Silva et al., *Cogent Food & Agriculture* (2016), 2: 1193925
http://dx.doi.org/10.1080/23311932.2016.1193925

cogent food & agriculture

FOOD SCIENCE & TECHNOLOGY | REVIEW ARTICLE

Pectin-rich by-products in feeding horses—A review

Rafael Henrique Prado Silva[1]*, Adalgiza Souza Carneiro de Rezende[1] and Diogo Felipe da Silva Inácio[1]

Received: 22 October 2015
Accepted: 20 May 2016
First Published: 27 May 2016

*Corresponding author: Rafael Henrique Prado Silva, School of Veterinary, Federal University of Minas Gerais, 6627, Antônio Carlos Avenue, Campus Pampulha, Belo Horizonte 31270-901, Minas Gerais, Brazil
E-mail: rafaelrhps@yahoo.com.br

Reviewing editor:
Pedro González-Redondo, University of Seville, Spain

Additional information is available at the end of the article

Abstract: Annually, million tons of agro-industrial wastes are generated in Brazil. A environmentally friendly and economically viable destination for agro-industrial by-products is their use in animal feed, reducing feed costs of the farm. Some products can replace conventional foods such as corn, soybeans and wheat, without incurring losses in animal performance. So the competition by using the same raw materials used in food and feed decreases and higher amount of grain will be used for human consumption. The by-products rich in pectins have high digestible energy content for its high rate of cecal degradation and are used as substitutes for grains rich in starch which traditionally make up the diet of horses. The objective of this review was to describe on the inclusion of by-products rich in pectins in the horses' diet, emphasizing their benefits to the animal's health. For the inclusion of pectin-rich by-products such as beet pulp, citrus pulp and soybean hulls in horse's diet will be observed the nutritional composition, presence of anti-nutritional factors, palatability, feeding behavior and digestibility of nutrients. More research will be realized to evaluate the effects of the use of pectin-rich byproducts in horse's diet.

Subjects: Environmental Management; Food Science & Technology; Nutrition

Keywords: equine; beet pulp; citrus pulp; diet; soybean hulls

1. Introduction

The agro-industrial sector generates millions of tons of wastes, whose destination is problematic not only due to the large amount, but mostly because the high polluting potential of most of these

ABOUT THE AUTHORS

Rafael Henrique Prado Silva and Diogo Felipe da Silva Inácio have a Masters degree in Animal Science and are PhD students at the Federal University of Minas Gerais, Brazil. Adalgiza Souza Carneiro de Rezende is a Titular Professor at the same institution and has great experience in equine nutrition, feed assessment for horses and exercise physiology. The authors are currently realizing researchs related to equine production and nutrition in Minas Gerais, Brazil. This review was carried out on the need to find a suitable destination for agro-industrial wastes in feeding horses. Other recent research made by the Equine Breeding Study Group researchers are related to the evaluation of sorghum silage for foals, effects of deworming on the digestibility of nutrients on pregnant mares and morphometry of Mangalarga Marchador breed foals.

PUBLIC INTEREST STATEMENT

This review addresses a problem faced in Brazil, which is the generation of large volumes of agricultural industries wastes. Brazil has a big potential for cereal production and has a big difficulty finding an environmentally friendly and economically viable destination for residues generated in the processing of theses cereals. Many residues, also known as byproducts, are sources of good quality fiber because they contain pectins and can be used to feed herbivorous animals such as horses. The pectins are almost entirely degraded by microbial flora which colonizes the cecum-colon of horses, releasing volatile fatty acids that are absorbed by horses and are used as a source of energy. Thus, foods rich in pectins, soy hulls, beet pulp and citrus pulp can replace partially concentrated energetic feed rations, reducing the risk of problems related to starch fermentation in the large intestine and keeping the energy content of the diet.

by-products. When they have good nutritional value, great availability and low cost, by-products can reduce feed supply costs and increase profitability and viability of the farming system (Furtado, Brandi, & Ribeiro, 2011).

According to Furtado et al. (2011), some by-products have comparable nutritional value with feeds traditionally used in equine diet such as corn, soybeans and wheat, replacing these without harming the performance. Thus, the competition using the same raw materials used in human food and animal feed decreases and larger amount of grain will be intended for human consumption.

