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Barley and its by-products in animal nutrition - Cevada e seus subprodutos na alimentação animal

Mariane Moreno Ferro[1], Anderson de Moura Zanine[2], Daniele de Jesus Ferreira[2], Luiz Juliano Valério Geron[3], Alexandre Lima de Souza[1], Henrique Nunes Parente[2], Michelle de Oliveira Maia Parente[2], Ricardo Martins Araujo Pinho[2], Ygor Nascimento Portela[2]

[1]Department of Animal Science. Federal University of Mato Grosso. Cuiabá, MT, 78735-901, Brazil. Email: mmf_zootecnia@yahoo.com.br, alexandre@ufmt.br. [2]Department of Animal Science. Federal University of Maranhão. Chapadinha, MA, 65500-000, Brazil. Email: anderson.zanine@ibest.com.br; dany_dosanjos@yahoo.com.br; ricardo-zootec@hotmail.com, hnparente@hotmail.com, michelle.parente@ufma.br, ygorportela@outlook.com
[3]Department of Animal Science, State University of Mato Grosso, Pontes e Lacerda,MT, 78250-000, Brazil. Email: ljgeron@yahoo.com.br

Abstract

Barley (*Hordeum vulgare L.*), originally from the Middle East, was one of the first plants domesticated for human consumption and was known for its vast geographical distribution. Brazil produces barley on a commercial scale since 1930, where among the various types of barley explored. Brewer's barley is the only type commercially produced in Brazil. Barley was originally cultivated and utilized as human food, but today it is primarily used for malt production and animal feed. Barley grains destined for animal intake must be free of toxic seeds, pesticide residues and musty material. The need to incorporate new nutrient sources such as agroindustrial by-products, it has been noticed an increase in the number of evaluating research alternative feeds with objective in reducing costs, facilitating management and increasing the productivity of herds. The use of agroindustrial by-products as substitutes of traditional energy sources (corn and sorghum) in animal diets can proportionately favorable development and to reduce costs. In Brazil, although the utilization of barley has been very restricted to the production of malt for brewing, it is of utmost importance that its chemical composition is known so that it can be used and optimized in animal nutrition.

Key words: alternative food, bagasse malt, brewer's grain, residue

Introduction

Barley occupies the fifth position in order of economic importance in the world with a global cultivation area of 530 000 km^2 (MAPA, 2012). Estimates indicate that the production of barley in Brazil was 352,000 Mg in the 2016/2017 harvest. Barley production is concentrated in southern regions of Brazil, spread across the states of Rio Grande do Sul, Santa Catarina and Paraná, with cropping also registered in the states of Goiás, Minas Gerais and São Paulo, with Paraná responsible for more than 60% of the total production (CONAB, 2017).

According to Vieira and Braz (2009) barley grain is used in brewing industry for beer and distilled spirit production, flour or cereals for baking, production of medicines, diet products and coffee substitutes. Barley is still employed in animal nutrition as green forage and ration formulation. In Brazil, multi-action is the principal economic use of barley, producing around 30% of the demand global brewing industry.

Albuquerque (2009) stated that practically all barley produced in and imported by Brazil is destined for malt production by the brewing industry, with only a small quantity employed directly in animal nutrition, as an energy source. According to the Cordeiro (2011), the varieties of barley are classified into three general classes that are utilized as a base for world trade, namely, livestock feed, raw material for alcohol and starch production, and human food. The principal factors to distinguish the destination of the barley are its growth habit in winter or spring, proportion of amylose as amylopectin, peeled or lower hulled barley and varieties of six, four or two lines.

Barley grain destined for the brewing industry can present a series of characteristics including a minimum of 95% germination, an 85% percentage of class 1 grains and protein levels greater than 12% (MAPA, 2012). In the case of animal nutrition, the grains are improved to levels beyond these parameters. Barley was originally cultivated and utilized as human food, but today it is primarily used for malt production and animal feed, with small quantities of seed being used for human consumption (OECD, 2004).

