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Abstract

The main objective of this study was to investigate the impact of incorporating dietary almond hull (AH) supplementation on various aspects, including the reproductive and growth performance of sows and their piglets, as well as nutrient digestibility, milk composition, and fecal score. For this purpose, a total of 21 sows (Landrace × Yorkshire), with an average parity of 3.3, were selected and divided into three dietary treatment groups: (i) a control group as basal diet (CON), (ii) the basal diet with 3% AH (TRT1), and (iii) the basal diet with 6% AH (TRT2). This study covered the period from 100th day of pregnancy until weaning. Dietary AH supplementation did not affect lactating sow's reproduction performance as well as body weight, backfat thickness, and body condition score during pre- and post- farrowing, and at weaning. Similarly, body weight loss, backfat thickness loss, average daily feed intake, and estrus interval did not show significant variations among the treatment groups. Furthermore, the inclusion of AH in the diet has not had a discernible impact on nutrient digestibility. However, dietary supplementation of the AH has improved the body weight ($P = 0.0464$) at weaning and average daily gain ($P = 0.0146$) of suckling piglets. Moreover, the milk content and fecal score of the sows did not exhibit significant differences across the treatment groups. Overall, the addition of AH to the sow diet had a favorable effect on the body weight and average daily gain of suckling piglets, without exerting any detrimental effects on the growth performance, nutrient digestibility, milk composition, and fecal score of lactating sows.

Key words: almond hull, fecal score, growth performance, lactating sow, milk content, and nutrient digestibility.

INTRODUCTION

The swine industry seeks innovative and sustainable approaches to optimize nutrition, improve animal health, and enhance productivity. In recent years, there has been growing interest in the utilization of alternative feed ingredients to address the challenges associated with traditional feed resources [1]. Almond hull (AH), a byproduct generated during almond processing, shows great potential as an alternative feed ingredient for lactating sows due to the rapid growth of almond production driven by human demand [2]. AH, with its fiber and various bioactive compounds like polyphenols and antioxidants, has the potential to boost animal performance as a valuable dietary component [3].

Lactating sows require specialized nutrition to accommodate the substantial demands of milk production while also ensuring their own maintenance and well-being [4]. Fiber is crucial for a healthy gastrointestinal tract, providing diet bulk, supporting proper gut motility, preventing constipation, and aiding overall digestive function and nutrient absorption; in sow nutrition, it helps manage body weight (BW), particularly during lactation, by imparting a sense of fullness without excess calories [5].

AH possesses several characteristics that make it an attractive feed ingredient. Firstly, it is an abundant agricultural byproduct, readily available, and potentially cost-effective [6]. Secondly, AH is a rich source of dietary fiber, which can promote gut health and modulate nutrient utilization [7,8]. Elevated levels of dietary fiber significantly influenced the performance, well-being, and behavioral aspects of sows [9]. It was shown that incorporating a fiber-rich diet during pregnancy enhances the reproductive outcomes, growth performance of nursing piglets, nutrient absorption, and milk composition in lactating sows [10]. Furthermore, AH contains bioactive compounds, such as antioxidants and phenolic compounds, which have been associated with various health benefits, including improved immune function and oxidative stress reduction [11]. However, the inclusion of AH in the diet of lactating sows has not been extensively investigated, and its impact on growth performance, nutrient digestibility, suckling piglet performance, and fecal score remains largely unknown.

Understanding the impact of AH inclusion on sow and piglet performance will enable swine producers to make informed decisions regarding its incorporation into their feeding programs, ultimately leading to improved animal welfare and economic profitability. This study presents an in-depth investigation into the effects of dietary AH on lactating sows, addressing critical aspects such as growth performance, nutrient digestibility, suckling piglet performance, fecal score, and milk content.

MATERIALS AND METHODS

The procedures for animal care and management outlined in the experimental protocols underwent thorough review and received approval from Dankook University's Animal Care and Use Committee (Approval Code: DK-2-2216) in South Korea.