For horses, the nutritional value of by-products is influenced, among other factors, by the content and quality of the fiber. Feeds with high lignified fiber content, such as straws, are difficult to ferment by cecal microbiota and less amount of volatile fatty acids will be absorbed for energy generation (National Research Council, 2007). Yet by-products rich in pectins have, in general, high content of digestible energy for its high rate of cecal degradation and are used as replacements of grains that traditionally make up the diet of horses (Jensen, Brøkner, Bach Knudsen, & Tauson, 2010; Kabe et al., 2016). This substitution reduces the risks of drops in intestinal pH, laminitis and cramping from the overload of starch in the large intestine, without compromising the nutritional value of the diet (Miraglia, Bergero, Polidori, Peiretti, & Ladetto, 2006).

The objective of this paper is to describe about the inclusion of by-products rich in pectins in the diet of horses, emphasizing its benefits to the health of the animal.

2. Pectins and its properties

The pectins are present in the middle lamella of plant cells and are made up of polymers of galacturonic acid. These polymers differ by the number of methoxy groups, which may also be associated with residues of rhamnose, galactose and arabinose. They are almost entirely degraded by microbes that colonize the cecum-colon of horses. Despite causing a high rate of fermentation, pectins generate predominantly acetic acid (Gilaverte et al., 2011). The galacturonic acid promotes an efficient buffering due to its ability to exchange of cations and connections with metal ions. This avoids the drop of intestinal pH which is harmful to the growth rate of cellulolytic bacteria (Van Soest, Robertson, & Lewis, 1991). However, the cation exchange capacity can influence the availability of calcium when the pectin complex to this mineral through non-covalent bonds (Theuwissen & Mensink, 2008).

The pectins alter the viscosity of the digest, being related to the water-holding capacity and electrolytes in the large intestine, and are therefore recommended for animals in moderate exercise (Furtado et al., 2011; Warren, Lawrence, Brewster-Barnes, & Powel, 1999).

The addition of pectins to the diet can also reduce blood levels of cholesterol and triglycerides, because they bind to cholic acid and stimulate its biliary excretion. Thus, the body must use the serum cholesterol for the synthesis of more cholic acid. This effect was observed by Grosseli et al. (2015) when induced rabbits to hypercholesterolemia, fed with hulls and pulp of passion fruit. However, Oliveira et al. (2002) observed that the addition of 3% of pectins of the equine diet did not affect ($p > 0.05$) cholesterol and triglycerides.

The high proportion of concentrate in the equine diet is associated with, among several factors, disorders related with intestinal acidosis, as laminitis and colic. The critical capacity of digestion of hydrolysable carbohydrates by equine is approximately 0.4% of the body weight and the maximum intake of starch should be 2 g/kg BW. Otherwise, a large amount of starch may reach the large intestine, be quickly fermented and generate predominantly lactic acid, reducing the intestinal pH, which causes an imbalance in the microbial profile in the cecum-colon and damage to the health of the animal (Lindberg, 2013; Potter, Arnold, Householder, Hansen, & Brown, 1992).

Replacing cereals rich in starch with alternative ingredients rich in pectins as soy hulls (*Glycine max*), beet pulp (*Beta vulgaris*) and citrus pulp (*Citrus sinensis*) can reduce the risk of problems related to starch fermentation in the large intestine, keeping the energy content of the diet (Miraglia et al., 2006).

Research conducted with rabbits, which are also herbivores with cecal fermentation, testing the replacement of starch by by-products rich in pectins has demonstrated positive results in the performance and health of the animal. Gómez-Conde et al. (2009) assessed the inclusion of beet pulp and apple pulp on diets of growing rabbits and related that the neutral detergent soluble fiber increased of 7.9 to 13.1% in dry matter (DM) which provided a reduction in mortality, due to the lower proportion of pathogens in the large intestine such as *Clostridium perfringens* and *Campylobacter* spp.

In general, plants of Fabaceae family contain more pectic substances, from 7–14% in DM, than grasses, which contain 2–5% on DM (Ezequiel & Galati, 2005). Yet the fruits and some agro-industrial by-products contain up to 35% of pectins in DM (Canteri, Moreno, & Wosiaki, 2012). According to Hall (2000), by-products such as citrus pulp, beet pulp and soybean hulls contain 29.0, 20 and 33.7% of pectins, respectively.

Studies that assess the use of by-products in feeding horses are scarce and are usually held for a short period or with small number of animals. Experiments that evaluated the use of the main by-products rich in pectins used in horses' diet are related bellow.