Traditionally, barley was a dominant grain, but was overtaken by rice and wheat in many countries and is seen as a very important grain by human in countries such as Morocco, India, China and Ethiopia (OECD, 2004). Barley is, however, processed industrially to generate some by-products of great importance in animal production such as bagasse malt or brewer's grain residue, straw, yeast or malt sprouts, among others.

Thus, the objective of this review was to emphasize the use of barley and its by-products, meanly bagasse malt or brewer's grain, in animal nutrition.

Characteristics of barley

Barley (*Hordeum vulgare L.*), originally from the Middle East, was one of the first plants domesticated for human consumption and was known for its vast geographical distribution. Barley is from the Triticeae tribe of the Poaceae family, in the *Hordeum* genera composed of 32 species and was first cultivated between 6,000 and 7,000 B.C. Became the main cereal utilized as human food, but was later overtaken by wheat.

Brazil has produced barley on a commercial scale since 1930, where among the various types of barley explored. Brewer's barley is the main type commercially produced in Brazil. There are two main types of barley cultivated, one with two rows of kernels per ear and the other six. These types are represented by the covariates *vulgare* and *distichum*, respectively. *Hordeum vulgare* ssp. *spontaneum* L. is the wild two row form, can be crossed with *H. vulgare* ssp. v*ulgare*, and is also considered as the ancestry of the domesticated species.

Cardova (2004) stated that barley is a cold climate plant and adapted well to temperate climatic regions through the development of specific cultivars to the local conditions. In Brazil, according to Minella (1981), the most favorable climatic conditions for barley are found in the states of Rio Grande do Sul, Santa Catarina and Paraná. These regions exhibit rainy weather with mean temperatures between 12 and 22°C in the coldest and warmest months, respectively.

According to Cardova (2004), barley grain presents 88% total digestive nutrients (TDN), 95% of the energy of corn, with this value a function of the decreased grain starch quantity (mean of 56%) and a greater level of fiber (mean 6%), which can be explained by the presence of bark covering the grain. The protein level varies according to cultivar variety, but the mean level in barley is 12%, significantly superior to the corn grain.

In Brazil, the main problems in relation to barley farming are rainfall (before or after planting), excessive rain (in the periods of grain filling and harvest), hail and wind storms (lodging), late frosts (until September), pests (aphids, white grubs and caterpillars) and diseases such as powdery mildew (*Blumeria graminis*), rust (*Puccinia hordei*) and *fusarium* head blight (*Gibberella zeae*) (Minella, 1981).

According to Cardova (2004), barley grains that contain more than 12% crude protein are classified as forage and are deemed unacceptable by the brewing industry. These grains can be used in domestic animal feed due to the negative relationship between the protein concentration and the energy of the barley. When the protein concentration of dry matter increases, the energy concentration decreases. This is not advantageous to the brewing industry. In addition, according to barley grain is versatile for feeding and used all over the world in varied animal species (Cardova, 2004).

Utilization of barley in ruminant nutrition

Barley grains destined for animal intake must be free of toxic seeds, pesticide residues and musty material (Zardo & Lima, 1999). The crude protein (CP) level of barley is superior to corn and inferior to wheat, however it is considered to have the lowest quality and low digestibility. One of the problems related to protein quality of barley is that the required characteristics of the brewing and barley industry, which dominate the preference in improvement programs, are opposed to the requirements for animal nutrition (Zardo & Lima, 1999). The energy level is slightly lower than wheat, and 10% less than corn, also exhibiting lower digestibility due to the increased fiber level (Zardo & Lima, 1999).

Cardova (2004) in study with lactating cows diets substituted different levels of corn with milled barley grain and observed that the mean proportion of barley increased along with the neutral detergent fiber (NDF) and acid detergent fiber (ADF) values. As a consequence of this, non-fibrous carbohydrates and starch levels decreased. The mean dry matter intake (DMI) reduced as the proportion of barley increased. These results can be associated with the high levels of fiber and the increased rate of starch degradation. Ingestion levels of CP, NDF and ADF were unaffected by the increased proportions of barley in the diet.