Experimental design, animals, and diets

A total of 21 sows, (Landrace × Yorkshire), with an average parity of 3.3 (4 sows in second pregnancy, 9 sows in third pregnancy, 6 sows in fourth pregnancy, and 2 sows in fifth pregnancy), were utilized in this study. The three dietary treatments: 1) CON, basal diet; 2) TRT1, basal diet incorporated with 3% AH; and 3) TRT2, basal diet incorporated with 6% AH. Each treatment group consisted of 7 sows.

Throughout the gestation period, the sows were housed in separate stalls furnished with partially slatted flooring composed of specific strips measuring 0.80 × 1.05 m. The experimental diets were administered from 100th day of gestation until weaning. Sows were weighed and moved to the farrowing room on the 107th day of gestation, where they received 2.5 kg of feed daily for adjustment to the lactation diet before parturition. However, sows were not provided with food on the day of farrowing. The nutrient compositions of the diets were designed to meet or exceed the nutritional standards outlined by the National Research Council [12] (Table 1).

The farrowing crate was equipped with controlled air conditioning for newborn piglets, while the temperature in the farrowing house was maintained at a minimum of 20°C, with supplementary ventilation generated through heat lamps. Within 24 hours of birth, all piglets underwent essential procedures including a 1 ml iron injection, ear notching, and tail docking. Male piglets were castrated within the first 5 days after birth. During the lactation period, the sow's feed intake increased to 7 kg, and piglets continued to be weaned within the farrowing room until day 21. Both sows and piglets had unrestricted access to feed and water throughout the duration of the experiment.

Chemical analysis, sampling, and measurements

Reproduction performance of sows

Body weight (BW), body weight loss (BWL), backfat thickness (BFT), and body condition scores (BCS) were assessed before and after farrowing, as well as at weaning on day 21. The back-fat thickness, situated 6-8 cm from the midline of the 10th rib, was gauged using a real-time ultrasonic device called piglet 105 (SFK Tech, Herlec, Denmark). These measurements were taken during the 100^{th} day of gestation, post-farrowing, and weaning stages to establish the back fat thickness loss (BFTL).

Throughout the gestation and lactation periods, the intake of feed and any leftover portions were computed to ascertain the average daily feed intake (ADFI). Various parameters related to piglets were also documented, such as birth weight, total number of pigs at birth, count of live, stillborn, and mummified piglets, which were then used to determine the litter size. Additionally, the number of piglets that were nurtured from birth until weaning, known as starter and fostered piglets, was recorded to calculate the survival rate (SUR).

Growth performance of piglets

On days 1, 7, 14, and 21, individual piglets' BW, and average daily gains (ADG) were recorded. The calculation of piglet ADG involved determining the difference between birth weight (kg) and weaning weight (kg) and then dividing it by the length of the lactation period. The growth performance of number of suckling piglets (INO), final number of suckling piglets (FNO), and SUR were recorded.

Nutrient digestibility of sows

To compute the total tract digestibility of dry matter (DM), nitrogen (N), and energy (E), 0.20% concentration of chromium oxide was introduced into the diet as an indigestible marker for a 7-day period leading up to fecal collection at the end of the lactation period. The rectum of the sows was gently stimulated by a handler, facilitating the collection of fresh fecal samples which were combined based on pen grouping and then stored at a temperature of -20°C until analysis.

Both the feed and fecal samples underwent freeze-drying and were finely ground to pass through a 1 mm screen. The assessment of DM and N digestibility followed procedures established by the Association of Official Analytical Chemists [13]. The concentration of chromium in the diets and feces was determined through ultraviolet (UV) absorption spectrophotometry using a UV-1201 instrument from Shimadzu, Kyoto, Japan. E analysis was conducted using a Parr 6100 oxygen bomb calorimeter from Parr Instrument, Moline, IL, USA, which measured the heat released during combustion in the samples. For N analysis, a Kjeltec 8600 system from Foss Tecator AB, Hoeganaes, Sweden, was employed. The calculation of digestibility was followed by our previous study [14].

