GRAIN PROCESSING – EQUIPMENT AND APPLICATION

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INTRODUCTION

Many research workers and livestock nutritionists have contributed to our understanding and application of feed processing for livestock. The machinery equipment industry has developed and modified grain-milling equipment to enhance feed production and feed handling. This gradual evolution has led to quite sophisticated systems for the processing of grain for beef and dairy cattle. Only a few of the highlights of the application and the changes in grain processing will be mentioned in this paper. It is impossible to credit all of the scientists and industry people that have contributed to our knowledge about grain processing. One recent review of the effect of processing applications on nutrient utilization by cattle is provided by an article in *Feedstuffs* (Owens, 2006).

REASONS FOR GRAIN PROCESSING CHANGES AT CATTLE FEEDLOTS

Cattle feeders are continuously upgrading their feed processing systems. Reasons for such changes in grain processing are attempts to: (1) increase speed of feeding, (2) improve material handling for efficiency and labor costs, (3) reduce purchased energy costs, (4) improve grain utilization, (5) reduce shrinkage from wind loss, and (5) attract customers with modern equipment (Sprague 2006).

PROCESSING EQUIPMENT USED

Gain processing equipment commonly used includes: (1) hammer mills and large capacity portable tub grinders, (2) roller mills whose rolls turn at the same speed for crimping and cracking/cutting dry grain, (3) roller mills with a differential drive so that one roll turns faster than the other to both cut and grind the grain, and (4) large diameter roller mills for steam flaking or crushing moist grain.

A TOTAL INTEGRATED APPLICATION SYSTEM

Processing of grain for cattle typically is only one-step or segment of totally integrated application feeding system. Specific steps inherent in the total feed handling system are: (1) selection of grain type and variety that will be impacted by the roughage program, (2) the grain receiving system, (3) the grain storage systems, (4) the pre-processing system (often used for moisture control), (5) the processing system and equipment required (each with unique opportunities and challenges), (6) the system for handling and storing processed grain, and finally (7) the feeding program that also differs depending on the target animal's diet (e.g., low roughage, high roughage and all concentrate.) In some cases, grain feeding is separated from grain processing to reduce investment by livestock producers that use smaller amounts of grain. For example, many feed mills will flake grain and deliver the dried processed grain to multiple dairies.

Various parts of a feeding system for cattle should be integrated with trade-offs to achieve the desired level and economics of livestock production. For example the process that leads to the most efficient grain utilization may not be the least costly when one considers the total system. Cost factors at each step will impact other decisions along the chain in order maximize each step's contribution. The economic law of diminishing returns also applies at each step.

All of the steps of the grain processing system offer unique opportunities to either assist in handling of grain or to improve feed conversion. One example is the development of rapid harvesting, efficient material handling and processing of high moisture (HM) grain with massive combines and trucks or wagons, front-end loaders, tub grinders, and roller mills. Equipment for steam flaking to improve feed conversion also can be massive, expensive, and quite labor-intensive.

THE GRAIN SOURCE AFFECTS APPLICATION OF GRAIN PROCESSING

The grain type (varieties or hybrids within each type) will impact the selection of a grain processing system. Corn may be processed in numerous ways including being fed whole (without processing). However, milo, barley and wheat must be processed to make full utilization of their energy and nutrients.

