Use of winter cultures for forage conservation

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Introduction

Forage production is seasonal throughout most of Brazil. Most of the country lies within the tropical zone, which favors development of C_4 plants. Furthermore, the climate in the south and parts of the southeast and central-west regions can be used for forage production of C_3 plants in the winter, since rainfall is sufficient for plant growth at this time of the year.

In countries with more severe summer climate than Brazil, it is difficult to cultivate forage without irrigation, which favors use of winter crops as conserved forage for shortages. According to Novak et al. (2011), grains at an immature developmental stage (silage or hay) can be harvested as a response to a cyclical demand for forage. Harvest can also be voluntarily integrated into a forage system as a means of overcoming seasonal shortages and consequently provide a forage resource in areas where irrigation is not possible or desired.

In Europe, winter grains have gone beyond the status of “sporadic” forage crops to that of a “base” forage crop. In the first case, the grain ensures forage supply during times of drought in the summer. In the latter, the crop ensures all or part of the forage stock under different situations, making this a true strategy in forage planning (LEMAIRE et al., 2006).

Use of winter cultures for forage production can be an important tool in improving animal production in Brazil. This strategy is interesting from an economical point of view. It is also greatly sustainable in some areas of the South, where pastureland or underused winter areas can be destined for silage production. In this way, the risks of seasonal culture loss (winter corn, grains or silage) can be minimized. Also, competition with summer cultures for silage production would be reduced, which would free up useful areas to produce grains for human consumption.

In this context, better use of qualitative and strategic aspects of silage production of winter crops will be discussed to better use these systems in animal production.

Nutritional potential of winter grain silage

The nutritional value of grasses grown in temperate climates (C_3 metabolism) is different from that of tropical grasses (C_4 metabolism). Temperate grass has more abundant cell content and thinner cell walls which make it easier for herbivores to digest and absorb nutrients. Furthermore, greater cell content positively affects the silage fermentation process, since a higher concentration of soluble carbohydrates favors lactic acid production. On the other hand, some negative aspects associated with this type of grass may jeopardize the fermentation process. The main disadvantage of this type of grass is its low dry matter (DM) content (Table 1).

Table 1. Chemical-bromatological composition and fermentation characteristics of winter grain silage.

Parameters (%)	Berto & Mühlbach (1997)	Emile et al. (2007)	Wallsten et al. (2010)	Oliveira et al. (2010)
	Oat	Wheat	Barley	Triticale
DM, %	15.30	33.50	41.60	29.20
CP, % DM	17.70	8.10	10.00	11.40
NDF, % DM	46.70	53.20	41.10	61.30
ADF, % DM	34.80	---	26.30	37.80
pH	4.60	3.91	4.50	4.30
$N\text{-}NH_3$ (% total N)	11.80	9.90	6.70	13.80
Acetic acid, % DM	3.60	2.98	0.80	1.93
Propionic acid, % DM	---	---	0.10	0.20
Butyric acid, % DM	0.18	0.09	0.00	0.13
Lactic acid, % DM	8.4	3.83	2.90	6.90
IVDMD, % DM	---	60.80	67.50	---

Berto & Mühlbach (1997) (Table 1) observed lower dry matter values in oat than those desired for good fermentation in the silo (desired values are between 30-35% - McDonald et al., 1991). Consequently, one can infer that this low dry matter content together with the greater protein values observed may have caused the elevated pH level (4.60) and probably increased proteolysis as well, which can be verified by the higher ammonia nitrogen rates (11.80% total N) present in the silage.

A similar effect was observed by Oliveira et al. (2010) with triticale silage. These authors observed elevated pH and ammonia nitrogen values with less than desired dry matter content. Lower dry matter content at the time of ensiling may also trigger the onset of clostridia activity in the silage material, favoring proteolysis and consequently greater ammonia nitrogen levels in the final product.

On the other hand, Emile et al. (2007) and Wallsten et al. (2010), working respectively with wheat and barley, presented more consistent results on the quality of silage fermentation when ensiled with more adequate dry matter levels. From a nutritional point of view, these forages present important nutrient and fiber levels for herbivores, making wheat and barley interesting options for forage conservation to overcome shortages in a forage planning strategy.

