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O. E. Olson
South Dakota State University

L. B. Embry
South Dakota State University

H. H. Voelker

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AGRICULTURAL EXPERIMENT STATION
SOUTH DAKOTA STATE UNIVERSITY, BROOKINGS

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O. E. Olson, Experiment Station Biochemistry Department
L. B. Embry, Animal Science Department
H. H. Voelker, Dairy Science Department

Through the years a number of materials have been suggested for incorporation into silage to improve the preservation of nutrients, nutritive value or palatability of the silage. In addition to being called additives, some of these materials are referred to as preservatives or conditioners. Especially during recent years, many commercial preparations have been made available to the farmer, who naturally wonders whether their use will be economically sound.

Thorough testing of these materials would require that each be used at several levels, with forages at various moisture contents, under different storage conditions and with many kinds of silage. Therefore, it is highly impractical, if not impossible, to attempt thorough testing of each. However, there is sufficient understanding of the process of silage formation, the requirements for preservation of its nutrients, and the principle of action of the ingredients used in the various additives to make sound decisions as to whether they might be economically worth-while. There is, in addition to this understanding, a rather large amount of research which has been done and reported, and this in its summation justifies the use of what is already known to make judgments.

In order to make an appropriate judgment, one should be able to answer certain questions, as follows:

1. What happens during the process of silage formation?

2. What does the additive being considered contain and what do its ingredients do?

3. What is the value of the silage and what is the cost of the additive?

4. How much preservation beyond that afforded by good ensiling procedures can one logically expect from the additive?

5. Can one expect to improve the feeding value of a silage by using a particular additive?

The discussion that follows deals with these questions.

The Silage-Forming Process

Ensiling is a means of preserving a feed by fermentation. By definition, silage is a feed stored in a silo of some type and at a moisture level sufficient for fermentation to occur. However, fermentation results in a loss of nutrients, and a primary objective in making silage is to keep these losses at a minimum. The amount and type of fermentation which occurs, and therefore the amount of loss, is influenced by the chemical composition of the material stored, its moisture content and the degree of its exposure to air.

When green or partially dry crops are put into the silo, regardless of the type of structure, certain changes begin immediately. The plant cells continue "breathing" for a time, using up the oxygen and giving off carbon dioxide. After a few hours the oxygen trapped in the silage is used up. Without oxygen, molds will not grow.

After a few hours, acid-producing bacteria begin to increase in numbers. They act on sugars and form principally lactic (the acid of sour milk) and acetic (the acid of vinegar) acids, as well as carbon dioxide. Starch also contributes to the acid production since in breaking down it forms a sugar. After so much acid is produced, it stops bacterial action, thus preventing further breakdown and spoilage of the silage. Thus by having removed the oxygen and having produced acidity, the silage will keep for long periods with very little change provided oxygen is excluded. The need to exclude oxygen (air) cannot be overemphasized. When this is not done, molds begin to grow and use up the acids. Then spoilage and putrefaction can take place. Further, if air penetrates into the silage, nutrients continue to be consumed by bacteria and molds and a considerable loss of dry matter occurs.

During the silage-forming process, proteins are "digested" to some extent (split into peptides and amino acids), similar to digestion by the animals. This partial digestion does not appear to be of any benefit in improving utilization of the protein by the animals.

Moisture content is important in silage formation. If it is over 70% in corn silage or over 65% in legume silage the fermentation may not be normal and an unpalatable silage containing strong smelling butyric acid may be formed. Furthermore, seepage occurs at moisture contents of about 65% and above in tower or upright silos, and seepage losses for very moist material may amount to as much as 10% of the dry matter stored. Excessive moisture in protein-rich crops may lead also to abnormal protein breakdown resulting in a putrid odor and a silage of low palatability and feeding value. When too little moisture is present (perhaps less than 50% in upright silos) excessive mold growth and heating may result unless special precautions are taken to exclude air.

It should be pointed out that the bacteria essential to the silage-forming process are naturally present in adequate numbers on all green forages. Furthermore, all ingredients essential to the process are present in the forages if ensiling and storage methods are proper.

Functions of Silage Additives

In considering the need for an additive, preservative, or conditioner in making silage, one should take into consideration the basic steps involved in the silage-forming process and the major factors which affect the process — air (oxygen), moisture and the chemical composition of the material. The benefit obtained from an additive depends upon its effects on these and is measured by the reduction in losses and/or the improvement in quality and feeding value of the silage. The various additives function in the following ways:

1. Adding dry matter and thus reducing moisture content. The objectives of adding dry matter are to reduce seepage losses and to provide a more suitable medium for the silage-forming process. Moisture content can also be regulated by wilting of grasses and legumes and by harvesting corn or sorghum at the proper stage of maturity. When it is possible to use them, these methods should be given preference over adding dry matter to the ensiled material.