Characteristics of corn varieties ideal for ensiling as high moisture (HM) corn or for steam flaking may not be the same characteristics preferred for feeding as whole or dry rolled corn. For example, waxy corn, either processed or fed whole, proved useful for improving cattle performance at South Dakota State University (Pritchard and Bruns 2003). However, during steam flaking, waxy hybrids can form gelatinous sheets; adhering to and accumulating on the flaking rolls, these thickening sheets can abruptly halt the rolls of a steam flaker (Owens, personal communication). Corona, Owens, and Zinn (2006) concluded that "differences in corn vitreousness have an appreciable impact on the feeding of dry processed corn for feeding cattle. This effect is minimized by steam flaking." Galen Erickson and his co-workers at University of Nebraska's 2006 Beef Cattle Day compared soft with hard endosperm types of corn hybrids being fed as dry rolled or ensiled HM corn. They indicated that "Producers feeding corn as dry rolled corn (DRC) may want to consider selecting hybrids with larger softer kernels. If a more intense processing method is used such as high moisture ensiled, hybrid selection may not be as important." (Luebbe et.al 2006) Animal scientists at other research station, practicing animal nutritionist consultants, and cattle producers also have recognized this fact Indeed, many commercial feedlots with steam flakers reject loads of corn grain with low density (under 57 pounds per bushel) to avoid floury hybrids and maintain flake quality and consistency.

QUALITY OF GRAIN

Quality of the grain also can impact the preferred processing method. For example, light test weight sorghum grain may be better utilized as finely ground ensiled high moisture or as reconstituted HM grain rather than as steam flaked grain due to wide variation in berry size within a batch of grain that complicates efficient flaking of the mixture.

THE STORAGE OF IN-BOUND GRAIN

Ensiled HM grain stored in bunkers silos will be ground or rolled before it is stored. But when stored in oxygen limiting structures, HM grain often is stored whole (without processing) and rolled when is removed from the storage structure. Speed of processing can be important. For rolling or grinding grain for storage in bunker silos, grinding must be very rapid to keep up with the rapid speed of grain harvest. This requires very large capacity hammer mill grinders or multiple roller mills to ensile an entire year's grain within just a week or two.

One advantage of bunker over tower silos is the reduced energy cost of storage; grain does not need to be elevated into bunker silos. Removal of the HM grain at feed-out time is simple and rapid though caution must be exercised when working near the silage face to avoid being trapped with an avalanche of grain.

For grain to be dry or steam processed, inbound grain may be stored on the farm or at the mill before it is processed. In some cases, drying of incoming grain is required and bin aeration may become part of the grain handling system.

PRE-PROCESSING SYSTEMS

Before grain is physically processed, additional steps may be needed. They can include: (1) removing trash (larger particles) and metal, (2) sizing with screens, (3) adding moisture with or without tempering agents (Sindt et. al 2006), and (4) adding inoculants and mold or yeast control agents.

Removing trash, screening for size, and removing the fine particles and dust from grain can occur during grain delivery or immediately before the grain is processed. Removal of trash is a routine step in steam processing systems, but usually this trash is re-added to the flaked grain. In some cases, fine particles are not removed prior to steam flaking so that weed seeds present in the grain will be sterilized by the steaming process. Separating grain by kernel size, though ideal for steam flaking of sorghum grain, is rarely used. Sizing would be beneficial because small barley and wheat kernels and small sorghum grain berries, especially, are difficult to flatten with the flaking rolls; small berries or kernels often are not cut or ground with dry rolling flaking equipment. Thus, distribution in kernel size distribution may be more important than mean kernel size to obtain adequate and uniform processing of grain.

Moisture control can be used with all processing systems including dry rolling but becomes an essential step for moisture added systems such as HM operations and steam processing. Prior to flaking, moisture is added to speed and enhance processing of the grain.

Though moisture can be added as steam in the steam chamber associated with the flaker, water also can be added to the grain in steep tanks where grain is held for several hours prior to flaking. Uptake of water by grain is much more rapid from hot than from cold water. Tempering agents to speed water uptake often are used and other nutrients such as urea or chemical like calcium hydroxide can be added to grain at this point. For ensiled HM grain, the moisture content is particularly critical for proper fermentation of the ensiling process. The amounts of water required can be huge. For example, to increase one ton of grain from 29% to 30% moisture requires addition of 29 pounds of water. So in this case, nearly 1.5% of the initial grain weight must be added simply to add one point of moisture to the final product. For large operations that ensile 250,000 bushel in a 24 hour period, adding 1 point of moisture requires about 18 gallons of water per minute. To reconstitute this quantity of dry grain, increasing moisture from 15 to 30% require delivery of over 4.6 gallons of water per second.