In order to improve the nutritional value of winter grain silage, intercropping these grains with legumes has been suggested. In Europe, mixing winter grains and legumes for silage production has raised producers' interest and motivated research for the ideal mix for this purpose.

Intercropping winter grains and legumes can provide advantages in agriculture (savings of nitrogen fertilizers) and animal production (better forage nutritional value), thereby strengthening the appeal of sustainable production systems, primarily European ones.

According to the Official Journal of the European Union (2002), development of legumes individually or by intercropping with grasses brings some important environmental advantages for the European Union. Some of which are: greater biodiversity, better crop rotation, better nitrogen balance, maintenance of the soil structure, healthy reaction to a tendency toward grain monoculture, and overall, decreased use of production factors such as nitrogen fertilizers, pesticides and fuel.

With this in mind, some studies have set out to verify the quality of forage produced by intercropping (Table 2).

Table 2. Chemical-bromatological composition and fermentation characteristics of winter grain silage intercropped with legumes.

Parameters	Dias, (2007)		Bumbieris Jr, (2009)		Huuskonen et al. (2010)	
	TSP	TSOPV	TSP	TSOPV	BSV	WSV
DM (%)	25.28	24.46	23.44	22.57	26.80	31.50
CP (% DM)	10.27	9.50	11.63	13.06	10.60	13.30
NDF (% DM)	56.85	56.90	58.52	56.39	54.00	54.70
ADF (% DM)	36.35	36.02	37.48	36.11	---	---

pH	3.44	3.80	3.83	4.20	3.98	3.85
$N\text{-}NH_3$ (% total N)	12.80	13.70	11.40	14.80	7.10	8.30
Acetic acid (% DM)	1.90	2.95	2.79	4.70	---	---
Propionic acid (% DM)	0.03	0.03	0.13	0.13	---	---
Butyric acid (% DM)	0.06	0.06	0.08	< 0.05	---	---
Lactic acid (% DM)	10.55	2.86	8.24	7.28	4.50	6.30
IVDMD (% DM)	60.94	61.03	59.70	60.28	68.5	57.80

TSP=Triticale Silage + Forage Peas; TSOPV= Triticale Silage + Oats + Forage Peas + Vetch; BSV= Barley Silage + Vetch; WSV= Wheat Silage + Vetch.

Dias (2007) and Bumbieris Jr (2009), working with triticale silage intercropped with oat and legumes, showed that insertion of legumes improves forage nutrient content. Although the ammonia nitrogen content was high, it was still within acceptable limits (15% total N), since legumes normally present higher nitrogen content than grass as well as some inorganic ions.

Furthermore, Huuskonen & Tokola (2010), working with barley (BSV) and wheat (WSV) silage intercropped with vetch, obtained very satisfying results regarding fermentation quality and bromatological composition.

In Brazil, research of intercropping winter crops with legumes for silage is still limited; however, some efforts show promising results. Fontaneli et al. (1991), in a study on the effect of intercropping grasses with winter legumes, observed that oat stood out among the grasses and vetch presented the best phytomass yield among the legumes studied. Tomm et al. (2003), in a study of hibernating grasses intercropped with forage peas, observed that the best grass adapted to intercropping with this specie was triticale. The greater stature and vigor of this plant allow it more access to light. Also, the fewer layers of triticale resulted in less loss of pea plants by rotting, resulting in greater pea and triticale production (triticale grain production nearly 2,300 kg/ha).

Of the different ways to utilize these temperate species, forage quality is an attractive factor in deciding use, because it has a direct effect on animal performance.

Wilted Winter Grain Silage

Wilting winter grains before ensiling increases forage dry matter content. Consequently, this technique is widely used to help assure appropriate conservation conditions for ensiled forage.

Furthermore, wilting is considered a management strategy to reduce environmental pollution (LORENZ et al., 2010; SCHMIDT et al., 2011). Cell rupture and cytoplasm leakage during forage storage create silage effluent, which can lead to significant feed losses. The drier the crop, the less silage effluent is produced. Thus, partial water removal from plants has been proposed as a method to reduce silage effluent (SCHMIDT et al., 2011). These authors also reported that effluent production is primarily influenced by the moisture content of the forage taken to the silo, and secondly by particle size, compacting, additives, silo type and plant characteristics at the time of ensiling.