2. Adding water to increase moisture content. When material to be stored as silage becomes too dry, it may be difficult to pack it properly and exclude air. Under such conditions, water is the most appropriate additive. Liquids such as molasses are too low in moisture content to be of much value for this purpose unless diluted with a sufficient amount of water. In adding water to silage, it requires 5 gallons per ton of ensiled material to raise the moisture content about 1 percentage unit, depending upon the original moisture content.

3. Altering rate, amount and kind of acid production. Acid production is one essential in the keeping quality of silage. The rate, amount and kind of acid production is influenced by the moisture and soluble carbohydrate contents of the crop when it is ensiled. Moisture can be regulated as already discussed. Some additives serve to add dry matter and also carbohydrates (sugars and starches) which are useful in acid production, as discussed later. With grasses and legumes wilted to 50-60% moisture content or with well-matured corn or sorghum crops, additives for these functions have not appeared to be of any consistent benefit except for the nutrients added.

4. Acidifying the silage. Acidifying silage at the time it is put into the silo has been practiced for the purpose of producing an immediate acid condition rather than waiting for the silage to produce its own acids. This is accomplished by adding a mineral acid. Such additives have been shown to be beneficial when added to high moisture silages which have a low soluble carbohydrate content (alfalfa and grasses).

5. Inhibiting bacterial and mold growth. While acid formation and the exclusion of oxygen stop bacterial and mold growth, several chemicals used as silage additives are capable of doing this. The problem with them, however, is primarily one of the concentration of each necessary to do an effective job. Further, some of these chemicals are relatively unstable under the conditions found in silage, and their effects are of limited duration.

6. "Culturing" the silage. Since silage is the product resulting from the action of bacterial enzymes on the material stored, attempts have been made to alter or regulate the type and amount of fermentation through various additives containing bacteria, yeasts or molds. It is much easier to regulate the silage fermentation by using proper moisture and storage conditions than by innoculating the silage to provide acid-forming bacteria (this is entirely unnecessary) or adding yeasts or molds as enzyme sources. At the rate these preparations are added, it is doubtful that they have any effect on the silage at all.

Further, the preparations are crude and in such a variable medium as silage they cannot be expected to give consistent results. There appears to be no basis for the benefits proposed for this type of additive.

7. Increasing the nutrients of the silage. Some materials added to silage increase its nutritive value to the extent that these materials themselves contain nutrients. Examples are grain, grain by-products, beet pulp, dried whey, molasses or urea. This practice may add materially to the cost of the final product and its economy is questionable except where the additive improves fermentation by reducing moisture content or increasing sugar content or where the resulting mixture fits better into the feeding operation (see discussion on "all-in-one" silage).

Some Silage Additives

A variety of silage additives which have been used either alone or in combinations are discussed below.

Molasses: Some green forages such as legumes and certain grasses have rather low sugar contents. Adding molasses as a sugar source may improve acid production and thus improve quality and preservation. For legumes, about 80 pounds per ton is generally used, and about 40 pounds is used for grasses. Additions of much less than these amounts, as an ingredient in mixed preservatives, would be of little value. Much of the feeding value of the molasses is retained in the silage under good storage conditions and where there is no seepage loss. However, wilting to 50-60% moisture content yields an excellent feed of good odor and keeping quality when the silage is adequately protected from air. Sugar additions are not necessary nor particularly helpful in this situation. Neither are they needed for corn silage.

Grain and other feed ingredients: Silage made from legumes or hay crops may be improved under certain conditions by the addition of ground grain, ground ear corn or other appropriate feed ingredients. The ground material will reduce the moisture content (adding 150 pounds of ground grain to a ton of green forage would, for instance, reduce the moisture content by about 5 percentage units), provide additional sugar and starch from which acids may be produced, and often improve palatability. Almost all of the feeding value of the grain would be retained if a silo which properly excluded air were used. However, when green forage is ensiled at an appropriate moisture content there is usually no advantage to adding grain for the purpose of preservation or palatability. If the primary concern is mainly a matter of reducing the moisture content of the silage, cheaper materials such as ground corn cobs, oat hulls and ground hay may be more appropriate than ground grain.

