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Abstract

Dietary fiber is a critical nutrient in sow diet and was addressed in several studies in the past decades. It plays a key role in improving digestive health, supporting metabolic functions, and enhancing the overall well-being of sows. Fiber, a plant-based feed ingredient is classified into soluble and insoluble fibers. Soluble fibers, such as pectin, dissolve in water and can form gels, influencing the fermentation process in the gut. Insoluble fibers, like cellulose, do not dissolve in water and contribute to the bulk of fecal matter, promoting intestinal motility. In sow nutrition, dietary fiber has been shown to offer several benefits. High-fiber diets are associated with better satiety which help to reduce constipation and support the digestive tract by enhancing gastrointestinal health. Despite the positive evidence, the practical application of fiber in sow nutrition has neither been clearly defined, nor have specific recommendations. The lack of information about fiber requirements is due to the insufficient characterization of its components in available ingredients and thus this review aims to examine the nutritional benefits of fiber in sow diets by emphasizing its importance in optimizing productivity through its effects on nutrient utilization and overall health.

Keywords: Fiber, sow, gestation, reproduction performance.

INTRODUCTION

Productivity and feed efficiency are the basic prerequisites for profitable swine production. In past decades, it was common for sows to receive a single diet through both pregnancy and lactation and this approach remains predominant in some regions where protein sources are readily available and affordable. However, today, sows are typically provided with a dual-diet regimen. During gestation, they were typically fed a diet lower in energy and protein to prevent excessive weight gain and maintain reproductive health. But when they enter the transition period (i.e. from gestation to lactation) they are subjected to have high-energy and protein diet to support the increased nutritional demands associated with the rapid development of the fetus and to optimize their performance during farrowing [1]. Earlier studies [2,3] demonstrate that a high-fiber diet provided to sows up to the point of farrowing has minimized the constipation and enhanced the farrowing outcomes. Energy requirements of sows during gestation and lactation are still difficult to assess because of the confounding effects of reproductive cycle. Particularly, during lactation period sows were offered with less fiber and higher levels of metabolic energy, and protein diet. [4]. Energy intake during pregnancy influences voluntary expenditure during lactation at the same time energy intake during lactation influences to maximize subsequent reproductive performance [5]. This increased reproduction performance intensifies the demands of sows, requiring them not only to successfully farrow but also to supply the essential nutrients to support piglet growth and survival. As a result, swine producers and researchers were driven to identify an optimal nutrient composition for gestation and lactation to improve feed intake, reproductive success, and healthy offspring.

Dietary fiber (DF) often called as the "seventh largest nutrient," has been identified as an essential and sustainable nutritional source [6]. Emerging data proved that dietary fiber during gestation plays a crucial role in optimizing sow performance and producing healthier piglets [7]. Incorporating appropriate amounts of fiber into the diet of gestation sows can help to maintain proper body condition and promote feed intake during lactation [1]. This, in turn, can help to reduce farrowing complications related to overweight, shorten farrowing duration, and improve lactation performance [8]. In recent years, a diverse range of fibrous feedstuffs were incorporated in pig diets such as distillers dried grains with soluble (DDGS), soybean hulls, wheat bran, sunflower meal, and sugar beet pulp [9]. As global demand for livestock feed rises, novel co-products like copra meal, palm kernel, rice bran, and canola meal are gaining prominence. Yet it is crucial to recognize that these fiber sources exhibit substantial variations in their nutritional composition, particularly in terms of fatty acid profiles. Also, the practical guidelines for incorporating these fiber feedstuffs into sow diets remain undefined and need specific recommendations. Thus, this review aims to explore the current information of the use of fiber-rich ingredients in contemporary sow diets and emphasizing its role in enhancing productivity by improving nutrient utilization and overall health (Fig. 1).