Fecal score of sows

During days 100 to 107 of pregnancy and in the third week of the lactating period, the fecal consistency of sows was monitored and recorded daily per pen. The fecal consistency was classified using the following grading system: 1 represented hard, dry pellets; 2 indicated firm, well-formed stools; 3 denoted soft, moist stools retaining their shape; 4 described soft, less formed stools taking the shape of the container; 5 signified watery liquid consistency that could be poured.

Milk contents of sows

Around 25 milliliters of colostrum were obtained from the active mammary glands of these sows within 12 hours after farrowing. Additionally, on the 21st day of lactation, 10 to 20 milliliters of mature milk were collected for analysis. The colostrum and milk samples were subjected to analysis for various components, including fat, protein, lactose, solids not fat, total solids, and freezing point. These analyses were conducted by a commercial laboratory utilizing a MilkoScan^{TM} FT1 (Foss North America, Eden Prairie, MN).

Statistical analyses

All data in this experiment were analyzed in accordance with a completely randomized design using the one-way ANOVA. Tukey's range test analyses were utilized to evaluate whether there were significant differences among the means. The experimental unit was represented by suckling piglets and sows. The standard error of the means (SEM) was a way of expressing the data’s variability. The significance of differences was determined at $P < 0.05$ was considered significant, $P < 0.10$ was considered a trend.

RESULTS

Reproduction performance and growth performance

Table 2 showed the impact of including AH supplement on sow reproductive performance. Lactating sows supplemented with AH showed no changes in BW, BWL, BFT, BFTL, and BCS across pre- and post-farrowing, as well as during weaning stages. Additionally, no discrepancies were observed in the ADFI of sows both pregnancy and lactation periods. Moreover, the AH supplementation in sow diet did not lead to significant differences in INO and FNO. However, in comparison to CON, TRT2 exhibited a notable increase in both piglet BW (P = 0.0464) and ADG (P = 0.0146) at the weaning stage (Table 3).

Nutrient digestibility, fecal score, and milk content

The inclusion of AH in the diet of sow did not significantly affect nutrient digestibility of DM, N, and E throughout the study period (Table 4). Moreover, fecal scores also remained consistent during pregnancy (day 100-107) and lactation period (week 3) (Table 5). Furthermore, the milk composition (fat, protein, lactose, solids not fat, total solids, and freezing point) of sows did not show significant alterations due to the dietary supplementation with AH throughout the study duration (Table 6).

DISCUSSION

The current investigation examined the influence of AH supplementation on various aspects of sow reproductive performance. Notably, no statistically significant distinctions were observed in terms of sow BW, BWL, BFT, BCS before farrowing and after farrowing, and at weaning. These findings align with the outcomes of [15]**,** who noted that the inclusion of 10% and 20% sugar beet pulp (SBP) in the diet did not yield significant effects on sow growth performance, BFT, BCS, or ADG. Similarly, the addition of 20% supplementation of wheat bran (WB), soybean hulls (SH), or rice hulls in diets did not result in any significant impact on reproductive performance of sows during both gestation and lactation phases [16]. Furthermore, sows consume a basal diet with either 5% beet pulp (BP) or 15% distillers dried grains with soluble exhibited comparable BWL during the lactation period [17]. In contrast, providing 55 g of fiber solely during lactation enhanced reproductive performance and well-being of sows [18]. Moreover, Weight gain of sows during pregnancy and their weight loss at farrowing were significantly higher for 500 g SBP and 500 g mixed fiber sources (dried grass meal, WB, and oat hulls) than for control diet [19]. Discrepancies between our findings and those of other studies may stem from factors such as variations in environmental conditions, distinct pig breeds, different developmental stages of pigs, diverse sources of dietary fiber, and varying levels of hull inclusion employed across these investigations.

