

FORAGE STORAGE DESIGN AND MANAGEMENT TOOLS

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ABSTRACT

The University of Wisconsin Team Forage Extension Programming team has created a website as a means of delivering forage-related information developed in Wisconsin. A page within the website is dedicated to Harvest and Storage information. On this page, one can access papers, spreadsheets and presentations that can be used to improve understanding of harvest and storage systems.

The objective of this website is to improve the management decisions being made by dairy producers so as to improve their profitability. As dairy producers adopt new technologies, proper management of those technologies largely determines their success. A producer desiring to learn more about forage harvest and storage systems can access a wealth of information at the Harvest and Storage web page before, during or after making a decision about feed management. General topics covered include forage harvesting equipment adjustment, economics of storage systems, storage systems design and management guidelines, and management influence on forage quality and losses during harvest and storage. Farm advisors have used the decision aids and publications to educate their dairy farmer clientele, resulting in making sound forage harvest and storage management decisions. This has improved the profitability of the producer and the credibility of the advisor.

KEYWORDS. Silage, Forage, Storage, Harvest, Website

INTRODUCTION

The University of Wisconsin Cooperative Extension Service has initiated a team approach for developing and delivering educational materials to its clientele. Team Forage was formed with the goal of delivering research-based forage production and management information to producers and those advising producers. The team consists of about 30 members including campus based and county based faculty. One activity of the team was to develop a website through which users could access production and management information. The website, developed in 1999, contains thirteen web pages. The intent was to make available Wisconsin-developed research and extension publications, software, and presentations that could be used to learn and teach about forage production and management. The five work groups of the team are: Forage Production; Economics; Harvesting, Storage and Handling; Testing and Feeding; and Grazing. Each work group identified available materials and those that needed to be developed. Where research was available to support the development of new materials, potential authors were asked to produce the desired materials. Where more research was needed, the appropriate researchers were contacted and asked to become involved in developing answers to field research questions.

The use of a website was selected as a delivery method for several reasons.

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- The most up-to-date materials could be delivered at all times.
- Materials could be revised and updated easily and quickly.
- A one-location storage would make finding materials convenient for users.
- Information could be obtained at any time and from anywhere.
- Users could access the information as their needs arose.

The Harvest and Storage page (<http://www.uwex.edu/ces/crops/uwforage/storage.htm>) was developed in response to a need for producers to improve their harvest and storage practices. Producers in Wisconsin are evolving into total mixed ration feeding programs and have recognized the impact of rain on dry hay quality and the cost of labor to handle dry hay. These motivators have resulted in more forage being harvested as silage and less as dry hay. The movement to silage has increased the need for more on-farm capacity for silage storage systems at a time when the number of silage storage options has been increasing. Adopting these new technologies requires knowledge of the benefits and limitations of each system and the management required of each to make the selected system perform well. The Harvest and Storage page offers materials that address a variety of topics. Table 1 lists the section headings and specific titles as of August 2002. Users can view and/or use the materials on-line or download them to their own computers for use off-line. Articles and presentation materials convey research-based information and recommendations on various harvest and storage practices. Most of the articles can be downloaded as Adobe Acrobat files (PDF). A few PowerPoint presentations are available. Spreadsheet (MS Excel) software is available to help users understand and make decisions on storage sizing, capacities, management, and costs. Spreadsheets are designed to help users evaluate the impacts of various "what if" type of changes they may be considering. Those serving producers can use the materials to substantiate their recommendations to producers as well as refer their clients to the site so the producers can increase their knowledge. Educators and those serving producers can use the materials directly with clientele or combine materials to synthesize their own materials for delivery to the clientele. The knowledge and recommendations contained within the Harvest and Storage page are useful to address questions that arise as well as to help identify and solve problems encountered while trying to implement specific technologies and practices.

WHAT ARE THE EXPERIENCES?