DIETARY FIBER: A GENERAL DESCRIPTION

Fiber, a carbohydrate and an anti-nutritional component is usually hard to digest by the endogenous enzymes and passes through the digestive system [10] of the host. Instead, they were fermented by micro-organisms within the colon into short chain fatty acids. DF is the primary component of fiber-rich feeds, constituting more than 40% of the total dry matter (DM) [11]. These fiber-rich feeds are cost-effective and plant-based which include barley, corn, wheat bran, soybean hulls, canola meal, and DDGS [12]. The main component of DF includes pectin, lignin, hemicellulose, cellulose, fructan, oligosaccharides, and resistant starch [13]. Previously, Sapkota et al. [14] demonstrated that DF has minimized the behavioral issues and enhanced the well-being of gestation sow by reducing their stress level. However, Portal et al. [15] reported that sows fed high fiber gestation diet had no better reproductive performance. While

David S. Rosero [16] found reduced wean-to-estrus interval in sow during the peripartum period when DF was top-dressed. Also, Li et al., [17] reported that DF had reduced nutrient digestibility and inhibited energy deposition in pig diets. Though DF inclusion offers benefits beyond lower feed costs ongoing research in animal nutrition has begun to emphasize its positive effects by showcasing its potential benefits for enhancing pigs' overall health and performance.

FIBER: CLASSIFICATION, TYPES, AND MODE OF ACTION

Fibers can be classified based on several key characteristics such as structure, solubility, fermentability, water-holding capacity, digestible and indigestible fractions, and viscosity. Soluble dietary fiber (SDF), such as pectins, hemicelluloses, arabinoxylans, xyloglucans, and fructooligosaccharides, are rapidly fermentable [18] while insoluble dietary fiber (ISDF), like cellulose, lignin, and different forms of resistant starches are slowly fermentable [19]. The functional properties of these fibers are largely defined by their solubility and fermentability. Solubility refers to the ability of fiber to dissolve in water. The degree of fiber solubility may stimulate the viscosity of the ileum and slow down the digestive process which results in reducing transit time and limiting the availability of enzymes for nutrient absorption [20]. Excess solubility is therefore undesirable as it can impair overall nutrient digestibility. Whereas insoluble fibers absorb water rather than dissolve. This water absorption helps maintain proper hydration of the digesta as it moves through the digestive system, and some of this water is released in the large intestine, where it may re-enter the body's circulatory system. However, we should not exclude all soluble fibers because many are fermentable, playing a vital role in gut health. Concurrently, ISDF can promote gut motility when consumed at the right concentration. This complex process involves both inert and fermentable fibers, with the latter providing nourishment for gut microbiota, which in turn produce neuro-mediators and regulate gut function. Most bacteria degrading DF are beneficial and can ferment DF into organic acid, thereby lowering the pH of the intestinal lumen, and inhibiting the proliferation of pathogenic bacteria [18]. Previously, Wu et al. [21] reported that xylan promoted the proliferation of *Bifidobacterium* in weaning pigs. The fibrous components extracted from feeds or feedstuffs are generally classified into three main types: total dietary fiber (TDF), crude fiber (CF), and neutral detergent fiber (NDF), and these fibers were often measured by different approaches: a) enzymatic-gravimetric method for TDF; b) chemical-gravimetric method for CF; and c) Van Soest method for NDF [22]. The detection methods for CF and NDF often exclude SDF components, while TDF analysis encompasses all types of fiber including SDF and IDF. DF enhances the beneficial bacteria in the lower gastrointestinal (GI) tract by fermenting carbohydrates and produces short-chain fatty acids (SCFAs), particularly butyrate which supports GI and overall productivity in sows. In the earlier study, Shang et al. [23] demonstrated that TDF increases beneficial bacteria in the hindgut, such as the genus *Christensenellaceae*, which is associated with improved gut health and SCFA production. Normally fiber cannot be digested by the animals, but it could provide feelings of fullness after feeding without spiking blood sugar or providing extra calories [24]. Also, it mitigates the symptoms of constipation by alleviating stress. Even if the addition of dietary fiber plays an important role in alleviating sow hunger and reducing abnormal behavior, it may be affected by the type of fiber and the inclusion level [25] thus incorporating DF into sow diets necessitates a clear understanding.

