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FIBER SOURCES IN PIGS FEEDING

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ABSTRACT - The trend in the industry is the slaughter of heavier pigs, where slaughterhouses obtain more meat per hour worked, dilute fixed costs, and intensify the value added of prime meat. This allows the operational costs of logistics, infrastructure and labor reduction. The objective of this review was to demonstrate the effects of dietary fiber on aspects related to the pigs' carcass quantitative and qualitative characteristics and the factors that affect these parameters. Corn and soybeans are the pig feed major constituents; however, they are used in human food. The biggest challenge is to maintain the animal production efficiency, using alternative foods that do not compete directly with human food. The nutritional and physiological effects of fiber depend not only on the amount of cell wall constituents incorporated into the diet, but on its chemical and structural composition and the way it is physically associated with other nutrients. Studies using soluble and insoluble dietary fiber in pig diets have significant advances in the identification of fiber sources and their functions on meat quality.
Key words: meat quality, non-starch polysaccharides, performance, pigs.

FONTES DE FIBRA NA ALIMENTAÇÃO DE SUÍNOS

RESUMO - A tendência verificada na indústria é o abate de suínos mais pesados, em que os frigoríficos obtêm maior quantidade de carne por hora trabalhada, diluem os custos fixo, e intensificam o valor agregado de carnes nobres. Isso permite a redução dos custos operacionais de logística, infraestrutura e mão de obra. Objetivou-se com esta revisão demonstrar os efeitos da fibra dietética sobre aspectos relacionados às características quantitativas e qualitativas da carcaça de suínos e os fatores que afetam esses parâmetros. O milho e a soja são os maiores constituintes das rações para suínos, entretanto, são usados na alimentação humana. O maior desafio é manter a eficiência da produção animal, utilizando alimentos alternativos, que não concorram diretamente com a alimentação humana. Os efeitos nutricionais e fisiológicos da fibra dependem não só da quantidade de constituintes da parede celular incorporados na dieta, mas da sua composição química e estrutural e a forma como ela está fisicamente associada com outros nutrientes. Estudos com uso de fibra dietética solúvel e insolúvel em rações para suínos têm avanços significativos na identificação de fontes de fibra e suas funções sobre a qualidade da carne.
Palavras-chave: qualidade de carne, polissacarídeos não amiláceos, desempenho, suínos.

INTRODUCTION

The trend observed in the meatpacking industry is the heavier pigs at slaughter, which contribute to operational cost savings such as logistics, infrastructure and manpower. With heavier pigs at slaughter the meatpacking industry achieve greater quantity of meat per hour worked, dilute the company fixed costs and can enhance the noble meats value such as ham, loin and shoulder. However, the heavier pigs slaughter can result in carcass fat accumulation, and to reduce this problem, measures related to genetic improvement and nutritional management are used to control unwanted carcass fat deposition and to get better prices for the animals, mainly in industries that adopt the carcasses classification system (MOREIRA et al., 2007).

The muscle tissue amount and the muscle distribution are the main quantity and quality meat determinants that can be obtained from pig's carcass. Muscle growth potential may varies according to the nutrition; it is therefore possible, that a proper diet manipulation result in different responses, due to the animal intrinsic characteristics (FANG et al., 2014). In general, the pigs fat increases with the body weight, thus the relationship between the energy intake and protein deposition decreases and the relationship between energy intake and lipid deposition increases. This ratio magnitude

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is not constant, being influenced by body weight and energy intake (GREEF, 1992).

A constant energy amount is required to maintain the protein deposition, which increases until a maximum rate be reached around 60 kg body weight, and then, it will be relatively constant until reaching the slaughter weight (EWAN, 1991). The protein and body fat mass are responsible for carcass characteristics and should be quantitatively related to body composition. The carcass fat deposition is mainly influenced by energetic intake. When the energy intake is higher than necessary to maintenance and protein deposition it will be used for the fat synthesis, although the muscle growth is always accompanied by a minimum fat (OLIVEIRA, 2001).

