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Title: Evaluation of Wet Brewers' Grain Ensiled with Low Quality Forages.

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James R. Males

Two experiments were conducted to evaluate the use of wet brewers' grain (WBG) alone and with straw so it can be used as part of the sole ration for ruminants. In Exp. 1, WBG was ensiled alone and was mixed with one of two straws, wheat or tall fescue grass seed, at 20% (20:80), 30% (30:70), and 40% (40:60) WBG (dry matter basis), respectively. Final mixtures were brought to 65% moisture content with water. Treatments were replicated three times. Treatments were thoroughly mixed, vacuum sealed, and ensiled for 30 days. After ensiling, bags were opened and measured for pH. Samples were freeze dried and analyzed for: ethanol, ammonia–N, lactic acid, acetic acid, propionic acid, butyric acid, and proximate analysis. Compared to the straw silage treatments, pH was lower ($P<0.01$) for WBG. Wet brewers' grain was higher ($P<0.01$) in CP than straw silage treatments as expected. Across straw treatments, CP was lower than expected. Ethanol production was high ($P<0.05$) for WBG versus straw treatments. Ammonia-N was higher ($P<0.05$) in WBG when compared to straw treatments. Acetic acid in WBG was higher ($P<0.05$) versus straw treatments. Wheat straw was lower ($P<0.05$) in acetic acid, lactic acid, and total acids than grass seed straw. Lactic acid in WBG versus straw treatments showed no difference ($P>0.30$). In Exp. 2, 30:70 WBG/straw was mixed and allowed to ensile for a minimum of 45 days. Water was added to bring moisture to a

desired content of 65%. Twelve Polypay X Suffolk X Dorset wethers (49 ± 3 kg BW) were used in a random complete block design to evaluate digestibility of ensiled WBG and 30% WBG to 70% Fescue grass seed straw silage. Wethers were blocked by weight and assigned randomly to one of three treatments (**TRT**). The TRT were **CON** -limit fed canola meal with ad libitum access to tall fescue grass seed straw, **WBG**- limit fed ensiled WBG with ad libitum access to tall fescue grass seed straw, and **SIL**- ad libitum 30% WBG/70% Tall Fescue grass seed straw silage. Dry matter intake was higher for CON vs. WBG ($P<0.01$) and vs. SIL ($P<0.01$). No difference in DMI was detected between WBG vs. SIL ($P>0.24$). The CON group consumed 1.18 kg/day as compared to WBG at .84 kg/day and SIL at .96 kg/day. Straw intake was affected by consumption of supplements, CON vs. WBG ($P=0.06$). No differences were detected in OM, NDF and ADF disappearance ($P>0.27$). There was no difference ($P>0.24$) in comparing CON (45.62%) vs. WBG (53.88%) and CON (45.62%) vs. SIL (41.70%) for CP disappearance. The ensiling of 30:70 WBG/straw silage for use as an alternative feedstuff proved effective for use in feeding of beef cattle or sheep.

Keywords: Wet brewers' grain, Straw silage, By-products

Evaluation of Wet Brewers' Grain Ensiled with Low Quality Forages

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CONTRIBUTION OF AUTHORS

Rogue Brewery donated the wet brewers' grain used for this study. Mark Keller assisted with collection of wet brewers' grain and laboratory analysis. Tom Nichols provided crossbred wethers and facilities. Dr. Males assisted with experimental design and data interpretation. Dr. Jim Thompson assisted in experimental design. Dr. Patrick French assisted with data interpretation. Dr. Chad Mueller assisted with data interpretation. Tessa Maggiulli assisted with sample collection in the digestion trials.

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Introduction

Wet brewers' grain (WBG) has been used as a livestock feed since the production of the first beer which is around 800 B.C. (Chandler, 1991). Traditionally it has been and still is today fed within the dairy industry as a protein supplement. Brewers' grain is produced from food-grade quality products that have been subjected to extensive heating for extended periods of time.

Within the state of Oregon, there were 49 brewing companies, operating 69 brewing facilities, and producing 591,000 barrels of beer in 2004 (Oregon Brewers Guild, 2005). In 2004, there was a 7% growth in the production of the microbrewery industry nationally (Brewers' Association, 2005). Along with this increase in production, there is an increasing amount of WBG available. This supply of WBG is also inconsistent with the months of May through August being high production months and the winter months low in production.

Wet brewers' grain is a high moisture feedstuff, ranging from 75-80% moisture, and is approximately 26% crude protein (CP) on a dry matter (DM) basis (Chandler, 1991). Wet brewers' grain is high in neutral detergent fiber (NDF) content and low in starch content therefore there is less energy loss through ruminal methane production in comparison to high starch feeds (McDonald et al., 1995). Variation within brewers' grain does exists between breweries due to differences attributed to the type of beer produced (Harrison, 1996).

Wet brewers' grain is normally fed fresh, but can be ensiled. The use of WBG as a feed ingredient has developed in areas close to breweries in livestock operations with high feed turnover such as dairies and feedlots. This is due to freight and handling costs.

When ensiling, the quality of silage can be improved by adding a readily fermentable carbohydrate source, such as molasses, that will accelerate the ensiling process and result in more acid production and more stable silage (AFRIS, 2005). Research has been conducted on the ensiling of straight WBG (Harrison, 1996). Little is known about WBG in mixed silages along with its efficacy in current production systems. European research evaluated the effects of absorbents to reduce WBG effluent loss, with straw being the most absorbent but resulting in a reduction of straw digestibility (Harrison, 1996).

A high amount of grass seed straw is produced in the Pacific Northwest. In 1999, approximately 900,000 tons of grass seed straw were available in Oregon (86%), Washington (8%) and Idaho (6%). Approximately 486,000 acres of harvested grass seed in 2004 was part of Oregon's economy (Oregon Agricultural Statistics Service, 2003-2004). It is a commonly harvested forage fed throughout the Willamette Valley. Grass seed straw is typically around 4-7% CP (Bohnert et al., 2003). Producers also use low quality forages such as wheat straw or barley straw (CP <3%).

The objectives of this study were to achieve a cost-effective, locally available feed to benefit producers and formulate nutritionally adequate silage to be used as a total mixed ration (TMR) for beef cattle or sheep.

Review of the Literature

The Ruminant Animal

The ruminant animal is an animal or a group of animals that are even-toed, hooved animals that ruminate. Rumination is the process of regurgitating previously chewed feed, in the form of bolus or cud (a soft mass of coarse feed particles), and chewing the cud (further masticate it). The word ruminant comes from the Latin word *ruminare* and means to chew over again (Church and Pond, 1974). The ruminant species currently make a very large and vast contribution to man's welfare from the primary forms of meat, milk, and fiber to secondary contributions of pharmaceuticals, plastics, etc. The ruminant species has also contributed greatly to development of man and countries throughout history in terms of work, recreation, and entertainment. There are 155 to 165 ruminant species currently in existence (Van Soest, 1994).

The Ruminant Stomach

The digestive system of the ruminant differs to that of the monogastric animal. The main differences between the groups are anatomically; the ruminant has evolved a four compartment stomach or fore gut that houses the principal site for microbial fermentation while a monogastric or simple stomach animal uses the hind gut for the principal site of microbial fermentation; example the cecum and colon of a horse (Church and Pond, 1974). The four compartments of the ruminant stomach can be broken down

by physiological function and anatomical differences. The four compartments that make up the fore gut are referred to as the reticulum, rumen, omasum, and abomasum.

The first compartment of the fore gut is the reticulum, which is then followed by the rumen. Some consider this to be one organ known as the reticulorumen. There is a partial separation between the compartments, the reticuloruminal fold. This fold allows for free passage or exchange of ruminal contents between the two compartments (Van Soest, 1994). The reticulum lining has small compartments similar to a honeycomb. The main function of the reticulum is to interact with the rumen to initiate the mixing activity and to provide an additional area for microbial fermentation. The reticulum is also the principal site of the accumulation of foreign objects such as hardware due to its proximity to cardia and its generally ventral position (Van Soest, 1994). The cardia is the terminal end of the esophagus, which is at the juncture between the reticulum and rumen (Church and Pond, 1974; Van Soest, 1994).