Dietary fiber has been recognized for its potential to enhance the growth of suckling piglets nursed by sows[20]. Our research aligns with previous findings, indicating that gestational sows fed a diet enriched with 3% purified fiber blend experienced significant improvements in piglet BW and ADG during the weaning period [21]. Additionally, supplementing sows' diets with 13.35% wheat straw over an extended period resulted in significant increases in piglet weight and daily gain at weaning [22]. Correspondingly, the introduction of 282 g per kg of dietary fiber into the lactating sow diet contributed to enhanced BW and ADG of piglets during weaning [23]. Recent studies have suggested a possible correlation between modifications in sow production performance caused by dietary fiber and the modulation of gut microbial composition [7]. Intestinal microbes may play a role in influencing changes in intestinal antioxidant capacity [24] . Building upon this perspective, antioxidants from sows to piglets through milk implies a potential mechanism for bolstering the antioxidant status and overall health of the piglets [25]. This transfer of antioxidant components might play a role in enhancing weaning BW and promoting improved ADG among piglets.

AH fiber has a greater proportion of cell wall components (i.e., cellulose, hemicellulose, and lignin) that are considered insoluble fibre and more difficult to digest [26]. Insoluble dietary fiber decreases intestinal transit time [27], which limits nutrient digestion and absorption [28]. Increasing insoluble fiber of diets by adding 12% wheat straw or 16% SBP depressed apparent N digestibility in lactating sows [29]. The relatively small decline in N digestibility caused by inclusion of insoluble fiber [30] . Insoluble fiber intake was related negatively to energy digestibility [29]. Lactating sows fed diets containing 22% oat hulls exhibited reduced E digestibility compared to those on the control diet [31]. However, in the present study, there was no negative effect on digestibility of DM, N, and E. Differences in level and fiber composition between AH and other fiber sources could explain their differential effects on digestibility.

Fecal score serves as an indicator for assessing the digestive health of lactating sows, where higher scores indicate a greater likelihood of diarrhea [32]. In our current study, the evaluation of fecal scores revealed the absence of diarrhea incidents among the lactating sows. This finding aligns with the results, where the addition of both 10% and 20% BP supplementation did not lead to any significant effects on fecal score [15] . Similarly, the inclusion of beet fiber particles at various levels (5%, 7.5%, and 10%) had no effect on the fecal score of lactating sows [33]. Notably, the water-binding capacity of insoluble fibers has been linked to a reduction in the occurrence of diarrhea [34]. Hence, the lack of diarrhea occurrence in both the treatment and control groups suggests that factors other than water-binding capacity might contribute to diarrhea prevention in this study. Further research is required to elucidate the precise mechanisms underlying the observed prevention of diarrhea in both groups.

The dietary nutrient level plays a crucial role in shaping the composition and synthesis of sow milk[35]. While dietary fiber cannot be directly utilized by sows, its fermentation byproducts serve as vital nutrient sources for the synthesis of sow milk [36]. In our current study, the inclusion of AH did not yield any significant influence on the milk composition of lactating sows. This outcome is consistent with earlier findings [37,38]. Moreover, numerous studies have indicated that dietary fiber in gestation diets does not exert effects on colostrum and milk yield [39–41]. Furthermore, the ingestion of 9.14% insoluble fiber during gestation did not produce significant effects on colostrum and milk composition [42]. However, the colostrum composition changed when sows ate a diet with 13.3% dietary fiber from SH, WB, and BP [40]. Conversely, the incorporation of alfalfa hulls in the diet led to a reduction in protein content in the milk of lactating sows [43]. These divergent outcomes may be attributed to variations in dietary fiber sources and the differing levels employed across various studies.