Recently, studies have been conducted in order to improve the quantitative and qualitative carcasses traits of pigs by including fiber sources in the diet (CASTELINI, 2011; CROSSWHITE et al., 2013; FANG et al., 2014). Fibrous ingredients and food processing by-product are among the main products to be used for diets energy dilution. In this context, its used the concept that the fiber is indigestible in the pigs gastrointestinal tract and thus has no nutritional value and can be provided as a component for boosting a diet volume and thereby provide satiety to the animals (PASCOAL; WATANABE, 2014). Thus, this review was to demonstrate the dietary fiber effects on quantitative and qualitative carcass traits of pigs and the factors that can affect these parameters.

DEVELOPMENT

Dietary fiber definition

Carbohydrates are the main components of pigs diets and contribute with 70% of dry matter. They can be divided into two major groups: reserve carbohydrates (non-structural), including starch, low molecular weight sugars, and oligosaccharides and structural carbohydrates or “dietary fiber”, including non-starch polysaccharides (NSPs) and lignin (BACK KNUDSEN et al., 1987).

Dietary fiber is mainly found in plant cell walls, made up mainly by lignin and NSPs, which may also be associated to small amount of protein, fatty acids, waxes, etc. (McDOUGALL et al., 1996). According to the physiological definition, dietary fiber means dietary components resistant to digestion by enzymes secreted by the non-ruminants digestive tract, but capable to partial or total hydrolysis in the large intestine through microbial fermentation (BACK KNUDSEN et al., 1987; AACC, 2001), however, according to the chemical definition dietary fiber is the NSPs and lignin sum (THEANDER et al., 1994).

Non-starch polysaccharides are macromolecules simple sugar polymers (monosaccharides) resistant to enzymatic hydrolysis in pigs’ gastrointestinal tract due to the connections between the existing units of sugars, which are beta type (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 great combinations can be found, due to 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).

Characterization of carbohydrates

Carbohydrates comprise a wide variety of organic compounds having different profiles digestion and fermentation, acting in different ways in animal organism (VAN SOEST, 1994). The polysaccharides oxidation is the primary pathway of energy release for animals, contributing approximately 80% of total calories (SILVA, 2002). According to the polymerization degree, carbohydrates are classified into monosaccharides (a monomer), oligosaccharides (2-20 monomers) and polysaccharides (> 20 monomers) (EVERS et al., 1999).

Simple carbohydrates are called monosaccharides, forming units of other classes, made up of 3-7 carbon atoms connected by single covalent bonds and represented mainly by glucose and fructose; oligosaccharides correspond to short carbohydrate chain, linked by glycolytic links, whose main office is sucrose and cellobiose; polysaccharides including carbohydrate chains with superior represented mainly by the starch and non-starch polysaccharides (NSPs) which include mainly cellulose, hemicellulose and pectic substances (EVERS et al., 1999; HALL, 2000).

Starch is the non-structural polysaccharide most abundant in all cereal grains, its structure is arranged in two polymers types: amylose (linear molecule with alpha 1-4 glucose bonds) and amylopectin (alpha 1-4 glucose polymers and beta branches 1-6) (VAN SOEST, 1994). These polymers ratio differs between sources, but a typical value is 75% of amylopectin and 25% of amylose (ELIASSON; GUDMUNDSSON, 1996). However, this ratio may change and influence the resistant starch content (RS), which according to Goñi et al. (1996) is defined as “the starch sum and its degradation products, not absorbed in the small intestine of healthy individuals”. This indigestible starch amount in cereal will depend, will depend of the polymers amylose: amylopectin, crystallinity; degree of gelatinization and treatment, especially thermal, used in grains processing (GOÑI et al., 1996; SAMBUCETTI; ZULETA, 1996).