3. Soybean hulls (*Glycine max*)

Soybean hulls are a by-product obtained from the processing of soybeans for oil extraction and production of soybean bran. A limitation for their use in animal feed is the variability in composition, which makes the balancing of diets very difficult. However, should ponder this disadvantage of its use with the cost of production, because this variation in composition also happens with other by-products. In general, soybean hulls have digestible energy value (DE) similar to alfalfa (*Medicago sativa)*, is rich in pectins, cellulose and hemicelluloses, and poor in lignins and starch, with good palatability and digestibility for horses. When overly powdery, it can be used in the form with added molasses pelletized (Furtado et al., 2011).

Soybean hulls represent about 2% of the amount of soybeans processed in Brazilian industries. Considering the Brazilian production of soybeans was 96 million tons in 2014/2015, can be generated 1.9 million tons of soybean hulls (Companhia Nacional de Abastecimento-CONAB, 2015).

Soybean hulls has been used for ruminants and rabbits with satisfactory results in performance (Morais, Susin, Pires, Mendes, & Oliveira Júnior, 2007; Oliveira et al., 2007; Retore, Silva, Toledo, & Araújo, 2010; Toledo et al., 2012).

Booth, Tyler, Miller-Auwerda, and Moore (2004), studying soybeans hulls as an alternative source of fiber for horses, used the basic diets of alfalfa and bromegrass *(Bromus sp.)* with substitutions of 25, 50 and 75% of the diet by soybean hulls. There was an increase in linear production of volatile fatty acids (VFA's) as the soybean hulls were introduced to the diet, with increased production of propionate, and the production of butyrate and acetate: Proprionate ratio decreased. The consumption of DM and the apparent digestibility of DM (ADCDM), organic matter (ADCOM), neutral detergent fiber (ADCNDF) and acid detergent fiber (ADCADF), cellulose and hemicelluloses showed no differences between the treatments, but the apparent digestibility coefficient of crude protein (ADCCP) decreased with the addition of by-product, because there was an increase of microbial protein synthesis; that cannot be used by horses and the excess is then excreted. The cecal pH decreased from 7.0 to 6.45, not being considered harmful. The authors concluded that soybean hulls stimulate cecal fermentation and can be considered as an alternative source of fiber for equines. The largest production of propionate can promote gluconeogenesis for being one of its substrates, in addition to representing less loss of energy.

Arruda and Ribeiro (2009) assessed the digestibility coefficients of nutrients in diets with the inclusion of four by-products: soybean hulls, soybean residues, wheat and corn hulls. The diet containing soybean hulls had the highest ADCDM and ADCADF, and the second largest ADCNDF. However, both the inclusion of soybean hulls as the corn hulls reduced the ADCCP, according to the results of Booth et al. (2004).

For a period of 75 days, Quadros, Furtado, Barbosa, and Trevisan (2004) evaluated the replacement of tifton bermudagrass hay by soybean hulls on a diet for foals in which the forage:concentrate ratio was 40:60. The replacements were 33, 66 and 100% of *Cynodon dactylon* cv. Tifton 85 hay in comparison to the control group (without replacement). There was an increase of ADCDM, ADCNDF and ADCFDA, and there was no damage at the height, thoracic perimeter and shin perimeter of foals. Garcia et al. (2010a), using a diet based in tifton 85 hay, evaluated the total substitution of corn for soybeans hulls (15.5% of diet) in concentrate for adult equines and did not observe differences in ADCDM, ADCNDF and ADCCP, ADCADF of diets studied.

In a test of preference, Garcia, Ezequiel, Gonçalves, Junqueira, and D'Áurea (2010b) have assessed equine preference by 50% concentrate by-product (soybean hulls, citrus pulp or maize germ) in comparison with standard concentrate (50% corn). There was no difference in the frequency of preference of standard concentrates and soybean hulls, but the frequency of the concentrate with citrus pulp was much smaller than the other.

Kabe et al. (2016) also evaluated the palatability, digestibility and quality of equine feces fed diets with 7, 14, 21 and 28% of soybean hulls compared to the standard concentrate. There was no negative effect on digestibility and palatability. Also there were no changes in color, pH and buffering capacity of feces and profile of AGV's produced with the inclusion of up to 28% of soybean hulls in concentrate or 11.2% of the diet ($p > 0.05$).

