Proceedings of the 3rd European Equine Nutrition & Health Congress, Mar. 17-18, 2006 -
Ghent University, Merelbeke, Belgium

Factors Affecting Glycaemic Index of Feds for Horses

I. Vervuert and M. Coenen

Institute for Animal Nutrition, University of Veterinary Medicine Hannover, Foundation, Bischofsholer Damm 15, 30173 Hannover, Germany
Ingrid.Vervuert@tiho-hannover.de

Introduction

The glycaemic response to foods has been of concern in humans for many years, especially in the management of obesity, diabetes mellitus and cardiovascular diseases. The glycaemic index (GI) is a ranking of starchy foods based on the postprandial blood glucose response compared with the response to a 50-g glucose test load (Jenkins et al. 1981). The GI was originally introduced to classify different sources of carbohydrate-rich foods, usually those with an energy content of > 80% from the available carbohydrates, as to their effect on post-meal glycaemia. By definition, the GI compares equal quantities of carbohydrate and provides a measure of carbohydrate quality but not quantity.
Thus, low-GI carbohydrates were classified as those that are digested and absorbed slowly and lead to a low glycaemic response, while high-GI carbohydrates are digested and absorbed rapidly and lead to a high glycaemic response (Foster-Powell and Brand Miller 1995). In 1997 the concept of glycaemic load (GL) was introduced to quantify the overall glycaemic effect of a meal as both, the quality and quantity of carbohydrate determines an individual´s glycaemic response to a meal (Foster-Powell et al. 2002). As defined, the GL is the product of a food´s GI and its total available carbohydrate content (GL = [GI x carbohydrate (g)] / 100). There are convenient international tables of glycaemic indexes and loads for more than 700 foods containing all published data on the GIs of individual foods (Foster-Powell and Brand Miller 1995, Foster-Powell et al. 2002).

There is interest in the glycaemic response in horses for conditions such as exercise performance, obesity, insulin resistance, laminitis and osteochondrosis (Kronfeld et al. 2005). There is information available on the influence of different grain sources on glucose and insulin responses in the horse, but little is known about the influence of different grain processing techniques and the effect of mixed meals (compound feeds or grain-roughage mixtures) on glucose and insulin control. Furthermore, no standardised glycaemic or insulinaemic index has yet been formulated for horses such as that for humans.