On the other hand, structural polysaccharides contained in the cell walls or NSPs are represented by three main groups: cellulose, hemicellulose and pectic substances (CHOCT, 1997). Together, NSPs represent the given total fiber fraction in foods and depending on their components solubility, can be fractionated into soluble and insoluble. Insoluble fiber according Jeraci and Van Soest (1990) is composed of cellulose, insoluble hemicellulose, lignin, tannin, and other minority compounds, while the soluble fiber is represented by soluble hemicellulose and pectic substances (VAN SOEST et al., 1991).

The cellulose is the main polysaccharide forming the plants and grains cell wall. It has high molecular weight and is composed of D-glicopiranoses residues linked by beta 1-4 bonds in long linear chains, which may be joined by hydrogen bonds (AMAN; WESTERLUND, 1996), as well as with other polymers like lignin, which significantly changes the cellulose digestibility. This configuration explains the greater strength of the polysaccharide to enzymatic degradation, acid hydrolysis and microbial (THEANDER et al., 1989).

The hemicelluloses are comprised of low molecular weight polysaccharides soluble in alkaline solutions, especially the pentosans, arabinoxylans and β-glucans (CHOCT, 1997; BARNEVELD, 1999). These polymers, when not linked to lignin may be partially soluble in water depending on their chemical composition (VAN SOEST, 1994).

The pectins refer to a complex colloidal polysaccharides mixture, which can be partially extracted in water (THEANDER et al., 1989). They are composed by galacturonic acid residues linked linearly through alpha 1-4 bonds to arabana inserts and sometimes galactans at the chains ends. This polysaccharide is mainly in the middle lamella and primary plants cell walls (VAN SOEST, 1994). By-products such as citrus pulp, beet pulp and soybean hulls contains 29; 33.7 and 20% pectin, respectively (HALL, 2000) and they are found in small amounts (less than 1%) in the cell walls of cereal grains (THEANDER et al., 1989). According to Choct (1997), maize and sorghum grains contain little amount of soluble NSPs, whereas, rye and triticale contain substantial amounts of soluble and insoluble NSPs, mainly arabinoxylans, while the barley and oats are dominated by β-glucans.

Fiber in pig nutrition

Corn and soybeans are the major contents of feed for pigs, however, these grains are also used in human food. The biggest challenge is to maintain the livestock production efficiency using alternative foods, which does not compete directly with human consumption, improving carcass characteristics and reducing production costs (GERON, 2007). The use of roughage food aims to control possible problems associated with excessive feed intake and stress arising from confinement (CAMARGO et al., 2005). Still, it is noteworthy that the study on the potential of these foods in pig production is also linked to the consumer market desires, whose demand is increasing for pork with low fat and more specialized cuts.

In this context, the fibrous diets effect on the animals digestive physiology is generating more and more interest, especially for use in diets for no ruminants animals (CASTRO JR et al., 2005). Among the alternative foods for pigs, with high fiber content, coming from the agricultural industry, the most important are bagasse from sugarcane, citrus pulp, soybean hulls, potato starch manufacturers of waste and cassava farinheiras, waste breweries, among others (GERON, 2007).

The effects exerted by fiber intake may be metabolic and/or physiological, which is distinguished as the fibrous fraction (soluble and insoluble). Such effects could be due to changes in food pass rate, the nutrients digestibility and microbial growth in the gastrointestinal tract (WENK, 2001; TOSH; YADA, 2010). Researches have been carried out using such by-products and/or roughage with a high fiber amount in pig’s diet. Close (1994) showed that the sows are more apt to use fibers than weaned pigs or growing and finishing pigs. Thus, dietary fiber has been considered a viable energy source in pigs feeding, especially for adult animals for slaughter and for the categories of male breeding animals (boars), growing females (gilts) and females in gestation (VIEIRA, 2012).