Urea: Urea has been added to corn or other low protein forages to improve the protein content of the silage. Generally it is added at the rate of 10 pounds per ton of green material, at which level it increases the protein content by about 1.3 percentage units. As a rule, there are no decided advantages in this practice as compared to feeding the urea in a supplement with the silage. Further, occasional problems with palatability or excessive urea loss may occur. If urea is added to silage, its cost will not be recovered unless advantage is taken of the higher protein content by reducing protein supplementation of the ration.

Limestone: Limestone (calcium carbonate) has been added to corn silage to increase acid production. It neutralizes some of the acids as they are formed, allowing the lactic acid bacteria to perform longer and therefore to produce more acids. Research to date, however, does not indicate any consistent increase in the nutritive value of silage treated with limestone. In rations composed largely of such silage, recommended limestone additions (0.5-1.0%) may increase the calcium content above that which is considered desirable.

Limestone additions have also been suggested as a means of reducing the nitrate content of silage. Work at this experiment station indicates that the level of limestone required for this is considerably above that which it is practical to add.

Bacteria and mold inhibitors: Bacitracin and other antibiotics have been used as silage additives. Sodium propionate, because of its mold inhibiting properties, has also been suggested as a preservative. Salt has been used because at an appropriate level it inhibits certain microorganisms without preventing the action of bacteria which produce the desirable acids. Mold inhibitors, antibiotics and salt are not essential and are of questionable value to the silage fermentation or preservation if air is properly excluded. If it is not, they do little if anything to preserve the silage unless they are added at exhorbitive levels.

Sodium metabisulfite: In experimental work, sulfur dioxide (a gas) forced into silage was found to decrease fermentation and improve carotene preservation. This was a complicated process, so sodium metabisulfite (sometimes called sodium sulfite) was used in its place. This salt acts like sulfur dioxide but is much easier to handle. Its use with legume forages reduces carotene losses and often improves the odor of the silage. Its effect on palatability is variable. It has no apparent value for corn silage beyond somewhat reducing carotene losses. The saving in carotene and improvement of odor in legume silages are of very little economic value and are outweighed by the cost and inconvenience of its application and occasional problems with palatability.

Sodium metabisulfite has been found to reduce the production of toxic gases in silage of high nitrate content. Whether its use for this purpose alone would be of enough value to outweigh its cost and the inconveniences of application is questionable. Even when it is used, the precautions usually suggested in connection with high nitrate silage should not be set aside.

Mineral acids: Mineral acids (hydrochloric acid, sulfuric acid, phosphoric acid) have been used as silage preservatives, almost entirely in Europe, in connection with the ensiling of high moisture material. These acids substitute for the acids produced by bacterial action. They are, however, very corrosive, causing problems in their application and with the silo walls and silage handling equipment. Of the three acids, phosphoric appears best, but it may introduce a problem of proper calcium:phosphorus ratio. This can result in some abnormal conditions and unsatisfactory performance in the animals to which it is fed. In general, the use of these acids offers more disadvantages than advantages.

Bacterial cultures: Silage preservatives containing cultures of acid-forming bacteria (*Lactobacillus*) have been offered for sale to the farmer. The basis for including these in the preservative is to provide an inoculum or to increase the numbers of these bacteria and insure rapid fermentation. The addition of such "cultures" is not only unnecessary but also of no value. There are always sufficient numbers of these bacteria present on the ensiled material to bring about the proper fermentation. Furthermore, the number of live bacteria present in these preparations cannot be guaranteed with accuracy and usually would add insignificantly to what is already present on the ensiled material.

Yeast cultures: Yeast cultures have also been included in silage additives offered for sale. Yeasts will sometimes grow in silage without an inoculum having been added. When this happens, the silage is of a yeast odor and this is considered undesirable. Yeast does have nutritional value, but the numbers added in these cultures would add almost nothing in this respect. Further, what was added would not be something not already present in the uninoculated silage. There is no good basis for adding yeast cultures to ensiled material.

Enzymes: Crude cultures of molds, or these cultures with other microorganisms, have been added to silage to provide a source of enzymes. As a rule, these enzymes are claimed to improve the nutritive value of the silage by improving its digestibility or its digestible nutrient content. Actually, the enzyme activity of these preparations has not been measured, and no doubt it would vary considerably from batch to batch. Further, the enzymes that are added are insignificant in amount as compared to those present in the silage itself, and adding them is something like "carrying coals to Newcastle." There is no reliable evidence that they improve the fermentation, improve the digestibility, or increase the level of any of the nutrients in the silage. The only improvement one should expect from such preparations would be that added in the preparation itself, and the amount generally recommended for use makes this insignificant.