ROLE AND IMPACT OF FIBER IN SOW FEED

GESTATION

Gestation sows are often subjected to a strict feeding and this controlled feeding regime might often lead to constipation and stereotypical behaviors such as sham chewing (chewing motion unrelated to eating), bar biting, and nosing or licking the floor in the absence of feed [26]. A previous study insists that feeding 5% resistant starch during the gestation period has enhanced postprandial satiety by alleviating stress and reducing abnormal behaviors [27]. Additionally, Ferguson et al. [28] reported that providing gilts with a high-fiber diet enhances follicle quality, oocyte maturation, and early embryo survival which seems to be linked with changes in estradiol (E2) and luteinizing hormone (LH) profiles. In 2023, Qin et al. [13] reported that adding 10.8%, 15.8% and 20.8% NDF to sows on different parity from day 1 through to day 90 of gestation has improved their reproductive performance. Similarly, Noblet and Le Goff G. [29] demonstrate that incorporating increasing levels of DF (3.3, 8.6, and 10.1 kJ for each gram of NDF, ADF, and CF, respectively) had increased digestible energy in adult sows. These effects were primarily attributed to the enhanced degradation of dietary fiber in the hindgut of the sows. A study by Lu et al. [30] proved that sows fed higher levels of TDF had lower constipation, which in turn led to reduced farrowing time. On the other hand, Tan et al. [31] demonstrate that inclusion of dietary fiber in late gestation has reduced oxidative stress on day 1 of lactation. Also, Zhou et al. [32], addressed that adding high fiber during gestation helps sows to maintain a suitable body condition scoring. Moreover, Lowell et al. [33] noted a high metabolic energy in gestation sow fed wheat middlings and soybean hulls. Additionally, Stein and Shurson. [34] described that replacement of soybean with DDGS had not adverse impact on gestation sow performance. Meanwhile, Kim et al. [35] reported that gestating sows fed a diet containing soybean hulls exhibited greater apparent total tract digestibility of DM and energy compared to those fed a diet containing pistachio shell powder (PSP). Several studies have examined the impact of varying fiber content in the diets of pregnant sows and the growth rates of piglets. For example, Oliviero et al. [36] reported that sows fed 7% versus 3.8% crude fiber had increased the piglet weight gain from 1 to 5 d of age, while Loisel et al. [37] stated that feeding a high fiber diet from d 106 of pregnancy until parturition did not influence piglet weight gain until d 21 of lactation. Sows often experience metabolic syndrome during late gestation and early lactation due to vigorous metabolism and diminishing antioxidant capacity, with intestinal microbiota imbalance playing a significant role in this condition [38]. Promoting beneficial bacteria in the intestine may help improve metabolic syndrome through "microbiota remodeling," thereby alleviating inflammation and oxidative stress, which effectively increases the average daily feed intake (ADFI) during lactation [39]. Research by Li et al. [12] demonstrated that maternal intake of SDF enhances intestinal health in neonates. Increasing the ratio of soluble to insoluble dietary fiber in the diets of pregnant sows improved antioxidant capacity and reduced inflammation in the colon of piglets. Briefly, maternal SDF intake benefits the intestinal health of piglets however, precise mechanisms related to various factors, including the vertical transmission of intestinal microbiota, and fetal intestinal development during pregnancy require further clarification. Overall, DF has been shown to improve the reproductive performance of sows at different stages, but the selection of fiber sources and optimal inclusion levels warrant further exploration.

FARROWING

The primary challenge faced by sows during parturition is the rapid depletion of energy, particularly when dealing with larger litter and prolonged farrowing times [40]. A swift farrowing process is crucial for the survival of piglets; however, prolonged farrowing can result in a higher number of piglet deaths at birth, lower survival rates, increased postpartum oxidative stress, and a greater incidence of anorexia in sows. Ultimately, these factors contribute to reducing the performance of the litter [41]. These challenges can be exacerbated by several factors: constipation, oxidative stress, and insulin resistance, which may result in inadequate physical endurance during farrowing [41,42,43]. Therefore, ensuring proper nutrition for sows during this critical period is paramount and has become a key focus for swine researchers. Earlier studies indicate that when the time between the last meal consumed and farrowing extends beyond approximately four hours, the length of farrowing increases, potentially leading to energy depletion [43]. To prevent sows from being depleted during farrowing, it is recommended to feed them three meals a day. Accordingly, adequate energy supply to sows is vital to reduce the farrowing length and stillborn piglets. The addition of fiber into sow diet during the last two weeks before parturition has been shown to decrease the frequency of stillborn piglets [44]. Feyera et al. [3] reported that sows fed high-fiber diet during the perinatal period alleviates prolonged farrowing duration by softening feces and providing energy from their hindgut. We proposed that above mentioned research outcomes might be due to fiber fermented in the hindgut which ensures to have constant energy uptake from the gastrointestinal tract and thus contributes to stable blood glucose level even though the sows are not able to eat while giving birth. So far, several studies have demonstrated the effects of DF addition on sow reproductive performance. However, only a few have explored the mechanisms by which DF supplementation enhances their fertility. Placenta plays a crucial role in material exchange between the fetus and the mother, and placental insufficiency is a common cause of low litter size, birth weight, and uniformity of piglets within a litter. A recent study indicated that dietary DF during gestation has resulted in three successive parities, high litter size and weight, as well as increased placental weight in the 2^{nd} and 3^{rd} parities [45]. This suggests that DF during gestation may enhance sow reproductive performance by improving placental development and function.