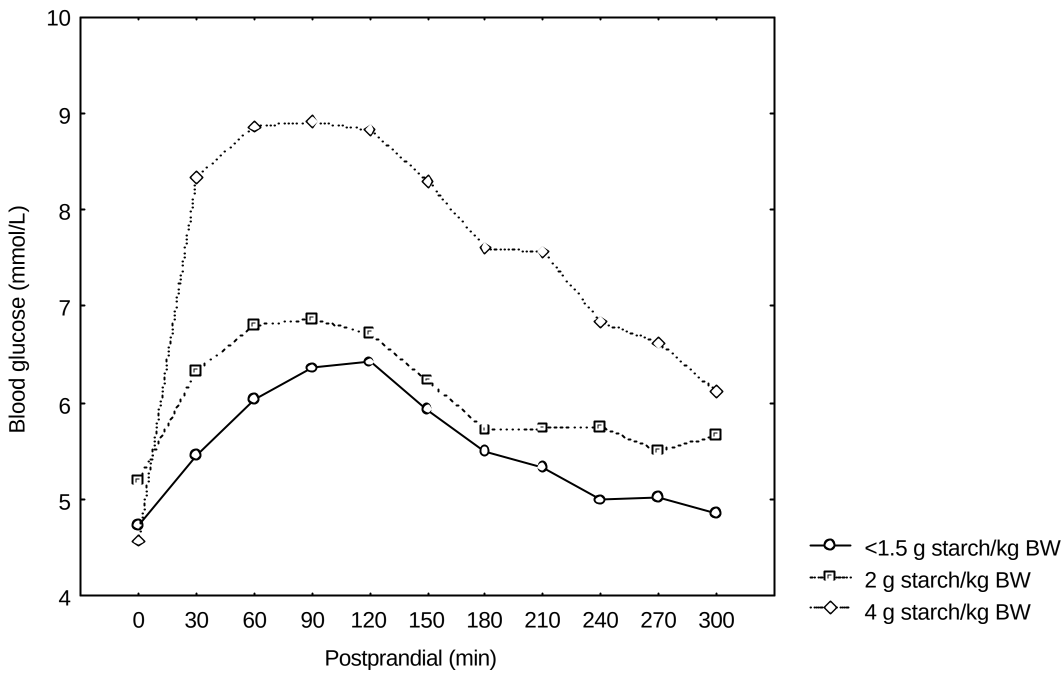
Starch digestibility

In horses, the total tract apparent digestibility of starch is usually very high for the different types of grains. Arnold et al. (1981) reported values of 97.0%, 96.7% and 97.0% for corn, oats and sorghum starch, respectively. However, considerable differences in precaecal starch digestibility were found between the different starch sources. In general, the precaecal digestibility of oat starch exceeds that of corn starch or of barley starch (Kienzle et al. 1992, Potter et al. 1992, Meyer et al. 1995). In general, precaecal starch digestibility of cereals is increased by improving the accessibility of the starch to enzyme degradation in the small intestine in both humans and animals (Brand et al. 1985, Holm et al. 1988, Kienzle et al. 1992, Potter et al. 1992, Meyer et al. 1995). The granular structure of starch can be destroyed mechanically (Kienzle et al. 1997) or by heat and pressure in combination with moisture (Ross et al. 1987, Granfeldt et al. 1994). The effect of thermal processing is the irreversible swelling and destruction of the internal crystalline structure of the starch granules; this transformation is termed gelatinisation (Holm et al. 1988, Selmi et al. 2000). Consequently, an increase in the availability of starch for enzymatic digestion might alter the metabolic response, as more substrate will be absorbed in the small intestine.

Importance of grain source and starch intake on glucose and insulin responses

In ponies (aged 3 to 18 years), oat feeding led to higher blood glucose levels than feeding whole corn or barley. However, increasing starch intake (by 2 or 4 g starch/kg BW per meal) did not influence blood glucose responses (Radicke et al. 1994). The higher glycaemic response to oat feeding was accompanied by a higher praececal starch digestibility of oats. On the other hand, Jose-Cunilleras et al. (2004) found no differences in the glycaemic response of Thoroughbred horses to cracked corn, oat groats and rolled barley when fed 2 g of available carbohydrates (starch and sugar)/kg BW .

Pagan et al. (1999) found no differences in mean postprandial peak plasma glucose concentrations in six Thoroughbred geldings fed whole oats and cracked corn. Furthermore, there was no difference in the area under the postprandial glucose curve between whole oats and cracked corn (0.75, 1.5, or 2.5 g/BW).



Our research group found no differences between whole oats, barley or corn in the response of healthy Standardbred horses with a moderate starch intake (between 1.2 and 1.5 g starch/kg BW, Vervuert et al. 2003, 2004), whereas increasing amounts of oat starch (1.2 – 1.5, 2 or 4 g starch/kg BW) resulted in higher glycaemic responses (Figure 1).

Figure 1:Glycaemic response to different levels of starch intake per meal from oats (Vervuert et al. 2003, current project)

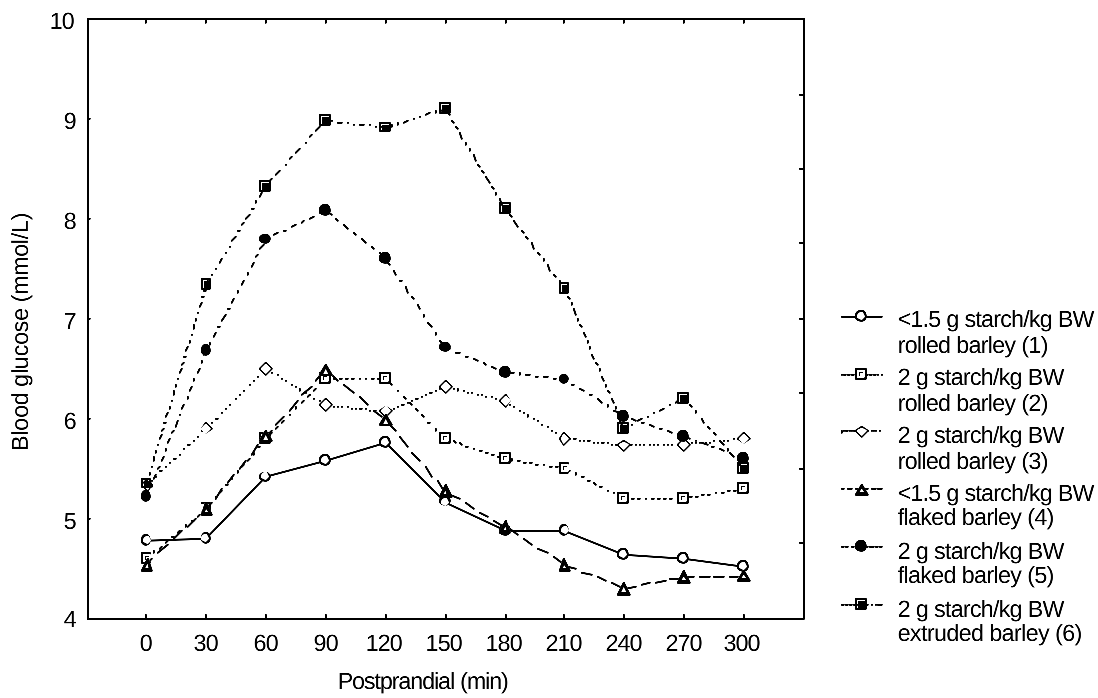
Rodiek and Stull (2005) created a glycaemic index for common horse feeds assuming that the starch intake comprises 25% of equines' daily digestible energy requirement. In general, concentrate feeds (rich in starch) were found to have the highest GI, while those of forages and by-products were relatively lower. The GI of oats was used as the reference (GI: oats = 100%, corn = 117%, barley = 101%, oats + oil = 86%, wheat = 71%, carrots = 51%, timothy hay = 32% and beet pulp = 1%).