4. Beet pulp (*Beta vulgaris*)

Some countries, like the United States of America, obtain commercial sugar from beet sugar extraction. By-product originating from this processing is the beet pulp, with high content of digestible fiber, as pectin, with water holding capacity greater than that of hay cubes or soybean hulls (Moore-Colyer, Hyslop, Longland, & Cuddeford, 2002). Harris and Rodiek (1993) included up to 45% of beet pulp on a diet based on alfalfa hay for horses without negative effects. Moore-Colyer et al. (2002) reported disappearance of 85% beet pulp by the technique of mobile bags in ponies, generating increased amounts of nutrients in the digestive tract than soybean hulls, hay cubes and oat hulls. However, the sugar pulp had lower protein digestibility.

Murray, Longland, Hastie, Moore-Colyer, and Dunnett (2008) evaluated the replacement of 10, 20 and 30% alfalfa hay for beet pulp and realized they may be replaced by up to 30%, when there was greater ADCOM, but reducing ADCCP.

Rodiek and Stull (2007) compared the glycemic response of soybean hulls, beet pulp, rice bran, wheat bran, oat flakes, corn, barley and rolled (corn, barley and oats and molasses) and alfalfa hay in a meal whose amount of all food was adjusted to provide 4 Mcal. The concentrate, corn and oats had the highest glycemic indexes and beet pulp, alfalfa, rice bran and soybean hulls had the lowest rates, due to the type of processing and starch content of feeds. These results demonstrated the potential of beet pulp, among other by-products to prevent hyperinsulinemia in equines.

Crandell, Pagan, Harris, and Duren (1999) observed that the replacement of sweet feed to beet pulp in 15% of the energy of the diet did not affect the performance of the horses, but it was not enough to reduce the glycemic and insulinemic responses in performance horses, as was observed reduction when soybean oil replaced the sweet feed in 15% of the energy of the diet. However, Palmgren Karlsson, Jansson, Essén-gustavsson, and Lindberg (2002) observed that, at rest, plasma insulin were lower ($p < 0.05$) 60 and 90 min postprandially when beet pulp replaced oat in the diet of performance horses, while no differences were found in plasma glucose and insulin between the diets during the exercise. Moreover, beet pulp, with represented 13% of the diet, reduced the peak plasma and muscle lactate values and increased the content of muscle glycogen after the exercise.

According to Olsman et al. (2004), beet pulp feeding at a level of 25% of the total dietary DM significantly lowered crude fat and non-structural carbohydrate digestibility, but had no significant effect on digestibility of other macronutrients, faecal and urinary nitrogen excretion and the faecal to urinary nitrogen excretion quotient. Jensen, Austbø, Bach Knudsen, and Tauson (2014) replaced barley to beet pulp (32% of the diet) without negative effects on nutrient intake for horses. The diets were isoenergetic and provided protein and digestible energy enough for light to moderate exercise for a 550 kg horse.

5. Citrus pulp (*Citrus sinensis*)

With low starch content, high content of pectin and citric scent, citrus pulp is from mainly orange juice extraction, but can be made up of by-products of other citrus fruits such as lemon, tangerine and pineapple (Frape, 2008).

The by-product of orange processing comprises approximately 50% of the total fruit. After extraction of the juice, the pulp is separated from the pulp, hulls and seeds. Subsequently, the pulp is crushed and added oxide or calcium hydroxide to remove excess water and reach pH 7. Then, pressing and drying temperature steam around 90°C. Finally, the citrus pulp is pelletized, facilitating storage and transport (Regina, 2010). The compositions of citrus pulp and the other two by-products already presented are in Table 1.

Manzano, Freitas, Esteves, and Novaes (1999) compared the replacement of 7.5 and 15% of the concentrate (26 and 55% substitution of corn) for citrus pulp for growing horses for 16 weeks in a diet based in *coast-cross* hay (*Cynodon dactylon*). They observed greater ADCDM, ADCCP and higher

Table 1. Chemical composition[a] of the soybean hulls, citrus pulp and beet pulp according to several authors

