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NON-STARCH POLYSACCHARIDES ON NUTRIENT DIGESTIBILITY OF DIETS FOR DIFFERENT PRODUCTION STAGES OF PIGS

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ABSTRACT - The corn and soybean are the major constituents in pigs diets, however, there is a constant search for non-starch polysaccharides (NSPs) food sources to feed pigs at different production stages. This review objective is to provide grants to improve the NSPs knowledge, in relation to their influence on the nutrients digestibility and availability in diets for pigs in different production stages. NSPs are macromolecules simple sugar polymers (monosaccharides) resistant to enzymatic hydrolysis in pigs' gastrointestinal tract due to the connections type between the existing units of low molecular weight carbohydrates, but subject to hydrolysis in the large intestine through microbial fermentation. Its inclusion in pig nutrition have shown positive effects on productivity, by reducing costs, by acting positively on physiology to improve enzyme secretion and digestibility in the initial phase, by acting as an energy source in the growth phase, the positive effects on carcass quality or to control possible problems associated with excessive food intake and stress arising from confinement in the reproductive stages. When soluble NSPs are highly fermentable they may increase the digesta viscosity forming a gel, affecting gastric emptying, increasing the chyme viscosity, leading to particles reduction in the diffusion rate and reducing the digesta enzyme-substrate contact. The studies with ingredients containing NSPs inclusion to feed pigs showed significant advances in identifying the sources and the many roles in the animal body at different production stages. However, there is a huge variation in the composition of NSPs in the various sources, and the experiments carried out in most cases are not conclusive. Thus, further research with the NSPs use, both soluble and insoluble, will be important, therefore, may potentiate the various sources use in pig diets without acting negatively.
Key words: alternative food, fiber, intestinal health, metabolism.

POLISSACARÍDEOS NÃO AMILÁCEOS (PNAs) SOBRE A DIGESTIBILIDADE DOS NUTRIENTES DAS DIETAS PARA SUÍNOS EM DIFERENTES IDADES

RESUMO - O milho e a soja são os maiores constituintes das rações para suínos, entretanto, há uma constante busca pela utilização de alimentos com fonte de polissacarídeos não amiláceos (PNAs) para suínos nas diferentes fases de produção. O objetivo desta revisão é fornecer subsídios para melhorar o conhecimento sobre os PNAs, em relação à sua influência sobre a digestibilidade dos nutrientes das dietas para suínos em diferentes fases de criação. Os PNAs são macromoléculas de polímeros de açúcares simples (monossacarídeos) resistentes à hidrólise enzimática no trato gastrintestinal dos suínos, devido ao tipo de conexões entre as unidades existentes de carboidratos de baixa massa molecular, mas, sujeitos a hidrólise no intestino grosso através de fermentação microbiana. Sua inclusão na nutrição de suínos têm demonstrado efeitos positivos na produtividade, pela redução dos custos, por atuar positivamente na fisiologia ao melhorar a secreção enzimática e a digestibilidade na fase inicial, por atuar como fonte energética na fase de crescimento, pelos efeitos positivos sobre a qualidade da carcaça ou ainda por controlar possíveis problemas decorrentes da excessiva ingestão de alimentos e o estresse oriundo do confinamento nas fases reprodutivas. Os PNAs são macromoléculas de polímeros de açúcares simples resistentes à hidrólise enzimática no trato gastrintestinal de suínos, devido ao tipo de ligações entre as unidades existentes de açúcares serem do tipo beta, mas passíveis de hidrólise no intestino grosso através da fermentação microbiana. Estes carboidratos estão presentes na parede celular dos vegetais, desta forma participam da constituição da fibra dietética. Quando solúveis os PNAs são altamente fermentáveis e podem aumentar a viscosidade da digesta formando um gel afetando o esvaziamento gástrico, aumentando a viscosidade do quimo, levando à redução da taxa de difusão das partículas na digesta e diminuindo o contato enzima-substrato. Os estudos com inclusão de ingredientes contendo PNAs na alimentação de suínos apresentaram significativos avanços em termos de identificação das fontes e as diversas funções exercidas no organismo animal nas diferentes fases de produção. Contudo, existe uma enorme variação na composição dos PNAs nas diversas fontes, e os experimentos realizados na maioria das vezes não são

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conclusivos. Desta forma, novas pesquisas com a utilização de PNAs, tanto solúveis como insolúveis, serão importantes, pois, podem potencializar o uso das diversas fontes nas dietas de suínos sem atuar de forma negativa na digestibilidade e disponibilidade dos nutrientes.