We have attempted to learn how users have accessed and benefited from the web page. Several methods were employed to make this assessment. A survey form was delivered by e-mail to all subscribers of the Silage-L Listserv (silage-L@listserv.ksu.edu) and a group of other known users. The summary of the seventeen responses is shown below (Table 2). A search was conducted of the Dairy-L Listserv Archives (<http://www.listserv.umd.edu/archives/dairy-l.html>) and selected comments were recorded. Some of those comments are shown below. A "request for comments" section was added to the Team Forage web page. Voluntary responses to the webmaster are summarized below. The server housing the website has the capability of collecting and summarizing data about the website use. Some of the pertinent data is summarized in Table 3.

Table 1. Section headings and titles on the Harvest and Storage web page.

<p>Silage Harvesting & Equipment Estimating the Weight of Forage in a Forage Wagon Harvest and Storage of High-Quality Corn Silage for Dairy Cows Machinery Designs and Adjustments for Minimized Field Losses Crop Processing Rolls on Forage Harvesters: Performance and Proper Machine Set-Up Bale Harvesting & Equipment Machinery Designs and Adjustments for Minimized Field Losses Rain Damage to Forage During Hay and Silage Making Large Baler Research and Storage Ideas Plastic Wrapping Bales at Different Moistures and at Different Times after Baling Custom Field Operations / Equipment Sharing 1998 Wisconsin Custom Rate Guide Working Successfully with a Custom Operator Equipment Sharing and Other Joint Ventures Storage Sizing and Management (silage) Silage Pile Capacity Calculator Silage Pile Dimension Calculator Managing Forage in Bunker Silos Management of Bunker Silos and Silage Piles Preventing Silage Storage Losses Managing Forage in Tower Silos Transferring Silage Between Silos Bunker Silo Cover Alternatives You Can't Judge a Bunker Silo by Its Cover Silage Bag Capacity Factors Affecting Bunker Silo Densities Bunker Silo Density Calculator Bunker Silo Sizing Spreadsheet</p>	<p>Hay and Silage Additives Corn Silage Inoculants that Work Lactobacillus buchneri for Silage Aerobic Stability Adding Anhydrous Ammonia to Corn Silage Preserving Baled Hay With Organic Acids Inoculants for Legume-Grass Silage Inoculants for Corn Silage Anhydrous Ammonia for Legume-Grass Silage Adding Enzymes to Silage Adding Urea to Corn Silage Silage Inoculation - Inoculation of Silage and its Effects on Silage Quality Silage Preservation--The Role of Additives Large Baler Research and Storage Ideas Storage Economics Cost of Forage Storage Spreadsheet Storage Types Density and Losses in Pressed Bag Silos Storing Forage in Piles Choosing Forage Storage Facilities Deciding on a Silage Storage Type Bagged Silage or Tower Silos? Options for the Non-Expanding Dairy Farm Bagged Silage or Bunkers? Options for the Expanding Dairy Farm Drive-Over Silage Pile Construction Safety Prevent Hay Mow and Silo Fires How to Store Silage with Increased Profitability & Safety Watch Out for Silo Gas Informational Safety Materials on Augers, Bales and Balers, Forage Wagons, Hitches, Mower-Conditioners, Power Take-Offs, Rollover Protection Structures, Silo Gas, SMV Emblems</p>
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Table 2. Results of a survey of Silage-L and other users conducted in May 2002.

What is your primary job responsibility?	
<u> 9 </u>	Extension educator
<u> 2 </u>	Dairy/livestock producer
<u> 2 </u>	Commercial advisor
<u> 0 </u>	Vo-Ag/Vo-Tech school instructor
<u> 4 </u>	Industry technical services
<u> 17 </u>	Total Responses

(continued)

(Table 2 continued)

What types of materials have you downloaded from the website to your computer?

- 17 Papers/articles
- 11 "Focus on Forage" articles
- 14 Decision aid software
- 6 Decision aid software documentation

How have you used the written materials/articles?

- 16 Used the articles myself – my own education.
- 5 Copied the articles for use in class or at presentations as "hand-out" materials.
- 8 Copied the articles to give to individual clients.
- 9 Filed the articles for future reference.
- 1 Copied the information for use by colleagues.