	DE Mcal/kg	CP%	NDF%	ADF%	EE%	Ca%	P%	Lys%	Pec%	Starch%
Soybean hulls										
Freeman, 1990	2.44	11	–	–	2.3	0.5	0.1	0.5	–	5.0
Hall, 2000	–	–	–	–	–	–	–	–	20.0	–
Quadros et al., 2004	–	11	64	52	–	–	–	–	–	–
Booth et al., 2004	–	13	61	44	–	–	–	–	–	–
National Research Council, 2007	2.25	14	60	45	2.7	0.6	0.2	0.87	–	–
Citrus pulp										
Hall, 2000	–	–	–	–	–	–	–	–	29.0	–
Perali, Lima, Fialho, Bertecchini, & Araújo, 2001	2.74	6.9	28	25	–	1.6	0.1	–	–	–
National Research Council, 2007	2.85	7	24	22	4.9	1.9	0.1	0.18	–	–
Lindberg, 2013	3.45	7	22	–	2.5	–	–	–	–	3.2
Beet pulp										
Freeman, 1990	2.44	9.0	–	–	0.6	0.2	0.1	0.5	–	3.0
Hall, 2000	–	–	–	–	–	–	–	–	33.7	–
National Research Council (2007)	2.80	10	46	23	1.1	0.91	0.1	0.44	–	–
Lindberg, 2013	3.30	9	45	–	1.0	1.5	0.1	0.79	–	0

[a]DE: Digestible Energy; CP: Crude Protein; NDF: Neutral Detergent Fiber; ADF: Acid Detergent Fiber; EE: Ether Extract; Ca: Calcium; P: Phosphorus; Pec: Pectins.

consumption with the addition of 15% citrus pulp, but there were no differences for weight gain, height at the withers and thoracic perimeter.

Tribucci, Brandi, Barielo, Titto, and Bueno (2013) compared the levels of 7, 14, 21 and 28% (0.28, 0.56, 0.84, 1.12 kg of citrus pulp) of inclusion of citrus pulp in concentrate, in forage:concentrate ratio of 60:40 in the behavior of confined equines and, due to the drop in consumption, it is recommended the use of 7% without adding taste additives as molasses. The same inclusion levels were tested by Moreira et al. (2015), which also observed reduction in consumption with increasing inclusion and therefore also found no negative effects when assessed the physico-chemical characteristics of feces (pH, color, consistency and buffering capacity).

Brandi, Tribucci, Balieiro, Hoffman, and Bueno (2014) evaluated concentrates containing increasing inclusion levels of citrus pulp (0, 7, 14, 21, and 28%) for maintenance horses, establishing a roughage-to-concentrate ratio of 60:40 with the coast-cross hay as the roughage. No effect of the diets was observed on the coefficients of digestibility of DM, organic matter, crude protein, ether extract, nitrogen-free extract, and non-fibrous carbohydrates; however, there was an increase ($p < 0.05$) on the soluble carbohydrates' digestibility.

6. Fruit waste

According Lousada, Costa, Neiva, and Rodriguez (2006), for certain fruits, such as mango (*Mangifera indica*), acerola (*Malpighia glabra*), passion fruit (*Passiflora edulis*) and cashews (*Anacardium occidentale*), it is estimated that, of the total quantity processed for the production of juices and pulps, 40% corresponds to agro-industrial waste. By-products from fruits have generally high content of soluble carbohydrates and can have high lignin content, such as acerola fruit, which has up to 20% of lignins in DM, and high content of hemicelluloses as pineapple (*Ananas comosus*) with 40% DM. Lousada et al. (2006) evaluated the chemical composition of residues from the extraction of pineapple juice, acerola, guava (*Psidium guajava*), passion fruit and melon (*Cucumis melo*) and pectins levels were of 13.33, 16.85, 15.63, 24.98 31.35%, and so good sources of pectins.

The characteristics of the waste of fruits in general are: high water levels (85%), crude fiber (30%), sugar and pectins, low-vitamin, mineral and protein, highlighting the risk of undesirable fermentations (Furtado et al., 2011). For horses, fruits are, therefore, more as a snack during training. On the other hand, Frape (2008) indicates that the waste of fresh fruit can be used in an amount of not more than 20% of the total diet MS.

7. Final considerations

For the inclusion of by-products in feeding horses, as well as observe its nutritional composition and presence of anti-nutritional factors, must be carefully observed the palatability, feeding behavior and digestibility of nutrients. The lack of research and the great variability in the chemical composition of the by-products, due to variation of component foods, still have limited its use by horses.

Funding
The authors received no direct funding for this research.

Competing Interests
The authors declare no competing interest.

Author details
Rafael Henrique Prado Silva[1]
E-mail: rafaelrhps@yahoo.com.br
Adalgiza Souza Carneiro de Rezende[1]
E-mail: adalgizavetufmg@gmail.com
Diogo Felipe da Silva Inácio[1]
E-mail: diogofsi@outlook.com
[1] School of Veterinary, Federal University of Minas Gerais, 6627, Antônio Carlos Avenue, Campus Pampulha, Belo Horizonte 31270-901, Minas Gerais, Brazil.