Conclusion: Grain source seemed to be of minor importance while starch intake per meal influences GI.

Importance of grain processing on glucose and insulin responses

Hoekstra et al. (2001) investigated the effect of corn processing on glycaemic responses in six horses (four Arabians and two Thoroughbreds aged 6 to 10 years). That experiment was conducted to evaluate the effect of cracking, grinding or steam processing on starch digestibility of corn. The glycaemic response was used as an indirect measure of precaecal starch digestibility. The glycaemic response to each grain was compared using a glycaemic index, so that the glucose area of each feed under the curve was expressed relative to that of cracked corn. The highest glycaemic index was found for steam-flaked corn (2 g starch/kg BW in a single meal). Those authors speculated that the high glycaemic response reflects changes in precaecal starch digestibility due to thermal corn processing.

Our own research group recently found that mechanical or thermal processing of oats, barley or corn had no clear influence on glycaemic or insulinaemic responses in horses when starch intake was moderate (between 1.2 and 1.5 starch/kg BW; Vervuert et al. 2003, Vervuert et al. 2004), but increasing the starch intake (to 2 g starch/kg BW) resulted in a clear distinction between rolled, steam-flaked and



extruded barley (Figure 2).

Conclusion: Effects of grain processing on GI depend on dosage of starch intake.

Figure 2: Glycaemic responses to different ways of processing barley (starch intake per meal; 1, 4: Vervuert et al., publication in preparation, 2: Jose-Cunilleras et al. 2004, 3, 5, 6: actual project)

Complex diets

Generally, foods are not eaten in isolation but in combination in mixed meals; furthermore, single foods are consumed as components of complex diets. It is therefore important to ensure that the GI concept is also applied in the context of mixed meals (Flint et al. 2004). Similarly to humans, horses consume compound feeds as well as grains enriched with roughage. This leads to two questions: Does a feed have the same GI when eaten alone and when combined with other feeds? Can we predict the GI of a meal by the GIs of the different feeds consumed within the meal? The results of pertinent studies in humans are equivocal: while some studies support the predictability of the GI in mixed meals, others indicate that several factors (gastric emptying, consumption rate and nutrient composition) will interact with the carbohydrates, reducing the predictability of the GI (Flint et al. 2004, Brouns et al. 2005).

The matrix structure per se seemed to influence the GI in horses, as a pelleted meal and a sweet feed meal was found to produce different glycaemic responses, despite the fact that the starch content of the two diets was similar (Harbour et al. 2003).

Stull and Rodiek (1988) found a significant increase in the plasma glucose concentration in two-year-old quarter horse geldings both after corn feeding as well as after a combined diet of 50% corn and alfalfa. Insulin concentrations closely followed the glucose curves. However, there was no difference in the postprandial response area for glucose between alfalfa feeding (100%), corn feeding (100%), and combined corn and alfalfa feeding (50% each). Similar results were obtained by Harris et al. (2005), who recently reported that the addition of 35% short Lucerne chaff did not influence the glycaemic response to oats.

