A TYPE OF LABORATORY SILO AND ITS USE WITH CROTALARIA

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INTRODUCTION

In regions where the usual forage crops are poorly adapted and climatic conditions render haymaking uncertain, the use of new crops and methods for their preservation must be further investigated. Various species of the genus Crotalaria have been found to be well adapted culturally to the lighter sands of the Coastal Plains region and are comparable in composition to the other legumes used in livestock feeding. The success attained at the Florida station in ensiling soybeans, the seasonal distribution of rainfall which makes natural curing of hay an unsatisfactory practice, and the independence of silage-making of weather conditions, suggested the desirability of determining the ensilability of the crotalarias. Preservation of forage as silage has the further advantages of economy of labor and storage space, reasonable efficiency of conservation of nutrients and succulence, and an increase in palatability brought about by the ensiling process.

The experiments were planned to test the merits of a type of silo which was developed for this work. Four of the silos were constructed so that several species of Crotalaria might be studied concurrently with a minimum expenditure of materials and labor, preparatory to more exact studies of digestibility and feeding value.

WORK OF OTHER INVESTIGATORS

The first report in American literature of the ensiling of forage in experimental quantities with determinations of nutrient losses was made by Jordan at the Pennsylvania station in 1884. Water-tight tubs 6 feet in height and 3 feet in diameter were filled with chopped sorghum and weighted to secure packing.

Cooke reported the use of tubs 3 feet in height and 2 feet in diameter, holding about 350 pounds of maize, at the Vermont station in 1889. A layer of roofing paper and a wooden disk weighted with stones to equal 50 pounds per square foot prevented all surface spoilage. A loss of 4.08 percent in total weight and 14.67 percent in dry matter was observed. Hills later made a satisfactory silage from sugar beets and straw in these silos.
The early work at the Wisconsin station with silage (12, 24) was done with rectangular silos, 7 by 8 feet and 14 feet deep, with a capacity of approximately 10 tons of forage. Clover was ensiled successfully with losses of 15.4 percent of dry matter and 12.7 percent of crude protein. Lawes and Gilbert (15) had ensiled clover as well as meadow grass in the pit silos at Rothamsted with smaller losses of nutrients.

A series of studies of the adaptation of many of the forage crops for making silage was instituted at the Missouri station by Eckles (8, 10) in 1915. The final results were tabulated by Ragsdale and Turner (21). Cypress-stave silos 6 feet tall and 3 feet in diameter were filled with corn, oats and cowpeas, cowpeas, soybeans, alfalfa, Sudan grass, wheat, oats, rye, and sunflowers. All but rye made good silage although it was recommended that the legumes be ensiled only when they had wilted sufficiently to give a 30 to 35 percent dry-matter content. A wire screen was placed in the silo when it was within 18 inches of being full. The silos were sealed with a felt-lined wooden disk and weighted with 1,000 to 1,500 pounds of rock. The weight and composition of the forage placed under the screen as compared with the same data for the silage, were used to measure the unavoidable losses in the ensiling of the crops.

Reed and Fitch (22) studied the ensilage of alfalfa in upright silos 7 feet in diameter and 16 feet high, made from 1-inch flooring. Alfalfa alone made poor silage. The addition of carbohydrates in the form of meal, molasses, or sorghum increased the acid production and improved the quality. Swanson and Tague (25, 26), using quart milk bottles as containers, made parallel studies with alfalfa and sweetclover. Carbohydrate additions were beneficial and sweetclover was more desirable than alfalfa for making silage. True, Woll, and Dolcini (27) encountered no difficulty in making good silage from alfalfa alone in a commercial silo. This could be taken to indicate that conditions in the experimental silos only approximated those in larger silos.

Westover and Garver (28) ensiled 150 to 200 pounds of alfalfa, sweetclover, corn, sorghum, Sudan grass, wild sunflowers, Russian thistles, and corn or sorghum mixed in equal parts with alfalfa, in oil barrels, reheading the barrels after they were filled. Neither the sunflower nor thistle silage was palatable.

Blish (6) utilized galvanized-iron cylinders 23 to 27 inches in diameter and 7.5 feet high in his studies of factors affecting the quality of sunflower silage at the Montana station. A good-quality silage was produced except with sunflowers low in sugars. Peterson, Hastings, and Fred (20) likewise used iron cylinders 4 feet in diameter and 8 feet high, when investigating the changes that take place in the making of silage.

Woodman and Amos (1, 2, 29, 30, 32) used wood-stave silos 6 feet high and 3 feet in diameter in a series of investigations with English forage crops. The forages included oats and vetch, maize, sunflowers, sugar-beet tops, and a mixture of oats, vetch, and beans. Metal extensions were placed on the silos during filling. The silage was covered with a layer of earth to pack it and to decrease spoilage. Sample bags buried in each silo at two different levels were used for the determination of changes in composition and losses of nutrients.
Losses with the mixed silages in the experimental silos were comparable to those in commercial silos (1, 29, 33) and were smaller than those in either clamp (3) or stack (31) silage.

