INTRODUCTION
Cereal grains generally are the primary source of energy in feedlot diets. Availability of energy from the grain depends largely on the type of grain used as well as processing of that grain (Owens et al., 1997). A variety of grain processing techniques are used including grinding, steam flaking, and compounding high moisture corn to ferment. Each processing method differs in its nutritional efficacy (Owens et al., 1997) and each has a unique associated cost (Macken et al., 2006). For grain processing to be effective, a positive balance between processing equipment and maintenance costs, labor availability and skill level, energy efficiency, cattle management practices, and cattle performance must be achieved.

Depending on the size of the feedlot and the type and availability of feedstuffs, simply rolling or grinding grain can be the most effective processing technique to improve nutrient utilization and cattle performance. Four basic physical principles are involved with grinding or particle size reduction. These are: (1) Compression; (2) Impact; (3) Attrition; and (4) Shear. Most grinding equipment employs a combination of these principles that ultimately defines the equipment’s suitability for certain situations. The two most common types of grinders used in the cattle feeding industry today are hammermills and roller mills. These same two processing methods are used to process high moisture corn into storage and to roll steamed corn to produce steam flaked or steam rolled corn. Hammermills primarily grind by impact and attrition whereas roller mills utilize shear and compression to reduce particle size. Consequently, both grinder-types have positive and negative attributes depending on the situation. The purpose of this paper is to review hammermills and roller mills and to discuss the factors that influence the efficiency of hammermill and roller mill operation.

HAMMERMILLS
Hammermills consist of a rotor assembly made from two or more rotor plates fixed to a main shaft and enclosed in a screened grinding chamber (Heiman, 2005; Figure 1).

Figure 1. Illustration of a hammermill (Heiman, 2005).
Numerous grinding chamber designs exist including a half circle, a full circle, a teardrop and a split screen. Hammers, either fixed or free-swinging, are attached to the rotor assembly. As the rotor assembly rotates, the hammers impact and consequently shatter the feed. Because hammermills grind primarily by impact, a minimum critical "tip speed" is needed to provide the needed energy to shatter the feed in the grinding chamber. Hammermills generally operate at a tip speed of 17,000 to 25,000 ft/minute; a mill with a small diameter mill must turn at a higher RPM than a mill with a large diameter mill to obtain the same tip speed.

The size of the screen hole size has the greatest influence on the particle size of the product. The screen prevents the ground feed from leaving the grinding chamber until it reaches an appropriate size. In split screen designs, screens with smaller holes are placed the "down" side while screens with larger holes are on the "up" side.

Modern hammermills become much more efficient when an “air assist” system is added. An "air assist" places the grinding chamber under negative pressure so that air flows through the screen with the ground feed. This increases throughput reduces the heat retained within the grinding chamber. Most mills can be retrofitted with an air assist system, but it must be designed and installed properly to be effective. Some modification to the mill may be needed to direct air into the grinding chamber.

ROLLER MILLS

The design of a roller mill varies considerably depending upon its application. Roller mills are often named for the work they do—such as crackers, crimpers, crimp-crackers, flakers, crumblers, grinders, crushers, and, more simply, just rollers. This illustrates the great versatility of roller mills. Roller mills can consist of a single, double, or triple pair of rolls that are stacked and enclosed in a steel frame (Figure 2).

Feed passing between the rolls is sheared and compressed to reduce the particle size depending on the speed differential between the rolls. The greater the differential in speed of the rollers, the greater the shear force that is applied to the feed. A feeder roll ahead of the grinding rolls regulates the feed rate and drops the product evenly into the nip of the rolls where the product size is reduced. The rolls are usually grooved or corrugated and driven by belts connected to an electric motor. The rolls turn about...
600 RPM. Alterations in roll grooving and machine design can make the roller mill useful in a very wide range of work requirements.

HAMMERMILL AND ROLLER MILL DIFFERENCES

In general, either grinder performs well with common grains including corn, grain sorghum, or wheat depending on their moisture content. However, roller mills do not grind fibrous materials efficiently; therefore, they are not typically used for finely grinding oats, barley, or other fibrous grains or ingredients. Grain moisture content will dramatically affect either mill. With more moisture, the endosperm of grain becomes elastic and absorbs the impact or crushing energy by deforming rather than shattering. Excessive moisture in hammermill ground grain can result in high heat due to friction and, because of the heat, moisture will be lost. A rollermill with differential speed of the rolls can generally handle high moisture grain more readily than a hammermill depending on the particle size desired.

A roller mill produces a less dusty, product that is more uniform in particle size than a hammermill does. This is because the product is crushed and sheared rather than shattered by impact. Impact grinding often results in excessive amounts of fine particles and dust, particularly with wheat and with very dry grain (<11% moisture).

Roller mills often are considered to be more energy efficient than hammermills. This statement must be qualified depending upon the target particle size. Roller mills are extremely efficient for producing a product with a large particle sizes (+1800 microns); however, as product size is reduced, energy consumption (or electrical efficiency) of the two types of mills becomes nearly equal when the target particle size is 600 microns or below. So depending upon the target particle size, energy efficiency may or may not be an important criterion for selecting a mill type.

Generally, roller mills are higher in cost than a hammermill with equal capacity; however, when the total installation cost is considered, cost of the two mills can be comparable. Hammermills usually require a larger, more expensive motor, a switch gear, and controls, an air assist system, and more elaborate noise abatement. Hence, the installed cost for either system usually is comparable.

Generally, hammermills produce particles with more spherical shape whereas roller mills produce particles with a cubic shape. After a kernel shatters in a hammermill, abrasion rounds off the sharp edges of the particle; this makes the particle more spherical and results in more dust generation. It seems unlikely that particle shape will influence on animal performance, but grain handling and mixing can be changed dramatically. For example, the bulk density of roller mill ground grain typically is lower (by about 5%) than hammermill ground grain of similar mean particle size. This can affect volumetric proportioning operations as with a portable grinder-mixer. In addition, the mixer can be overloaded (if batch weight is not adjusted) that this reduces the efficiency of the mixer.

Roller mill ground grain does not mix with vitamins, drugs, and minerals as readily as hammermill ground grain. This likely is due to the shape of the particle. This may increase the amount of power required for mixing. Again, this likely is due to the differences in flow characteristics of cubic versus round shaped particles. These areas need additional research before definitive quantitative recommendations can be made.

CONCLUSION

Depending on the size of the feedlot and the type and availability of feedstuffs, rolling or grinding of grains both can be effective processing technique to improve nutrient utilization and cattle performance. The two common types of grinding systems used by the cattle feeding industry today are hammermills and roller mills. Both grinder-types have positive and negative attributes depending on the situation and application. Roller mills are most appropriate for cereal grains being ground to a larger particle size. However, the roller mill is more versatile and can be modified for application to a wide range of feeds and particle sizes and shapes. Hammermills are more suitable for grinding fibrous material or when grain is being ground to a very fine particle size.
LITERATURE CITED