Citation information
Cite this article as: Pectin-rich by-products in feeding horses—A review, Rafael Henrique Prado Silva, Adalgiza Souza Carneiro de Rezende & Diogo Felipe da Silva Inácio, *Cogent Food & Agriculture* (2016), 2: 1193925.

References

Arruda, M. V., & Ribeiro, L. B. (2009). Digestibility of agro-industrial by-products in the horses feeding. *Archivos de Zootecnia, 58*, 451–454.

Booth, J., Tyler, H., Miller-Auwerda, P., & Moore, J. (2004). Soybean hulls as an alternative feed for horses (ASL R1931). *Animal Industry Report, 650*, 1–4.

Brandi, R. A., Tribucci, A. M. O., Balieiro, J. C. C., Hoffman, R. H., & Bueno, I. C. S. (2014). Citrus pulp in concentrates for horses. *Food and Nutrition Sciences, 5*, 1272–1279. doi:10.4236/fns.2014.513138

Canteri, M. H. G., Moreno, L., & Wosiaki, L. G. (2012). Pectin: From raw material to end product. *Polymers, 22*, 149–157. doi:10.1590/S0104-14282012005000024

Companhia Nacional de Abastecimento-CONAB. (2015). Monitoring of the Brazilian crop. *Observatório Agrícola, 2*, 109 p.

Crandell, K. G., Pagan, J. D., Harris, P., & Duren, S. E. (1999). A comparison of grain, oil and beet pulp as energy sources for the exercised horse. *Equine Veterinary Journal, 30*, 485–489. doi:10.1111/j.2042-3306.1999.tb05270.x

Ezequiel, J. M. B., & Galati, R. L. (2005). Quality of raw material and new laboratory tests as a means of maximizing the balanced diet. In *Annual Meeting of the Brazilian Society of Animal Science, 42, Symposium on ruminant Nutrition. Proccedings* (pp. 296–321). Goiânia.

Frape, D. (2008). *Nutrition and equine nutrition* (3rd ed., 616 p.). São Paulo: Roca.

Freeman, D. W. (1990). Use of by-product and nontraditional feeds for horses. *Division of Agricultural Sciences and Natural Resources, Oklahoma State University*, no 3923, 1–4.

Furtado, C. E., Brandi, R. A., & Ribeiro, L. B. (2011). Use of by-products and alternative feeds for horse diet in Brazil. *Revista Brasileira de Zootecnia, 40*, 232–241.

Garcia, H. A. C., Ezequiel, J. M. B., Gonçalves, J. S., Junqueira, D. R., D'Áurea, A. P., & Furtado, C. E. (2010a). Apparent digestibility of nutrients in diets containing by-products as substitutes of corn for horses. In *Annual Meeting of the Brazilian Society of Animal Science, 47, Proceedings*, Salvador.

Garcia, H. A. C., Ezequiel, J. M. B., Gonçalves, J. S., Junqueira, D. R., & D'Áurea, A. P. (2010b). Free choice of horses receiving concentrate with complete replacement of corn for soybeans hulls, maize germ and citrus pulp. In *Annual Meeting of the Brazilian Society of Animal Science, 47, Proceedings* (pp. 1–2). Salvador.

Gilaverte, S., Susin, I., Pires, A. V., Ferreira, E. M., Mendes, C. Q., Gentil, R. S., & Rodrigues, G. H. (2011). Diet digestibility, ruminal parameters and performance of Santa Ines sheep fed dried citrus pulp and wet brewer grain. *Revista Brasileira de Zootecnia, 40*, 639–647. doi:10.1590/S1516-35982011000300024

Gómez-Conde, M. S., de Rozas, A. P., Badiola, I., Pérez-Alba, L., de Blas, C., Carabaño, R., & García, J. (2009). Effect of neutral detergent soluble fibre on digestion, intestinal microbiota and performance in twenty five day old weaned rabbits. *Livestock Science, 125*, 192–198. doi:10.1016/j.livsci.2009.04.010

Grosseli, M., Moraes, M. B., Damaceno, B. F., Okawabata, F. S., Tardivo, A. C. B., & Alves, M. J. Q. F. (2015). Uso da polpa e da casca do maracujá (*Passiflora edulis* f. flavicarpa) sobre o colesterol em coelhos com hipercolesterolemia experimental. *Revista de Pesquisa e Inovação Farmacêutica, 6*, 12–20.