McEniry et al. (2007), in a study on wilting perennial ryegrass (*Lolium perene*) after 0, 24 and 48 hours, observed that silage effluent was only produced in non-wilted silage with a value of 39 g/kg ensiled forage. Weinberg et al. (2010) reported that silage porosity and its susceptibility to air penetration depend on the degree of silo compaction, which is directly influenced by culture DM content and particle size.

McEniry et al. (2008) observed that the silage process became progressively more restrictive as DM content increased in the ensiled forage, with lower concentrations of fermentation products and increased pH values (Figure 1).

Previous reports relate the importance of wilting on silage, primarily by reducing effluent production and restricting fermentation. However, decreased moisture benefit silage as long as levels are at least 30% DM (WOOLFORD, 1984) and associated with a quick drying rate (DAWSON et al., 1999).

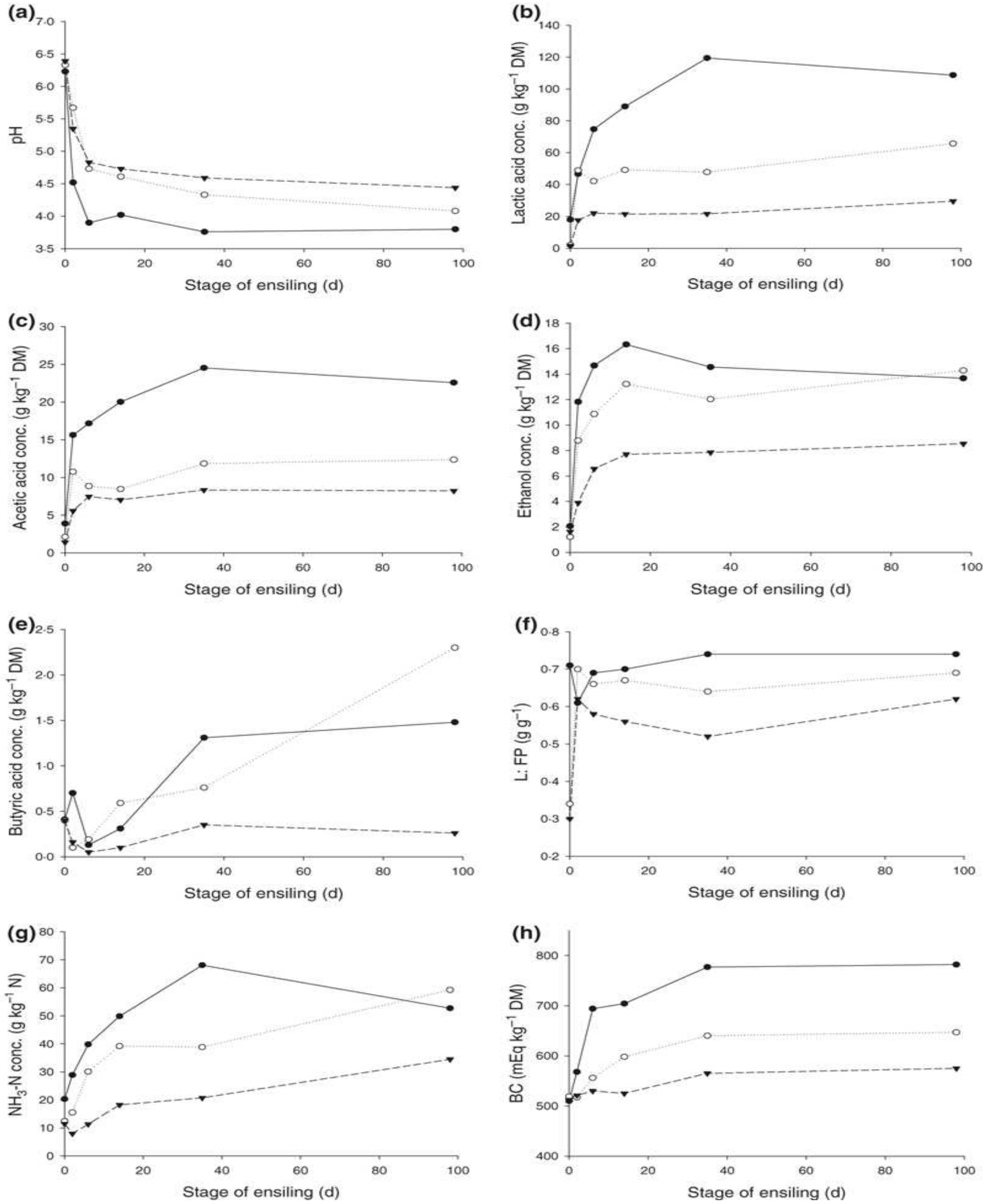

Figure1. Effects of wilting duration and stage of ensiling on (a) pH, (b) lactic acid, (c) acetic acid, (d) ethanol, (e) butyric acid, (f) ratio of lactic acid (L) to total fermentation products (FP), (g) N-amoniacal concentration and (h) buffering capacity (BC) of silage during fermentation at 0h(-●-), 24h (-○-), and 48h (-▼-) of wilting.
Source: McEniry et al. (2008).

Maturation stage X winter grain silage quality

It is well known that forage chemical composition is influenced by plant developmental stage. Consequently, different maturation stages are recommended for silage.

Beck et al. (2009) reported that DM production increased as wheat (*Triticum aestivum* L) matured, producing between 2,781 kg/ha DM (21.5% DM) and 6,261 kg/ha DM (46.7% DM) respectively for flowering and dough stages. Working with oat (*Avena sativa* L.) silage, David et al. (2010) obtained productivity values from 3,547 kg/ha DM at flowering to 9,170 kg/ha DM at soft dough stage.

Crude protein (CP) decreased as winter grains matured (FONTANELI & FONTANELI, 2009; COBLENTZ & WALGENBACH, 2010). Beck et al. (2009) also observed decreased CP in wheat silage respectively for flowering and dough stages (from 15.2 to 8.9%). Fontaneli & Fontaneli (2009) evaluated the nutritional composition of wheat, oat and rye silage based on CP at three maturity stages. These authors observed average CP values around 17.7, 13.0 and 10.2% respectively for boot, milk and dough development stages. Coblentz & Walgenback (2010) observed that reductions in digestible CP levels as plants matured were offset by an increase in non-fibrous digestible carbohydrate levels.