The rumen is lined with numerous papillae or finger like projections to increase ruminal surface area. The three compartments of forestomach (rumen, reticulum, and omasum) all originate from the same embryological tissue. These organs are lined with nonglandular, non-mucus producing, keratinized stratified squamous epithelial tissue. The forestomach is recognized as the major site of digestion.

In the forestomach, ingested feed materials are soaked with digestive secretions and subjected to digestion by the microbes. The reticulorumen is a large fermentation vat where anaerobic microbes thrive and breakdown roughages and concentrates to obtain nutrients for their and the host animal's use, a symbiotic relationship. The microbial fermentation leads mainly to the production and absorption of volatile fatty acids (VFA)

and ammonia (Fahey and Berger, 1988; Owens and Goetsch, 1988; Van Soest, 1994). The microbes are bacteria, protozoa, fungi, and arachea. Researchers have discovered over 250 species of bacteria in the rumen, which makes up roughly 60-90% of the total rumen microbial biomass (Van Soest, 1994). Bacteria can be divided into classifications of: amylolytic, cellulolytic, proteolytic, acetogens, methanogens, lipolytic, and saccharolytic. Protozoa are second in total microbial biomass at 10-40% (Van Soest, 1994). There are over 100 species that have been identified. Protozoa act primarily in the digestion of starch or sugar. They also act as a predator of ruminal bacteria. Fungi are present in the rumen at 5-10% and are primarily involved in fiber digestion. Three species of arachea were recently discovered in the rumen and are believed to be involved in methane production.

Ruminants have the ability to ingest or consume large volumes of course, poor quality forages. Rumination gives the ability to further utilize these low-quality forages. Rumination occurs as a result of the stimulation of course material against the rumen wall, this is known as the *scratch factor*. The scratch factor is related to both particle size and diet cell wall content. This further mechanical breakdown of ingesta into smaller particles allows more microbial surface area attachment.

The third compartment of the forestomach and foregut is the omasum. This organ is characterized by the presence of a large number of leaves and is spherical or ovoid in shape. The leaves or many plies are believed to help with absorption of some water and nutrients, while acting as a barrier to prevent the passage of large digesta particles. The omasum pumps digesta directly from the reticulum to the abomasum (Rucklebrush, 1988; Van Soest, 1994). Van Soest suggests that the omasum is believed to be an absorption

site for VFAs (40-69%), water at 30-60%, sodium, potassium and other ions. The omasum may be less important in its absorptive role for smaller ruminant species such as sheep and goats.

The fourth compartment of the fore gut is the abomasum. The abomasum has a homologous function to that of the glandular stomach in monogastric species. It is divided into a cardiac region near the omasal entrance, the fundus which is the main part of abomasum, and antrum near the pylorus. The antrum is the generally acid secreting area with the upper part being non-acid secreting (Van Soest, 1994). When VFAs and lactic acid are present in the abomasum, they cause the stimulation of gastric juice secretion. This is in contrast to non-ruminants who are stimulated by cephalic stimuli.

Ruminal Fermentation

Feedstuffs after consumption undergo degradation first in the rumen via ruminal fermentation. This fermentation occurs in a microbial environment that is void of oxygen (anaerobic). This fermentation of feedstuffs or conversion of feedstuffs leads to the production of various components. The useful components are VFA, microbial protein, and B Vitamins. Non useful items such as methane (CH_4), CO_2, and nitrate are also produced. As suggested by Owens and Goetsch (1988), ruminal fermentation must be considered as an independent function of the needs of the host ruminant for maximal efficiency of feed utilization. The host animal does have control over factors such as feed intake; they do not have complete control over the symbiotic relationship that is maintained with rumen microbes and fermentation environment.

Ruminal pH is the first and foremost factor that will affect fermentation and digestion. For ideal ruminal pH, conditions need to vary between 5.5 and 7.2. The lower value of 5.5 is for high concentrate diets and more amylolytic microbes. In diets that maintain a high portion of fiber and require a large presence of cellulolytic bacteria, a pH of 6.0 and above is acceptable with 6.7 being the most desired. Salivary buffering helps in maintaining normal pH, but is not the main source of buffering. Feedstuffs present a buffering capacity. Forages are known to offer a buffering capacity due to the plant cell wall having a cation exchange capacity (Van Soest, 1994). Fluctuations in ruminal pH have been shown to reflect changes in the quantities of organic acids that accumulate in the ingesta and the amount of saliva that is produced (Church and Pond, 1974).

Ruminal Volatile Fatty Acids

The main end product of the microbial fermentation in the rumen is VFAs. This is the ruminant animal major source of metabolizable energy. Owens and Goetsch (1988) state that 50-85% of metabolizable energy utilized by ruminants consuming forage-based diets come from VFA production. It has been estimated that 76% of ruminal VFA was absorbed in the rumen, 19% in the omasum and abomasum, and 5% passing on through to the small intestine.

At normal pH (5.5-7.2), VFAs are present in small amounts in the free acid form. VFAs are readily absorbed across the rumen wall by passive transport. The proportion of free acid results in lower pH and higher concentration of VFA. Blood pH is ordinarily more basic than the rumen, therefore favoring movement of acid toward the blood. The gradient similarly discourages the flow of the fatty acid anion. This proves the rumen pH

influences rates of VFA absorption (Van Soest, 1994). A high rumen pH narrows the gradient of rumen to blood and increases the fatty acid anion absorption. It has been demonstrated that absorption of VFAs (pH 6.6) decreased as chain length of acid increased. There was more rapid absorption of VFAs with a lower pH of 5.0-5.5 than at pH of 7.5-8.0 (Church, 1975).

Wet Brewers' Grain

Brewers' grain (BG) is a by product of the beer-brewing industry and have been used as a livestock feed since almost the time of the first beer, which is around 800 B.C. (Chandler, 1991). Brewers' grain mainly consists of barley, but there may be some corn and/or rice depending on the processor.

Brewers' grains are a concentrated source of digestible fiber (NDF), a high moisture feedstuff that is around 75-80% moisture, and are high in CP at approximately 26% (DM basis) (Chandler, 1991). There is special emphasis directed towards the mineral balance in diets containing brewers' grains due to high phosphorus content and being low in most other minerals. There is lower energy loss from the rumen as methane when brewers' grains are fed as compared to high starch feeds such as corn and oats. This is due to the brewers' grain being high in NDF content and the starch being heavily fermented (McDonald et al., 1995). Variation in brewers' grain does exist between breweries due to differences attributed to the type of beer produced (Harrison, 1996). Wet brewers' grain has been shown to have a superior amino acid balance to soybean meal (Cozzi and Polan, 1994).

Milling

The first step in the brewing process is milling. Malted Barley and other specialty malted grains are crushed into grist (slightly smaller than kernel width) in the grist mill. Milling the grains opens them to allow maximum conversion or hydration of starches for the extraction of fermentable sugars.

Mashing

Mashing is the brewer's term for the hot water steeping process which hydrates the grist, activates the malt enzymes, and converts the grain starches into fermentable sugars through the process of saccharification. This fermentable sugar is known in brewer's term as wort, German for "sweet liquid". There are several key enzyme groups, primarily alpha and beta amylase, that take part in the conversion of the grain starches to sugars.

The temperature most often quoted for mashing is about 67.2°C (Lewis and Young, 1995). This is a compromise between the two temperatures that the two enzymes favor. Alpha works best at 67.7-72.2°C, while beta is denatured at that temperature. Beta converts at a steadier rate between 55.0-65.6°C. A lower mash temperature, less than or equal to 65.6°C, yields a thinner bodied, drier beer. A higher mash temperature, greater than or equal to 68.9°C, yields a less fermentable, sweeter beer (Palmer, 1999).