How have you used the decision aid software?

- 11 Used the software myself to learn concepts.
- 7 Used the software in a classroom/meeting setting to explain concepts.
- 8 Used the software with or for clients to help them make decisions.
- 1 Gave the software to clients to use by themselves.
- 7 Filed the software for future use.

If you have used the information from the website to make your own improvements or to help producers make improvements to their operations, please indicate by number how many people have been informed and, of those, how many have made beneficial management changes.

NUMBER OF RESPONSES TO PRACTICE QUESTIONS: 9

PRACTICE	NUMBER INFORMED	NUMBER WHO MADE CHANGES
Cover bunker silo with plastic	215	18
Increase plastic weighting on bunker silo	3	2
Pack bunker silo with heavier tractor	100's* +58	100's +32
Pack forage in bunker in thinner layers	100's+60	100's +15
Pack bunker silo with more than one tractor	1	1
Design horizontal silo with face removal rate greater than 6 in/day	52	12
Use a cost analysis to decide on a forage storage type	75	18
Improve drivability of surface on which horizontal silage storage is placed (Macadam, concrete, asphalt)	2	2
Improve horizontal silo face removal to control forage heating and dry matter loss at feed out	10	6
Select an additive to improve forage preservation	20	9
Improve harvest moisture content for storage type	204	23
Improve use of corn silage processing	2	2
Adjust forage harvester to obtain proper length of cut	30	10

Have you recommend this website to a colleague? YES 10 NO 3 No Response 4

*One respondent used the term 100's.

Dairy-L Archives Search Summary

The following comments related to information on the Harvest and Storage web page were extracted from the Dairy-L Listserv Archives.

From Agency Person in New Brunswick, CA:

I have a paper which I printed off the net some time ago. It is a synopsis of a University of Wisconsin study that compared silage storage costs in bags, bunkers and uprights. Can anyone direct me to the website where I found this item or tell me where I could find the original study?

Response to Above:

Sounds like a tip sheet our research group developed a couple years ago. You may have downloaded this through a link from another site, but you will find the 2-page tip sheet at our site: <http://bse.wisc.edu/hfhp/>

The longer version comparison documents (bulletins) are not available at the site (to be revised). I can send you a hard copy. Our economic cost analysis was based on a model developed by Brian Holmes, an Ag Engineering extension specialist at UW-Madison. The model was the only approach that I could find at the time (a couple of years ago) that included costs for capital as well as operation costs (including labor, tractor costs etc.). I believe the spreadsheet software is available for free through the Univ. of Wisconsin Extension website. I will check with Brian Holmes and may post that info separately. A farmer or farm advisor can plug in farm-specific information and arrive at the estimated costs for those silage storage options that make sense for a particular farm.

Inquiry from Farmer:

Hi everyone, ... Can someone tell me what a cubic yard of corn silage, and a yard of haylage weighs. I am getting very different answers and I really don't have the time to run down to the scales and dealing with that. I also understand it depends on the quality and moisture but a general idea would be a great help

Response From Farmer:

At a recent nutrition meeting I attended, Pro-Dairy's (name deleted) showed a chart comparing silage densities of different farms that used bunk silos. The haylage ranged from 6.6 to 27.1 lbs/cu ft and the corn silage ranged from 7.8 to 23.6. (The averages were 14.8 and 14.5 respectively). It depends on how much you pack it, length of cut, DM at ensiling, so you may have to go through the trouble of measuring it if you really want to know your own figures.

Response from Co. Service Representative:, Subject: feed: weight of silage/haylage per yard?

Here are Compaction Benchmarking Goals as determined by Holmes and Muck research at University of Wisconsin. Data Deleted for Brevity.