Even with the comparability of losses between the experimental silos and commercial silos as found by Woodman and Amos with mixed silages, and as found by Eckles (8) with maize, the complete comparability of the two types of silos may be questioned. Eckles found the legumes should have a dry matter content of 30 to 35 percent for successful ensilage in the experimental silos, while a dry-matter content of 25 percent with soybeans was found sufficient at the Florida station (f8). However, all the evidence indicated the value of the laboratory silo as a tool with which to study the ensilability of forage crops.

EXPERIMENTAL METHODS AND MATERIALS

Four small pit silos were constructed in a hillside having good surface drainage. They were 43 inches in inside diameter without any taper, and between 74 and 81 inches in depth, with smooth concrete walls, and clay and limerock bottoms.

Each silo was filled with one of the crotalarias on September 22–23, 1932. The forage was cut in 1½-inch lengths in a silage cutter, weighed in tubs, and packed in the silo by tramping and tamping. When the top of the silo was reached, a piece of burlap was placed over the surface, additional cut material was packed over it, and finally the whole was covered with approximately 2 feet of earth. This earth layer was cone-shaped to carry off the rainfall. (See fig. 1.) The silos and manner of filling were designed to simulate as closely as possible the conditions found in large silos.

A 10-kg sample of the forage in a muslin bag was buried about midway in depth in the silo as it was being filled. This was covered by a thin layer of crotalaria, over which a moist piece of burlap was placed as a marker. A 1-kg sample representative of the forage in the muslin bag was taken for analysis.

The silos were opened on December 12, 1932, 81 days after they were filled. The earth and silage were stripped off to the burlap
cover. Spoiled silage underneath the burlap was removed and weighed. Good silage was removed, weighed, and offered to cattle over a 16-day period to determine its palatability. The small bags were weighed as they were recovered, and sampled for analysis.

Analyses were made by the methods of the Association of Official Agricultural Chemists (4). Juice for the hydrogen-ion determinations was obtained by pressing samples of the fresh silage, and the determinations were made with a quinhydrone electrode. Losses of nutrients were calculated from the weight and composition of the forage placed in and the silage removed from the sample bags.

Four species of *Crotalaria* were used to test the feasibility of these laboratory silos and the ensilability of the forages, namely. *C. spectabilis* Roth, *C. striata* DC., *C. intermedia* Kotschy, and *C. incana* L. All were further advanced in growth than is usually considered desirable for hay, with flowers and many seed pods present. Many of the lower leaves of *C. spectabilis* and *C. incana* had fallen.

**PRESENTATION OF DATA**

The quantity of forage ensiled, the quantity of spoiled and sound silage recovered, and the density of the silage at each foot in the silo for each species, are presented in table 1. It will be observed that from 2,088 to 2,609 pounds of forage were cut, weighed, and packed in the silos, and from 47 to 241 pounds of spoiled silage were removed from beneath the top piece of burlap 81 days later when the silos were opened. From 1,854 to 2,329 pounds of sound silage were removed during the next 16 days. The forage over the burlap was not weighed but was estimated at 500 pounds. Over the *Crotalaria striata* silo much of this material was unspoiled, but over the others it did not keep.

<table>
<thead>
<tr>
<th>Species of <em>Crotalaria</em></th>
<th>Forage ensiled</th>
<th>Silage</th>
<th>Depth of silage</th>
<th>Silage density per cubic foot</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pounds</td>
<td>Pounds</td>
<td>Inches</td>
<td>First foot</td>
</tr>
<tr>
<td><em>C. spectabilis</em></td>
<td>2,609</td>
<td>233</td>
<td>80.50</td>
<td>58.9</td>
</tr>
<tr>
<td><em>C. striata</em></td>
<td>2,420</td>
<td>47</td>
<td>74.00</td>
<td>54.5</td>
</tr>
<tr>
<td><em>C. intermedia</em></td>
<td>2,526</td>
<td>131</td>
<td>67.00</td>
<td>67.0</td>
</tr>
<tr>
<td><em>C. incana</em></td>
<td>2,088</td>
<td>241</td>
<td>74.00</td>
<td>53.0</td>
</tr>
</tbody>
</table>

* Gravitational moisture evident.

The changes that took place in the forage were determined by comparing the weight and composition of the forage ensiled with the weight and composition of the silage recovered in the sample bags. The composition of the forage and silage, and the percentage recovery of the various constituents of the forage ensiled are presented in table 2.
The crotalaria forage ensiled in the laboratory silos was found to have undergone the typical changes encountered in large silos with other crops. The destruction of protein was not so great, but the losses of dry matter and nitrogen-free extract were greater than had been obtained previously by the writers with soybeans. The increase of ether extract was more marked. There had been some leaching of soluble ash. The silage had a pungent acid odor, and hydrogen-ion measurements showed it to be acid, although less so than corn silage, which was found to have a pH value of 3.47.