Beta amylase is favored by a low wort pH, about 5.0. Alpha is favored by a higher pH, about 5.7. However, a beta-optimum wort is not a very fermentable wort, leaving a

lot of amylopectin starch unconverted; alpha amylase is needed to break up the larger chains so beta can work on them (Palmer, 1999).

The grist/water ratio is another factor influencing the performance of the mash. A thinner mash of >2 quarts of water per pound of grain dilutes the relative concentration of the enzymes, slowing the conversion, but ultimately leads to a more fermentable mash because the enzymes are not inhibited by a high concentration of sugars. A thick mash of <1.25 quarts of water per pound is better for protein breakdown, and results in a faster overall starch conversion, but the resultant sugars are less fermentable and will result in a sweeter beer (Lewis and Young, 1995). A thicker mash is gentler to the enzymes because of the lower heat capacity of grain compared to water. A thick mash is better because the enzymes are not denatured as quickly by a rise in temperature (Palmer, 1999).

Time is another factor in the mash performance. Starch conversion may be complete in only 30 minutes, so that during the remainder of a 60 minute mash, the brewer is working the mash conditions to produce the desired profile of wort sugars. Depending on the mash pH, water ratio and temperature, the time required to complete the mash can vary from under 30 minutes to over 90. At a higher temperature, a thicker mash and a higher pH, the alpha amylase is favored and starch conversion will be complete in 30 minutes or less. Longer times at these conditions will allow the beta amylase time to breakdown more of the longer sugars into shorter ones, resulting in a more fermentable wort, but these alpha-favoring conditions are deactivating the beta; such a mash is self-limiting.

Lauter Turn

Lautering is the method most brewers use to separate the sweet wort from the mash. A lauter turn consists of a large vessel to hold the mash and a false bottom or manifold to allow the wort to drain out and leave the grain behind.

Wet brewers' grain is basically sterile material when it leaves the brewery. The material is produced from grains that are food-grade quality that have been subjected to extensive heating for extended periods of time. This heating serves two purposes, one being increased palatability and the other is the establishment of high levels of bypass proteins (Stengel, 1991).

Beer Production

There were approximately 209,922,000 barrels of beer produced in 2004 throughout the United States (Brewers' Association, 2005). This number includes all major breweries (Anheuser – Busch, Coors, and Miller) and all the numerous micro breweries. The number of microbreweries or craft brewing has increased production to 6,590,000 barrels of microbrew in 2004 compared to 6,200,000 barrels produced in 2003 or a 7% growth in production (Brewers' Association, 2005).

Within the state of Oregon, there are 49 brewing companies, operating 69 brewing facilities in 2004 and producing 591,000 barrels of beer. That is equal to 1.18 million kegs or 195 million bottles of beer. The Oregon brewing industry accounts for $2.24 billion of Oregon's economy (Oregon Brewers Guild, 2005).

Feeding of Wet Brewers' Grain

Brewers' grain comes marketed in two forms to ruminants; wet brewers' grain (WBG) or dry brewers' grain (DBG). Dried brewers' grain is easy to store due to low moisture content but drying leads to additional cost. Dried brewers' grain is very bulky, not very palatable, and requires more time for cows to consume. Dhiman et al. (2003) reported no difference in feed intake, fat corrected milk yield, milk composition, and feed consumption when comparing DBG vs. WBG at 15% of dietary dry matter. Swain and Armentano (1994) reported similar results when comparing DBG as nonforage fiber source to alfalfa hay. Dhiman et al. (2003) reported a cost analysis of the average price of DBG vs. WBG from July 2001 to June 2002 with $145.30 and $96.90/metric ton DM. Using WBG instead of DBG will save $49/metric ton minus the difference in storage cost.

Wet brewers' grain was added to dairy rations to decrease forage NDF while simultaneously decreasing nonfiber carbohydrate concentration (Firkins et al., 2002). As a replacement of forage NDF, there were no differences in DMI and lactation performance with increasing WBG in diet as described by Firkins et al. in 2002. Younker et al. (1998) reported reduced DMI when replacing concentrate with DBG, but no difference when replacing forage. When feeding WBG to replace concentrate, it has been shown to depress dry matter intake (DMI) when fed at high amounts of 30-40% of the ration in dairy cows (Davis et al., 1983; Murdock et al., 1981; Porter and Conrad, 1975). In hot, humid weather, West et al. (1994) found no difference in DMI and milk yield with treatments of 15% and 30% WBG.

Yebou (1977) reported higher weight gains in crossbred weaned heifers that were supplemented with 2 lbs per day of WBG per animal while grazing vs. control group of regular grazing animals during the dry (6.9 vs. 32.6 lbs.) and wet (21.1 vs. 46.5 lbs.) seasons in Ghana. Crickenberger and Johnson (1982) evaluated WBG as feed source for growing Angus heifers and found that WBG when mixed with corn silage resulted in higher average daily gain than conventional corn silage with no supplement.

Ojowi et al. (1997) compared WBG vs. a canola based control diet and found WBG had no negative effect on feedlot performance and marbling score, but there was less intermuscluar and subcutaneous fat. Shand et al. (1997) found that there is no difference in subcutaneous fat, marbling score, and longissimus area; raw proximate composition of moisture (%), fat (%), and pH, and fatty acid composition when feeding WBG vs. conventional barley based diet in feedlot cattle.

Ensiling of Wet Brewers' Grain

Wet brewers' grain is normally fed fresh, but can be ensiled. The use of WBG as a feed ingredient has developed in areas close to breweries. The movement of WBG is limited to around 200 miles due to freight cost and handling. Wet brewers' grain is very palatable. The dairy industry and beef feedlots are the primary outlets of WBG with fast feed turnover. Depending on time of year and weather, WBG can be stored fresh for 7-14 days.

Ensiling of WBG has been noted as far back as 1955 by Dijkstra, who ensiled 110 ton quantities of WBG in waterproof concrete silos (to prevent effluent loss) and in a pit silo and stored them for nine months prior to conducting digestibility trials. Mean

digestibility coefficients for silo and pit ensiled WBG were: organic matter 65 and 55%; CP, 51 and 38%. The WBG stored in the concrete silo was of better quality, having less butyric acid, and losses of digestible crude protein (12 vs. 30%) and starch equivalent (14 vs. 31%) were less. This clearly establishes the value of the effluent and the need to prevent loss.

Addition of short-term preservatives to fresh WBG was reported by Allen et al. (1975b). They added 85% formic acid at .20 % and .40%; propionic acid and formic-propionic mixture (1:1) at .20, .30, and .40%; and molasses at 2.00%. The two rates of formic acid and high rate of propionic acid were effective in reducing subsurface deterioration but unable to reduce the amount of surface spoilage. The .40% formic-propionic acid mixture reduced effectively all deterioration to maintain quality material.

When ensiling, the quality of silage can be improved by adding a readily fermentable carbohydrate source, such as molasses, that will accelerate the ensiling process and result in more acid production and more stable silage (AFRIS, 2005). Ensiling characteristics can be improved by blending WBG prior to ensiling with other material that is high in dry matter content, such as straws, beet pulp, bran, and hulls. There has been considerable research in Europe evaluating the effect of absorbents to reduce the loss of effluent from WBG. Of the nine absorbents experimented, straw was shown to absorb more effluent than all other materials used. The digestibility of the straw/WBG was the lowest of the nine materials (Harrison, 1996).

Schnieder et al. (1995) found that addition of microbial inoculants, beet pulp, or propionic acid to WBG was beneficial in promoting a more efficient fermentation during long term storage but limited results for short term storage. The addition of lactic acid

bacteria (LAB) in ensiling WBG clearly showed beneficial effects by a faster pH decline, increased concentration of lactate, and decreased concentrations of acetate and butyrate (Schnieder et al., 1995). Allen et al. (1975a) sampled WBG in lauter turn and in holding tanks and found that there is lactobacillus , which is responsible for lactic acid production, were not present in the lauter turn but were evident in holding tanks. Therefore the addition of LAB would satisfy the ensiling of WBG.