Additives and inoculants often are added. Mold preventing chemicals and preservatives may be used for either dry grain or steam processed grain. Mold preventing agents can be added either when grain is received to be processed later or they can be added at the time of feeding to improve shelf life in the feed bunk. With grain flaked for dairy operations, preservatives usually are added after flaking to reduce the high energy costs associated with drying flakes.

DRY GRAIN PROCESSING SYSTEMS

Categories of dry processing include: (1) hammer mill grinding, (2) “burr” milling, (3) crimping/cracking (no differential grind), (4) dry rolling with a differential grinding action, (5) dry heat processing, (popping, micronizing, roasting,) (6) pelleting, (7) others (extruding, expanding).

The choice among methods of processing dry grain will depend on the grain and specific feeding and management factors. Finely processed grain may, if fed correctly, can yield better feed efficiency than coarsely cracked grain, particularly with sorghum grain.

Dry heat processing of sorghum, i.e., popping and micronizing, will improve feed efficiency, but the risk of mill fires has reduced commercial interest in these processing methods.

Pelleted grain is rarely used as the primary energy source in high energy rations, but pelleting is recommended for grain screenings to sterilize most of the weed seeds. Pelleted grain often is combined with medium or high protein ingredients to form receiving rations.

Finely hammer milled sorghum grain was demonstrated to be effectively processed by Bob Totusek at Oklahoma State University more than 50 years ago. Jack Freeman of Texoma, Oklahoma was successfully feeding dry hammer milled sorghum grain with corn silage in the 1960s.

Even though sorghum grain often is lower in cost than corn grain, most cattle feeders prefer corn because it has more consistent quality and it is easier and less costly (but more noisy) to process than sorghum grain.

In contrast with sorghum grain, finely ground or rolled corn is not recommended for high energy feedlot rations because an increased incidence of digestive disorders associated with rapid ruminal fermentation of fine corn particles that tend to separate during grain handling or in the feed bunk as well as the high palatability of corn grain. However finely processed dry corn can be fed quite successfully with a wet roughage or wet grain co-products such as distillers grain or corn gluten feed or when sufficiently diluted with roughage in diets for starting feedlot cattle or dairy cattle.

PARTICLE SIZE REDUCTION OF SORGHUM GRAIN WITH MULTIPLE STACK ROLLER MILLS

One important equipment innovation useful for dry grain processing of sorghum grain was the double and triple stack roller mill. John Brethour at the Hays Station of Kansas State University showed that finely rolled sorghum grain when processed with a double stack roller mill had 94% the value of corn (Brethour 1982; 1983). He recognized that cattle feeders and rancher in his area previously had been using roller mills with corrugations that were too coarse for grain sorghum processing (Brethour, 2006).
For dairy cattle, dry corn processed through multiple stack roller mills has been widely accepted (Burge 2006).

MOISTURE ADDED PROCESSING SYSTEMS

Most large feedlots process grain with added moisture. These systems include (1) steam rolling or crushing with minimum steam exposure, (2) steam flaking (cooling and drying systems may be added), (3) crushing with added water but without steam (often with tempering agents added).

Most moisture-added systems are steam flaking operations. Research with steam flaking has involved many researchers. In the early days, steam rolled barley and oats were used in the dairy and cattle feeding industry and this work stimulated adoption of this process for corn and milo.

The seminal research of feeding flaked corn was conducted at Michigan State University (Newland et al., 1950) and at University of Florida (Hentges, 1962). John Matsushima and co-workers, particularly Bob Montgomery and the late Donald Johnson at Colorado State University also were at the forefront of research with steamed flaked corn.