LACTATION

Lactation is a critical phase in the reproductive cycle of sows [1], and their feed intake during this period is more crucial for their subsequent performance [46] as well as the growth and development of their suckling's [47]. Previously, Shang et al. [23] investigated the effect of sugar beet pulp (SBP) and wheat bran (WB) in sows and found that maternal feeding of SBP improved the weaning weight of piglets, whereas WB had no significant impact on their growth rate. Additionally, Kim et al. [35] found low energy digestibility in lactation sow by the inclusion of PSP (high in IDF). Based on these findings, we hypothesize that soluble fiber sources like SBP may be more effective than insoluble fiber sources like WB and PSP in supporting lactation performance. During early lactation, maternal nutrition plays an important role in regulating the immune development of their offspring as they largely rely on the colostrum (first source of nutrients and energy) supplied from their dam. Prolactin, an essential hormone, is responsible for initiating and maintaining milk production [48]. Also, it plays a vital role in cell proliferation, mammary gland development, and milk secretion which ultimately helps to deliver nutrients to suckling and improve their survival rates [7]. Such prolactin hormone showed tendency to increase when gestation sows were offered with high fiber diet [49], however some studies showed no difference in the prolactin concentrations with high fiber diet. We hypothesize that these inconsistencies may be attributed to maternal obesity [50] and offering a high-fiber diet to gestating sows may help reduce obesity, thereby boosting prolactin levels in the serum to produce sufficient milk during lactation. Oxytocin is a neurohypophysial hormone that plays a key role in regulating parturition and lactation, including the initiation of uterine contractions and milk secretion [51]. Li et al. [52] reported that sows fed a diet supplemented with 2.26% inulin and 18.2% cellulose during gestation showed increased plasma oxytocin levels. This increase was linked to postprandial satiety resulting from the consumption of a high-dietary fiber diet [53]. Though the concept of fetal programming through maternal nutrition is well-established yet specific mechanisms by which maternal DF intake benefits the intestinal health of piglets remain unexplored, highlighting the need for further research. In recent times, functional fiber such as chitosan oligosaccharides (COS), konjac glucomannan, and inulin have been shown to effectively manage oxidative stress in lactating sows [41,42]. COS, a depolymerized form of chitosan, exhibits excellent water solubility and a range of biological activities, including immune stimulation, anti-inflammatory, and antioxidant properties [54]. These characteristics suggest that COS might play a beneficial role in sows, particularly in neutralizing reactive oxygen species (ROS) and mitigate oxidative damage within their bodies [21]. Also, by scavenging free radicals, COS supports sows to enhance their immune system and protects against cellular damage during pregnancy and lactation. Konjac glucomannan is a natural neutral polysaccharide extracted from konjac tubers [55]. Over the decades, it has been used as a food additive and dietary supplement [56]. The inclusion of 0.25% konjac glucomannan to late gestation sows reveal better lactation feed intake [57] while some studies showed no improvements [58] the inconsistent results may be attributed to factors like leptin hormone secretion, which can suppress appetite. Further research is needed to fully understand the mechanisms and optimize the use of these functional fibers in enhancing the performance of sows during lactation.

CONCLUSION

Effective fiber management in sow diets promotes satiety, supports gut health, stabilizes energy levels, and enhances reproductive outcomes. Though dietary fiber contributes to the well-being of both the sow and piglets, determining the ideal ratio of soluble to insoluble fiber is still challenging. Therefore, further investigation is necessary to understand how processing methods and the timing of fiber supplementation can enhance its nutritional value, enabling the development of effective feeding standards to optimize sow performance.

REFERENCES

1. Li S, Zheng J, He J, Liu H, Huang Y, Huang L, Wang K, Zhao X, Feng B, Che L, Fang Z. Dietary fiber during gestation improves lactational feed intake of sows by modulating gut microbiota. J. Anim. Sci. Biotechnol. 2023; 5;14(1):65.