In contrast, Radicke et al. (1994) observed a blunted glycaemic response after the addition of roughage to the oat diet. Similarly, Pagan and Harris (1999) found that the glycaemic response was significantly reduced by feeding hay either before or with a sweet feed (42% oats, 31% corn, 8% molasses and 19% supplement pellet).

Conclusion: The modifying effect of dietary fibre on GI seemed to be overestimated in horses, however results are equivocal. Complex diets and GI needs further clarification.

Relationship between glucose and insulin responses

A major rationale for using the GI is the assumption that there is a close correlation between the postprandial blood glucose response and insulin regulation, and for that reason glycaemic response is used to control insulin resistance in horses (Kronfeld et al. 2005). However, only limited information is available in the horse, as there are only a few studies on the relationship between GI and insulinaemic index (II). Zeyner et al. (2005) found a close relationship between GI and II in adult Quarter horses fed mixed diets with sugar beet pulp, rice bran, grass meal and soybean oil which means that the feed with the highest GI also showed the highest II, and contrariwise.

In three other studies no correlation was found between GI and II as the ranking between the GI and II for the same food was different (Jose-Cunilleras et al. 2004, Vervuert et al. 2003, 2004).

Other factors affecting glycaemic and insulinaemic responses

It is interesting to note that the same feedstuff (e.g. flaked barley) was found to induce different glycaemic responses in different studies (Figure 2). These differences appear to be related to the consumption rate, gastric emptying rate, the digestibility of the starch, and the factors determining digestibility, including the interaction of starch with fibre, protein, fat and antinutrients (e.g. phytate) in the food, together with the nature of the starch itself and its physical form (Thorne et al. 1983, Table 1). For example, larger meal size and higher starch content were found to be associated with slower gastric emptying in horses (Métayer et al. 2004). Furthermore, dietary fat is known to slow down the rate of gastric emptying and absorption of nutrients from the gut, which in turn slows the release of glucose to the blood. Increased amounts of fat and protein in the gut also induce increased secretion of certain gut hormones; this in turn increases the insulin response and glucose clearance. Much attention has been focused on dietary fibre in the equine diet. High fibre meals have been shown to produce lower blood glucose responses in healthy and diabetic humans by altering the rate of nutrient absorption (Thorne et al. 1983), but the results of comparable studies in horses were equivocal (see the chapter on complex diets). The rate and extent of starch digestion is further influenced by the botanical origin of the feed, as this determines the amylase:amylopectin ratio and the structural type of the starch granule (Kienzle et al. 1997, Kienzle et al. 1998). Another important factor is food processing, which determines the extent of starch gelatinisation, particle size and the integrity of the plant cell wall (Granfeldt et al. 1994, Granfeldt et al. 2000).

Table 1: Factors affecting the GI of foods and meals in humans [1]

Food factor	Influencing factor	Effect on GI
Gross matrix structure	Grinding	Homogenised: GI ↑
Cell-wall and starch structure	Degree of ripening	Ripe: GI ↑
Granular starch structure	Mechanical and thermal treatment	High degree of gelatinization: GI ↑
Amylose & amylopectin	Digestibility: amylopectin > amylose	Amylopectin ↑: GI ↑
Dietary fibre	Adding fibre	Fibre ↑: GI ↓
Dietary protein	Adding protein	Protein ↑: GI ↓
Dietary fat	Adding fat	Fat ↑: GI ↓
Organic acids	Adding organic acids	Organic acids ↑: GI ↓
Molecular composition of carbohydrates	Type of carbohydrates	Increased number of bonds other than $\alpha 1-4$ and $\alpha 1-6$: GI ↓
Resistant starch, retrogradation	Heating – cooling cycles	Resistant starch ↑: GI ↓
Antinutrients	Amylase inhibitors, phythate	Antinutrients ↑: GI ↓

[1] adapted from Thorne et al. 1983, Rooney and Pflugfelder 1986, Brouns et al. 2005

Furthermore, a standardised methodology is required for both the nutrient composition of foods and their classification according to their impact on blood glucose and insulin. Differences in results obtained for horses might be due to differences in experimental protocols. One important question is what the reference food should be, and a variety of feedstuffs like corn, oats or glucose have been used as the reference for GI measurement in horses. Nor have other parameters been standardised for horses, such as consumption time, amount of carbohydrates, mixed meals, blood sampling times, adaptation to the diets and calculation of the area under the curve, which greatly limits the possibility to compare data from different research groups.