Bill (William) Hale and his team at the University of Arizona were the first to quantify and employ quality control standards for steam flaking and feeding sorghum grains. Because many California and Arizona feedyards already were feeding flaked barley, transition to flaked sorghum grain was primarily one of more extensive steam to ensure a flat flake with less than half of the original bulk density for sorghum grain (28 versus 56 pounds per bushel for USDA #2 sorghum grain).

RECENT FLAKED GRAIN RESEARCH

Since 1995, three groups have studied the factors that influence production and feeding of flaked corn. Richard Zinn and co-workers at the University of California have evaluated numerous quality control factors including processing mechanics (Zinn et al., 2002). The team at Kansas State University led by James Drouillard has focused on combinations of flaked corn with corn co-products, flake density, site of digestion, tempering agents, and moisture addition (Sindt et al., 2006), while research at Nebraska has evaluated kernel traits as it impacts the energy cost of flaking and digestibility (Harrelson et al., 2006).

ROLLER MILLS FOR FLAKING AND CRUSHING GRAIN

The original processing machines that were used for flaking or crushing of grain were modified from the roller mills used for wheat flour milling. Those rolls were 18 inches in diameter and 36 inches long. Today, most rolls are 24 x 56 inches and some very large mills use 32 x 68 inch rolls. Most instillations use 24 x 48 and 24 x 56 inch mills (Petrakos, 2006).

STEAM GENERATION

Steam generation equipment includes boilers and steam generators. “Marine” fire type boilers are the primary units for producing steam, however steam generators also are used. The “Vaporator®” system which injects both the steam and the exhaust gases from the steam generator into the steaming/conditioning chamber also was developed with exhaust gases helping to sterilize the grain.

A Clayton steam generator was used for producing the original flaked sorghum grain research by Hale at the University of Arizona. An up-to-date steam generator now is available from Clayton Industries (Clayton Industries 2006).

STEAM CHAMBER FOR MOISTURIZING GRAIN

Specialized steam chambers (“steam chests”) were developed by suppliers of milling equipment. Mounted above the roller mills, these chambers have evolved over time to reduce separation of grain flowing through the chamber and to insure proper moistening of the grain before it is steam rolled or flaked (Gearn, 2006; Petrakos, 2006).

HEAT AND MOISTURE REMOVAL FROM FLAKES

Flaked grain leaving the flaked can be pulled by draglines into bins for storage or delivery or vacuumed with an airlift system into storage. An airlift system cools the flakes and removes a slight amount of moisture. Removal of heat helps reduce starch retrogradation whereas moisture removal will permit longer-term flake storage and simplify handling. Cooling flakes for material handling reasons can use horizontal or vertical equipment modified from devices used for production of pelleted feed. Gearn Incorporated (Gearn, 2006) developed a system for cooling flakes for dairy and beef rations using perforated plates that allow air to flow through the flaked grain. Other cooling and dry equipment will pull water through a steam-heated radiator that warms the air that is blown through the flakes (Petrakos, 2006).

TEMPERING AGENTS AND MOISTURE CONTROL

With very dry grain, water usually is added to the grain before the grain is dry-rolled or flaked. Specialized moisture monitoring and control equipment has been developed that monitors moisture content of the grain and incorporates the proper amount of water into the grain to attain a specified moisture content before the grain is processed. Tempering agents may be included with water to speed uptake of moisture and improve "toughness" of the flakes. Some tempering agents also can improve utilization of the grain. Such agents usually are added with the specialized moisture control equipment and tempering agent suppliers often provide and maintain the application equipment. Often, grain processing is delayed for several hours after the grain is moistened to allow more moisture to be added and for moisture to penetrate more deeply into the grain. For addition of moisture for several hours before flaking, a "soak tank" or a "day tank" is used.

Three different types of tempering agents or their combinations are available. These include (1) acid based products, (2) plant extracts that are natural surfactants, and (3) biodegradable detergent type surfactants.