Ensiling of WBG with dried and fresh barley straw was reported by Ridla and Uchida (1994). They reported that increasing proportions of WBG improved fermentation as shown by higher lactic acid production and lower pH levels. Crude protein increased and all fibrous components decreased with increasing proportions of WBG. Silage digestibility increased as a result of increasing proportions of WBG. These results are supported by the suggestions that when carbohydrate-rich materials (molasses, sugars, starches such as cereal grains, potatoes) are mixed with the forages that they stimulate fermentation and result in accelerated growth of LAB.

Grass Seed Straw

Grass Seed production and history

The soil type for the southern half of the Willamette Valley consists of poorly drained clay soils while the northern half has well-drained, rich, loamy soils that are ideal for grain, fruit, vegetables, and nursery stock. In the 1920's, it was suggested that grass seed production be an alternative crop for southern valley farmers (Young and Barker, 1997). It was believed that this viable agricultural product could withstand the southern

valley's poorly drained clay soils. This has since resulted in a steady increase in grass seed production.

Grass seed production of cool-season forages and turf-type grasses is important to the agricultural economy of Oregon and the Pacific Northwest. Mild, moist winters and dry summers in the Willamette Valley have contributed to making Oregon the major producer of the grass seed crops of perennial ryegrass, annual ryegrass, tall fescue, orchardgrass, and Kentucky bluegrass. Approximately 486,000 acres of harvested grass seed in 2004 was part of Oregon's economy (Oregon Agricultural Statistics Service, 2003-2004). Oregon now accounts for 100% of U.S. bentgrass production, 87.2% of U.S. ryegrass seed production, 82.7% of U.S. orchardgrass production, 66.2% of U.S. fescue production, and 26.3% of U.S. Kentucky bluegrass production (Oregon Agricultural Statistics Service, 2003-2004).

Straw Disposal

A by-product of grass seed production is straw. Bohnert et al. (2003) stated that approximately 900,000 tons of grass seed straw were available in 1999 in Oregon (86%), Washington (8%), and Idaho (6%). The traditional method of grass seed straw disposal is open field burning. Straw burning was developed in 1948 in an effort to control the spreading of blind seed disease in perennial ryegrass (Hardison, 1964). These efforts led to the adoption of open field burning as the most common practice of straw disposal and disease control (Hardison, 1964; Conklin and Bradshaw, 1971; Bohnert et al., 2003; Fisher, 2003). The large amount of smoke produced has caused environmental impact and created dangerous/fatal scenarios to humans (Fisher, 2003). This has resulted in

legislation that has and will restrict open field burning and required alternative management of grass seed straw disposal.

Alternative disposal of Grass Seed Straw

There have been several ways investigated for alternative means of straw disposal. One technique is to flail chop the straw residue and return it into the soil, but there are concerns being expressed regarding disease proliferation. Some grass seed producers compost the straw residue and market it as a soil conditioner (Edgar, 1996). It has been marketed as a mulch to berry farms, Christmas tree farms, mushroom producers, and vineyards (Bohnert et al., 2003). The Oregon Department of Transportation annually utilizes straw residue as soil erosion preventative at construction sites. It has been used for alternative uses of paper production and insulation board. But concern over the stability of supply has hampered progress in this direction (Conklin et al., 1989). Other research has been reported evaluating grass seed straw as an alternative fuel source; however this has proved to be cost prohibitive (Conklin et al., 1989). An alternative method of straw disposal is the use of grass seed straw as a forage source for ruminants.

Straw and the ruminant animal

The ruminant animal and the rumen microbial population can utilize low-quality forage sources if used with proper nutritional management. Straw is a major feed source for ruminants in Third World countries (Van Soest, 1994), but in the United States, it is estimated that less than 1% of total straw supply is used as a forage source (Han, 1978). The current major market of grass seed straw as a ruminant feed source is exporting to

the Pacific Rim, primarily Japan, Korea, and Taiwan. These countries imported 613,175 tons of Oregon's grass seed straw during the 2002-2003 market year (Bohnert et al., 2003). Grass seed straw has potential as an alternative to traditional sources of low-quality forages such as meadow hay, cornstalks, etc. that are used to maintain cow herds in the U.S. and Canada requiring harvested or stockpiled forage for extended periods of time (Bohnert et al., 2003).

Grass seed straw is nutritionally comparable to meadow hays in CP and is higher in CP then cereal grain straws. Grass seed straw does differ in CP content among straw species, with Kentucky bluegrass being the highest at 7.0% and annual ryegrass being low at 4.0% (Bohnert et al., 2003). When feeding grass seed straw as a major portion of the diet, it can be fed to non-lactating, mature cows. But protein supplementation is required for beef cattle in high nutrient requirement production stages to meet CP requirements. Protein is the first limiting and most beneficial nutrient to supplement with grass seed straw diets. A protein deficiency can occur and severely depress animal performance and productivity if the animal's and ruminal microbes' requirements for protein are not met. Protein supplementation of grass seed straws less then 5% CP can increase total intake and digestibility of nutrients when ruminants are consuming high portions of grass seed straw in diets (Horney et al., 1996, Bohnert et al., 2003).

Silage

Silage may be defined as fermented forage plants. It is a feedstuff produced by the fermentation of a crop, forage, or agricultural byproduct of greater then 50% moisture

content. Silage is commonly a beef or dairy feed and is used as part of the roughage portion of the diet. Silage making is less weather dependent when compared to hay making, is suited better for large scale livestock operations such as dairies and feedlots, and can be adapted to a wide range of crops (corn, sorghum, grass, etc.).

Silage dates back to about 2000 B.C. Columbus found that American Indians used pits or trenches to store grain. A Frenchman, Auguste Goffart, was awarded a Cross of the Legion of Honor by the French government for his discovery of preserving forage in a silo. He later published a book based upon his experiences with corn silage (Bolsen et al., 2005). In 2002, there were more then 125,000 million tons of silage made with corn (U.S. Department of Agriculture – National Agricultural Statistics Service, 2002). The amount of silage being produced has and is steadily increasing due to the expense of haymaking.

Ensiling Process

The ensiling process refers to the changes that take place when a forage or feed with sufficient moisture to cause fermentation is stored with the absence of air. This process is governed by three factors. The first is the chemical composition of the plant material, second is the amount of air trapped or allowed to enter the biomass, and third the activity of the bacterial population (Ensminger et al., 1990). The ensiling process can be broken into four phases: 1) aerobic 2) anaerobic 3) stable and 4) feedout. The ensiling process requires two to three weeks to complete.

Aerobic

This is the phase where respiration and proteolysis occur. During respiration, the plant enzymes and aerobic bacteria breakdown plant sugars and respire oxygen, producing carbon dioxide, water, and heat. Plant proteases simultaneously degrade proteins primarily into amino acids and ammonia (McDonald et al., 1995). The oxygen supply is depleted in 4-5 hours while carbon dioxide accumulates for 48 hours. The temperature of the ensiled material should increase over a period of 15 days (Ensminger et al., 1990).

The loss of sugar is the key to silage preservation. Sugar is the principal substrate for LAB to produce acids to preserve the silage. Excessive heat production can result in the Browning/Maillard reaction. This occurs when heat causes the carbohydrates to combine with protein and form an insoluble product. This reaction can reduce digestibility of protein and energy sources.

Anaerobic

This phase is the fermentation stage, which lasts seven to twenty one days. Once all oxygen is removed, anaerobic bacteria start to multiply and grow at high rates. The main types of bacteria growing are acid-forming and proteolytic. The most important of these anaerobic bacteria are LAB, because forages are preserved by lactic acid. Other microorganisms such as yeasts and molds, clostridial spores, and members of the family *Enterobacteraceae*, compete with LAB for fermentable carbohydrates and their end products have no preservation action (Woolford, 1984). When pH levels are between 5-7, enterobacteria, yeasts, and clostridial spores will grow and effect silage quality. Clostidial

spores can cause secondary fermentation and convert sugar and organic acids to butyric acids. This results in losses in DM and energy. When forages are ensiled at moisture levels between 55-75%, active fermentation occurs more rapidly (7 to 14 days). At this point, LAB fermentation has concluded due to a pH drop below 4.0-4.2 stopping growth or lack of sugars for fermentation (Ensminger et al., 1990; Bolson et al., 2005).