Lopes et al. (2008), in a study of triticale (*X Triticosecale Wittimack*) silage at different harvesting ages (83, 90, 97, 104, 111 and 118 days), observed that as plants matured the neutral detergent fiber (NDF) also increased until flowering. Then, fiber fraction levels decreased (53.9, 65.9, 57.7, 54.9, 52.5 and 48.2% DM). This element may become diluted by the greater starch levels produced as the grain matures. Coblentz & Walgenbach (2010) observed that NDF concentrations presented a quadratic response in wheat, triticale and oat cultures at different harvesting times. On the other hand, Beck et al. (2009) and David et al. (2010) did not observe any reduction in NDF as plants matured.

Coblentz & Walgenbach (2010) observed a linear effect in concentrations of total digestible nutrients (TDN) with longer cutting intervals. David et al. (2010), in a study on oat ensiled with 26.6 and 31.9% DM, found TDN to respectively increase from 53.7 to 56.3% DM. However, Beck et al. (2009) did not observe any changes in TDN as wheat matured.

Wallsten & Martinsson (2009) observed that as barley (*Hordeum vulgare* L.) matured, NDF and DM digestibility reduced and starch accumulated. These authors also reported that higher stages of maturity decreased milk production, fat, protein and feed efficiency in dairy cows. Beck et al. (2009) did not detect any effect of maturity stage of wheat silage on beef cattle performance. On the other hand, Wallsten et al. (2010) in an evaluation of wheat and barley silages reported that as plants matured, digestibility of organic material decreased (68.3 to 63.3% DM and 69.8 to 66.1% DM) as did NDF (74.6 to 60.7% DM and 69.8 to 59.6% DM) respectively for flowering and dough stages.

Coblentz & Walgenbach (2010) suggested a wide window for harvesting according to the nearly constant energy density at different harvesting times. However, Ashbell & Weinberg (2000) recommended using late cultivars for silage production in hopes of extending the harvesting window since the drying rate in hot climates is very quick which hinders control of the correct silage stage.