2. Krogh U, Bruun TS, Amdi C, Flummer C, Poulsen J, Theil PK. Colostrum production in sows fed different sources of fiber and fat during late gestation. Can. J. Anim. Sci. 2015; 95(2):211-23.

3. Feyera T, Højgaard CK, Vinther J, Bruun TS, Theil PK. Dietary supplement rich in fiber fed to late gestating sows during transition reduces rate of stillborn piglets. J Anim. Sci. 2017; 95:5430–5438.

4. Adi YK, Taechamaeteekul P, Ruampatana J, Malison M, Suwimonteerabutr J, Kirkwood RN, Tummaruk P. Influence of prepartum feed levels on colostrum production and farrowing performance in highly prolific sows in a tropical environment. Animal. 2024 1;18(2):101066.

5. Dourmad JY, Etienne M, Noblet J. Reconstitution of body reserves in multiparous sows during pregnancy: effect of energy intake during pregnancy and mobilization during the previous lactation. J. Anim Sci. 1996 Sep 1;74(9):2211-9.

6. Tan Z, Meng Y, Li L, Wu Y, Liu C, Dong W, Chen C. Association of Dietary Fiber, Composite Dietary Antioxidant Index and Risk of Death in Tumor Survivors: National Health and Nutrition Examination Survey 2001-2018. Nutrients. 2023;15(13): 2968.doi: 10.3390/nu15132968.

7. Jo H, Kim BG. Effects of dietary fiber in gestating sow diets—A review. Anim. Biosci. 2023;36(11):1619.

8. Theil PK, Flummer C, Hurley WL, Kristensen NB, Labouriau RL, Sørensen MT. Mechanistic model to predict colostrum intake based on deuterium oxide dilution technique data and impact of gestation and pre-farrowing diets on piglet intake and sow yield of colostrum. J Anim Sci. 2014; 92(12):5507-19.

9. Jarrett S, Ashworth CJ. The role of dietary fibre in pig production, with a particular emphasis on reproduction. J. Anim. Sci. Biotechnol. 2018; 9:59. doi: 10.1186/s40104-018-0270-0.

10. Jha R, Berrocoso JD. Dietary fiber utilization and its effects on physiological functions and gut health of swine. Animal. 2015; 9(9):1441-52.

11. Woyengo TA, Beltranena E, Zijlstra RT. Nonruminant nutrition symposium: controlling feed cost by including alternative ingredients into pig diets: a review. J. Anim Sci. 2014; 92(4):1293-305.

12. Li Y, Liu H, Zhang L, Yang Y, Lin Y, Zhuo Y, Fang Z, Che L, Feng B, Xu S, Li J. antioxidative capacity, inflammatory response, and gut microbiota in a sow model. Int. J Mol Sci. 2019; 19:21(1):31.

13. Qin F, Wei W, Gao J, Jiang X, Che L, Fang Z, Lin Y, Feng B, Zhuo Y, Hua L, Wang J. Effect of dietary fiber on reproductive performance, intestinal microorganisms and immunity of the sow: A review. Microorganisms 2023; 11 (9): 2292. https://doi.org/10.3390/microorganisms11092292

14. Sapkota A, Marchant-Forde JN, Richert BT, Lay Jr DC. Including dietary fiber and resistant starch to increase satiety and reduce aggression in gestating sow. J Anim Sci. 2016; 94:2117–2127. doi: 10.2527/jas.2015-0013.

15. Portal XAP. 2022. Effects of Dietary Fiber during Gestation on Sow Reproductive Performance (Doctoral dissertation, Oklahoma State University).

16. David S Rosero, 170 Feeding the modern sow: Unlocking the value of dietary fiber, J. Anim Sci. 2024; 102 (2),188. https://doi.org/10.1093/jas/skae102.210.

17. Li Y, He J, Zhang L, Liu H, Cao M, Lin Y, Xu S, Fang Z, Che L, Feng B, Jiang X. Effects of dietary fiber supplementation in gestation diets on sow performance, physiology and milk composition for successive three parities. Anim Feed Sci Technol. 2021 1;276:114945.

18. Williams BA, Grant LJ, Gidley MJ, Mikkelsen D. Gut fermentation of dietary fibres: physico-chemistry of plant cell walls and implications for health. Int. J. Mol. Sci. 2017 20;18(10):2203.