Utilization of barley in non-ruminant feeding

The inclusion of elevated levels of barley in non-ruminant feeds can be limiting due to the increased levels of fiber (Zardo & Lima, 1999).

Mayer et al. (2007) pointed out the importance to quantify chemical composition of barley grain with respect to the feed fiber levels because it is one of the most representative constituents of food. This acts through its insoluble and soluble fractions causing metabolic and physiological effects in animal organism, such as changes in digestion as well as in intestinal microorganism activity and diversity. Integral barley grains, the crude fiber level is approximately 22%, with 16% considered insoluble and 6% soluble (Mayer, 2007).

Fialho et al. (1992) found that barley has been considered as an adequate ingredient for pig feed, mainly because it contains greater levels of crude protein and essential amino acids than those found in corn, although it also contains greater levels of crude fibre and lower levels of energy. The same authors substituted corn by different levels of barley (0, 20, 40, 60 and 80%) in grower and finisher pig diets supplemented with soy oil and observed that the coefficient of protein digestibility was lower (85.64%) compared with corn (86.52%). The energy value found was 9.9% lower than that found in corn, possibly a result of the increased fiber level, which was considered as one of the factors which interferes in effective utilization of energy in pigs. The authors concluded that barley could be included in grower and finisher pig diets at levels up to 80%. In this case, the digestible energy levels in diet can be met through supplementation with oils.

Agroindustrial by-products of barley: Bagasse malt or brewer's grain

Some food resources are becoming scarce due reduction in pasture areas arising from increased agricultural production and forage establishment. This becomes an obstacle in pasture production due to its low production during the dry season (Cabral Filho, 1999). Production costs increase from elevated input costs, generating economic pressure (Cardova, 2004).

The need to incorporate new nutrient sources such as agroindustrial by-products has been a challenge in researching the demand for alternative feeds with objective in reducing costs, facilitating management and increasing the productivity of herds. This has gone beyond to warranty the rational destination of industrial wastes and to contribute with environmental preservation.

According to Santos (2005), brewer's grain is obtained through brewing, where grains received are submitted to cleaning for retained straw, stones and other foreign bodies present during harvesting. After this process, the grains pass through sieves in order to homogenize the mass with grains much closer in size and nutritional value approximately equal. The grains are then deposited in tanks where they receive water under controlled temperature and oxygen concentrations, until reaching 45% of humidity. Grains are processed to leave latency in order to be ready for germination. On germination, the grains are transferred to a greenhouse for the sprouting of rootlets. Once rootlets reach a mean size of 8 cm, they pass through sieves until moisture is removed, then transferred to drying ovens at a mean temperature of 45-50°C in order to interrupt the germination process and then heated further to around 80-100°C to caramelize the grains to obtain malt with 4-5% of humidity by volume. They are then ground by mills, knives or rolls to break the grain husk and expose the contents and access the starch of the dead grain. During this process, aspirators capture the powder generated by the attrition between the seeds, directing the flow to a baggy filter.

Grains are physically prepared by milling, which permits the availability of proteins and starch present in the malt grain interior. Only a small part of these substances is soluble in water, which makes chemical preparation of malt necessary in a step known as maceration. Maceration is a process developed in moisture, where the milled malt grains are mixed in heated water (generally around 65°C) in order to activate the enzyme action present in grain. These enzymes promote the breaking of complex and insoluble substances into smaller, more simple and water soluble substances. Proteins are therefore converted into peptides and other organic nitrogenous complexes, and later into amino acids. The starch is meanwhile broken into glucose, maltose and dextrin molecules, assimilated by the yeasts which carry out subsequent fermentations.

It should be emphasized that to alter parameters such as flavor, color, aspect or even cost, the additions of other sugar sources (or grits) beyond barley malt are often utilized. The most common additions are wheat, rice or corn, which differentiate from barley by not being malted, and most importantly, not possessing enzymes. To promote its maceration, the addition can be heated in a boiler, but following this it is necessary to blend and macerate into malt for the enzymes to act on the starch of this addition.