Clinical application of the glycaemic and insulinaemic index in horses

The nutritional importance of postprandial glucose and insulin response with regard to different sources of cereals and processing techniques is gaining greater awareness. On the one hand a high prececal starch digestibility is important to minimize starch flow into the large intestine which might lead to considerable alterations in the microbial fermentation. On the other hand exaggerated plasma glucose and insulin responses after carbohydrate intake have been associated with noninsulin-dependent diabetes and cardiovascular diseases in human subjects. Foods, which elicit low postprandial glycemic responses, are considered beneficial in subjects with metabolic diseases as well as in healthy human subjects. In horses, glucose and insulin control maybe impaired in a number of life stages and/or conditions such as diabetes, obesity, gestation, pituitary dysfunction, laminitis and aging. In horses with impaired glucose metabolism, plasma glucose concentration remains higher for longer periods of time and horses were less sensitive to insulin than control individuals.

Glycaemic and insulinaemic responses and the incidence of OCD in foals

High grain rations are frequently cited as a potential cause of osteochondrosis dissecans (OCD) in horses. Ralston (1996) observed higher glucose and insulin responses after a meal with textured sweet grain (1.7 – 2.5 kg grain/horse in a single meal) in young Standardbred horses with OCD lesions when compared to healthy foals. The endocrinological response to grain starch appears to be relevant as insulin has an effect on chondrocyte survival.

These results by Ralston (1996) were supported in a field study with 218 Thoroughbred weanlings where a high glucose and insulin response to a concentrate meal was associated with an increased incidence of OCD (Pagan et al. 2001). At Rutgers University a patented glucose challenge to foals has been developed to identify foals with a higher risk to OCD by their glycaemic and insulinaemic responses. Based on theses results it would be beneficial to feed young growing horses feedstuffs that are known to elicit a moderate or low glycaemic and insulinaemic response.

Metabolic dysfunctions and the glycaemic and insulinaemic index

Ponies that were fat or had previously suffered laminitis were found to be more intolerant to oral glucose loads than healthy ponies or Standardbred horses (Jeffcott et al. 1986). These ponies exhibited a far greater response in plasma glucose and insulin levels after glucose loading. Furthermore, ponies with previous incidents of laminitis were less insulin sensitive and demonstrated compensatory insulin hypersecretion compared to ponies not at risk (Treiber et al. 2005).

Aged horses often exhibit a relative glucose intolerance characterized by hyperglycaemia and hyperinsulinaemia following a glucose challenge (Ralston et al. 1988). The glucose intolerance in old horses is caused by a high incidence of pituitary adenomas. The pituitary adenoma causes excess corticosteroid secretion and an impaired glucose metabolism.

The dietary management of glucose intolerance in horses is not well defined. However, there are two different ways of influencing dietary glycaemic load: reducing carbohydrate intake, or using feedstuffs with a low glycaemic index. However, in humans there is good evidence that a high-carbohydrate intake with a low glycaemic index improved pancreatic ß-cell function in subjects with impaired glucose tolerance in comparison to a low-carbohydrate and high-monounsaturated fat diet

(Wolever et al. 2002). In consequence, diets with a low glycaemic index might be preferable in dietary prevention and management of glucose intolerance in horses.

Glycaemic and insulinaemic responses prior to exercise and training

The dietary management prior to exercise may affect performance by altering energy metabolism during exercise in horses. In several investigations corn feeding 1, 2, 3 or 4 hours prior to exercise resulted in a marked drop in plasma glucose and insulin concentration below pre-feeding levels during exercise (Lawrence et al. 1993, Pagan and Harris 1999). In general, horses that begin exercise with high blood glucose and insulin levels e.g. after corn feeding showed a transient hypoglycaemia during exercise, but the size of the meal (1, 2 or 3 kg) did not affect the response, although higher pre-exercise glucose levels were observed when the horses received 3 kg of corn (Lawrence et al. 1993). In contrast, horses with lower pre-exercise blood glucose and insulin concentrations e.g. after alfalfa feeding maintained steady glucose and insulin levels throughout exercise.

A drop in blood glucose concentration may indicate a lack of glucose availability for the muscle or brain and might has a deleterious effect on performance. In addition, FFA concentrations during exercise as a major substrate for energy metabolism were very low when horses received a pre-exercise meal of corn (Lawrence et al. 1993, Pagan and Harris 1999). In the performance horse it might be useful to develop feeding strategies which include feedstuffs with a high carbohydrate content (e.g. starch, pectins or cellulose) and low glycaemic index.