19. Mudgil D, Barak S. Classification, technological properties, and sustainable sources. In Dietary fiber: Properties, recovery, and applications. Academic Press. 2019; 1; 27-58.

20. Guo K, Yao Z, Yang T. Intestinal microbiota-mediated dietary fiber bioavailability. Front. Nutr. 2022; 28; 9:1003571.

21. Wu X, Chen D, Yu B, Luo Y, Zheng P, Mao X, Yu J, He J. Effect of different dietary non-starch fiber fractions on growth performance, nutrient digestibility, and intestinal development in weaned pigs. Nutrition. 2018; 1; 51:20-8.

22. Agyekum AK, Nyachoti CM. Nutritional and metabolic consequences of feeding high fiber diets to swine: a review. Engineering. 2017;3(5):716-25.

23. Shang Q, Liu H, Liu S, He T, Piao X. Effects of dietary fiber sources during late gestation and lactation on sow performance, milk quality, and intestinal health in piglets J Anim Sci. 2019; 97:4922-33. https://doi.org/10.1093/jas/skz278.

24. Suresh A, Shobna, Salaria M, Morya S, Khalid W, Afzal FA, Khan AA, Safdar S, Khalid MZ, Mukonzo Kasongo EL. Dietary fiber: an unmatched food component for sustainable health. Food Agric. Immunol. 2024; 31;35(1):2384420.

25. Williams BA, Mikkelsen D, Flanagan BM, Gidley MJ. "Dietary fibre": moving beyond the "soluble/insoluble" classification for monogastric nutrition, with an emphasis on humans and pigs. J. Anim. Sci. Biotechnol. 2019; 10:1-2.

26. Meunier-Salaün MC, Edwards SA, Robert S. Effect of dietary fibre on the behaviour and health of the restricted fed sow. Anim Feed Sci Technol. 2001; 15;90(1-2):53-69.

27. Huang S, Wei J, Yu H, Hao X, Zuo J, Tan C, Deng J. Effects of dietary fiber sources during gestation on stress status, abnormal behaviors and reproductive performance of sows. Animals. 2020 Jan 15;10(1):141.

28. Ferguson EM, Slevin J, Hunter MG, Edwards SA, Ashworth CJ. Beneficial effects of a high fibre diet on oocyte maturity and embryo survival in gilts. Reproduction. 2007;133(2):433-9.

29. Noblet J, Le Goff G. Effect of dietary fibre on the energy value of feeds for pigs. Anim. Feed Sci Technol. 2001; 90:35–52.

30. Lu D, Pi Y, Ye H, Wu Y, Bai Y, Lian S, Han D, Ni D, Zou X, Zhao J, Zhang S. Consumption of dietary fiber with different physicochemical properties during late pregnancy alters the gut microbiota and relieves constipation in sow model. Nutrients. 2022;14(12):2511.

31. Tan C, Wei H, Ao J, Long G, Peng J. Inclusion of konjac flour in the gestation diet changes the gut microbiota, alleviates oxidative stress, and improves insulin sensitivity in sows. Appl Environ Microbiol. 2016; 82:5899–5909. doi: 10.1128/AEM.01374-16

32. Zhuo Y, Feng B, Xuan Y, Che L, Fang Z, Lin Y, Xu S, Li J, Feng B, Wu D. Inclusion of purified dietary fiber during gestation improved the reproductive performance of sows. J Anim Sci Biotechnol. 2020; 11:1-7.

33. Lowell JE, Liu Y, Stein HH. Comparative digestibility of energy and nutrients in diets fed to sows and growing pigs. Arch. Anim. Nutr. 2015;69(2):79-97.

34. Stein HH, Shurson GC. Board-invited review: the use and application of distillers dried grains with solubles in swine diets. J Anim Sci. 2009;87(4):1292-303. doi:10.2527/jas.2008-1290.

35. Kim Y, Lee SA, Stein HH. Determination of energy values in pistachio shell powder and soybean hulls fed to gestating and lactating sows. Transl anim sci. 2024; 8: 135, https://doi.org/10.1093/tas/txae135.

36. Oliviero C, Kokkonen T, Heinonen M, Sankari S, Peltoniemi O. Feeding sows with high fibre diet around farrowing and early lactation: Impact on intestinal activity, energy balance related parameters and litter performance. Res Vet Sci. 2009; 86:314–9.