Hall, D. B. (2000). *Neutral detergent-soluble carbohydrates: nutritional relevance and analysis*. University of Florida, Gainesville, FL. Bulletin, 339.

Harris, D. M., & Rodiek, A. V. (1993). Dry matter digestibility of diets containing beet pulp fed to horses. In *Equine Nutrition and Physiology Symposium, 13. Proccedings* (pp. 100–101). Gainesville.

Jensen, R. B., Brøkner, C., Bach Knudsen, K. E. B., & Tauson, A. H. (2010). A comparative study of the apparent total tract digestibility of carbohydrates in Icelandic and Danish Warmblood horses fed two different haylages and a concentrate consisting of sugar beet pulp and black oats. *Archives of Animal Nutrition, 64*, 343–356. doi:10.1080/1745039X.2010.504606

Jensen, R. B., Austbø, D., Bach Knudsen, K. E., & Tauson, A. H. (2014). The effect of dietary carbohydrate composition on apparent total tract digestibility, feed mean retention time, nitrogen and water balance in horses. *Animal, 8*, 1788–1796. doi:10.1017/S175173111400175X

Kabe, A. M. G., de Souza, A. D., de Moro Sousa, R. L. M., da Silva Bueno, I. C. S., Mota, T. P., Crandell, K., & Brandi, R. A. (2016). Soybean hulls in equine feed concentrates: Apparent nutrient digestibility, physicochemical and microbial characteristics of equine feces. *Journal of Equine Veterinary Science, 36*, 77–82. http://dx.doi.org/10.1016/j.jevs.2015.10.008

Lindberg, J. E. (2013). Feedstuffs for horses. In R. J. Geor, P. A. Harris, & M. Coenen (Eds.), *Equine applied and clinical nutrition: Health, welfare and performance* (pp. 319–331). Philadelphia, PA: Ed Saunders.

Lousada, Jr., J. E., Costa, J. M. C., Neiva, J. N. M., & Rodriguez, N. M. (2006). Physical-chemical characterization of tropical fruit by-products for use in animal feed. *Revista Ciência Agronômica, 37*, 70–76.

Manzano, A., Freitas, A. R., Esteves, S. N., & Novaes, N. J. (1999). Citrus Pulp equine feed pelletized. *Revista Brasileira de Zootecnia, 29*, 1327–1332. http://dx.doi.org/10.1590/S1516-35981999000600021

Miraglia, N., Bergero, D., Polidori, M., Peiretti, P. G., & Ladetto, G. (2006). The effects of a new fibre-rich concentrate on the digestibility of horse rations. *Livestock Science, 100*, 10–13. doi:10.1016/j.livprodsci.2005.11.003

Moore-Colyer, M. J. S., Hyslop, J. J., Longland, A. C., & Cuddeford, D. (2002). The mobile bag technique as a method for determining the degradation of four botanically diverse fibrous feedstuffs in the small intestine and total digestive tract of ponies. *British Journal of Nutrition, 88*, 729–740. doi:10.1079/BJN2002734

Morais, J. B., Susin, I., Pires, A. V., Mendes, C. Q., & Oliveira, Jr, R. C. (2007). Replacement of coastcross hay by soybean hulls in ewe lambs diets. *Ciência Rural, 37*, 1073–1078. doi:10.1590/S0103-84782007000400025

Moreira, C. G., Bueno, I. C. S., Menezes, M. L., Mota, T. P., Souza, A. D., Tavares, A. F., … Brandi, R. A. (2015). Palatability and digestibility of horse diets containing increasing levels of citrus pulp. *Revista MVZ. Córdoba, 20*, 4544–4555.

Murray, J. M. D., Longland, A. C., Hastie, P. M., Moore-Colyer, M., & Dunnett, C. (2008). The nutritive value of sugar beet pulp-substituted lucerne for equids. *Animal Feed Science and Technology, 140*, 110–124. doi:10.1016/j.anifeedsci.2007.02.013

National Research Council. (2007). *Nutrient Requirements of horses*. (6th ed.). Washington, DC: National Academies Press.