Quantities of the different silages were offered to growing dairy heifers to determine the relative palatability. All four of the crotalaria silages were placed in compartments of the same feed bunk, and the order changed from day to day. Records taken were limited to notations on order of choice and approximate amount refused.

*Crotalaria incana* and *C. intermedia* silages were eaten immediately and with almost no waste. *C. spectabilis* was eaten after the first two had been taken, and without significant refusal. The *C. striata* silage was refused almost completely by all of the animals (14 head) used in this study.

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5 Unpublished work indicates a toxic principle in the seeds of *C. spectabilis* when eaten by chickens. The forage also may be poisonous, but the limited quantities of the silage offered caused no visible symptoms of poisoning. Further toxicity studies are in progress.
DISCUSSION OF RESULTS

This investigation was planned to determine whether or not such laboratory silos as are described could be used in preliminary studies with forages, and also to ascertain whether or not any of the crotalarias might be desirable as silage crops. Such an investigation was necessary because the climatic conditions in Florida favor the preservation of forages as silage rather than as naturally cured hay.

The silos and the manner of filling them were designed to simulate the conditions in large silos with a minimum expenditure of labor and materials. The use of the pit type of silo, which could be capped easily with additional forage and earth, was an important feature. Leakage of air through the walls was minimized and the weight of the cap of forage and earth aided in packing the silage. How well this was accomplished is shown by the density of the silage, in table 1. The surface foot was of a density equivalent to corn silage at the eighth foot (11), or of soybean silage at the fifth foot (5). The loss by spoilage of the crotalaria forage actually placed in these silos was very small.

If the changes in composition and the recovery of nutrients in the laboratory silos were equivalent to those found with other crops in large silos, it could be concluded that a typical silage had been produced. If such a silage were produced, tests of its palatability would determine whether or not additional investigation of the feeding value of the silage was justified.

The demonstration in commercial practice that good silage may be made from the legumes alone, the indifferent success with alfalfa in experimental stave silos at the Kansas station (22), and the probable necessity of a dry-matter content of 30 to 35 percent in legumes for ensilage at the Missouri station (8) would indicate that commercial conditions had not been achieved in those types of experimental silos used in testing the ensilability of legumes. Chemical studies of the nutrient losses in the Kansas investigation were not presented, but the legumes of a higher dry-matter content at the Missouri station underwent normal changes and suffered the expected losses of nutrients.

In the laboratory silos filled with crotalaria the loss of dry matter was only slightly greater than that found with corn silage (19, 20, 23) and soybean silage (18) in commercial silos. The recovery of crude protein was good, and the increase in ether extract indicated that the fermentations resulting in ether-soluble acids had occurred, as found in normal ensilage. These results were secured with forage containing from 20.9 to 25.9 percent of dry matter from which silages containing 18.2 to 23.5 percent of dry matter were obtained. The silage had a pungent acid odor, and from both physical appearance and chemical composition, could be considered typical.

The palatability studies showed three of the four species to be much more desirable as silage than as either green forage or hay. Not only were they eaten readily, but the amounts refused were insignificant. Crotalaria striata has not seemed to be adapted as a livestock feed, and careful toxicity studies of C. spectabilis are necessary. Final selection of a particular species for ensilage must depend on additional tests with other species, as well as on the consideration of

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*Unpublished material from another phase of the cooperative investigation.*
yields, freedom from insect pests and diseases, and similar matters of an agronomic nature. All of the species studied apparently underwent typical ensilage changes to a degree that would be expected in large silos. The possible use of *C. incana* and *C. intermedia* is indicated definitely. However, they should not be recommended without additional investigation.

The potential place of a slightly larger silo of the type used in this experiment, with a capacity sufficient to supply silage for digestibility studies is worthy of consideration.

**SUMMARY AND CONCLUSIONS**

Typical silage was produced in laboratory pit silos of 2,000 to 2,500 pounds capacity with crotalaria forage. Chemical changes and losses of nutrients were of the same order as usually are encountered in large silos with other crops. Conditions more nearly comparable to those in large silos were secured than appear to have been obtained heretofore by others working with small experimental silos of other kinds in the ensiling of legumes.

*Crotalaria incana* and *C. intermedia* forages made palatable silage which was eaten readily by cattle. *C. spectabilis* silage also was eaten readily, but its possible toxicity requires further investigation. *C. striata* does not seem to be adapted for use as a livestock feed.

Even though some species of the genus *Crotalaria* may be ensiled with only reasonable losses and the resulting product may be palatable to cattle, there yet remains the testing of other species in the manner herein described, the consideration of cultural characteristics of the various species, and an evaluation of crotalaria silage as a livestock feed, before any recommendations can be made concerning the use of crotalaria as silage.

The potential place of a larger laboratory silo of the type used in these experiments is suggested.

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