Sodium formate and sodium nitrite: Mixtures of sodium formate and sodium nitrite have been used in preparing silages without satisfactory results. The use of these mixtures has been very limited and it is doubtful that their application to ensiled material is practiced at all in this country at the present time.

Comments

A variety of mixtures of the above substances and no doubt others have or will be suggested as silage additives. As already pointed out, for most there will be inadequate testing. The individual farmer will often be required to use his own good judgment in deciding whether an additive should be used. In addition to understanding the silage-forming process and how certain additives function, he should also consider the following:

1. The proper exclusion of air is vital to efficiency in using silage as a feed.

Whenever silage forms from green material there is always carbon dioxide produced. This causes some loss of dry matter, but the loss is small when air is excluded. When air is not excluded, however, decomposition of all nutrients except the minerals can cause excessive losses and disappearance of much of the dry matter. It may seem strange at first, but where air has not been properly excluded, the silage usually contains a higher percentage of crude protein in the dry matter than that which is properly stored. This is because the sugars and starches are lost more rapidly in the presence of oxygen than is the crude protein, resulting in a higher percentage of protein for what remains. The same is true for minerals and for fiber. This, of course, does not mean that there is a greater total amount of protein saved in the improperly stored silage. It is, in fact, a sign of the presence of too much air. Therefore, preservatives that are effective should not increase the crude protein percentage in the silage unless they themselves are high in protein.

2. Preservatives will not substitute for the proper exclusion of air.

Air is excluded by storage structures, permanent or temporary, and by covering the silage with some material such as plastic sheets, bales of hay or straw, dirt, sawdust, etc. The silage itself tends to form a seal on the surface of open stacks, tops of trenches, bunkers or upright silos by forming a somewhat compact mass through spoilage and sticking together. This type of seal is not very effective. It is more effective when a high moisture forage is used for the top layer, but in any case may be rather expensive since the spoilage layer may amount to several inches or even a few feet of material.

It has been suggested that such a seal would likely be benefited by soaking the surface with molasses. However, this is a very uneconomical process in view of the losses which would occur from such a readily decomposed material exposed to the air. Further, it is doubtful that the seal formed would be any more effective than that formed from the green material itself. Generally speaking, this procedure could be considered nothing more than a waste of molasses.

3. Preservatives do not produce nutrients in silage.

The amount of crude protein or any other major nutrient does not increase during the formation or storage of silage, and preservatives cannot cause an increase in them. A silage can increase in the amount of protein or other major nutrient it contains only by the amount the preservative or additive has in it. If a preservative contained 40% crude protein, 10 pounds of it per ton would increase the protein content of the dry matter by only one-fifth of one percentage unit.

4. Additives that provide nutrients in the silage will be lost with the spoilage.

With legume, grass, or cereal silages, the moisture content is often too high at the time of cutting and this is best corrected by wilting before putting into the silo. With corn or sorghum forages, the proper moisture content is attained through cutting at the proper stage of maturity. These methods of obtaining the proper moisture content should be followed when it is possible to do so. Field losses should be low when forages are not wilted below 40-50% moisture using proper equipment and with minimum handling of the forage. Crushers or conditioning equipment may be helpful in speeding the wilting process, especially the wilting of the stems.

There are situations, however, where wilting or harvesting at the appropriate stage of maturity are not possible. Unfavorable drying weather may be encountered at times, particularly during harvest of first-cutting alfalfa. Delaying harvest results in overmature forage, a reduction in feeding values and reduced yields for later cuttings. Also, long periods of time in the windrow may result in some decomposition of the forage and a silage of lower palatability and feeding value. Early frost may necessitate harvesting corn or sorghum for silage at an immature stage. In such cases, the addition of some dry material is helpful in reducing seepage losses and improving fermentation of the silage.

With legume or grass silages, ground grain is usually added, but whenever grain is added to silage stored in a stack, pile, bunker or trench much of it may be lost due to spoilage or excessive fermentation. With the stack or pile, and probably with the bunker, a little higher than normal moisture content is less harmful than in other types of storage, and it would be most economical not to add the grain but rather to feed it along with the silage as it is fed out. In the case of the trench, grain should not be added to the top two feet of the silage, thus avoiding the spoilage area.