Oliveira, G. J. C., Lima, J. A. F., Araújo, K. V., Fialho, E. T., Bertechini, A. G., Pérez, J. R., & Freitas, R. T. F. (2002). Influence of pectin on physiological parameters in equines. *Ciência e Agrotecnologia, 26*, 858–864.

Oliveira, A. S., Campos, J. M. S., Valadares Filho, S. C., Assis, A. J., Teixeira, R. M. A., Valadares, R. F. D., … Oliveira, G. S. (2007). Substitution of corn for coffee pods or soybeans in diets for dairy cows: Consumption, nutrient digestibility, milk production and composition. *Revista Brasileira de Zootecnia, 36*, 1172–1182.

Olsman, A. F. S., Huurdeman, C. M., Jansen, W. L., Haaksma, J., Van Oldruitenborgh-Oosterbaan, M. M. S., & Beynen, A. C. (2004). Macronutrient digestibility, nitrogen balance, plasma indicators of protein metabolism and mineral absorption in horses fed a ration rich in sugar beet pulp. *Journal of Animal Physiology and Animal Nutrition, 88*, 321–331. doi:10.1111/j.1439-0396.2004.00487.x

Palmgren Karlsson, C., Jansson, A., Essén-gustavsson, B., & Lindberg, J. E. (2002). Effect of molassed sugar beet pulp on nutrient utilisation and metabolic parameters during exercise. *Equine Veterinary Journal, 34*, 44–49. http://dx.doi.org/10.1111/j.2042-3306.2002.tb05390.x

Perali, C., Lima, J. A. F., Fialho, E. T., Bertecchini, A. G., & Araújo, K. V. (2001). Nutritional values of feed for horses. *Ciência e Agrotecnologia, 25*, 1216–1224.

Potter, G. D., Arnold, F. F., Householder, D. D., Hansen, D. H., & Brown, K. M. (1992). Digestion of starch in the small or large intestine of the equine. *Pferdeheilkunde, 1*, 107–111.

Quadros, J. B. S., Furtado, C. E., Barbosa, E. D., & Trevisan, A. G. (2004). Apparent digestibility and development of growing horses fed diets with different levels of substitution of tifton 85 hay for soybean hulls. *Revista Brasileira de Zootecnia, 33*, 564–574. doi:10.1590/S1516-35982004000300006

Regina, R. (2010). *Animal nutrition, main ingredients and handling of poultry and swine*. São Paulo: Cargill Foundation.

Retore, M., Silva, L. P., Toledo, G. S. P., & Araújo, I. G. (2010). Effect of agricultural by-products fiber and its nutritional evaluation for rabbits. *Arquivo Brasileiro de Medicina Veterinária e Zootecnia, 62*, 1232–1240. doi:10.1590/S0102-09352010000500028

Rodiek, A. V., & Stull, C. L. (2007). Glycemic index of ten common horse feeds. *Journal of Equine Veterinary Science, 25*, 205–211. doi:10.1016/j.jevs.2007.04.002

Theuwissen, E., & Mensink, R. P. (2008). Water-soluble dietary fibers and cardiovascular disease. *Physiology Behavior, 94*, 285–292. doi:10.1016/j.physbeh.2008.01.001

Toledo, G. S. P., Eggers, D. S., Silva, L. P., Pacheco, P. S., Klinger, A. C. K., Capitânio, J. R., & Ortiz, J. (2012). Soybean hulls in the replacemennt of alfafa hay in diet non pelleted for growing rabbits. *Ciência Rural, 42*, 1896–1900. doi:10.1590/S0103-84782012001000029

Tribucci, A. M., Brandi, R. A., Barielo, J. C. C., Titto, E. A. L., & Bueno, I. C. S. (2013). Palatability of horse diets containing citrus pulp (*Citrus sinensis*) through the preference test. *Italian Journal of Animal Science, 27*, 204–207. doi:10.4081/ijas.2013.e33

Van Soest, P. J., Robertson, J. P., & Lewis, B. A. (1991). Methods for dietary fiber, neutral detergent fiber, and nonstarch polysaccharides in relation to animal nutrition. *Journal of Dairy Science, 4*, 3583–3597. doi:10.3168/jds.S0022-0302(91)78551-2

Warren, L. K., Lawrence, L. M., Brewster-Barnes, T., & Powel, D. M. (1999). The effect of dietary fibre on hydration status after dehydration with frusemide. *Equine Veterinary Journal, Suppl., 20*, 508–513. doi:10.1111/j.2042-3306.1999.tb05275.x