In practice, malt maceration is performed in the mash boiler, heating water to 65°C, with the addition mixed with the water at a temperature of 120°C in an industrial boiler. One hour later, the content of the second boiler is added to the first boiler, giving rise to the mash, a sugar solution derived from the starch saccharification present in the added grits, by malt action on the enzymes. Following mash preparation, it is colded from 80-100°C to around 75-78°C in a heat exchanger, and then filtered to remove residue from malt and grit grains. This filtration is made by the method of sieves used as filter of elements for the proper malt shells present in mash. The solid part retained called bagasse malt or brewer's grain.

Bagasse malt represents around 85% of the total by-product generated from beer production. Every 100 L of beer, approximately 20 kg of bagasse would be produced (Reinold, 1997). According to Geron et al. (2007), in the year 2005 about 2-3 million of Mg of brewer's grain was generated from beer production.

Vieira (2010) suggested that increased in humidity levels can cause changing in nutritional composition of brewer's grain, resulting from barley grain usage or with the type of processing used in manufacturing beer of different flavors. According to Santos & Ribeiro (2005) brewer's grain is primarily constituted of remains of barley pulp and peel, but also consists of other grains including rice, corn and wheat.

According to NRC (1998), dried brewer's grain presented a digestible energy value of 2100 kcal kg^{-1} in pigs, with respective levels of crude protein, lysine, methionine, tryptophan, calcium and phosphorus totaling 26.50%, 1.08%, 0.45%, 0.26%, 0.32% and 0.56%, respectively.

Wet brewer's grain was evaluated by Cappelle (2001), who found 26.02% of DM, 23.68% of CP, 6.50% of ether extract (EE), 4.66% of mineral matter, 55.06% of NDF, 20.58% of ADF and 62.89% of TDN. In addition, DePeters (1992) found values of 25.66% of CP, 5.99% of EE, 3.62% of mineral matter, 48.34% of NDF, 18.55% of ADF, 0.27% of calcium, 0.40% of phosphorus and 72.96% of TDN.

Conservation of brewer's grain is also becoming a limitation during its storage due to the development of fungi and yeasts in aerobic conditions, responsible for grain degradation. Bezerra Junior et al. (2010) emphasized that stocking cereals in a high humidity environment in temperatures greater than 13°C, are susceptible to fungal developments, mostly of *Aspergillus spp.*, which is related to the development of neurological diseases in cattle and sheep in diverse countries. Cabral Filho (1999), suggested shorter storage periods for brewer's grain, with a maximum of 10 days under aerobic conditions. On other hand, Ferreira et al. (2016a) observed that the inclusion of up to 40% of brewer's grain to Marandu grass silage provide better silage fermentation and improved protein and carbohydrate fractions and the kinetic parameters of ruminal degradation of dry matter, crude protein and neutral detergent fiber.

In Brazil, brewer's grain is marketed moist (20-30% of DM) (Cabral Filho, 1999). Salt addition has been adopted as a practice in an attempt to reduce microorganism attacks. Dehydration has been adopted in many countries as another alternative to minimize the problem. Dehydration also provides a longer storage period, with Rogers et al. (1986) observing a reduction in the percentages of soluble nitrogen in dehydrated brewer's grain. The difference attributed to the alterations in acid detergent insoluble nitrogen (ADIN) was used as an indicator of potential protein alterations.

Utilization of barley by-products in ruminant nutrition

The use of agroindustrial by-products as substitutes of traditional energy sources (corn and sorghum) in animal diets can proportionately favorable development and reduce costs (Gilaverte et al., 2011; Ferreira et al., 2017).

According to Geron et al. (2008), wet brewer's grain conserved by anaerobic fermentation can be an alternative to the formulation of ruminant diets. However, a study carried out by Cabral Filho (2007) showed that the addition of fermented brewer's grain in exclusively grass sheep diets limited the voluntary DMI when supplied in quantities greater than 33% of DM in the total diet. Brewer's grain has some factors that limit its utilization in animal nutrition which include its low values of DM, 20-30%, as reported by Cabral Filho (1999). In addition, its elevated water quantity made it difficult to transport over long distances.