ENSILED HIGH MOISTURE PROCESSING SYSTEMS

Ensiled HM corn feeding to livestock was used initially in the farming areas of the United States and Canada; it probably evolved from the practice of soaking grains for "slopping" the hogs. Whole or ground corn was stored in tower silo or oxygen limited silos. This whole HM corn either was crushed with crimping roller mills before feeding or fed whole. Ear corn with or without the husk was ground and ensiled in open topped tower silos.

CATEGORIES OF HIGH MOISTURE GRAIN PROCESSING

There are several categories of high moisture grain. These include: (1) hammer mill ground and ensiled, (2) roller mill processed and ensiled, (3) ground or kernel processed high moisture ear corn with or without the husk (commonly called earlage), (5) whole grain stored in oxygen limited structures (corn and sorghum grain), (6) reconstituted whole grain stored in oxygen limiting structures (particularly sorghum grain), and (7) reconstituted ground or rolled grain stored in bunker silos (particularly sorghum grain).

EARLY RESEARCH: THE 1976 HIGH MOISTURE GRAIN SYMPOSIUM

A symposium that summarized the early research with high moisture grains was held at Oklahoma State University in July 1976 (Gill et. al, 1976) and is now available on the internet from OSU. Conference participants included many of the early research workers. Among these animal scientists was T. W. Perry from Purdue University and Jimmy Clark from the University of Illinois who studied HM corn for dairy cattle. Others included H. L. Self, Doug Ware and Rich Vetter from Iowa State University. Dr. Vetter later worked with the Harvestore® group. Wise Burroughs, H. L. Self and Mitch Geisler reviewed their research at the 1971 Iowa State University Grain Feeders Seminar. W. C. (Wally) Koers was one of the early researchers at the University of Nebraska. At the University of Minnesota, high moisture corn research was led by Dick Goodrich and Jay Meiske. While at Minnesota, John Thornton studied the effect of corn maturity on composition in classical research publications (Thornton 1969a and b). Individuals at Oklahoma State University including Don Wagner, Don Gill, Fred Owens and many others evaluated ground ensiled HM corn. The initial studies from OSU were published in 1968 by Jock Buchanan-Smith, Bob Totusek, and A. D. Tillman (Buchanan-Smith et. al 1968).

Two intriguing papers from the symposium included Ed Prigge's explanation of the importance of moisture content of ensiled HM corn (Prigge et al., 1976) and Jim Sprague's discussion of protein solubilization during the fermentation process (Sprague, 1976). Discussions about effects of moisture level on energy value and of particle size on fermentation and of storage time on protein solubility were presented by John Thornton (Thornton, 1976).

CONCLUSIONS FROM THE 1976 SYMPOSIUM…MOISTURE IS CRITICAL FOR ENSILED GRAIN

The consensus of speakers at the symposium was that ground ensiled HM corn must have adequate moisture (above 30%), be adequately processed for packing and feeding, can be stored in various structures (open top, bunker, or oxygen limited) with very limited weight loss, and has a feeding value for cattle superior to that of dry rolled or ground grain. Likewise with high moisture ensiled sorghum grain, moisture appears critical if one expects to dramatically improve energy and protein utilization when compared with dry sorghum grain.

MANAGEMENT CONSIDERATION FOR HARVEST, PROCESSING AND STORAGE HIGH MOISTURE GRAIN

Below is a list of processing and storing considerations for harvest and management to make high moisture grain ideal for feeding:

Ideal moisture content at harvest is over 30%. Speed during harvest and processing is necessary to obtain grain that is moist enough for proper storage and has a high feeding value. Holding high moisture corn overnight prior to storage allows aerobic yeasts to multiply; these germinate when re-exposed to oxygen during feeding and will increase the loss of readily available energy (oxidizing lactic acid) and cause the grain to heat.

Add moisture as needed. Note that 1.5 percentage of the weight of grain as water is needed to increase moisture content by 1%.