Stable

When pH has reached a level of 4.2 or lower, all active fermentation will cease. This the stable phase. If stored properly, with no air introduction into silage, it can be kept for years with little biological activity. If fermentation ceased due to a lack of sugar availability, the hemicellulose sugars can be fermented, causing a slower rate of pH decline (Bolson et al., 2005).

If there is oxygen permeability of the silage, this can cause aerobic microorganisms to proliferate and affect silage quality. Populations of yeasts and molds will increase and lead to losses in silage DM and nutrients, and heating will occur.

Feedout

When opening the silage for feeding, oxygen access to silage can lead to the same conditions as during oxygen infiltration during the stable phase. The loss of DM and other nutrients can occur because aerobic microorganisms will consume sugars, fermentation products (lactic and acetic acids) and other soluble nutrients in the silage (McDonald et al., 1995).

Proper silage face and silo management can minimize losses that occur during the feedout phase. A fast filling rate, adequate packing, and tight sealing minimize the build up of aerobic bacteria in silage and the distance that oxygen can penetrate the exposed silage. Also feeding rate and silage density determine length of time the silage is exposed to oxygen (Bolson et al., 2005).

Conclusion

With a growth rate of 7.2% in new microbreweries through out the U.S. in 2004, there are going to be high amounts of brewers' grain available to livestock operations for feed. With this growth there is a new supply of brewers' grain that is inconsistent in amount. With majority of brewing being heavy from May through July and also in the winter months, this brings forth the problem of how to make the byproduct feed available to beef producers who only need it for certain times of the year. The focus of this research was to make wet brewers' grain an option to beef producers by ensiling wet brewers' grain with locally available forages such as straws (i.e. grass seed straw) to formulate a total mixed ration that is cost effective and nutritionally adequate for feeding to beef cows.

Evaluation of Wet Brewers' Grain Ensiled with Low Quality Forages

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Abstract

Two experiments were conducted to evaluate the use of wet brewers' grain (WBG) alone and with straw so it can be used as part of the sole ration for ruminants. In Exp. 1, WBG was ensiled alone and was mixed with one of two straws, wheat or tall fescue grass seed, at 20% (20:80), 30% (30:70), and 40% (40:60) WBG (dry matter basis), respectively. Final mixtures were brought to 65% moisture content with water. Treatments were replicated three times. Treatments were thoroughly mixed, vacuum sealed, and ensiled for 30 days. After ensiling, bags were opened and measured for pH. Samples were freeze dried and analyzed for: ethanol, ammonia–N, lactic acid, acetic acid, propionic acid, butyric acid, and proximate analysis. Compared to the straw silage treatments, pH was lower ($P<0.01$) for WBG. Wet brewers' grain was higher ($P<0.01$) in CP than straw silage treatments as expected. Across straw treatments, CP was lower than expected. Ethanol production was high ($P<0.05$) for WBG versus straw treatments. Ammonia-N was higher ($P<0.05$) in WBG when compared to straw treatments. Acetic acid in WBG was higher ($P<0.05$) versus straw treatments. Wheat straw was lower ($P<0.05$) in acetic acid, lactic acid, and total acids than grass seed straw. Lactic acid in WBG versus straw treatments showed no difference ($P>0.30$). In Exp. 2, 30:70 WBG/straw was mixed and

allowed to ensile for a minimum of 45 days. Water was added to bring moisture to a desired content of 65%. Twelve Polypay X Suffolk X Dorset wethers (49 ± 3 kg BW) were used in a random complete block design to evaluate digestibility of ensiled WBG and 30% WBG to 70% Fescue grass seed straw silage. Wethers were blocked by weight and assigned randomly to one of three treatments (**TRT**). The TRT were **CON** -limit fed canola meal with ad libitum access to tall fescue grass seed straw, **WBG**- limit fed ensiled WBG with ad libitum access to tall fescue grass seed straw, and **SIL**- ad libitum 30% WBG/70% Tall Fescue grass seed straw silage. Dry matter intake was higher for CON vs. WBG ($P<0.01$) and vs. SIL ($P<0.01$). No difference in DMI was detected between WBG vs. SIL ($P>0.24$). The CON group consumed 1.18 kg/day as compared to WBG at .84 kg/day and SIL at .96 kg/day. Straw intake was affected by consumption of supplement, CON vs. WBG ($P=0.06$). No differences were detected in OM, NDF and ADF disappearance ($P>0.27$). There was no difference ($P>0.24$) in comparing CON (45.62%) vs. WBG (53.88%) and CON (45.62%) vs. SIL (41.70%) for CP disappearance. The ensiling of 30:70 WBG/straw silage for use as an alternative feedstuff proved effective for use in feeding of beef cattle or sheep.

Keywords: Wet brewers' grain, Straw silage, By-products

Introduction

Wet brewers' grain (WBG) has been used as a livestock feed for protein supplementation since the production of the first beer, which is around 800 B.C.

(Chandler, 1991). Brewers' grain is produced from food-grade quality products that have been subjected to extensive heating for extended periods of time during the mashing process. Wet brewers' grain is high in NDF, a high moisture feedstuff ranging from 75-80% moisture, and is approximately 26% CP on a DM basis (Chandler, 1991).

In 2004, there was a 7% growth in the production of the microbrewery industry nationally (Brewers Association, 2005). Along with this increase in production, there is increasing amount of WBG available. However, this supply of WBG is inconsistent with the months of May through August being high production months and the winter months being low in production (Schneider et al., 1995).

Wet brewers' grain is normally fed fresh, but can be ensiled. The use of WBG as a feed ingredient has developed in areas close to breweries with high feed turnover such as dairies and feedlots. Research has mainly been conducted on the ensiling of straight WBG (Harrison, 1996). Little is known about WBG in mixed silages along with its efficacy in current production systems. European research has evaluated the effects of absorbents to reduce effluent loss, with straw being the most absorbent but resulting in a reduction of straw digestibility (Harrison, 1996).

A large amount of grass seed straw is produced in the Pacific Northwest. In 1999, approximately 900,000 tons of grass seed straw was produced in Oregon (86%), Washington (8%) and Idaho (6%). It is a commonly harvested forage fed throughout the Willamette Valley in Oregon and its use would increase if nutrient value is improved. Grass seed straw is typically around 4-7% CP (Bohnert et al., 2003). Producers also use lower quality forages such as wheat straw for beef cattle.

Materials and Methods

Experiment 1: Silage Trial

Experimental Design

Wet brewers' grain (WBG) was collected on April 15th, 2004 from Rogue Brewery in Newport, OR. The WBG was ensiled alone and was also mixed with one of two straw treatments (TRT), wheat and tall fescue, at 20% (20:80), 30% (30:70), and 40% (40:60) WBG on a dry matter basis, respectively. The feedstuffs were thoroughly mixed in each respective treatment by use of the Uebler® mixer (Table 1). Water was added to bring desired moisture content to 65%. Each silage treatment (3 replicates) was randomly assigned to one of twenty one bags; which had been altered to measure internal temperature using thermocouples (Omega Engineering, Stamford, CT), and gas production throughout the ensiling process. Each bag contained 2.3-6.8 kg (DM Basis) of the assigned silage treatment with the heavier bags being 100% WBG and the lighter bags being silage mixtures. Bags were then vacuum and heat sealed (Foodsaver, Tilia Inc., San Francisco, CA) to ensure complete oxygen removal and to provide an anaerobic environment to begin the ensiling process. Over the first 5 days, temperature and gas production were monitored at 8 hour intervals. After that period, temperature was monitored every 24 hours for the remainder of the 30 day period.