Here is a link to a UW website that discusses weight of forage in a Forage box or truck (<http://www.uwex.edu/ces/crops/uwforage/ForageBox.htm>) Weight of silage coming *out* of the storage structure is dependant on compaction (weight of pack tractor and thickness of layer being packed), height of silage (gravity factor) and moisture ... If you are looking for densities coming *out of tower silos*, silo manufacturers are probably your best source of info. Here is a link to the International Silo Association (<http://www.silo.org/links.htm>) and a Good article from UW on managing tower silos (<http://bluto.uwex.edu/ces/crops/uwforage/ManagingTowerSilos.pdf>). Bag silage info can be found at http://bluto.uwex.edu/ces/crops/uwforage/sil_bag_cap.htm or by contacting bagger companies (<http://www.ag-bag.com/>) For densities coming *out of bunker silos*, a very general, ballpark value we use is 15lbs DM/cu ft for haylage, 18 lbs DM/cu ft for corn silage, 30 lbs DM/cu ft for high-moisture ear corn and 40 lbs DM/cu ft for high-moisture shelled corn. USDFRC researcher (and engineer by training) Dr. Rich Muck (<http://www.dfrc.wisc.edu/profiles/rem.html>) and UW engineer, Dr. Brian Holmes have reported on an extensive survey (http://www.dfrc.wisc.edu/RS98_pdfs/wwwpp28-29.pdf) of Wisconsin bunker silo densities. Haylage averaged 14.8 lbs DM/cu ft (but range was 6.6 to 27.1) and corn silage averaged 14.5 (range of 7.8 to 23.6). Given those ranges, now you know why folks are hesitant to throw out an average number for important factors such as calculating inventory. Here is another link to a bunker management poster from USDFRC (<http://www.dfrc.wisc.edu/cd/posters/bunkerSilo.pdf>)

At (company name omitted), we have developed a silage density probe and calculation spreadsheet that allows us to determine more specifically the density in our customer's storage structures. I do think direct measurement is the best approach. It also allows dairies to develop benchmarking standards to challenge or incent those packing our bunkers.

If direct measurement is not an option, here is another UW link that contains a decision aid to help you work plug in various factors to arrive at an estimated density (http://www.uwex.edu/ces/crops/uwforage/bunkdensity_master1-13-02.xls). At the recently 20th year anniversary of the USDFRC (<http://www.dfrc.ars.usda.gov/index.html>), I had an interesting conversation with Rich Muck regarding his silage density research. It proves that common sense is not always correct. Two examples....their data showed that dual wheels did not have a significant effect on densities. Secondly, we have always thought that the higher the moisture, the better the compaction. Their data (and some others too) shows just the opposite....the dryer the forage, the higher the density. Rich's explanation was that dryer forage particles are probably broken and crushed easier than more "flexible" higher-moisture particles (we have all witnessed the "sponge effect" with haylages). However, Rich was quick to point out to me that another important silage factor is at play....that of porosity. If silage gets too dry, you may have more lbs DM/cu ft but you also increase the porosity which allows more air to penetrate the forage mass and possibly predispose the silage to aerobic instability problems. I took Rich's equations and made a simple spreadsheet developed to calculate porosity. Send me a personal e-mail if you want it. Bottom line, stick with the general moisture recommendations that storage structure companies and Universities recommend and you should be OK

Response From W. Terry Howard, UW Madison Professor Emeritus

I was working on a feed budget this week and called Brian Holmes, University of Wisconsin Extension Ag Eng. for density information. Holmes uses 14 LB of dry matter per cubic foot. It has also been my experience that a density of 14 LB per cubic foot works out fairly well when projecting silage use rates. The dry matter density will drop somewhat as dry matter of the silage increases above 40-45%. You should not be ensiling forage above 45% dry matter as a usual practice due to the difficulty in getting a good pack.

Response from Consultant:

Several years ago, the Extension Service conducted a DM/cu ft study here in Eastern Wisconsin. Dr. Howard referred to Brian Holmes at the University of Wisconsin, if I recall Brian was involved in the study. Brian could fill in the things I don't remember accurately. Dr. Howard is correct with the 14#/cuft. But the study I am referring to demonstrated that the range is huge. My recollection was that DM per cu ft went up to the low 20#. I believe there to be some variability with the measuring technique used but I do believe there is big differences in the density of silage packs. The message I used with my clients is that the overhead in silage storage can be reduced by as much as 25% when silage and haylage is put up at the right moisture and chop length. Of more importance is the quality of the forage coming out of a properly managed bunker and less shrink of DM in the pile. Waste on the top of the pile is very minimal in properly packed forage.