Effects of different dietary fiber on pig’s performance

The fiber content in the ingredients can affect important nutritional characteristics in pigs, such as digestibility, intestinal fermentation, and the feed intake, resulting in different effects on performance and carcass traits (POVETA-PARRA et al., 2008; URRIOLA et al., 2012; ZIEMER et al., 2012). It must be considered that the nutritional and physiological fiber effects depend not only on the amount of cell wall constituents incorporated into the diet, but also its chemical and structural composition and the way it is physically associated with other nutrients (POVETA-PARRA et al., 2008). The dietary fiber sources commonly used in pig diet includes a wide variety of products, agro-processing by-products and roughage raw or preserved. The most common ingredients used as insoluble source in pig's diets are alfalfa meal (POND et al., 1988); peanut shell (HALE et al., 1986); coffee husk (POVETA-PARRA et al., 2008); corncob (FRANK et al., 1983); residue processing wheat (Lee et al., 2002); soybean hulls (CASTELINI, 2011); rice husk (FRAGA et al., 2008); Hay “coast-cross” (GOMES et al., 2007); Tifton hay (*Cynodon dactylon*) (GOMES et al., 2008); and wheat bran (MOLIST et al., 2009). As for products that are rich in soluble fiber sources, we can highlight the beet pulp (MOLIST et al., 2009) and citrus pulp (WATANABE et al., 2010; CROSSWHITE et al., 2013).

Alfalfa flour has been used in pig’s feed as an insoluble fiber source, due to its high content of cellulose and lignin. Kass et al. (1980) evaluating alfalfa meal, for pigs in growing and finishing phase, observed no significant effects on performance when added 20% to feed, however, the average daily gain reduced at 40 and 60% supply levels. Pond et al. (1988) using the same fiber source, at the level of 80% in the feed, observed decrease in weight gain and feed efficiency in pigs at the finishing phase. According to Thacker et al. (2008), the optimum level of the feed alfalfa meal for growing pig’s was 7.5%, because higher concentrations impaired the growth rate, while for the finishing phase they observed that the inclusion of 15% resulted in improvement of weight gain.

Evaluating the inclusion levels of alfalfa meal (0, 5, 10 and 20%) for finishing pigs, Chen et al. (2014) observed linear decrease in the average daily gain as fiber increasing in the diets. Growing pigs can consume a diet low in fiber and get the required average daily gain, however, the addition of more than 5% alfalfa meal to the diet reduced animal performance in this phase. On the other hand, finishing pigs tolerate higher fiber levels, because the digestive tract is already fully developed (CROSSWHITE et al., 2013).

Significant differences on performance of growing and finishing pigs were also observed by Hale et al. (1986), when tested a source of insoluble fiber arising from peanut hulls. When animals were fed with 10% of peanut hulls a decrease of 5% in average daily weight gain was observed and feed intake increased 12%. According to the authors, this byproduct is rich in cellulose, so can reduce the energy digestibility and interfere in the animal's performance.

Another insoluble fiber source used to feed pigs is the coffee hulls. Oliveira et al. (2001) observed a linear reduction in the of average daily feed intake (ADFI), average daily gain (ADG) and worst feed conversion (FC), at the time that the inclusion levels increased (0, 5, 10 and 15%) in the diets for pigs at growing and finishing phases. The authors found a reduction of 13.2 and 32.2 g in ADG and ADFI, respectively, for each additional unit of coffee hulls included into the diet. Moreover, Poveta-Parra et al. (2008), testing coffee hulls levels (0%, 5%, 10% and 15%) for growing and finishing pigs found no difference in ADFI, ADG and FC , but observed a difference at inclusion level of 20% of coffee hulls. According to the authors, these results may be explained by the lower amount of nutrients available to the tissue synthesis, since animals fed diets containing coffee hulls have a lower feed intake and reduced digestibility. The responses observed in FC indicate the lowest weight gain per unit of feed intake, showing the worst nutritional quality of diets containing coffee hulls.

The soybean hulls have 75.5% insoluble fiber, approximately 42.2% of cellulose, 16.4% hemicellulose and 3.0% lignin (JOHNSTON et al., 2003). Shriver et al. (2003) evaluated 10% of soybean hulls for growing and finishing pigs and found no effect on performance compared to the control diet. Moreover, Gentilini et al. (2004), working with gestation sows providing diets with low and high dietary fiber (including 7.0% and 35.0% of soybean hulls, respectively), found a reduction in weight at 110 days of gestation for females that received diet containing the highest level. Later, Gentilini et al. (2008) tested four levels (0%, 6%, 12% and 18%) of soybean hulls for pigs in growing and finishing phase and observed a higher ADG at 6% of inclusion level.