37. Loisel F, Farmer C, Ramaekers P, Quesnel H. Effects of high fiber intake during late pregnancy on sow physiology, colostrum production, and piglet performance. J Anim Sci. 2013; 1;91(11):5269-79.

38. Cheng C, Wei H, Yu H, Xu C, Jiang S, Peng J. Metabolic syndrome during perinatal period in sows and the link with gut microbiota and metabolites. Front Microbiol. 2018; 9:1989.

39. Xu C, Cheng C, Zhang X, Peng J. Inclusion of soluble fiber in the gestation diet changes the gut microbiota, affects plasma propionate and odd-chain fatty acids levels, and improves insulin sensitivity in sows. Int J Mol Sci. 2020;21(2):635.

40. Ju M, Wang X, Li X, Zhang M, Shi L, Hu P, Zhang B, Han X, Wang K, Li X, Zhou L. Effects of litter size and parity on farrowing duration of Landrace× Yorkshire sows. Animals. 2021; 12(1):94. https://doi.org/10.3390/ani12010094.

41. Tummaruk P, Sang-Gassanee K. Effect of farrowing duration, parity number and the type of anti-inflammatory drug on postparturient disorders in sows: a clinical study. Trop Anim Health Prod. 2013; 45:1071–7. https://doi.org/10.1007/s11250-012-0315-x

42. Oliviero C, Kothe S, Heinonen M, Valros A, Peltoniemi O. Prolonged duration of farrowing is associated with subsequent decreased fertility in sows. Theriogenology. 2013; 79:1095–9. https://doi.org/10.1016/j.theriogenology.2013.02.005.

43. Li Y, He J, Zhang L, Liu H, Cao M, Lin Y, Xu S, Fang Z, Che L, Feng B, Jiang X. Effects of dietary fiber supplementation in gestation diets on sow performance, physiology and milk composition for successive three parities. Anim Feed Sci Technol. 2021; 276:114945.

44. Bilkei Papp, G. "The effect of increased fibre content fed in the previous week on the parturition of sows." (1990): 597-601.

45. Le Bourgot C, Ferret-Bernard S, Le Normand L, Savary G, Menendez-Aparicio E, Blat S, Appert-Bossard E, Respondek F, Le Huërou-Luron I. Maternal short-chain fructooligosaccharide supplementation influences intestinal immune system maturation in piglets Plos One. 2014; 9(9): e107508.

46. Gomez de Agüero M, Ganal-Vonarburg SC, Fuhrer T, Rupp S, Uchimura Y, Li H, Steinert A, Heikenwalder M, Hapfelmeier S, Sauer U, McCoy KD. The maternal microbiota drives early postnatal innate immune development. Science. 2016; 351:1296–1302. doi: 10.1126/science. aad2571.

47. Mirończuk-Chodakowska I, Witkowska AM. Evaluation of Polish wild mushrooms as beta-glucan sources. Int. J. Environ. Res. Public Health. 2020; 17:7299. doi: 10.3390/ijerph17197299.

48. Farmer C, Robert S, Matte JJ. Lactation performance of sows fed a bulky diet during gestation and receiving growth hormone-releasing factor during lactation. J Anim Sci. 1996; 1;74(6):1298-306.

49. Agyekum AK, Columbus DA, Farmer C, Beaulieu AD. Effects of supplementing processed straw during late gestation on sow physiology, lactation feed intake, and offspring body weight and carcass quality. J Anim Sci. 2019; 3;97(9):3958-71.

50. Lepe M, Gascón MB, Castañeda-González LM, Morales ME, Cruz AJ. Effect of maternal obesity on lactation: systematic review. Hospital Nutrition. 2011;26(6):1266-9. doi: 10.3305/nh.2011.26.6.5388.

51. Kim SH, Bennett PR, Terzidou V. Advances in the role of oxytocin receptors in human parturition. Mol. Cell. Endocrinol. 2017; 5; 449:56-63. doi: 10.1016/j.mce.2017.01.034.