Table 1. Feedstuff composition in silage trial(DM Basis)

Item	DM, %	CP, %	NDF, %	ADF, %
Fescue straw	88.0	8.1	66.5	35.6
Wheat straw	88.3	3.1	75.0	44.1
WBG	20.4	26.3	52.0	22.0

Analytical Procedures

At the end of 30 days of ensiling, bags were opened and the pH was determined. Fifty grams of wet sample was homogenized with 100 mL of deionized water for 5 min in a laboratory blender (Waring Blender 700, New Hartford, CN) and pH was measured. The remaining silage from each bag was freeze dried (Freeze Dyer, Virinits Co., NY) and stored (-12° C) for later analysis. Thawed silage was prepared for fermentation analysis by adding 250 g of distilled water to 30 g of silage and homogenization for 5 min in a laboratory blender (Waring Blender 700, New Hartford, CN). The silage was analyzed for ethanol, lactic acid, acetic acid, propionic acid, and butyric acid by gas chromography (Hewlett Packard 5890, with a Carbopack column, oven temperature at 220° C, injector and detector temperature at 175° C, and helium gas as carrier gas; Horney et al, 1996). Total acids were computed as the sum of lactic acid and volatile fatty acids. Ammonia-N was measured by a phenol hypochlorite assay as described by Broderick and Kang (1980) with the use of UV spectrometer. All silages were analyzed for DM (AOAC, 1990). Crude protein content was determined by the Kjeldahl method (Buchi 322, Brinkman, Switzerland). Neutral detergent fiber (Robertson and Van Soest, 1981) and acid detergent fiber (Goering and Van Soest, 1970) were analyzed using procedures modified for use in an Ankom 200 Fiber Analyzer (Ankom Co., Fairport NY). Soluble protein was determined for WBG by borate-phosphate buffer as described by Licitra et al. (1996).

Statistical Analysis

Data were analyzed as a completely randomized design using the PROC Mixed procedure of SAS (SAS Inst. Inc., Cary, NC). The model included all replications, treatment, straw type, percentages, and straw type X percentage interaction. Preplanned contrasts were used to compare treatment means: 1) linear effect of WBG vs. Grass & Wheat; 2) linear effect of straw type and percentage; 3) quadratic effect of straw type and percentage.

Experiment 2: Digestion Trial

Experimental Design

Silage was made on January 14th, 2005 using a 30% WBG to 70% tall fescue grass seed straw mixture (DM Basis). Water was added to bring moisture to a desired content of 65%. Feedstuffs were thoroughly mixed using a vertical mixer (502 NDE Vertical Mixer, Sioux Falls, SD). Silage and 100% WBG were packed and stored in Rubbermaid containers until the start of feeding trial on March 4th of 2005.

Twelve Polypay X Suffolk X Dorset wethers (49 ± 3 kg BW) were used in a random complete block design to evaluate digestibility of ensiled WBG and 30% WBG to 70% Fescue grass seed straw silage. Wethers were blocked by weight and assigned randomly to one of three treatments (**TRT).** The TRT were **CON** -limit fed canola meal with ad libitum access to tall fescue grass seed straw, **WBG**- limit fed ensiled WBG with ad libitum access to tall fescue grass seed straw, and **SIL**- ad libitum 30% WBG/70% Tall Fescue grass seed straw silage (Table 2). Canola meal and WBG were fed at isonitrogenous level to that of the silage treatment. Animals were housed in individual

pens (1.2 X 1.3 m) within an enclosed barn. Each wether had ad libitum access to fresh water and trace mineralized salt (≥8.00% Ca, 6.00% P, ≥ 33.50% NaCl, 2.70% Mg, 60 ppm Co, 210 ppm I, 1350 ppm Fe, 1700 ppm Mn, 200 ppm Se, 7700 ppm Zn, 256000 I.U./lb. vitamin A, 32000 I.U./lb. vitamin D, 56 I.U./lb. vitamin E). Tall Fescue straw was provided at 110% of previous day intake at 0730, with feed refusals from previous day determined before feeding.

Table 2. Feedstuff composition in digestion trial (DM Basis)

Item	DM, %	CP, %	NDF, %	ADF, %
WBG	22.54	22.52	45.35	15.59
Canola Meal	91.90	26.11	30.33	18.93
Fescue Straw	88.90	6.44	52.81	29.60
30:70 Silage	44.08	10.51	58.09	32.60

Sample Collection and Analysis

The experimental period was 21 d, with the first 14 d used as an adaptation period. Intake and orts of all treatments were monitored throughout the trial, however official measurements for intake were taken d 15 through d 20 and orts were taken d 16 through d 21. Samples (approximately 100g) of WBG, straw, canola, and 30/70 silage were collected on d 15 through d 20 and composited by animal. Ort samples were collected and a sub sample obtained (10% wet weight) on d 16 through d 21. Silage and WBG, intake and ort samples, were freeze dried (Freeze Dyer, Virinits Co., NY) and reweighed for calculation of DM. All samples were ground to pass a 1-mm screen in a Wiley mill.

Intake sub samples of silage and ensiled WBG were stored (-12° C) for later analysis of ammonia-N and VFA. The pH was determined by homogenizing 50 g of wet

sample with 100 mL of deionized water for 5 min in a laboratory blender (Waring Blender 700, New Hartford, CN) and pH was measured. Thawed silage and WBG were prepared for fermentation analysis by adding 180 g of distilled water to 20 g of TRT and homogenized for 5 min in laboratory blender (Waring Blender 700, New Hartford, CN). The silage and WBG were analyzed for ethanol, lactic acid, acetic acid, propionic acid, and butyric acid by gas chromography as described in Experiment 1. Total acids were computed as the sum of lactic acid and volatile fatty acids. Ammonia-N was measured by a phenol hypochlorite assay as described by Broderick and Kang (1980) with the use of UV spectrometer.

Wethers were fitted with fecal bags at 0700 on d16. Bags were emptied once daily at 700. Feces were weighed, and hand mixed with a 10% sub-sample (wet weight) collected. Sub samples were weighed, dried for approximately 24h at 55° C, reweighed for DM. Sub samples were then ground through 1-mm screen in Wiley mill and compositied by wether.

All ground feed, orts, and fecal samples were analyzed for DM and OM (AOAC, 1990). Crude protein content was determined by the Kjeldahl method (Buchi 322, Brinkman, Switzerland). Neutral Detergent Fiber (Robertson and Van Soest, 1981) and acid detergent fiber (Goering and Van Soest, 1970) were analyzed using procedures modified for use in an Ankom 200 Fiber Analyzer (Ankom Co., Fairport NY).

Statistical analysis

Data were analyzed as a randomized complete block design using the PROC GLM procedure of SAS (SAS Inst. Inc., Cary, NC). The model included wether, TRT,

and block. Preplanned contrasts were used to compare treatment means: 1) linear effect of WBG vs. canola; 2) linear effect of canola vs. silage; 3) linear effect of WBG vs. silage. Experimental protocols for this study were approved by the Oregon State University Institutional Animal Care and Use Committee.

Results and Discussion

Experiment 1: Silage Trial

Wet Brewers' Grain vs. Straw Silage Treatments

Wet Brewers' Grain had lower DM (18.8%) than straw silage treatments (39.6%; P<0.01; Table 3). Neutral Detergent Fiber was lower (P<0.01; Table 3) in ensiled WBG (52.3%) as compared to straw silage treatments (66.8%). Acid Detergent Fiber content displayed the same trend as NDF, with ensiled WBG lower at 24.1% versus the straw silage treatments at 38.5% (P<0.01; Table 3). As expected, WBG (28.3%) was higher (P<0.01) in CP compared to straw silage treatments at 8.5% (Table 3). There was no soluble protein detected in WBG.