When evaluating inclusion levels (0%, 9%, 18% and 27%) of soybean hulls in diets for pigs, Castelini et al. (2011) pointed out that this byproduct affected animal performance, linearly increasing ADFI and the total feed intake and feed-gain, as soybean hulls levels increased in the diets. According to the authors, pigs compensate the low energy feed levels, increasing consumption and worsening the feed, although no difference was observed in the weight gain.

Similarly, Stewart et al. (2013) included 30% of soybean hulls in the diets for growing pigs observed reduction in feed intake and final weight gain, when compared with the basal diet. On the other hand, no differences were observed in the finishing phase, which indicate that finishing pigs are more efficient in nutrients and energy utilization from the soybean hulls compared to growing pigs. These results are due to the better utilization of fed at the large intestine, by fermentation, in which the efficiency of use short chain fatty acids (SCFA) for lipids synthesis exceed the utilization for ATP synthesis (BLACK, 1995).

Rice husk is another alternative as an insoluble fiber source in pig diets. Fraga et al. (2008), using rice husk in qualitative feed restriction program for pigs observed effect on animal performance. The daily energy intake and daily weight gain were reduced with increasing levels of dietary restriction in the ratio of 1.0% and 0.7%, respectively, for each level of feed restriction, and the time required for animals reach slaughter weight increased with inclusion. Moreover, Gomes et al. (2007) using coast-cross hay to growing and finishing pigs, found no difference in performance, however, when using Tifton hay, with 10% inclusion in the growing phase, observed a difference in the ADFI.

For piglets, studies have shown that the inclusion of insoluble fiber in the diet produces beneficial effects on gut health. It has been found that the fiber inclusion influence the physico-chemical properties, the digesta composition, the population and microbial activity, and animals which were subjected to low levels of insoluble fiber had better weight gain and feed intake, lower gastrointestinal transit time and increased water retention capacity by digesta (MOLIST et al., 2009).

Evaluating the pectin sources and barley hulls at different fiber concentrations (7%; 10.4%; 14.7%) in diets for piglets on intestinal morphology, enzymatic activity and mucin production, Hedemann et al. (2006) observed that animals fed diets containing pectin showed less weight gain, lower feed intake, reduced villus height, crypt depth, mucin production and higher number of villi per square millimeter. However, animals fed diets containing barley hulls showed improvement in intestinal morphology, with increased villus height and increased enzyme activity. Thus, we conclude that the insoluble fiber is useful for improving intestinal function.

Insoluble fiber and qualitative and quantitative carcass traits of pigs

Studies have highlighted that the fiber sources can negatively affect growth performance of pigs due to the low ability of these animals to degrade fibrous components. On the other hand, pigs at the finishing stage, due to the low nutritional requirements, increases the possibility of fibrous foods inclusion for presenting at this stage constant muscle deposition and high fat deposition then, diets are formulated with less nutritional density and energy as compared to the pigs in the growing stage.

Overall, it has been observed beneficial effects on pig carcass quality in the finishing phase submitted to insoluble fiber source. Aspects related to quality and meat quantity in pig carcass has been the meatpacking industry goal. In order to meet the market demand for higher amounts of cuts and lean meat, the characterization and the resulting bonus for carcasses that meets the requirement of the market, i.e., higher quality carcasses are becoming common practice in the pork market. Thus, carcasses with high fat receive lower values when compared with those that have less fat and more lean meat (FACCO, 2003).

Evaluating different levels of ground corn cob for finishing pigs, Camargo et al (2005) observed reduction in backfat thickness (BF) and larger loin eye area (LEA), justifying that diets with high levels of insoluble fiber are more efficient in reducing the energy intake of animals. This is due to reduction of energy available for storage in the form of lipids (FRAGA et al., 2009). Regarding the increase in LEA, diets with high dietary fiber content may indicate an improvement in the use and energy consumed redirection, allowing more energy for lean tissue deposition and less for fat deposition, since the protein deposition is more efficient than fat deposition, in energy terms (FRAGA et al., 2009).

