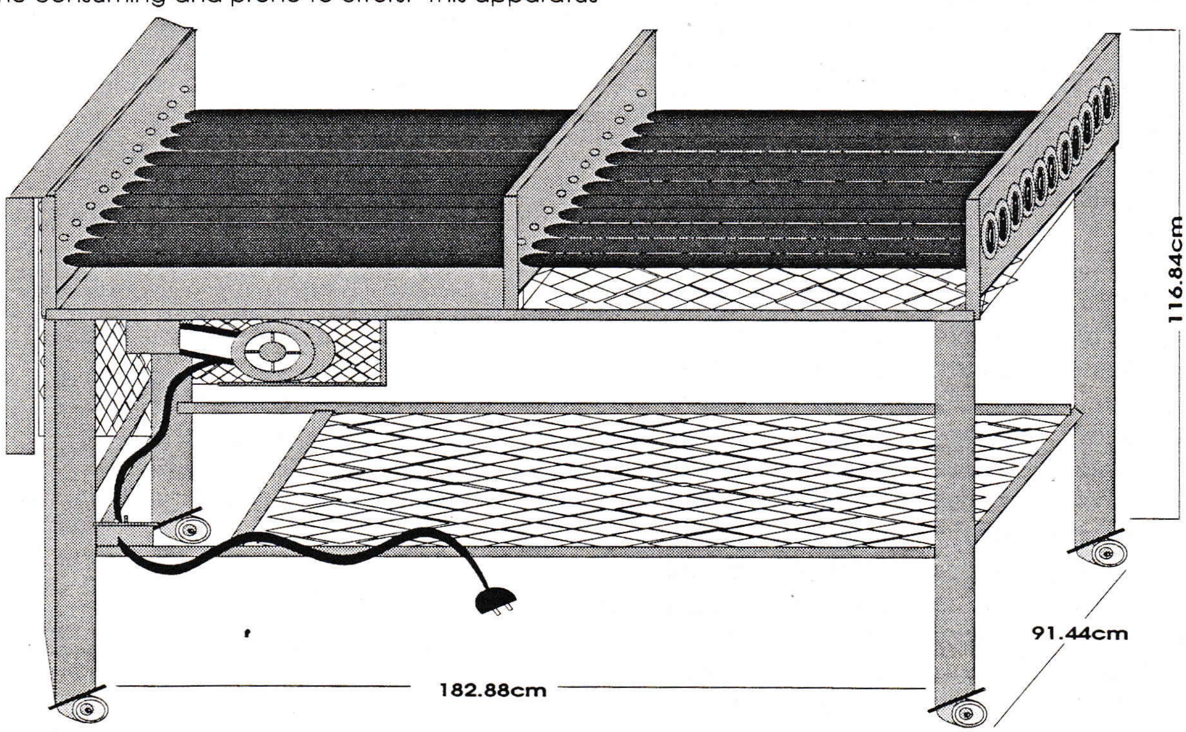

Figure 1. Side view of the automated grinding unit

errors. Smith and Um (1990) found that by gluing two metal bars opposite each other and placing these on the inside of a glass jar jointly with a straw samples, outside rotation induced an internal hammering action which effectively ground the sample material.

The objective of this work was to develop a reliable grinding unit using external horizontal rolling for internal bar hammering within french square glass jars.

Materials and Methods

The frame of the grinder was 182.88 x 91.44 x 116.84 cm in length, width, and height, respectively, consisting of 5.08 cm square tubing, 5.08 cm angle iron and 30.48 cm flat strap. Figure 1 shows a side view of the frame. The device will continuously roll 140 bottles that contain plant, grain or soil material. The unit utilizes 2 oz. french square bottles which are 2.54 x 2.54 x 7.62 cm in length, width, and height, respectively. The bottles rest on eleven steel shafts (1.905 cm in diameter) covered with rubber hose. The shafts are turned by a 0.75 horsepower electric motor that turns a gear reducer. The electric motor and gear reducer were bolted to the under side of the grinder. (Figure 2.) The shafts 0.75 traverse three