CONCLUSION

To conclude, the results of our experiment indicate that supplementing the basal diet of lactating sows with AH positively influenced the growth performance of piglets at weaning, without adversely affecting milk composition. Our findings suggest that an optimal concentration of 6% AH in the diet can enhance piglet BW and ADG during the weaning period.

REFERENCE

1. Rauw WM, Rydhmer L, Kyriazakis I, Øverland M, Gilbert H, Dekkers JCM, et al. Prospects for sustainability of pig production in relation to climate change and novel feed resources. J Sci Food Agric. 2020; 100(9):3575-3586.

2. Almond Board of California. Almond Almanac 2017 annual report. Almond Board of California. 2017.

3. Kahlaoui M, Bertolino M, Barbosa-Pereira L, Ben Haj Kbaier H, Bouzouita N, Zeppa G. Almond Hull as a Functional Ingredient of Bread: Effects on Physico-Chemical, Nutritional, and Consumer Acceptability Properties. Foods. 2022;11(6):777.

4. Whitney MH. Lactating Swine Nutrient Recommendations and Feeding Management. National Swine Nutrition Guide. 2010.

5. Einarsson S, Rojkittikhun T. Effects of nutrition on pregnant and lactating sows. J Reprod Fertil Suppl. 1993. p. 229–239.

6. Garcia-Perez P, Xiao J, Munekata PES, Lorenzo JM, Barba FJ, Rajoka MSR, et al. Revalorization of almond by-products for the design of novel functional foods: An updated review. Foods. 2021;10(8): 1823.

7. Cronin P, Joyce SA, O'toole PW, O'connor EM. Dietary fibre modulates the gut microbiota. Nutrients. 2021 ;13(5): 1655.

8. DePeters EJ, Swanson KL, Bill HM, Asmus J, Heguy JM. Nutritional composition of almond hulls. Applied Animal Science. 2020; 36(6):761-770.

9. Kasani PH, Oh SM, Choi YH, Ha SH, Jun H, Park K hyun, et al. A computer vision-based approach for behavior recognition of gestating sows fed different fiber levels during high ambient temperature. J Anim Sci Technol. 2021; 63(2):367.

10. Li S, Zheng J, He J, Liu H, Huang Y, Huang L, et al. Dietary fiber during gestation improves lactational feed intake of sows by modulating gut microbiota. J Anim Sci Biotechnol. 2023;14(1):1-21.

11. Takeoka GR, Dao LT. Antioxidant constituents of almond [Prunus dulcis (Mill.) D.A. Webb] hulls. J Agric Food Chem. 2003; ;51(2):496-501.

12. Nutrient Requirements of Swine. Nutrient Requirements of Swine. 2012.

13. AOAC. Official Methods of Analysis of AOAC INTERNATIONAL Gaithersburg, MD, USA Official Method 2004.02. articulo original. 2020;1.

14. Biswas S, Kim MH, Park JH, Kim Y, Kim IH. Comparative study of the effects of high-versus low-dose zinc oxide in the diet with or without probiotic supplementation on weaning pigs' growth performance, nutrient utilization, fecal microbes, noxious gas discharges, and fecal score. Can J Anim Sci. 2022; 103:33–43.

15. Zhao P, Zhang Z, Kim IH. Effects of beet pulp supplementation on growth performance, fecal moisture, serum hormones and litter performance in lactating sows. Animal Science Journal. 2015;86:610–616.

16. Weng RC. Dietary supplementation with different types of fiber in gestation and lactation: Effects on sow serum biochemical values and performance. Asian-Australas J Anim Sci. 2020;33 (8): 1323.

17. Hill GM, Link JE, Rincker MJ, Kirkpatrick DL, Gibson ML, Karges K. Utilization of distillers dried grains with solubles and phytase in sow lactation diets to meet the phosphorus requirement of the sow and reduce fecal phosphorus concentration. J Anim Sci. 2008; 86(1):112-118.