Reports on the maturity stage of winter grains in the literature are inconsistent. These discrepancies can be justified by differences in plants, nutrient translocation, soil types, hydric availability, growth stage, cultivars, fertilization program, and the distinct drying rates between hot and temperate regions.

Winter grain silage X corn silage

According to Jobim et al. (2007), forage quality refers to the nutritional value of the forage mass interacting with the animal's consumption and potential performance. In this way, forage quality effects consumption and energy density, which determine animal productivity.

It is important to remember that winter grain silage is less productive than that of tropical grasses. Fontaneli et al. (2009) evaluated productivity of 14 genotypes of six winter grain species. They observed that rye (cv. BRS Serrano) presented the greatest DM yield in cutting for silage (9.721 kg/ha), with productivity of the other winter grains varying from 3.641 for barley (cv. BRS 195) to 7.027 for rye (cv. BR1) (Table 3). These authors reported that variations in winter silage yields is caused by interactions among the genetic potential of the cultivars, management practices, climatic conditions and the maturity stage at the harvesting time

Table 3. Cutting height, dry matter content and production (kg/ha) of winter grains.

Winter Grain	Cutting height (cm)	DM (%)	kg/ha DM
White Oat UPF 18	111b	29.5ef	6,159bc
Black Oat IPFA 99009	117b	28.5fg	6,455bc
Black Oat Agro Zebu	112b	25.7g	5,419bcde
Rye BR 1	136a	37.8ab	7,027b
Rye BRS Serrano	142a	39.1a	9,721a
Barley BRS 195	57f	31.7def	3,641e
Barley BRS 224	73de	30.2def	4,696cde

Barley BRS 225	66ef	32.5cde	3,962de
Triticale BRS 148	99c	33.0cd	5,375bcde
Triticale BRS 203	96c	32.8cd	4,738cde
Triticale Embrapa 53	93c	35.2bc	5,590bcd
Wheat BRS Figueira	68ef	36.9ab	5,022cde
Wheat BRS Umbu	77de	38.1ab	5,091cde
Wheat BRS 277	80d	38.4ab	5,175cde
Average	**94.7**	**33.5**	**5,577**

Averages followed by the same letter in a column are not significantly different (P>0.05) according to the Tukey test.
Source: Adapted from Fontaneli et al. (2009)

Winter grains produced lower energy silage compared to corn silage for several reasons, being anatomical, morphological and physical-chemical in nature (FONTANELI & FONTANELI, 2009). However, Coblentz & Walgenbach (2010) observed greater concentrations of TDN in wheat cultivars compared to oat and triticale (69.3 compared to 67.8%), which demonstrates the potential of this crop for silage.

Assessing nutrient intake and cattle performance of perennial ryegrass and a 40:60 ratio of corn and wheat silage, Keady et al. (2007) concluded that perennial ryegrass plus corn provided better carcass weight due to better use of metabolizable energy. However, these authors also reported that perennial ryegrass plus wheat did not alter DM intake (DMI) or digestible energy intake (DEI) compared to the corn silage mix.

In test animals receiving silage of perennial ryegrass (17.4% DM), corn (31.5% DM) and wheat (40.4% DM) in addition to 3 kg concentrate/day, Walsh et al. (2008a) did not observe any differences in DMI (7.02 vs. 7.31 kg DM/day), DEI (1.2 vs. 1.15 kg/day) and carcass weight (335 vs 329 kg) respectively for corn and wheat silage.

Walsh et al. (2008b) evaluated nutrient intake, digestibility and performance in beef cattle fed wheat and barley silage ensiled at two cutting heights (0.12 and 0.29 m) compared to corn silage. They did not detect any influence of diet on DMI, *in vivo* digestibility, DEI and final carcass weight. Therefore, the authors concluded that wheat and barley silage with high grain levels (> 50% DM) provide the same level of performance as those obtained with corn silage. Similarly, Addah et al. (2011) found no significant differences in weight gain of animals fed corn or barley silage (1.26 and 1.43 kg/day, respectively).

On the other hand, Oltjen & Bolsen (1980) found different weight gains for animals fed corn or oat silage with respective gains of 1.15 and 0.5 kg/animal. Coombs et al. (1997)

observed similar behavior in animals fed corn or wheat silage with respective gains of 1.07 and 0.77 kg/animal/day.