When assessing inclusion levels (0%, 7.5%, 15%, 22.5% and 30%) of alfalfa meal, Thacker et al. (2008) observed a linear increase in the lean meat yield and decrease in back fat. Reduction of fat in the carcass, using alfalfa flour as an energy source, has also been reported in previous studies (BOHMAN et al., 1955; POWLEY et al., 1981). Hale et al. (1986) observed a decrease in backfat thickness in growing and finishing pigs when using the same fiber type from peanut hulls. Lee et al. (2002) also observed reduction in BF when evaluated the addition of 35% of wheat processing residue in pigs, with 59 ± 0.6 kg of body weight.

Evaluating 10% of soybean hulls for finishing pigs, Shriver et al. (2003) observed a benefic effect on carcass quality, in which this fiber source reduced BF. Similarly, Quadros et al. (2007) observed a linear reduction in BF when tested inclusion levels of soybean hulls (0%, 4%, 8%, 12%, 16%) in finishing pigs. The reduction in BF is currently one of the main targets set by the meatpacking industry, particularly when this reduction is accompanied by an increase in the amount of lean meat and LEA (GOMES et al., 2007).

Using different levels of soybean hulls (0%, 8%, 16%, and 24%) for pigs in the finishing phase, Castelini (2011) noted that the carcass yield decreased linearly as soybean hulls levels increased in the diet. The animals showed a reduction in the pH45’ values in semimembranosus muscle, being 6.36; 5.95; 6.10 and 6.24, respectively. Considering these results, it is possible that with the diets energy dilution by soybean hulls inclusion, muscle glycogen reserves has been reduced, resulting in lower meat acidification. Furthermore, the authors observed a quadratic effect for drip loss, with the smallest loss estimated at 12.07%. The water holding capacity in muscle influences the raw meat aspect and their appearance during cooking (BROSSI et al., 2009).

In carcass quality, color is an important variable due to the fact that the fresh meat has the function to attract the consumer and determine the positive first impression. Castelini (2011), evaluating the effect of the insoluble fiber for pigs, observed lower values for brightness (L*). Moreover, Fraga (2009), including rice hulls in pig diets, slaughtered around 130 kg, did not find difference for L*, however, observed reductions in the meat values of a* and b*, possibly due to the pigments reduction in the diet by the smallest corn percentage. Similarly, Castelini (2011) observed reduced lipid oxidation and total lipids as fiber levels increased in the diet. The lipid oxidation is related to the modification of taste, odor, appearance and taste characteristic rancid, which are extremely important in product impairment or rejection (SILVA et al., 1999).

Testing the inclusion (30%) of soybean hulls and wheat bran (30%) compared to the control diet, Stewart et al. (2013) observed a reduction in final body weight, hot carcass weight, carcass yield, cold carcass weight and increase in the visceral organs weight of pigs in the growing and finishing phases. According to the authors, the inclusion of insoluble fiber sources in growing pigs also influenced the energy (Mcal kg^{-1}), protein (g kg^{-1}) and lipids retention (g kg^{-1}) with a significant reduction, however, for finishing pigs the protein carcass retention increased. Similarly, Barnes et al. (2010) observed reduction in final body weight, carcass yield, BF and loin depth, justified that the viscera increased weight relative to body weight by adding the fiber source in the diet is the main reason for the yield carcass reduction.

Soluble fiber and qualitative and quantitative carcass of pigs

Currently soluble fiber sources have been studied as well as its possible effects on the carcass characteristics and meat pork quality (FANG et al., 2014). Diets containing high soluble fiber concentrations modulate the large intestine microflora composition, the short chain fatty acids concentration (SCFA) (HAENEN et al., 2013) however, information about the soluble fiber effects in pigs intestinal extra level is relatively limited.