Palavras-chave: alimento alternativo, fibra, saúde intestinal, metabolismo.

INTRODUCTION

Corn and soybeans are the major contents in feed for pigs, however, there is a constant search for non-starch polysaccharides (NSPs) food source for pigs at different production stages of. Its use should also meet the challenge of maintaining animal production efficiency. In this sense, NSP inclusion in pig nutrition has shown positive effects on productivity by: reducing production costs (GERON, 2014); positively acting on physiology to improve enzyme secretion and nutrient digestibility in animals at the early stages of development; serving as an energy source in pigs diet in the growth phase, with positive effects on carcass quality in finishing animals; controlling possible problems associated with excessive food intake and stress arising from confinement in reproductive stages (CAMARGO et al., 2005).

We know that NSPs comprise polymers of monosaccharides joined by glycosidic bonds. Due to the nature of its links, NSPs are resistant to hydrolysis in pigs' gastrointestinal tract (CABRAL et al., 2013). On the other hand, digestible and metabolizable energy diets value and ingredients are related to the animal's body weight and its feeding level. All nutrients digestibility except starch is improved with increasing body weight, and this variation becomes important for diets rich in NSPs in various stages of pig production (SHI; NOBLET, 1993).

Thus, the purpose of this literature review is to provide a better understanding of NSPs in relation to their influence on the digestibility and nutrient availability for pigs' diets in different production stages.

DEVELOPMENT

Non-starch polysaccharides (NSPs) characterization

NSPs are macromolecules simple sugar polymers (monosaccharides) resistant to enzymatic hydrolysis in pigs' gastrointestinal tract due to the connections type between the existing units of low molecular weight carbohydrates being beta type (SLAUGHTER et al., 2002; MONTAGNE et al, 2003), but subject to hydrolysis in the large intestine through microbial fermentation (AACC, 2001). The NSPs monomer constituents are arabinose and xylose (pentose - $C_5H_{10}O_5$); glucose, galactose and mannose (hexoses - $C_6H_{12}O_6$); fucose and rhamnose (deoxy-hexoses - $C_6H_{12}O_5$); glucuronic acid and galacturonic (uronic acids - $C_6H_{10}O_7$) (PASCOAL; WATANABE, 2014).

These carbohydrates are present in the plant cell wall, thus participating in the dietary fiber creation, the main polysaccharides constituting the dietary fiber are: cellulose, arabinoxylans, β-glucans, xyloglucans, arabinogalactans and ramnogalacturanas (ENGLYST, 1989). However, a greater combinations numbers can be found, given the carbohydrate diversity forming polysaccharides (CHOCT, 1997). The lignin, as a major structural plants component, is also related to the NSPs, mainly due to the varied complexation of these fractions as a herbaceous development function or the actual plant morphology, and for these reasons it is important to analyze these compounds together (PASCOAL; WATANABE, 2014).

As they are found in the cell wall components, the NSPs, along with the lignin, resistant starch digestion, non-digestible oligosaccharides, waxes and some indigestible proteins are part of the fraction named dietary fiber (HARRIS; FERGUSON, 1990; FERGUSON et al., 1993; BACH KNUDSEN, 2001; WENK, 2001). Thus, NSPs as other dietary fiber components can vary in relation to the plant species, plant age and tissues (BACH KNUDSEN, 2001).

Effects of soluble and insoluble NSPs in the digestive tract and in pig metabolism

Dietary fibres include carbohydrates with diverse physico-chemical properties. The effects of one fibre, therefore, may not be the same as the effects of another fibre. Resistant starch is a dietary fibre that has various health benefits, including improving bowel health, acting as a prebiotic, and increasing satiety. The intake of resistant starch is usually accompanied by the consumption of other dietary fibres, which are grouped as non-starch polysaccharides (NSPs) (JONATHAN et al., 2013).