Response from Univ. Assistant Scientist:

One must remember that dividing the dry matter per cubic foot gives the as fed amount per cubic foot. As you approach 18 LB dry matter per cubic foot you have made the 28% dry matter silage as dense as water, 62.5 LB/cubic foot. I have trouble believing that we can make silage denser than water.

Response from Univ. Assistant Scientist:

I am responding to a few recent messages on comparing types of storage ... I would like to share what I learned while trying to get a grip on what storage costs can be expected with different types of silage storage. Going through the literature, I found that different authors arrived at quite different numbers, which can be expected because different authors assumed different % shrinkage for the storage alternatives they compared. More confusing, however, was the fact that different authors made their comparison in quite different ways. The main problem was that one author, e.g., included nothing but principal and interest on the capital invested while another included some rule of thumb estimate for machinery/equipment maintenance in addition to the basic capital costs, a third author included estimated labor but excluded machinery operation costs during filling and unloading of silos etc. So, even if I managed to find half a dozen or so studies comparing the costs of bunkers, tower silos, and bagged silage - these studies were not comparable since they all differed in what they tried to measure (comparing apples and oranges). My way out of this dilemma was to find one study which clearly spelled out which costs were included in the estimate, and how these costs were derived. My hat off to Brian Holmes, professor and ag engineering extension specialist at University of Wisconsin-Madison. He actually tailored a spreadsheet software and made multiple estimates for different storage capacities (herd sizes). He included, I think, all the relevant costs that apply to storing silage from filling/packing through running a silo unloader or using a skidsteer to load a mixer wagon. This software is available at no cost. It is very useful when planning for new silage storage facilities, since you can plug in the exact costs or best estimates for any farmer's individual situation. The MS Excel format spreadsheet and it's documentation is available on the TEAM FORAGE website listed below: <http://www.uwex.edu/ces/crops/uwforage/h&s-fp.htm> A new and more user friendly

version of the spreadsheet will be posted at the website in the near future. Interested people can check in to see when that happens. According to Brian, users should like the new version a lot better. If you are interested in ready-made example comparisons of bunkers, stave silos, and bagged silage, you can view or download information materials from the website of the Dairy Profitability and Safety Project at the University of Wisconsin-Madison: <http://bse.wisc.edu/wi-dpsp/> Click on the highlighted area in the first text paragraph "...fact sheets and informational flyers..." and then make your choices: Flyer (2p.): Store Silage With Increased Profitability & Safety Fact sheet (about 10 p.): "Bagged Silage or Bunkers: Options for the Expanding Dairy Farm" Fact sheet (about 10 p.): "Bagged Silage or Tower Silos: Options for the Non-Expanding Dairy Farm" It should be noted that the cost estimates in these publications are based on the assumption that well managed silage can be stored with the following losses: Bunkers: 13%, Tower silos: 10%, Silage bags: 10%. In the case of bagging, this probably is erring on the conservative side, but we did not want to push the numbers, in the absence of independent documentation of lower storage losses achieved under field storage conditions. Experienced baggers with good management should be able to achieve lower storage losses. When interviewing feed preservation researchers some time ago, they estimated that ideal bag management may possibly reduce the storage losses to about 5%. We need new data about this! In the case of bunkers, the expected storage loss depends a great deal on what level of management is applied. If the bunker is not well packed, filled as quickly as possible and covered with plastic weighted down with tires, the storage loss may be considerably higher than the 13% we assumed. One can engage in an eternal debate on what should be the assumed level of storage loss when comparing storage alternatives. Instead of using our energy to define a non-existing "average" situation, let's concentrate on specific, individual investment situations. If you use the spreadsheet software, you can plug in whatever % shrink you and your advisor/s believe is realistic for your situation and management routines for each storage alternative you are considering.