18. Odakura AM, Caldara FR, Burbarelli MF de C, Almeida Paz IC de L, Garcia RG, Oliveira dos Santos VM, et al. Dietary Supplementation of Eubiotic Fiber Based on Lignocellulose on Performance and Welfare of Gestating and Lactating Sows. Animals. 2023; 13(4):695.

19. Danielsen V, Vestergaard EM. Dietary fibre for pregnant sows: Effect on performance and behaviour. Anim Feed Sci Technol. 2001; 90(1-2):71-80.

20. Van Hees HMJ, Davids M, Maes D, Millet S, Possemiers S, Den Hartog LA, et al. Dietary fibre enrichment of supplemental feed modulates the development of the intestinal tract in suckling piglets. J Anim Sci Biotechnol. 2019;10: 1-11.

21. Wu J, Xiong Y, Zhong M, Li Y, Wan H, Wu D, et al. Effects of purified fibre-mixture supplementation of gestation diet on gut microbiota, immunity and reproductive performance of sows. J Anim Physiol Anim Nutr (Berl). 2020; 104(4):1144-54.

22. Veum TL, Crenshaw JD, Crenshaw TD, Cromwell GL, Easter RA, Ewan RC, et al. The addition of ground wheat straw as a fiber source in the gestation diet of sows and the effect on sow and litter performance for three successive parities. J Anim Sci. 2009; 87(3):1003-1012.

23. Oelke CA, Ribeiro AML, Noro M, Bernardi ML, Denardin CC, Nunes PR, et al. Effect of different levels of total dietary fiber on the performance of sows in gestation and lactation. Revista Brasileira de Zootecnia. 2018;47.

24. Zhou P, Zhao Y, Zhang P, Li Y, Gui T, Wang J, et al. Microbial mechanistic insight into the role of inulin in improving maternal health in a pregnant sow model. Front Microbiol. 2017; 8:2242.

25. Meng Q, Guo T, Li G, Sun S, He S, Cheng B, et al. Dietary resveratrol improves antioxidant status of sows and piglets and regulates antioxidant gene expression in placenta by Keap1-Nrf2 pathway and Sirt1. J Anim Sci Biotechnol. 2018;9 :1-13.

26. Tomishima H, Luo K, Mitchell AE. The Almond (Prunus dulcis): Chemical Properties, Utilization, and Valorization of Coproducts. Annu Rev Food Sci Technol. 2022;13:145-166.

27. Anderson JW. Physiological and metabolic effects of dietary fiber. Fed Proc. 1985; 2902-2906.

28. oz Z, Partridge IG, Mitchell G, Keal HD. The effect of oat hulls, added to the basal ration for pregnant sows, on reproductive performance, apparent digestibility, rate of passage and plasma parameters. J Sci Food Agric [Internet]. 1986 [cited 2023 Jul 25];37:239–47. Available from: https://onlinelibrary.wiley.com/doi/full/10.1002/jsfa.2740370308

29. Renteria-Flores JA, Johnston LJ, Shurson GC, Gallaher DD. Effect of soluble and insoluble fiber on energy digestibility, nitrogen retention, and fiber digestibility of diets fed to gestating sows. J Anim Sci. 2008;86:2568–2575.

30. Chabeauti E, Noblet J, Carré B. Digestion of plant cell walls from four different sources in growing pigs. Anim Feed Sci Technol. 1991; 32(1-3):207-213.

31. Kennelly JJ, Aherne FX. The effect of fiber in diets formulated to contain different levels of energy and protein on digestibility coefficients in swine. Can J Anim Sci. 1980; 60(3):717-726.

32. Hu J, Kim YH, Kim IH. Effects of two bacillus strains probiotic supplement on reproduction performance, nutrient digestibility, blood profile, fecal score, excreta odor contents and fecal microflora in lactation sows, and growth performance in sucking piglets. Livest Sci. 2021;244:104293.