Conclusion

A simple index is needed that could help in the development of nutritional recommendations for horses for specific issues, such as insulin resistance, laminitis or exercise performance. However, it appears that the GI cannot serve as the only such criterion, as it is considerably influenced by several factors: consumption rate, nutrient composition and gastric emptying, especially in the case of mixed feeds. Furthermore, a standardised methodology should be developed for the estimation of GI and II in feedstuffs for horses to make it possible to compare the results of different research groups.

References

Arnold FF, Potter GD, Kreider JL, Schelling GT. Carbohydrate digestion in the small or large interstine of the equine. Proc 7th Equine Nutr Phys Symp 1981; 19-22.

Brand JC, Nickolson PL, Thorburn AW, Truswell AS. Food processing and the glycemic index. Am J Clin Nutr 1985; 42: 1192-1196.

Brouns F, Bjorck I, Frayn KN, Gibbs AL, Lang V, Slama G, Wolever TMS. Glycaemic index methodology. Nutr Res Rev 2005; 145-171.

Flint A, Moller BK, Raben A, Pedersen D, Tetens I, Holst JJ, Astrup A. The use of glycaemic index tables to predict glycaemic index of composite breakfast meals. British J Nutr; 91: 979-989.

Foster-Powell K, Brand Miller JC. International table of glycaemic index. Am J Clin Nutr 1995; 62: 871-893.

Foster-Powell K, Holt SHA, Brand Miller JC. International table of glycaemic index and glycaemic load values. Am J Clin Nutr 2002; 76: 5-56.

Granfeldt Y, Eliasson AC, Björck I. An examination of the possibility of lowering the glycaemic index of oat and barley flakes by minimal processing. J Nutr 2000; 130: 2207-2214.

Granfeldt Y, Liljeberg H, Drews A, Newman R, Björck I. Glucose and insulin responses to barley products: influence of food structure and amylose-amylopectin ratio. Am. J. Clin. Nutr. 1994; 59: 10751082.

Harbour LE, Lawrence LM, Hayes SH, Stine CJ, Powell DM. Concentrate composition, form, and glycemic response in horses. Proc 18 Equine Nutr Phys Symp 2003; 329-330.

Harris PA, Sillence M, Inglis R, Siever-Kelly C, Friend M, Munn K, Davidson H. Effect of Lucerne chaff on the rate of intake and glycaemic response to an oat meal. Proc 19 Equine Nutr Phys Symp 2005; 151-152.

Hoekstra KE, Newman K, Kennedy MAP, Pagan JD. Effect of corn processing on glycemic responses in horses. Proc 16 Equine Nutr Phys Symp 1999; 144-148.

Holm J, Lundquist I, Björck I, Eliasson AC, Asp NG. Degree of starch gelatinization, digestion rate of starch in vitro, and metabolic response in rats. Am J Clin Nutr 1988; 47: 1010-1016.

Jeffcott, lB, Field JR, McLean JG, O´Dea K. 1986. Glucose tolerance and insulin sensitivity in ponies and Standardbred horses. Equine Vet J 1986; 18:97.-101.

Jenkins DJ., Wolever A, Taylor TMS, Barker RH, Fielden H, Baldwin H, Bowling JM, Newmann AC, Jenkins HC, Goff AL. Glycemic index of foods: a physiological basis for carbohydrate exchange. Am J Clin Nutr 1981; 34: 362-366.

Jose-Cunilleras E, Taylor LE, Hinchcliff KW. Glycemic index of cracked corn, oat groats and rolled barley in horses. J Anim Sci 2004; 82: 2623-2629.

Kienzle E, Pohlenz J, Radicke S. Microscopy of starch digestion in the horse. J Anim Physiol Anim Nutr 1998; 80: 213-216.

Kienzle E, Pohlenz J, Radicke S. Morphology of starch digestion in the horse. J Vet Med A 1997; 44: 207-221.

Kienzle E, Radicke S, Wilke S, Landes E, Meyer H. Praeileale Stärkeverdauung in Abhängigkeit von Stärkeart und –zubereitung. 1. Europ Conf Horse Nutr, Pferdeheilkunde, 1992; 103-106.