Particle size reduction for air exclusion during packing and to avoid air penetration into the silage face during feeding.

Narrow width of the bunker to match the feeding rate of grain's exposure to oxygen on the face of the bunker. This will prevent losses associated with volatiles and heating at the exposed surface of the bunker, particularly during warm months. Very wide silos often are split for feeding to decrease the time that the feeding face is exposed to air.

Prompt covering to prevent surface spoilage.

Detailed management from harvest to the feeding of HM grain.

COVERING ENSILED GRAIN

The surface covering of ensiled HM grain in bunker silos has gradually evolved. Methods include:

- A thick layer of ensiled silage
- A layer of silage covered by plastic sheets weighted with tires
- Plastic sheets placed directly on the silage covered with wet hay silage
- White or black plastic sheets only, held with tires (or clean soil with soil removed when grain is removed from the bunker.) White plastic, though typically slightly more expensive and often thicker than black plastic, reduces heat uptake from solar radiation and has a lower rate of deterioration than black plastic sheets. Thicker, oxygen excluding covers and even edible coverings have been developed that can reduce surface losses from silage bunkers even further.

RECONSTITUTION OF GRAIN

The early research concerning reconstitution of sorghum grain was reviewed by Ray Hinders at the 1976 High Moisture Grain Symposium (Hinders, 1976). His review indicated that if adequate moisture was added at reconstitution, the product had feed efficiency, starch digestibility, and protein digestibility that were superior to dry processed sorghum grain.

Later, quality control of reconstituted sorghum grain was studied in four experiments that were summarized at the University of Arizona Cattle Feeders Day in 1982 by Bill Hale and his colleagues (Hale et al., 1982; Prouty et al., 1982; Prouty, 1983). For reconstitution, water was added to dry sorghum grain in a two-step process to bring moisture content of the grain up to 30%; this was allowed to ferment in an oxygen-limiting structure (Harvestore®) for 20 to 30 days. (With a single step wetting process, sorghum grain will expand. Expansion of reconstituted sorghum has caused oxygen limiting upright structures to split open!) Before feeding, the grain was crushed with a large roller mill. These trials demonstrated that reconstituted sorghum grain produced a feed efficiency comparable to steam flaked sorghum grain (Prouty, 2006). Because many believed that the benefits associated with reconstitution were due to berry changes during the germination process, sorghum was stored whole, and to avoid spoilage of whole grain, oxygen-limiting structures were considered to be required to produce reconstituted grain.

LATE HARVESTED SORGHUM GRAIN WITH WATER ADDED

Prior to harvest, grain remaining on the plant is much more exposed with sorghum than with corn grain. Hence, sorghum grain dries faster. This shortens the time window for harvest at an ideal moisture content. The short harvest time window for harvesting sorghum grain at the proper moisture level has reduced commercial interest in production of high moisture sorghum grain. However, water can be added readily to dry ground grain after harvest. Ground, moistened sorghum grain packed into storage will ferment but, being ground, such grain will not germinate. A processing method similar to reconstitution but with ground sorghum grain was developed by cattle feeders in Colorado and Kansas. Late harvested sorghum grain (15 to 30% moisture) is processed with a roller mills (with differential speed rolls to produce a grinding action). Water is added to the ground grain as it is ground to attain a moisture content of over 30% moisture, preferably 35% moisture. The processed grain is stored in bunker silos covered with plastic sheets. Tested at the Garden City Experiment Station of Kansas State University by Huck and others (Huck et al., 1999), this processing method produced feed efficiencies equal to that for steam flaked corn (Huck, 2007).

EQUIPMENT FOR HANDLING PROCESSED GRAIN

The equipment for physically handling of processed grain has evolved with time to alleviate problems ("bridging" in bins) associated with the low bulk density of processed grains.