Recently, has growing the interest to understand the soluble fiber impact in the metabolism and adipose tissue modeling from pigs. Lipogenesis decrease in adipose tissue but not in muscle tissue of growing pigs was observed with the soluble dietary fiber inclusion (MARTINEZ-PUIG et al., 2003). Similarly, studies reported that diets with high soluble fiber resulted in lower values of total body fat, subcutaneous fat and visceral fat with no change in total body weight (SO et al., 2007). The pig industry is focused on improving the meat quality. Thus, adipose tissue modulation, including BF and intramuscular fat is considered an important factor affecting the meat pork quality.

A significant reduction in carcass yield, chest circumference and lipogenesis in adipose tissue was observed by Fang et al. (2014) when fed growing pig with potato starch. Previous studies showed significant reduction in body fat with no change in body weight with the inclusion of soluble dietary fiber (SO et al., 2007).

According to Fang et al. (2014), pigs feeding diet containing soluble fiber showed a significant increase in the concentration of SCFA (acetate, proprionate and butyrate) in the colon, compared to the control diet, and it is believed that the highly soluble fiber used in the experiment is related to lipid metabolism. According to Bergman (1990), more than 95% of SCFA are rapidly absorbed from the colonic lumen.

It is known that butyrate is almost entirely used by the colon cells as the preferred energy substrate, whereas the acetate and propionate move to the liver via the portal vein. Propionate is metabolized in the liver and used for gluconeogenesis, whereas the acetate is a substrate for cholesterol synthesis and lipogenesis. Another important aspect is that the acetate is returned to the muscle and adipose tissue (BERGMAN, 1990; BLOEMEN et al., 2009). Moreover, the glucose gradual release and absorption from the digestion resistant starch modulates insulin response, so that energy can be used more efficiently for lean meat deposition, which in turn can reduce the nutrients participation in fat deposition (DOTI et al., 2014).

When working with inclusion levels of cassava byproduct (0%, 20%, 30%), Len et al. (2008) observed a linear reduction in the carcass yield of finishing pigs. It may be associated with the largest weight of visceral organs and the gastrointestinal tract, as observed in other studies (JORGENSEN et al., 1996; ZHAO et al., 1996; QIN et al., 2002).

Using 10% of beet pulp for finishing pigs, Ko et al. (2004) observed reduction in BF, however, no differences for other carcass characteristics were observed. These results corroborate with Li et al. (2011) using 5% of potato pulp, that found no effect on the parameters examined in the pigs carcasses.

Evaluating citrus pulp for finishing pigs, Watanabe et al. (2010), observed no reduction in feed intake, however, noted a linear reduction in carcass yield depending on the citrus pulp levels. Conversely, Croswhite et al. (2013) found no difference in the carcass yield and BF with inclusion of citrus pulp for finishing pigs. These results suggest that energy dilution by adding citrus pulp was not sufficient to reduce the BF and increasing the lean meat percentage.

However, the lack of statistical difference for BF between diets with citrus pulp inclusion, contradicts the Cerisuelo et al. (2010) findings, which reported that pigs fed citrus pulp had reduced carcass BF compared to the control diet. This difference results with citrus pulp inclusion in pig diets may be related to the different location of BF measurement, since Cerisuelo et al. (2010) measured at the last rib, unlike Croswhite et al. (2013), which measured at 10º rib. The results for rib lean eye area are similar between authors, which do not observed differences.

FINAL CONSIDERATIONS

Dietary fiber can help to meet the maintenance energy requirement of pigs. The studies with the soluble and insoluble dietary fiber use in pigs feed have significant advances in terms of identifying fiber sources and the functions on the carcass qualities.

The influence degree of dietary fiber will depend on several factors such as the fiber type, animal, age, diet and feeding frequency, sanitation, feed handling and the ingredients used in the diet. It is observed that dietary fiber has influence on the physiology and pigs performance, in which the digestive organs increase, and the BF and feed conversion increased.

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