Geron et al. (2008) observed a reduction of 15% in DMI when different levels (0, 8, 16 and 24%) of fermented brewer's grain were included in steer diets, with significant changes related to the water content and the concentration of neutral detergent insoluble nitrogen (NDIN). These results corroborated with those reported by Gilaverte et al. (2011), which had 30% of corn substituted by wet brewer's grain in concentrate for confined Santa Inês sheep, with an approximate reduction of 54.2% in nutrient (DM, OM, CP and NDF) intake, emphasizing that the main factors can be related to the increased humidity content (32.4% of DM) and increased NDF concentration of the diet. Bovolenta et al. (1998) observed a linear increasing effect of the total digestibility coefficients of DM, OM, CP, EE and NDF in lambs when dry brewer's grain was increasingly added in diets, although a reduction in DMI was also observed.

According to Gilaverte et al. (2011), during the production of wet brewer's grain, the majority of soluble proteins (albumins and globulins) are removed or fermented, which can also reduce the CP digestibility of the wet brewer's grain compared to other foods such as corn and citrus pulp pellets. A reduction in the concentration of ammonia nitrogen in the rumen was also observed.

Another way to use barley by-products in ruminant nutrition is through their addition as additive in ensilage process. Ferreira et al. (2017) showed that the addition of up to 30% of dehydrated barley in Marandu grass silage improved the silage fermentation and positively influenced the dry matter intake of sheep.

Utilization of barley by-product in non-ruminant nutrition

In pig and poultry production, large quantities of corn and soybean meal are used; corn and soybean are costly and are also consumed by humans (Braz, 2008).

Girotto & Santos Filho (2000) found that feed represents 75% of pig production costs. The knowledge of food sources that may reduce these costs without compromising animal development is soon to be validated for any production system. Braz (2008) found that many animal nutrition research and studies sought to enable the use of alternative feeds seeking to substitute traditionally ingredients which also promoted excellent animal performance, although these had high prices. The use of determined ingredients, as in the case of barley bagasse, information about its chemical composition and nutritional value should be obtained, with adequate levels for its incorporation in diet according to the animal type, productive phase, and climatic characteristics of the region. All information regarding the best methods of manipulation, transport and storage of ingredients must also be obtained (Braz, 2008).

Albuquerque (2009) emphasized that the digestibility of a foodstuff assumes high economic importance, because depending of the improvement degree of the nutrient it can be determined whether or not it is viable for the animal.

Braz (2008) utilized five inclusion levels (0, 12.5, 25, 37.5 and 50%) of barley bagasse substitutions in a ration based on DM and observed that the intake decreased linearly, while the barley bagasse intake behaved quadratically. The total diet intake also behaved quadratically, decreasing linearly after 14.91% of bagasse inclusion, being influenced primarily by moisture and fiber content.

Vieira (2010) evaluated the chemical composition and nutritive value of barley bagasse and observed reduced digestibility of DM, CP, EE, ash, NDF, and ADF of the grower pig rations containing bagasse.

Braz (2008) observed a quadratic effect on total weight gain, increasing until 12.89% bagasse inclusion in diet and reducing at inclusions greater than this, with main factor being the increase in digestive passage by the gastrointestinal tract and thus reducing the use of nutrients. Albuquerque (2009) used levels of dried brewer's grain (0, 5, 10, 15 and 20%) and observed that inclusion up to 20% did not influence performance or physiological parameters of grower pigs.

Conclusions

In Brazil, although the utilization of barley has been very restricted to the production of malt for brewing, it is of utmost importance that its chemical composition is known so that it can be used and optimized in animal nutrition.

Alternative feeds to optimize animal production are of great importance in the livestock economy, as the cost of feeding corresponds to 70% of the total production cost.

The search for industrial by-products for diet composition is gaining in prominence, particularly for ruminant diets with the utilization of wet brewer's grain. However, it is of great importance the continuity of research aimed at the use of these industrial products in animal feed, making it an alternative in the competition with the production of grains such as corn and soybean.

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