Table 3. Chemical Composition of ensiled wet brewers' grain (WBG) vs. WBG/Straw silages

Diet	DM (%)	CP (%)	NDF (%)	ADF (%)
WBG	18.75 [c]	28.30 [c]	52.30 [c]	24.08 [c]
Straw Treatments [a]	39.59 [d]	8.50 [d]	66.77 [d]	38.49 [d]
SEM [b]	2.86	0.54	0.99	0.68

[a] Mean of six WBG/Straw Treatments
[b] SEM, Standard Error of difference of the least square means
[c,d] Means within a column without common superscript differ $P < 0.05$

Ensiled Wet Brewers' Grain was higher ($P<0.05$) in ammonia-N, ethanol, and acetic acid (Table 4). This could be due to additional fermentation of residual starch in the WBG and variability of fermentation in the straw silage treatments. The lactic: acetic ratio was lower for WBG at 7.66% vs. the straw silage treatments at 11.29% ($P<0.01$, Table 4). Wet brewers' grain was lower ($P<0.01$) in pH (Table 4). Schneider et al. (1995) reported pH was lower for the control of ensiled WBG with no additives by day 57 of ensiling as compared to additive treatments such as LAB and preservative propionic acid. Allen and Stevenson (1975a) reported lower pH and increased lactic acid production over the first 10 days of ensiling when comparing WBG with no additives to WBG with additives. After day 10, they reported decreased lactic acid production and an increase in butyric acid and ammonia-N. This lead to no control of secondary fermentation and resulted in poor quality silage. The additions of a carbohydrate source such as molasses or a preservative formic acid can help in control of secondary fermentation by encouraging LAB growth and causing a drop in pH. The natural buffering capacity of straw silage treatments may have contributed to higher pH compared to WBG (3.88 vs. 3.49). There were no differences ($P>0.30$) in lactic acid production comparing WBG (7.10%) to straw silage treatments (7.96%; Table 4). Schneider et al. (1995) reported lactic acid production was higher for control ensiled WBG (1.11%) vs. additive treatments of LAB (.29%) and propionic acid (.61%) through day 90 with the treatment of LAB + hemicellulase enzymes being the only non-significant difference (.94 %). Total acid production was not different ($P>0.70$, Table 4) for WBG (8.52%) vs. straw

Table 4. Fermentation Analysis of ensiled wet brewers' grain (WBG) vs. WBG/straw silages [a]

Diet	pH	Ammonia-N, ppm	Ethanol, %	Acetic Acid, %	Lactic Acid, %	Lactic:Acetic Ratio	Total Acids, %
WBG	3.49 [d]	601.8 [d]	6.02 [d]	0.93 [d]	7.10 [d]	7.66 [c]	8.52 [d]
Straw Treatments [b]	3.88 [e]	346.4 [e]	0.91 [e]	0.69 [e]	7.96 [d]	11.29 [d]	8.65 [d]
SEM [c]	0.07	31.39	0.25	0.07	0.77	1.11	0.81

[a] Based on Dry Matter Basis

[b] Means of six WBG/Straw Treatments

[c] SEM, Standard Error of difference of the least square means

[d,e] Means without common superscript differ $P < 0.05$

silage treatments (8.65%). This is a result of lactic acid production being the primary acid produced and therefore influencing total acid profiles. Butyric acid was only detectable in WBG at 0.13%. A low level of butyric acid production leads to a better quality silage. Propionic acid was greater ($P<0.05$) for WBG versus straw silage treatments (0.09 vs. 0.01%). There was temperature probe error and malfunction due to insufficient contact of the probe with silage which resulted in the inability to measure differences in silage temperature.

Straw Silage Treatments

Dry matter content of straw silages resulted in a straw type x percentage interaction ($P<0.05$) and a quadratic effect ($P<0.05$, Table 5). This can be credited to less water absorption of the 20:80 WBG/wheat. The 20:80 WBG/wheat is believed to have the greatest natural buffering capacity as a result of the 80% wheat straw in the silage, therefore slowing down the fermentation of the ensiling process. This resulted in a straw type x percentage interaction ($P<0.05$) and a quadratic effect ($P<0.05$) in CP, NDF, ADF, and ammonia-N (Tables 5, 7). The higher wheat straw percentage resulted in higher NDF and ADF values (Table 5). Results in NDF and ADF values were consistent with decreasing values of fiber content of barley straw mixed with WBG as shown by Ridla and Uchida (1994). Lower values for CP and ammonia-N were expected as percentage straw increased, since both wheat straw and grass seed are low in nitrogen content. The actual CP was lower than expected CP for all silages with differences ranging from being .77 percentage points lower for the 20:80 Grass to 4.55 percentage points lower for the 40:60 Grass than expected (Table 6). One assumption for the difference in expected CP

vs. actual CP among straw type percentages is that when mixing, water escaped through holes in the Uebler mixer along with WBG effluent that wasn't absorbed by the straw. Also when adding water, some WBG was washed down to the bottom of the mixer, underneath the mixing paddles, and wasn't allowed to mix with straw. These results were inconsistent with the results reported by Ridla and Uchida (1994) who reported higher CP results with increasing WBG levels.

Table 5. Chemical Composition of WBG/Straw silages

Diet	DM	CP (%)	NDF (%)	ADF (%)
20:80 Wheat	49.46 [b]	4.39 [b]	73.65 [b]	45.42 [b]
30:70 Wheat	35.72 [c]	8.10 [c]	68.80 [c]	41.15 [c]
40:60 Wheat	35.70 [c]	7.89 [c]	69.18 [c]	41.80 [c]
20:80 Grass	37.02 [c]	10.12 [d]	62.77 [d]	33.78 [d]
30:70 Grass	40.00 [c]	10.36 [d]	63.20 [d]	34.38 [d]
40:60 Grass	39.64 [c]	10.11 [d]	63.02 [d]	34.40 [d]
SEM [a]	1.62	0.38	0.92	0.65

[a] SEM, Standard Error of difference of the least square means
[b,c,d] Means without common superscript differ $P < 0.05$

Table 6. Expected crude protein compared to actual crude protein of WBG/Straw silages

Diet	Expected CP (%)	Actual CP (%)	Difference
20:80 Wheat	7.38	4.39	-2.99
30:70 Wheat	9.70	8.10	-1.60
40:60 Wheat	12.03	7.89	-4.14
20:80 Grass	10.88	10.12	-0.77
30:70 Grass	12.77	10.36	-2.41
40:60 Grass	14.66	10.11	-4.55

There was a linear effect ($P<0.01$) in pH, ethanol, lactic acid, lactic: acetic ratio, and total acids (Table 7). The decreasing straw percentages lead to linear decrease in pH

Table 7. Fermentation Analysis of WBG/Straw silages [a]

Diet	pH	Ammonia-N, ppm	Ethanol, %	Acetic Acid, %	Lactic Acid, %	Lactic: Acetic Ratio	Total Acids, %
20:80 Wheat	4.10 [c]	227.4 [c]	0.64 [c]	0.56 [cd]	4.09 [c]	7.28 [c]	4.65 [c]
30:70 Wheat	3.81 [d]	417.0 [d]	0.82 [cd]	0.44 [c]	4.36 [c]	9.94 [cd]	4.80 [c]
40:60 Wheat	3.76 [d]	372.9 [d]	0.88 [cd]	0.50 [c]	6.55 [c]	13.17 [d]	7.05 [c]
20:80 Grass	3.88 [d]	388.3 [d]	0.97 [cd]	0.82 [de]	10.14 [d]	12.39 [d]	10.96 [d]
30:70 Grass	3.87 [d]	332.0 [d]	1.03 [d]	0.93 [e]	11.38 [d]	12.20 [d]	12.32 [d]
40:60 Grass	3.85 [d]	340.8 [d]	1.09 [d]	0.88 [e]	11.24 [d]	12.77 [d]	12.12 [d]
SEM [b]	0.05	30.92	0.13	0.09	0.92	1.13	0.98

[a] Based on Dry Matter Basis

[b] SEM, Standard Error of difference of the least square means

[c,d,e] Means without common superscript differ $P < 0.05$

for silages (Table 7). The natural buffering capacity of the straw, not allowing a decrease in pH. The ethanol, lactic acid, lactic: acetic ratio, and total acids increased linearly as the WBG percentage increased. This is a result of higher fermentation with high ratios of WBG to straw and the lowering of silage pH. Acetic acid differed ($P<0.01$, Table 7) among straw types with wheat straw being lower. These results are consistent with Ridla and Uchida (1994), who reported higher values of lactic acid, and acetic acid production with increasing levels of WBG.