When NSPs are soluble, in general, they are characterized by being highly fermentable and possess the ability to increase the digest viscosity forming a gel solution (HOPWOOD et al., 2004). Thus, these characteristics affect gastric emptying (FISCHER, 2011) increasing the chyme viscosity, leading to reduced particles diffusion rate in the digest, reducing the enzyme-substrate contact (PASCOAL; WATANABE, 2014). In this sense, the digestibility and energy is affected by reducing nutrient absorption and increasing the retention time in the gastrointestinal tract. In view of this, there is a decrease in feed intake and high availability of nutrients for microorganisms' proliferation (BEDFORD, 1995).

On the other hand, the longer digest retention in the gastrointestinal tract due to the NSPs' solubility may be beneficial to metabolism by decreasing LDL-cholesterol and total lipid (SRICHAMROEN et al., 2008). The cholesterol lowering is related to the natural soluble NSPs viscosity and can reduce cholesterol absorption from the intestine, increasing the bile acids excretion in the feces and the liver to compensate produce more bile acids from cholesterol degradation. Furthermore, the short chain fatty acid (SCFA) propionate produced by microbial's fermentation, was absorbed and converted to succinyl coenzyme A in the liver, which may inhibit cholesterol synthesis (LÓPEZ et al., 1997).

The other effects of short-chain fatty acids (SCFA, butyrate, acetate and propionate) in the intestine are related to the fact promote secretion of glucagon, stimulating the mucosa's growth, improving the protective barrier function and reducing bacterial translocation. Thus, the bacterial fermentation in the large bowel will have greater or lesser impact on intestinal health depending on the various SCFA proportions produced (FISCHER, 2011).

Unlike soluble NSPs, insoluble ones do not form gel, they are little fermentable and are not viscous, being eliminated in the stool almost intact. Due to their indigestibility, increase stool and consequently the stool weight, may stimulate peristalsis through their aggressive action in the gut wall muscle (NRC, 2012). Furthermore, the microorganisms' action in the small intestine of such NSPs can create a physical barrier to the certain digestive enzymes action, reducing the absorption and nutrients digestion (VANDEROOF, 1998).

For irritating the gut lining by mechanical abrasion, insoluble NSPs leads to increased mucous endogenous secretions, water and reduction in villus height (JIN et al., 1994), however, can be beneficial for gut morphology, the ability to reducing enteric diseases (HANCZAKOWSKA et al., 2008).

Among the NSPs, the main differences of the soluble and insoluble fractions that are soluble affects the digest viscosity, increasing the retention time and can provide favorable environment for the pathogenic bacteria's proliferation. On the other hand, insoluble NSPs directly alter the intestinal transit rate, reducing the intestinal transit rate, decreasing the food in the digestive tract residence time (SVIHUS et al., 2004).

NSPs' effects on the digestion and absorption of nutrients by pigs

Weaned piglets

There has been an increasing interest in adding NSPs in piglet weanling diets due to their potential prebiotic properties, namely, the growth stimulation and/or activity of one or a limited number of beneficial bacteria species and competitive exclusion pathogens (WELLOCK et al., 2008; MOLIST et al., 2009). The interest in NSPs knowledge assumes that they are the main source of energy for the enteric organisms, and their manipulation in the diet can improve gastrointestinal health and reduce enteric disorders such as post-weaning colibacillosis (BACH KNUDSEN; HANSEN, 1991; BACH KNUDSEN et al., 2012).

PNAs have also shown beneficial effects on physiological aspects such as increased gastric and intestinal secretions improving the feed digestibility, enterocytes turnover and intestinal motility stimulating (WHITNEY et al., 2006). For the proper use of dietary nutrients, intestinal health is an essential factor in this way, the composition knowledge and the SCFA diversity produced in the digestive tract is extremely important for understanding digestive and microbiological changes (PASCOAL; WATANABE, 2014).