Comments to Team Forage Webmaster

A comments request section was added to the Team Forage website. A summary of comments voluntarily submitted by users to the webmaster are listed here.

From General Manager of Seed/Supplies Co.

Seeing as I use this about 5 times per week, I felt it time to compliment you and others for all the informative and easy to find info contained on this site. For example, I just posted a response to a question on Dairy-L and I think I used 4 links to your website for the readers to find more info. Thanks again for the good work!

From Nutrition Consultant

The Team Forage web page is great. I am a dairy nutritionist. I use the information from Team Forage to help inform my clients about growing and harvesting high quality forages which will help improve the economics on their dairies. Thank you for Team Forage.

From Seed Co. Representative

I like this format and content. Excellent work!

From Veterinarian

As a veterinarian this is the place I send farmers to. I have printer off articles on everything from equipment setup to bunker management. Great job!

From Consultant

I consider this website to be one of the premier websites for forages. I visit it regularly to get new information. It's valuable to me in my work with dairy producers.

From Unknown Profession

Yes, the website is well worth the effort expended! This website is the best site available for specific technical information on forage issues. Thank you for the valuable information and keep it coming.

From Unknown Profession

FYI - The forages website is excellent - great information and great organization.

From Unknown Profession

This is a great site! This information about Alfalfa is very helpful for me. Thank You

From Dairyman

We really enjoy your website. It is our source for forage info. We have a large irrigated dairy in Montana thank you.

From a Product Manager

You folks are doing a great job! I have your site marked as a favorite and try to check it at least every other week for new ideas and research reports. I use much of your info. on forages -- especially on harvesting, silage management, silage density (we use Brian Holmes silage density probe idea and have several probes in use from IN to Maine, testing silage density in horizontal silos.) to train and to share with our dairy farmers in the NE U.S. Your site is very easy to use and I encourage our Dairy ...Consultants to use it to gather up-to-date information and to share this info. with the dairy farmers they work with. Although there are other university sites to access, your site seems to be the easiest to navigate through and find the information we are looking for. Continue to do the research and share it via your website and we will continue to learn. Thanks for the great site!!

From Forage Account Specialist

... I find a great deal of value from your website. I work for (employer omitted), Forage Account Specialist position. The information presented on your website is very valuable and timely for my particular needs. Hopefully, you will continue the time and effort into the website. Thank you,

Harvest and Storage Web Page Statistics

The tracking features of the website server were used to obtain information about user access to the Harvest and Storage page of the website. In 2000, the page was visited by users 1522 times and in 2001 the frequency nearly doubled to 2787 times. During that time, the top ten documents downloaded by users are presented in Table 3. These downloads do not reflect the number of times users may have viewed a document online.

Table 3. Top 10 documents downloaded from the Harvest and Storage web page.

Title	Downloads by Year	
	2000	2001
Management of Bunker Silos and Silage Piles	454	2572
Machinery Designs and Adjustments for Minimized Field Losses	175	840
Factors Affecting Bunker Silo Densities	595	807
Documentation for Bunker Silo Density Calculator Spreadsheet	133	566
Preventing Silage Storage Losses	331	1462
Choosing Forage Storage Facilities	88	687
Deciding on a Silage Storage Type	232	467
Documentation for Cost of Forage Storage Spreadsheet	301	425
Documentation for Bunker Silo Sizing Spreadsheet	258	428
Inoculants for Corn Silage	174	332
Total of Top 10 Downloads	2741	8586

CONCLUSIONS

A Harvest and Storage web page has been developed as part of a University of Wisconsin-Extension Team Forage website. The page was developed to provide Wisconsin-developed, research-based information to clientele interested in learning more about proper harvest and storage of forages to feed livestock. Several methods have been used to assess the value of information for the clientele. It appears as if many of the users find the information very useful and refer others to the web page when there is a need to learn more about harvesting and storing forage.