5. <u>The cost of a preservative is often high in terms of the value of the silage.</u>

The value of silage in the silo is generally in the range of $6.00 to $10.00 per ton, depending on kind and moisture content. The addition of a preservative at a cost of only 50 cents per ton would mean that an improvement of 8 to 10% would be necessary to pay the cost of the preservative. Many preservatives added at suggested rates cost considerably more than 50 cents per ton of silage. Storage losses of as little as 10-12% are attainable with properly used upright silos, and losses of 1-2% always occur when silage forms. Thus, the potential improvement from a preservative over good silage making procedures is not likely to justify the cost except when the preservative itself contributes a significant amount of nutrients to the silage.

6. <u>Chemical analyses are of very limited use in evaluating a silage preservative.</u>

Oftentimes samples are submitted to the laboratory for chemical analysis for the purpose of evaluating a preservative. If only a sample from the silage to which a preservative has been added is analyzed, this can be of no value since there is nothing with which to compare the results. If two samples are sent, one from a treated and one from an untreated silage, this is naturally better, but the results would still reveal but little concerning the effectiveness of the preservative. The values for carotene might be the most revealing.

Any other differences would be small unless the preservative itself contained significant amounts of nutrients. Since silage will vary considerably in its analysis throughout a silo, one can expect these variations to be greater than the differences in the average analyses of the treated and untreated silages. To make proper comparisons, one should analyze many samples of the treated and untreated material at the time of filling and at the time of feeding out. Far more important in making a comparison would be the actual percentages of stored green forage that are fed out or the beef produced or other animal response per ton of green material ensiled. The farmer should, in fact, be wary when chemical composition is used as a measure of the effectiveness of an additive in preserving nutrients (except in the case of carotene).

7. "All-in-one" or "spiked" silages, while having a place in certain feeding programs, have disadvantages.

If one can include in a silage, at the time of ensiling, certain additives that yield a balanced and complete ration, the process of feeding out the material is simplified. Used more effectively, perhaps, with dairy cattle than with beef cattle or sheep, "all-in-one" or "spiked" silages may increase dry matter and nutrient intake, reduce labor and equipment for feeding, and possibly reduce feed loss on windy days. This practice, however, offers certain disadvantages which should be taken into consideration before it is used. In the first place, if the additive is expensive as compared to the value of the silage, then the dollar losses in the spoilage and through excessive fermentation are increased. Unless the resulting mixture is one that would be suitable throughout an entire feeding program, then there may be a waste of nutrients that are present or difficulty in adjusting the total ration through the use of other feeds to make it appropriate to the feeding program. Storing the various ingredients separately and mixing them at the time of feeding gives the greatest flexibility and often the most efficiency in use of the nutrients.

Recommendations

1. Certain materials added to silage will increase the amount of nutrients it contains. These are: (1) urea, which increases the crude protein; (2) grain or grain by-products, which increase protein, total digestible nutrients and dry matter; (3) molasses, which increases total digestible nutrients and may improve fermentation in legumes and certain grasses; and (4) limestone, which increases calcium content. None of these are essential to good silage formation when conditions of moisture and storage are proper. Under special circumstances they can be recommended for use. For instance, grain, grain by-products or molasses might be a wise addition to silage when conditions do not allow for proper wilting prior to ensiling, or when an "all-in-one" silage is being made. Urea may be an appropriate addition to an "all-in-one" silage or where increasing the protein content of the silage will simplify its feeding. It is doubtful that there is any justification for adding limestone unless this is a convenient method of calcium supplementation. The economy of most additives of this type depends largely on how well their nutrients are retained in the silage and the use made of them in balancing the rations.

2. When forages are stored at the proper moisture content and when air is properly excluded, nutrient losses are low and a good quality silage forms. Additives such as lactic acid bacteria, sodium metabisulfite, mold inhibitors, antibiotics, salt, mold cultures (enzymes), yeast cultures, mineral acids and sodium formate plus sodium nitrite can, therefore, do little if anything to improve the preservation of the silage or its feeding value. When high moisture material is ensiled, grain (in some cases molasses) is better than any of these additives to use. When air is not properly excluded, none of these additives will correct the large fermentation and spoilage losses. At the present time, there seems to be no sound economic basis for recommending their use.

3. In short, there is no substitute for good management of forage crops for silage, with proper control of factors such as stage of maturity at harvest, harvesting methods, moisture content, fineness of chopping, distribution and packing and exclusion of air. With such management, a good quality silage should be formed with a minimum of losses.