However, when compared to adult pigs, piglets have a disadvantage in NSPs use, because adult animals possess the gastrointestinal tract fully developed thus have slower transit time and higher cellulolytic activity (LINDBERG, 2014). Thus, adult females had greater ability to take advantage of the fibrous components compared to piglets (SHI; NOBLET, 1993) and a higher percentage of NSPs digested in the small intestine that growing pigs (JØRGENSEN et al., 2007). These authors also found that breeding sows showed higher capacity of insoluble NSPs utilization, while the difference in digestibility between NSPs soluble growing pigs is only marginal.

As mentioned above, NSPs are not digested by endogenous digestive enzymes of the digestive tract and therefore are the primary substrates for bacterial fermentation to the distal part of the intestine and can act as a prebiotic for piglets (TURNER; LUPTON, 2011). The main fermentation products are the SCFA, predominantly lactate, acetate, propionate and butyrate. These can act beneficially on the digestive tract development and growth in post-weaning, through stimulation of epithelial cell proliferation, reflects positively on digestibility and nutrient availability (MONTAGNE et al., 2003).

In acidic medium, the SCFA can inhibit the bacterial enteric pathogens growth, such as *Salmonella*, *Escherichia coli* and *Clostridium* species (HENTGES, 1992). Studies have shown that several polysaccharides types from plants behave differently in the digestive tract, depending on their structural characteristics. The inclusion of soluble dietary NSPs can stimulate the intestinal organisms growth, leading to SCFA increased production, and a lower pH in the large intestine (BACH KNUDSEN et al., 2012). On the other hand, insoluble NSPs can reduce transit time and provide the substrate for slowly degradable by piglets distal intestine microorganisms (FREIRE et al., 2000), and modulating the intestine morphology, increasing the villi's length (HEDEMANN et al., 2006).

Piglets, to be fed with soluble NSPs showed an increase in enterotoxigenic *E. coli* proliferation (McDONALD et al., 1999), while feeding insoluble NSPs reduced the hemolytic *E. coli* occurrence, and reduced the severity of post weaning colibacillosis (LINDBERG, 2014; WELLOCK et al., 2008). However, it was demonstrated that soluble NSPs by themselves are not harmful to the piglets health (WELLOCK et al., 2008). Instead, it was found that soluble NSPs do not increase the digest viscosity may beneficially affect the intestine's health, increasing the ratio lactobacilli: coliforms and reducing the occurrence of post-weaning diarrhea.

Insoluble NSPs sources most commonly used in post-weaning diets are husks and bran cereals and legumes. The most common ingredients used as insoluble sources in the post-weaning pigs diet are alfalfa meal (FREIRE et al., 2000), barley hulls (HEDEMANN et al., 2006; GERRITSEN et al., 2012), oat hulls (MATEOS et al, 2006; KIM et al., 2008), cereal brans (FREIRE et al., 2000; HOGBERG; LINDBERG, 2006; SCHEDLE et al., 2008; MOLIST et al., 2009, 2010a,b), straw (GERRITSEN et al., 2012) and purified cellulose (FONSECA et al., 2012). On the other hand, beet pulp (FREIRE et al., 2000; MOLIST et al., 2009; MONTAGNE et al., 2012), citrus pulp (FONSECA et al., 2012), bran oats (BACH KNUDSEN et al., 1993), pearl barley and inulin (HOPWOOD et al., 2004; WELLOCK et al., 2007) are interest as ingredients rich in soluble NSPs sources available in diets for weanling pigs.

Soybean husk for example, have a high content of insoluble NSPs, but also a high content of fermentable oligosaccharides and soluble NSPs (CHOCT et al., 1996). The positive fibrous ingredients effects probable inclusion in the post-weaned pigs diets depends on their ability to help them to overcome the limitations of an immature gastrointestinal tract (e.g., intestinal function, digestion, fermentation and absorption capacity) in order to maximize digestion and growth in animals (DE LANGE et al., 2010).

In this context, Högberg and Lindberg (2006), evaluating diets for weanling pigs based on cereals and NSPs co-products, reported that diets with high levels of NSPs provided increase in weight gain, on the other hand, decreased in organic matter digestibility and the dietary fiber constituents. They also observed that diets with high levels of NSPs increased total organic acids production in the stomach and ileum and propionic and butyric acids proportions in the ileum, by changing the intestinal environment in relation to pH and total microbial population.