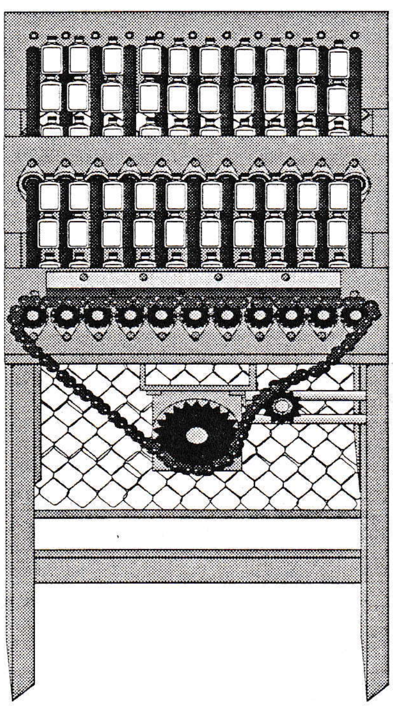

Figure 2. Frontal view of the automated grinding unit illustrating sample placement.

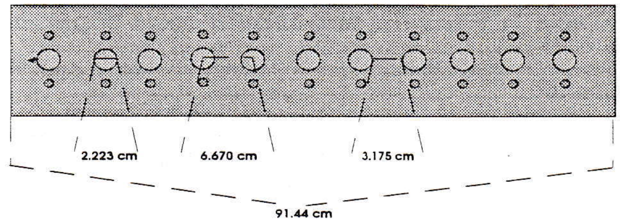

Figure 3. Shaft hole spacing and bearing fasteners distance employed.

pieces of 30.48 cm flat strap that weremachined with eleven 2.223 cm holes. The three pieces of strap were located at the ends and the middle of the device. Bearings were fastened to the three pieces of flat strap which allowed the shafts to turn freely. A twelve tooth sprocket was located on each shaft in the front of the device. The 0.75 horsepower electric motor turns the gear reducer 1850 rpm. The gear reducer decreases the rpm to 385. A twenty-two tooth sprocket was attached to the output shaft of the gear reducer which then turns the twelve tooth sprockets by utilizing a #40 chain. The twelve tooth sprocket was needed to reduce rpm from 385 to 125. Figure 3. gives specific details on hole spacing for shafts and bearing fasteners. All chains and belts were covered with safety shields to prevent accidents.

The grinding unit can be loaded with 140 of the 59.15 ml. bottles that contain plant, grain or soil material. Four stainless steel rods (.61cm diameter, 5.08cm length for soil, .32cm diameter, 5.08cm length for grain, plant and straw) are placed inside the bottles which produces a hammering action comparable to that of the pestle. Bottles are capped to prevent material leakage and cross-contamination. Bottles are left rolling on the grinder overnight to reach the desired fineness (100 mesh).

Results and Discussion

The grinding unit was completed in approximately two weeks. Table 1 gives a list of components and current costs associated with the materials used. Once the unit was complete, a trial run showed that the 59.15 ml, bottles were not large enough. Also, the bottles were sticking to the rubber hose after the unit had run for a while. To correct this, 118.30 ml bottles were utilized instead of 59.15 ml. To prevent the bottles from sticking, a silicone spray was applied to the rubber hose. It was also observed that the chain was rising off the sprockets, causing the shafts to intermittently skip. A 2.54 cm x 76.2 cm piece of angle iron was fastened to a 12.7 cm x 76.2 cm oak

Table 1. Parts list and current costs of purchased materials for the automated grinder.

Parts	Cost
Peerless-Winsmith gear box(Model 3CB;Peerless-Winsmith, Inc., Springville, NY)	$408
3/4 horsepower electric motor	206
Sprockets	91
Pulleys, chain, belts	62
Stainless steel rods (.61cm diameter)	292
Steel: flat strap, channel iron, angle iron, expanded metal, tubing	350
Bearings	413
Bottles & caps(118.30 ml. French square glass)	187
Miscellaneous: bolts, nuts, screws, castors rubber hose, electrical switch	75
Labor	
80 hours @ $7.00/hrs	560
TOTAL	$2644

board which acts as a chain guide to prevent the chain from rising off the sprockets. Once all the problems were eliminated the unit was left on overnight to observe sample fineness. Samples (grain, soil, and plant) were ground fine enough to pass through a 200 mesh screen. Future work will focus on the time required for sample fineness, alternative size and shape of internal hammering bars and type of sample employed.

References

Smith, J.L., and Myung Ho Um. 1990. Rapid procedures for preparing soil and KCl extracts for ^{15}N analysis. Commun. Soil Sci. Plant Anal. 21:2173-2179.