As can be seen, there are varying reports in the literature regarding winter grain silage and animal performance. These different responses may be attributed to differences in the nature of the diets, roughage: concentrate ratio and the genetic potential of the animals. The roughage ratio of a diet can equally influence animal performance and product characteristics through its effect on DMI differences in rumen fermentation and digestion kinetics (Galyean & Defoor, 2003).

Additives for producing winter grain silage

In Brazil the most common silage additive is bacteria. However, there are several other types of additives such as nutrient additives [absorbent (grains or not), non-protein nitrogen (NPN), urea and ammonia], enzymes, as well as organic and inorganic acids. Their main function is to increase the nutritional value of silage, and/or improve fermentation by reducing losses during storage and/or silage use.

Additive response will depend on the type of forage being treated as well as the treatment itself. Corn silage has little need for additives to improve fermentation. It is easily ensiled since values of DM, soluble carbohydrates and buffering capacity are all within the desired range. On the other hand, nutrient additives, like urea and ammonia, are beneficial, because they increase the CP level of the ensiled material (COOMBS et al., 1997). When use of NPN is compared for animal performance, the literature shows mixed results. Coombs et al. (1997) observed that corn and wheat silage with added N ammonia (3.5g/kg fresh basis) resulted in weight gain similar to that of silage with no additives, but with protein levels corrected at feeding.

Winter grain silage often has problems in the fermentation process, since DM content at the moment of ensiling can be below desired levels (DIAS, 2007; BUMBIERIS JR, 2009; HUUSKONEN et al., 2010), which facilitates fermentation of undesirable substances. Consequently, use of additives that increase DM content (absorbent) and increase the amount of desirable bacteria may help improve the conservation process in this feed.

Positive results of these additives can be seen in the works of Coan et al. (2000 and 2001); Evangelista et al. (2002) and Lima et al. (2002).

Chemical composition and subsequently the fermentation characteristics of corn and winter grains are very different. Corn has a low level of protein and minerals, but high concentrations of fermentable carbohydrates. On the other hand, winter grains vary in proteins, but when harvested at an adequate maturity stage they generally have high concentrations of this nutrient and are good sources of minerals, although they have a low concentration of fermentable carbohydrates.

Higher DM levels of material that is wilted before ensiling have sometimes proven to be prejudicial to the fermentation process (McEniry et al., 2008) as well as labor intensive. Thus, use of absorbent additives, especially nutrient additives (corn grits, wheat bran, citrus pulp) may be a more practical strategy. In addition to increasing DM content, these additives also increase the concentration of nutrients of high nutritional value in the ensiled material.

Corn, sorghum, other grains (wheat, oat and triticale) and molasses may be added to forage at the time of ensiling. Addition of these grains has several advantages. Two of which are increased silage energetic value and decreased need for supplementary concentrates. If silage were the primary or the only feed offered it will become a more complete food. Another interesting aspect is that the grain added to the silage will already have been stored and will not need any preservation treatment. These additives (grains) are not intended to be used as a source of soluble carbohydrates, since starch (the main carbohydrate in grains) is not readily fermented in the silo. The main purpose is to increase DM levels and nutritional value. Molasses, unlike grains, provides fermentable carbohydrates; therefore, its addition may improve fermentation of some forage crops.

Microbial inoculants are added to forage to increase the number of desirable bacteria at the time of ensiling. A number of different inoculants are currently available and many studies have evaluated their efficiency, although research results are varied. The main microorganisms used in additives are *Lactobacillus plantarum*, *L. acidophilus*, *Pediococcus acidilactici*, *P. pentosaceus*, and *Enterococcus faecium* among others.

The population of epiphytic bacteria in corn has proven to effectively promote good fermentation and conservation of these materials. However, it may not be enough for winter crops. Inoculation may reduce storage losses, since most experiments with added bacteria inoculants increased the rate at which pH decreased and increase of lactic acid concentration in the silage (ADDAH et al., 2011).