Carneiro et al. (2007) found that weaned piglets fed with ground corn cob-based diet showed lower NDF digestibility than fed piglets with wheat bran based diet; the authors probably due to the higher cellulose proportion in corn cob compared to wheat bran. The reduced ADF digestibility on the corn cob-based diet compared to wheat bran based diets can be explained by the higher lignin content on the corn cob, which can decrease the NSPs digestibility (STAGONIAS; PEARCE, 1985). In addition, the higher NDF and ADF fractions digestibility explains the higher organic matter digestibility in wheat bran than in diet based on corn cob.

Pigs in growth

In the growth phase, pigs show a high capacity for muscle deposition. In that sense, the NSPs use in diets in this phase can become a limiting factor in animal development when relate to physical effects that they may cause, either by increasing satiety, decrease the digest transit time and hence reduction in use of nutrients (URRIOLA; STEIN, 2012; ZIEMER et al., 2012; PASCOAL; WATANABE, 2014).

Although the growth phase there are more studies using soluble NSPs by their high fermentability, the same compared to insoluble may also reduce the nutrients absorption, because the digestion point of view, the high viscosity formed in the digestive tract reduces the interaction enzyme/substrate by decreasing the nutrients diffusion rate in the intestinal lumen, thus hindering the digestion/absorption and increasing the water content in the faeces (BEDFORD, 2000). Thus, the increased levels of these NSPs in the diet also causes dietary energy dilution, leading to a compensatory increase in consumption for the animal to reach the energy levels required to growth (WARPECHOWSKI, 1996).

In addition, increased the digest viscosity has a negative relationship with mineral absorption characteristics, by the fact reduce the certain minerals retention reducing its bioavailability as a result of cation exchange capacity provided by vegetable fiber (mostly associated with waste methylated galacturonic acid in vegetables) and phytic acid in cereal grains (NOBLET; PEREZ, 1993; WENK, 2001). Castro Júnior and Budinô (2005) reported that the introduction of 5.0% of pectin in the feed decreased the ileal sodium availability, potassium, magnesium, calcium and potassium.

Simdes Nunes and Malmlof (1992) observed reduced glucose absorption and gastric inhibitory polypeptide with increased NSPs production in the diet. The authors report that one of the main responsible for the great variation in NSPs digestibility is lignin, it is apparently not degraded by the pigs, reducing the NSPs digestibility, mainly due to covalent bonds maintained with cellulose and hemicellulose, in addition to being digested by microorganisms present in the intestine (CASTRO JÚNIOR; BUDINÔ, 2005).

Comparing the NSP soluble and insoluble influence, Owusu-Asiedu et al. (2006) found that the substitution of 7% per guar gum corn starch (galactomannan) and cellulose in a corn and soy based diet for growing pigs reduced the energy digestibility 9 and 21% respectively, while a combination 7% guar gum, cellulose and 7% led to a 31.4% reduction in energy digestibility. On the other hand, the resistant starch addition in the pig diet had no effect on organic matter (OM) digestibility. Fecal resistant starch digestibility is almost complete as shown by Martinez-Puig et al. (2003), who compared starch digestibility in diets containing 250 g raw potato starch and 250 g of corn starch (99.4 vs. 99.9%) and observed no effect on digestibility.

Heimendahl et al. (2010) evaluated the intestinal development and nutrient absorption in three groups of pigs, with a hybrid and two German pure breeds genetically not improved fed a basal diet and a soluble NSP source (beet pulp). The authors observed that the beet pulp additional supply decreased total intestine length, however, it increased colon size (15.02 vs 20.61 cm/kg$^{0.75}$). The total digestibility of the digestive tract was reduced to CP, and MO, while NDF and ADF increased, which is consistent with previous results (KREUZER et al., 1990). As only the total NDF digestibility was influenced by breeds, the study found that modern pigs showed the same NSP utilization capacity of beet than pigs not improved.

Similarly, Anguita et al. (2007) found that growing pigs fed diets containing beet pulp, which have high pectins and arabinans content, had lower feed intake when compared to animals fed diets consisting of corn and soybean meal. Thus, the use of soluble fiber sources for pigs in the growing stage is limited to low inclusion levels, because there is a reduction in consumption due to physical satiety effect as well as increase in viscosity, reducing nutrient utilization.