33. Klopfenstein' CF. Nutritional Properties of Coarse and Fine Sugar Beet Fiber and Hard Red Wheat Bran. I. Effects on Rat Serum and Liver Cholesterol and Triglycerides and on Fecal Characteristics. 1990;67(6):538-541.

34. Chen T, Chen D, Tian G, Zheng P, Mao X, Yu J, et al. Effects of soluble and insoluble dietary fiber supplementation on growth performance, nutrient digestibility, intestinal microbe and barrier function in weaning piglet. Anim Feed Sci Technol. 2020; 260:114335.

35. Boyd DR, Kensinger RS, Harrell RJ, Bauman DE. Nutrient Uptake and Endocrine Regulation of Milk Synthesis by Mammary Tissue of Lactating Sows. J Anim Sci. 1995;73:36-56.

36. Tian M, Chen J, Liu J, Chen F, Guan W, Zhang S. Dietary fiber and microbiota interaction regulates sow metabolism and reproductive performance. Animal Nutrition. 2020 ;6(4):397-403.

37. Schoenherr WD, Stahly TS, Cromwell GL. The effects of dietary fat or fiber addition on yield and composition of milk from sows housed in a warm or hot environment. J Anim Sci. 1989; 67(2):482-495.

38. Li Y, Zhang L, Liu H, Yang Y, He J, Cao M, et al. Effects of the ratio of insoluble fiber to soluble fiber in gestation diets on sow performance and offspring intestinal development. Animals. 2019; 9(7): 422.

39. Quesnel H, Meunier-Salaün MC, Hamard A, Guillemet R, Etienne M, Farmer C, et al. Dietary fiber for pregnant sows: Influence on sow physiology and performance during lactation. J Anim Sci. 2009;87:532–543.

40. 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; 91(11):5269-5279.

41. Li Y, Liu H, Zhang L, Yang Y, Lin Y, Zhuo Y, et al. Maternal dietary fiber composition during gestation induces changes in offspring antioxidative capacity, inflammatory response, and gut microbiota in a sow model. Int J Mol Sci. 2020; 21(1):31

42. Li Y, He J, Zhang L, Liu H, Cao M, Lin Y, et al. 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.

43. Krogh U, Bruun TS, Poulsen J, Theil PK. Impact of fat source and dietary fibers on feed intake, plasma metabolites, litter gain and the yield and composition of milk in sows. Animal. 2017; 11:975–983.

Table 1. Ingredient composition of experimental diets as-fed basis

Items	Lactation		
	CON	**TRT1**	**TRT2**
Ingredient, %			
Corn	41.93	38.38	34.81
Wheat	23.00	23.00	23.00
Wheat bran	8.31	8.31	8.31
Soybean meal, 48%	4.48	4.72	4.95
Dehulled soybean meal	12.96	12.96	12.96
Molasses	2.00	2.00	2.00
Soybean oil	3.40	3.73	4.07
Monocalcium phosphate	1.20	1.20	1.25
Limestone	1.18	1.16	1.10
Magnesium oxide	0.02	0.02	0.02
Salt	0.50	0.50	0.50
Threonine (99%)	0.17	0.17	0.18
Methionine (99%)	0.02	0.02	0.02
L-lysine (78%)	0.31	0.31	0.31
Vitamin / Mineral premix[1]	0.40	0.40	0.40
Choline (25%)	0.12	0.12	0.12
Almond hull	-	3.00	6.00
Total	100.00	100.00	100.00
Calculated value			
Crude protein, %	16.50	16.50	16.50
Metabolic energy, kcal/kg	3,300	3,300	3,300
Fat, %	5.71	6.00	6.31
Calcium, %	0.76	0.76	0.76
phosphorus, %	0.65	0.65	0.65
Lysine, %	0.96	0.96	0.96
Threonine, %	0.65	0.65	0.65
Methionine, %	0.26	0.26	0.26
Neutral detergent fiber %	10.79	11.78	12.76
Acid detergent fiber %	4.33	4.89	5.47