Experiment 2: Digestion Trial

Dry matter intake was higher for CON vs. WBG ($P<0.05$, Table 8) and vs. SIL ($P<0.01$, Table 8). No difference in DMI was detected between WBG vs. SIL ($P>0.24$, Table 8). The CON group consumed 1.18 kg/day as compared to WBG at .84 kg/day and SIL at .96 kg/day. These results are consistent with depressed DMI for dairy cows fed WBG at high amounts of 30-40% of the diet (Porter and Conrad, 1975; Murdock et al., 1981; Davis et al., 1983). Younker et al. (1988) reported reduced (-9.3%) DMI when replacing DBG for concentrate and no depression but an increase of 4.9% (not significant) when replacing DBG for forage NDF. Ojowi et al. (1997) reported no difference in DMI when feeding WBG to feedlot steers. Though no measurement to evaluate digestion kinetics was made, Firkins et al. (2002) suggested the high passage rate of WBG could affect ruminal fill and DMI if used to replace concentrate and not forage NDF.

Table 8. Comparison of CON and WBG and 30:70 SIL on nutrient disappearance

Item	TRT [a]			SEM [b]	P-Value [c]		
	CON	WBG	SIL		CON vs. WBG	CON vs. SIL	WBG vs. SIL
DM Intake, kg/day							
Straw	0.91	0.72		0.2 [d]	0.06	NA	NA
Silage			0.96				
Supplement	0.27	0.12					
Total	1.18	0.84	0.96	0.28	0.04	0.01	0.24
CP Intake, g/day	130	73.9	100.9	11.3	0.01	0.01	0.02
OM disappearance, %	6.97	7.71	7.05	0.86	0.89	0.27	0.33
NDF disappearance, %	51.47	53.35	54.01	8.35	0.68	0.76	0.92
ADF disappearance, %	54.95	55.16	54.28	9.09	0.92	0.97	0.9
CP disappearance, %	45.62	53.88	41.7	8.86	0.55	0.24	0.1

[a] CON -limit fed canola meal with tall fescue grass seed straw, WBG- limit fed ensiled WBG with tall fescue grass seed straw, and SIL- 30% WBG/70% Tall Fescue grass seed straw silage.
[b] n=12.
[c] Linear effect
[d] n=8

Straw intake was affected by consumption in CON vs. WBG (P=0.06, Table 8). The range for straw intake for CON was .78-1.03 kg/day and WBG was .67-.76 kg/day. This trend to less consumption of grass seed straw resulted in a replacement of WBG NDF for straw NDF. The ruminal fill effect of WBG could affect straw intake.

No differences were detected in OM disappearance (P>0.27, Table 8) for all contrasts tested. Younker et al. (1998) reported no difference in OM digestibility on % of intake between the diets with partial replacement of DBG replacing forage, DBG replacing concentrate, and DBG replacing both forage and concentrate.

There were no differences between treatments in NDF disappearance (P>0.68, Table 8). The amount of effective fiber from the WBG and SIL is comparable to CON. The amount of effective fiber is shown to impact chewing, especially rumination to stimulate salivary buffering. Wet brewers' grain NDF has been estimated based on chewing response to effectiveness values ranging from 32% to 80% of alfalfa silage (Mertens, 1997).

Swain and Armentano (1994) compared single batch of DBG to alfalfa silage for the impact of effective fiber on a milk fat percentage in two trials. There was great variance shown within the batch of DBG for effectiveness of NDF with 0.22 value to 1.00 of alfalfa silage for trial one, and 0.46 to 1.00 for trial two. The difference between the trial one and two can be attributed to the use of sulfite in NDF analysis used in trial one. Swain and Armentano (1994) stated ADF analysis showed similar results as NDF analysis. There were no differences in ADF disappearance among all contrasts (P>0.90, Table 8). This is consistent with NDF disappearance.

Crude protein intake was higher for CON (130.0 g/day)vs. WBG (73.9 g/day; $P<0.01$; Table 8), and vs. SIL (100.9 g/day; $P<0.01$; Table 8). There was a difference in CP intake of WBG vs. SIL ($P<0.05$, Table 8). The supplements were fed to be isonitrogenous to SIL. Straw intake resulted in CP intake being greater for the CON treatment when compared to WBG and SIL.

There was no difference ($P>0.24$) in comparing CON (45.62%) vs. WBG (53.88%) and CON (45.62%) vs. SIL (41.70%) for CP disappearance (Table 8). Canola meal and WBG are considered sources of ruminal undegraded protein, therefore they should have similar disappearance results. The supplements were balanced to be isonitrogenous; therefore no differences in CP disappearance were expected.

The fermentation analysis of the WBG and SIL is presented in Table 9. There is no indication of secondary fermentation for WBG and SIL with low levels of butyric acid (0.04% and 0.07%), acetic acid (0.27% and 1.18%), ammonia-N (136.00 and 484.47ppm) and low pH (4.0 and 4.2).

Table 9. Fermentation Analysis of WBG/Straw silage in Exp. 2. [a]

Diet	pH	Ammonia-N, ppm	Ethanol, %	Acetic Acid, %	Lactic Acid, % .	Butyric Acid, %
WBG 30/70 Grass	4.0	136.00	5.27	0.27	2.92	0.04
	4.2	484.47	0.74	1.18	5.92	0.07

[a] Based on Dry Matter Basis

Conclusion

The higher ratio of 30 % or 40% WBG used with either straw offers the most nutritionally adequate silage in CP, NDF, and ADF while maintaining a fermentation profile that is conducive for high quality silage by maintaining low pH, high lactic acid production, and controlling secondary fermentation.

The 20:80 WBG/wheat straw silage resulted in poor fermentation with a low lactic acid production of 4.09%, low CP at 4.4%, and the high DM content (49.46). Reasons for poor fermentation could be the natural buffering capacity of the high amount of wheat straw, or the low amount of nitrogen availability from the straw for fermentation.

The reduction in CP levels in expected versus actual can be credited to washing out of WBG to the bottom of the Uebler mixer and also wasting on the floor. This is also a realistic comparison to a producer situation where mixing WBG with straw and adding water to increase the moisture level. Producers could encounter the same problem of effluent loss in a bunker silo or ag bag scenario. The use of WBG alone as a silage can be used if storage is in a closed system to prevent spoilage and effluent runoff .

The use of 30:70 WBG/grass seed straw mixture in the digestion study produced a high quality silage that offers a balanced ration based on OM, CP, and NDF disappearance ($P>0.24$). Wet brewers' grain and the 30:70 WBG/ straw silage is comparable to grain supplementation for ruminant animal function based on no differences being detected in CP and NDF disappearance. Dry matter intake was higher for CON vs. WBG and SIL ($P<0.05$). The passage rate and ruminal fill of WBG and SIL

could have affected DMI. Straw Intake was lower for the WBG vs. CON therefore showing that passage rate and ruminal fill could influence results. Wet brewers' grain alone should be used as a replacement for forage NDF not for concentrate due to reduced DMI.

Implications

The combination of WBG and by-product straws proved to be effective in providing an adequate total mixed ration for ruminant species. The ensiling of this silage could be key to providing a cost effective, locally available nutritionally adequate ration for producers to use. This information should provide livestock producers, straw producers, and breweries valuable information concerning feeding practices for use in livestock while providing an economical ration that gives all parties involved solid reasons for use and sales.

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