Accordingly, studies using exogenous enzymes shown to improve NSPs degradation to improve the energy and nutrient utilization by pigs in the growing stage. Previous studies have reported that supplementation of diets with low energy mannanase can improve these animals performance (LV et al., 2013) and supplementation of wheat-based diets with xylanase and β-glucanases resulted in reducing the intestinal digest viscosity, promoting digestion and nutrients absorption (BEDFORD, 1995).

Thus, the NSP insoluble or soluble inclusion in the growing pig diets can limit the nutrients use by the animal. Accordingly, it is necessary to further studies to determine the NSP level and type that can be used without detriment to the development and protein deposition along the new application specific enzyme complex to NSPs present in food.

Finishing pigs

The low nutritional requirements in this development phase allow greater NSPs inclusion in the diet. In this sense, two aspects must be crimped for the NSPs effects in that stage, initially from the point of view of the carcass characteristics and later from the point of view of animal welfare (PASCOAL; WATANABE, 2014).

In general, finishing pigs have better foods energy utilization with high NSP levels when compared to growing pigs (LE GOFF et al., 2002). It is considered that the gastrointestinal tract larger size and the consequent higher digest retention time, contribute to better energy utilization. Another important aspect is the improved energy utilization by the animals during this phase, mainly soluble food containing NSPs, such as pectin. However, foods with NSPs insoluble high content are associated in promoting improved carcass traits, because of the qualitative feed restriction (LEE et al., 2002).

Accordingly, Degen et al. (2007) describe the different soluble and insoluble NSPs characteristics compared nutrient digestibility due to a distinct number in properties such as fermentability, the most fermented soluble NSPs in the gastrointestinal tract (GUILLON et al., 2007), water holding capacity (JOHANSEN et al., 1996) and passage rate (WILFART et al., 2007). These characteristics are directly related to the digestibility and availability of nutrients for finishing pigs.

Chen et al. (2014) used an insoluble NSP source (alfalfa meal) as energy dilutive (3220; 3148; 3060 and 2909 kcal kg^{-1}) in finishing pigs diets and observed linear reduction ($P < 0.01$) in total apparent digestibility MS, MO, CP, NDF, ADF and EB with the inclusion of 0, 5, 10, 20% alfalfa meal, corresponding to 10.5; 12.6; 14.8 and 19.0% NSP insoluble, respectively. Thacker; Haq (2008) evaluated the inclusion of 0 to 30% alfalfa meal for finishing pigs and also observed reduction in energy digestibility and nitrogen, a fact explained in the type of NSP found in alfalfa meal, which corresponds to 94% cellulose and hemicellulose.

Urriola and Stein (2012) studied two cannulated pig breeds (Meishan - 77.2 ± 15.2 kg and Yorkshire - 102.1 ± 3.5 kg), fed dry diets containing distillers solubles (DDGS) soybean hulls (SBH), beet pulp (SBP) and pectin derived from fruits, with 1.7; 5.4; 8.9; 21.0; 39.9 cellulose values respectively. The authors found that the Meishan pigs had higher total dietary fiber digestibility than Yorkshire, when fed diets in which most of the fiber was insoluble. When the animals were fed with soybean hulls and beet pulp, there was no difference between the breeds. This indicated that the Meishan pigs were more efficient in the insoluble fraction fermentation than the Yorkshire and there are no differences between animals from Meishan and Yorkshire breeds the ability to ferment the soluble fraction.

Ziemer et al. (2012) evaluated the use of diets with low inclusion NSP (hemecellulose 6.3% and 2.7% cellulose) and high addition (hemecellulose 10.4% and 7.7% cellulose) with addition of cellulose's isolated bacteria and xylan prepared as follows: A (basal diet with low NSP inclusion and bacteria), B (high NSP inclusion + isolated bacteria SDCMC3f/cellulose), C (NSP high inclusion + isolated bacteria RFCell1b2/cellulose) and D (NSP high inclusion + isolated bacteria SDCC2c/xylan). They observed improvement in CP and ADF digestibility for treatments containing bacteria. According to the authors, the increase in CP digestibility may have been a result of its release associated with the diet fiber fraction. Although the NDF digestibility values have not varied, the increase in digestibility to ADF was probably due to the soybean hulls inclusion, that is easily digested in the pigs intestine and have high cellulose content 35 to 50% (KORNEGAY, 1981).