Kronfeld DS, Treiber KH, Hess TM, Boston RC. Insulin resistance in the horse: Definition, detection, and dietetics. J Anim Sci 2005; 83: 1-10.

Lawrence LM, Soderholm LV, Roberts, Williams J, Hintz H. Feeding status affects glucose metabolism in exercising horses. J Nutr 1993; 123:2152-2157.

Metayer N, Lhöte M, Bahr A, Cohen ND, Kim I, Roussel AJ, Julliand V. Meal size and starch content affect gastric emptying in horses. Equine Vet J 2004; 436-440.

Meyer H, Radicke S, Kienzle E, Wilke S, Kleffken D, Illenseer M. Investigations on preileal digestion of starch grain, potato and manioc in horses. J Vet Med A 1995; 42: 371-381.

Pagan JD, Harris PA. The effects of timing and amount of forage and grain on exercise response in Thoroughbred horses. Equine Vet J 1999; Suppl 30: 451-457.

Pagan JD, Harris PA, Kennedy MAP, Davidson N, Hoekstra KE. Feed type and intake affects glycaemic response in Thoroughbred horses. Proc 16th Equine Nutr Phys Symp 1999; 149-150.

Pagan JD, Geor RJ, S. E. Caddel SE, Pryor PB, Hoekstra KE. The relationship between glycemic response and the incidence of OCD in Thoroughbred weanlings: A field study. AAEP Proc. 2001; 47:322-325.

Potter GD, Arnold FF, Householder DD, Hansen DH, Brown KM. (1992) Digestion of starch in the small or large intestine of the equine. 1. Europ Conf Horse Nutr, Pferdeheilkunde, 1992; 107-111.

Radicke S, Meyer H, Kienzle E. Über den Einfluß von Futterart und Fütterungszeitpunkt auf den Blutglucosespiegel bei Pferden. Pferdeheilkunde 1994; 10: 187-190.

Ralston SL, Nockels CF, Squires EL. Differences in diagnostic test results and hematologic data between aged and young horses. Am J Vet Res 1988; 49:1387-1391.

Ralston, S. L. 1996. Hyperglycemia/hyperinsulinemia after feeding a meal of grain to young horses with osteochondritis dissecans (OCD) lesions. 2. Europ. Conf. Horse Nutr., Pferdeheilkunde, 1996; 320-322.

Rodiek AV, Stull CL. Glycemic index of common horse feeds. Proc 19 Equine Nutr Phys Symp 2005; 153.

Rooney LW, Pflugfelder RL. Factors affecting starch digestibility with special emphasis on sorghum and corn. J Anim Sci 1986; 63: 1607-1623.

Ross SW, Brand BS, Thorburn AW, Truswell AS, 1987: Gylcemic index of processed wheat products. Am J Clin Nutr 1987; 46: 631-635.

Selmi B, Marion D, Perrier Cornet JM, Douzals JP, Gervais P. Amylogluosidase hydrolysis of high-pressure and thermally gelatinized corn and wheat starches. J Agric Food Chem 2000; 48: 2629-2633.

Stull CL, Rodiek AV. Responses of blood glucose, insulin and cortisol concentrations to common equine diets. J Nutr 1988; 206-213.

Thorne MJ, Thompson LU, Jenkins JA. Factors affecting starch digestibility and the glycaemic response with special reference to legumes. Am J Clin Nutr 1983; 38: 481-488.

Treiber KH, Hess TM, Kronfeld DS, Boston RC, Geor R, Harris PA. Insulin resistance and compensation in laminitis-predisposed ponies characterized by the Minimal Model. Proc Equine Nutrition Conference Hannover, 01.-02.10.2005; 91-92.

Vervuert I, Coenen M, Bothe C. Effects of oat processing on the glycaemic and insulin responses in horses. J Anim Physiol 2003; 87: 96-104.

Woelver, T S, Mehling, C. High-carbohydrate – low-glycaemic index dietary advice improves glucose disposition index in subjects with impaired glucose tolerance. British J Nutr 2002; 87:477-487.

Vervuert I, Coenen M, Bothe C. Effects of corn processing on the glycaemic and insulinaemic responses in horses. J Anim Physiol 2004; 88: 348-355

Zeyner A, Hoffmeister C, Einspanier A, Lengwenat O. Glycemic and insulinaemic responses of Quarter horses to concentrates high in fat and low in soluble carbohydrates. Proc 19 Equine Nutr Phys Symp 2005; 312-313.