According to Addah et al. (2011), inoculation with a combination of *L. plantarum, E. faecium* and *P. acidilactici* did not alter DM losses, but during ensiling losses were greater for barley silage than for corn silage. Barley silage was more stable than that of corn after two days of aerobic exposure. Inoculation of barley and corn silage did not affect DM intake, average daily gain (ADG) or feed efficiency compared to animals fed non-inoculated silage. Nevertheless, animals fed barley silage in general had higher DM intake, greater ADG and higher feed efficiency compared to animals fed corn silage. Inoculation was more effective in improving aerobic stability and fermentation in barley than in corn.

Hristov & McAllister (2002) did not observe any effect of microbial additives on the degradation rate of DM in barley silage. These authors concluded that more consistent results for barley and grasses depend on the microbial composition of the inoculant. However, it is known that multiple factors interfere with response to microbial inoculants in silage.

The decision to use an additive should take into consideration the forage species, DM content of the forage, animal category and the potential productivity of the animals to be fed. Addition of grains to winter silage can reduce production of effluents. Although no additive can substitute good silage practices, it can improve fermentation and nutritional value.

Use of winter grain silage as a strategy to feed cattle

Use of winter grains to feed dairy cattle has become increasingly popular in regions that favor their cultivation. Seeking to maximize use of these grains as a source of roughage, the potential of forage conservation in the form of silage has increasingly grown.

Use of these grains as a strategy has been accomplished by integrating crop and livestock production for grazing use. More recently, pasture management begins before harvesting for conservation in the form of silage. Dias (2007) observed that after grazing triticale, grain production reached 78% compared to non-grazed areas (5,300 kg grains); consequently, the use of this grain for grazing and following harvest is recommended.

With this in mind, silage production after recovering a culture under grazing is possible, as suggested by Meinerz (2009). This author managed winter grain areas (oat, triticale, rye, wheat and barley) in the Santa Maria region of Rio Grande do Sul by cutting before harvesting for silage. After recovering the crops, plants were ensiled. This study concluded that winter grains may be used in this region for a dual purpose. Of the genotypes evaluated, triticale cv. BRS 148 and rye cv. BR1 were the earliest for silage production, and rye BR1 and oat cv. UPF 18 provided the best yields of pre-ensiled mass. Also, wheat cv. Umbu presented the greatest participation of grains in the ensiled mass, providing greater nutritional quality to the silage.

According to Novak et al. (2011), winter grain silage intercropped with legumes can be used to feed dairy cows in late lactation, dry cows and heifers with no adverse effects. These authors observed that lactating cows fed triticale silage and triticale + legumes silage respectively produced 19 and 21 liters/animal/day. Inclusion of these silages for cows with greater production potential should be evaluated and possibly be partially substituted for corn silage.

Concerning feed for Braford heifers weaned early, Eifert et al. (2004) used triticale silage as a strategic source of roughage associated with 35, 45, 55 and 65% concentrate. These authors observed weight gains of 0.270, 0.536, 0.728 and 0.784 kg/animal/day respectively for the four concentrate levels studied. These results are encouraging, since the cost of producing winter grains is normally less expensive than corn or sorghum cultures. Another positive point to the use of these silages is that areas set aside for fall and winter crops were used so that these areas remain being used over the whole year, which even decreased risks involving any unpredictable climatic factors (such as frost) that could affect sorghum and corn cultures.

Development of dual-purpose cultivars (grazing, grain and/or silage) has been crucial in advancing the use of winter grain silage within animal production systems. Such use is often strategic over climatic factors and has managed to be successful when correctly used as an adequate forage resource for the region.

Further research should be performed in order to validate the use of these grains for silage as a strategy to feed ruminants and adapting the best genotypes for each region. In the central – south region of Brazil, winter grains have the potential to move from the status of a secondary crop to that of a staple crop. The benefits of this strategy have already been observed in producers who are currently using it.

Considerations

In Brazil, use and research of winter grain silage are still sparse. The southern region, which favors these silages, widely uses integration of pastureland and crops. Winter grazing of these species is widespread and is preferable to conservation methods, like hay and silage, which are more expensive.

Use of intercropping winter grains and legumes for silage as well as wilting and additives may be considered strategies to improve the fermentation quality of these silages.

Research to validate the use of these silages as feed in Brazil may effectively motivate the strategic use of forage planning, thereby promoting greater use by producers.

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