Breeding

Pigs in the reproductive phase have more total apparent digestibility in the tract of various nutrients in comparison to other production phases (FERNANDEZ et al., 1986). It is known that the digestible and metabolizable energy values and ingredients diets are directly related to the animal physiological stage/BW and/or power level (NOBLET; PEREZ, 1993). All the nutrients digestibility except starch is improved with increasing body weight, this variation becomes more important for diets rich in NSPs (SHI; NOBLET, 1993).

Several research results and practical evaluations showed that breedings are able to ferment NSPs of rich in fiber foods better, because the digestive system is higher compared to growing pigs, there also correlated with the increase of the intestine weight (BRUNSGAARD, 1998). As a result, the intestinal tract of a breeding female or male is larger and more developed, moreover, have a higher amount in number and bacteria species that degrade NSPs (FERNANDEZ et al., 1986; SHI; NOBLET, 1993; LE GOFF; NOBLET, 2001).

In this sense, Renteria-Flores et al. (2008) evaluated the energy and protein digestibility for sows in gestation, using four diets with NSP soluble and insoluble inclusions, as follows: control diet (CD - 2.22% cellulose and hemicellulose 6.13), 34% bran oats (DFA - 0.5% cellulose and hemicellulose 10.56), 12% of wheat straw (DPT- 6.67 8.96% cellulose and hemicellulose) and 16% of beet pulp (DPB - 8.28 cellulose and hemicellulose 6.37). The authors observed that the energy digestibility was higher ($P < 0.01$) for females fed DC (87.9%) and DFA (89.3) compared to females fed DPT and DPB (82.9 and 86.8%).

Serena et al. (2008) evaluated a mixture of ingredients for sows, three diets, control, NSP high including-1 (+ soluble) and NSP high including-2 (+ insoluble), corresponding to 14.0; 35.5 and 37% NSP total, 2.5; 13.7 and 15.2 cellulose and 1.9; 5.6 and 7.1% lignin, respectively. The NSP high supply resulted in 1.7 to 1.8 times larger than ileal digest flow compared to the control diet, with a substantial absorption of liquid from the large intestine of 4.4; 9.0 and 7.6 liters for the animals fed with control diet, high NSP-1 and NSP-2 respectively. The NSP amount and type influenced the diet digestibility, with reduced digestibility in MO, carbohydrates and starch in the ileum and MO in total tract compared to the control diet. Moreover, the diet with a high concentration of soluble NSP showed higher protein digestibility in the ileum compared to the other diets.

Thus, research has shown that the NSP effect on digestibility depends on the type and level in the diet (LE GOFF et al., 2002; RENTERIA-FLORES et al., 2008). According to these authors, the soluble NSP has shown better digestibility of nutrients, which may be associated with higher digest retention time, increased population and microbial activity, allowed further degradation of the components complexed to the fiber fraction. Accordingly, there is need for further studies; since due to the solubility and the potential degradation of the dietary fiber compounds have different effects must be considered in the formulation to improve the nutrients digestibility.

FINAL CONSIDERATIONS

The studies include ingredients containing NSPs to feed pigs showed significant advances in identifying the sources and the various functions carried out in the animal body at different production stages.

Regarding the NSP effect on nutrient digestibility, that is, the regardless of type the studies have shown negative effects either by increasing the viscosity of the digest or reducing the transit time. But the NSPs degree of influence on digestibility of nutrients will depend on factors, other than the type, such as animal category, age, diet and feeding frequency, sanitation and food handling.

However, there is a huge variation in the NSPs composition in the sources, and the experiments carried out in most cases are not conclusive. Thus, further research with the NSPs use, both soluble and insoluble, will be important as they may potentiate the use of various sources in pig diets without acting negatively in digestibility of nutrients.

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