52. Li H, Liu Z, Lyu H, Gu X, Song Z, He X, Fan Z. Effects of dietary inulin during late gestation on sow physiology, farrowing duration and piglet performance. Anim. Reprod. Sci. 2020; 219:106531. doi: 10.1016/j.anireprosci.2020.106531

53. Moturi J, Hosseindoust A, Tajudeen H, Mun JY, Ha SH, Kim JS. Influence of dietary fiber intake and soluble to insoluble fiber ratio on reproductive performance of sows during late gestation under hot climatic conditions. Sci Rep. 2022 Nov 17;12(1):19749. doi: 10.1038/s41598-022-23811-8.

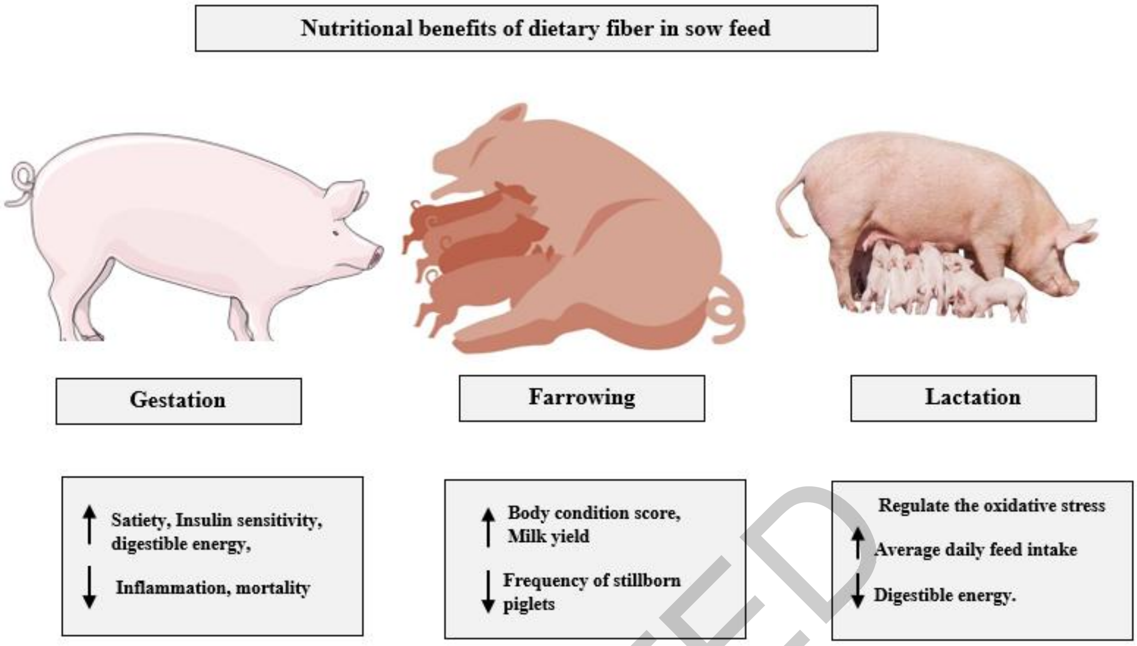
54. Ngo DH, Vo TS, Ngo DN, Kang KH, Je JY, Pham HN, Byun HG, Kim SK. Biological effects of chitosan and its derivatives. Food hydrocolloids. 2015 Oct 1; 51:200-16.

55. Zhu B, Xin C, Li J, Li B. Ultrasonic degradation of konjac glucomannan and the effect of freezing combined with alkali treatment on their rheological profiles. Molecules. 2019 May 14;24(10):1860.

56. Tan CQ, Wei HK, Sun HQ, Long G, Ao JT, Jiang SW, Peng J. Effects of supplementing sow diets during two gestations with konjac flour and Saccharomyces boulardii on constipation in peripartal period, lactation feed intake and piglet performance. Anim Feed Sci Technol. 2015; 210:254-62. https://doi.org/10.1016/j. anifeedsci.2015.10.013

57. Gao F, Du Y, Liu H, Ding H, Zhang W, Li Z, Shi B. Maternal supplementation with konjac glucomannan and κ-carrageenan promotes sow performance and benefits the gut barrier in offspring. Anim. Nutr. 2024; 19: 272-286.

58. Sun HQ, Zhou YF, Tan CQ, Zheng LF, Peng J, Jiang SW. Effects of konjac flour inclusion in gestation diets on the nutrient digestibility, lactation feed intake and reproductive performance of sows. Animal. 2014;8(7):1089-94.



410 **Fig 1**. A Schematic view on the nutritional benefits of dietary fiber in sow.

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