Dry processed grain can be stored in flat storage, in overhead bins, or in "live bottom" bins until it is fed. However, steam flaked grains typically are conveyed to bulk flat storage or into specially designed "live bottom" bins. The methods used for handling flaked grain include: (1) belt or auger conveyers to move flakes into flat storage, (2) conveying with vacuum "airlifts" into live bottom bins, and (3) producing the flakes at an elevated level so that flakes dropping directly into flat storage. Care should be taken in handling processed grain to avoid separation of fine particles. Separation can alter moisture and nutrient composition of the product.

FEEDING AND MANAGEMENT IMPACTS PROCESSING APPLICATIONS

The preferred grain processing system will be impacted by several aspects of the feeding programs. These include (1) the roughage source, level, and moisture content, (2) availability of wet grain co-products that will add moisture and reduce separation of fine particles, and (3) the bunk management strategy that will alter feed bunk residence time and thereby influence its potential to spoil.

Dry roughages work well with fermented grains. Silages and wet grain co-products, such as distillers grains, help with mixing and enhance palatability of rations with dry processed grains. With moist ingredients included in the diet, a finer particle sizes will be tolerated and can be used to increase digestibility and feed efficiency.

Two animal nutritionists that pioneered the art and science of bunk management are Bob Lake of the Hitch Industries of Oklahoma and Kansas (Lake, 1976) and John Thornton, a feedlot consultant formerly with Hitch's Garden City operation. Proper feed mixing and handling is one of the primary training activities of consulting nutritionists and feedlot management people, and training and supervision of the employees that call bunks and deliver feed to the cattle is critical to achieve optimum feed intake by the cattle.

SPECIAL GRAIN PROCESSING EQUIPMENT

The manufacturers of feed processing equipment have developed custom products and techniques to improve grain processing. These include:

- Special configuration of hammers and screens for hammer mills and tub grinders.
- Roller mill corrugation specifications (lands and groves) are available from 4 to 12 per inch and various surface cuts (the Stevens and the Deep V cut being the most common for flaking corn grain).
- In-line moisture control equipment.
- Large diameter roller mills with greater nip for flaking grain.
- Specially designed large capacity and tall steam chambers for moisturizing grain.
- Heat and moisture removal equipment for steam flaked grain.

SPECIAL PRE-PROCESSING TREATMENTS

- Scarification machines to damage the pericarp of sorghum grain and speed water uptake before flaking was tested but is no longer being used.
- Coarsely cracking corn followed by steam rolling.
- Moisture conditioning augers used at pellet mills are now used to moisten grain prior to steam flaking.
- The use of "day tanks" or bins for temporary storage of grain for moisture uptake before the grain is flaked.
- In-line moisture monitoring with automatic controls for moisture additions.
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IMPLICATIONS

Research and experience by university and industry animal scientists as well as innovative consultants and producers have developed sophisticated methods and equipment for processing grain for feeding beef and dairy cattle.

The reasons why livestock operators might alter their grain processing systems are attempts to (1) increase speed of feeding, (2) improve material handling for efficiency and worker safety, (3) reduce the cost of purchased energy, (4) improve grain utilization, (5) reduce costs for maintenance (e.g., re-surfacing flaker rolls) and for personnel, (6) reduce shrinkage from wind loss, and (7) attract customers with modern efficient equipment to minimize livestock production costs. Although grain processing and handling equipment often represent an immense physical and financial investment, every progressive feedlot manager and consultant will monitor their operations and equipment and will alter their diet and grain processing method when economic advantages dictate. Changes are more frequent when feedlots expand or when grain prices change abruptly. Innovation and change is why every feedlot has a "junk yard" for used equipment and a "dead file" filled with logical ideas that did not work.

Utilization of energy from grain can be increased by more extensive grain processing when coupled with the appropriate management of the feeding program. However, grain processing is only one segment of a livestock production system that must be totally integrated financially. The economic balance between feed utilization and the cost of feed processing usually will dictate when changes in grain processing methods are needed and should occur.

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