[1]Provided per kg of complete diet: 16,800IU vitamin A; 2,400IU vitamin D_3; 108mg vitamin E; 7.2mg vitamin K; 18mg Riboflavin; 80.4mg Niacin; 2.64mg Thiamine; 45.6mg D-Pantothenic; 0.06mg. Cobalamin; 12mg Cu (as $CuSO_4$); 60mg Zn (as $ZnSO_4$); 24mg Mn (as $MnSO_4$); 0.6mg I (as Ca $(IO_3)_2$); 0.36mg Se (as Na_2SeO_3).

Table 2. The effect of dietary Almond hull additive on reproduction performance in lactating sow[1]

Items	CON	TRT1	TRT2	SEM[2]	P-value
Parity	3.3	3.3	3.3	0.2	0.9687
Litter size					
Total birth, head	12.9	12.4	12.7	0.7	0.8756
Total alive, head	12.6	12.1	12.6	0.8	0.7643
Stillbirth, head	0.3	0.1	0.1	0.2	0.5698
Mummification, head	0.0	0.1	0.0	0.1	0.3645
SUR1[3], %	97.47	97.62	98.81	1.69	0.1197
Body weight, kg					
Before farrowing	241.8	249.7	252.0	6.2	0.4929
After farrowing	213.4	223.2	226.3	6.2	0.3359
Weaning	203.6	215.4	219.1	5.9	0.1994
Body weight difference 1[4]	28.4	26.4	25.7	1.7	0.9622
Body weight difference 2[4]	9.8	7.8	7.2	1.1	0.6346
Backfat thickness, mm					
Before farrowing	20.9	20.1	20.9	0.5	0.5732
After farrowing	18.6	18.6	19.1	0.6	0.6464
Weaning	15.9	16.3	16.9	0.6	0.3991
Backfat thickness difference 1[5]	2.3	1.6	1.7	0.2	0.3486
Backfat thickness difference 2[5]	2.7	2.3	2.3	0.2	0.1680
Body condition score					
Before farrowing	3.6	3.3	3.7	0.2	0.0663
After farrowing	3.1	3.0	3.4	0.1	0.2801
Weaning	2.8	2.7	2.9	0.1	0.1313
ADFI, kg					
Pregnancy	2.92	2.94	2.96	0.03	0.2578
Lactation	7.62	7.67	7.74	0.14	0.5753
Estrus interval, d	5.3	5.1	5.0	0.3	0.5635

[1] Abbreviation: CON, basal diet; TRT1, CON + 3% almond hull; TRT2, CON + 6% almond hull; ADFI, average daily feed intake.
[2] Standard error of means.
[3] SUR1: Survival rate of number of alive pigs per number of total born pigs.
[4] Body weight difference: 1, before farrowing to after farrowing; 2, after farrowing to weaning.
[5] Backfat thickness difference: 1, before farrowing to after farrowing; 2, after farrowing to weaning.

Table 3. The effect of dietary Almond hull additive on growth performance in suckling piglets[1]

Items	**CON**	**TRT1**	**TRT2**	**SEM[2]**	**P-value**
INO	12.6	12.1	12.6	0.1	0.0549
FNO4	12.1	11.9	12.3	0.3	0.6897
SUR2, %	96.70	97.62	97.71	1.58	0.7472
Body weight, kg					
Birth weight	1.46	1.55	1.51	0.03	0.2119
Weaning	6.08^{b}	6.37^{ab}	6.53^{a}	0.11	0.0464
Average daily gain, g					
Overall	216^{b}	230^{ab}	239^{a}	5	0.0146

[1] Abbreviation: CON, basal diet; TRT1, CON + 3% almond hull; TRT2, CON + 6% almond hull.

[2] Standard error of means.

INO- Initial number of piglets, FNO- Final number of piglets

SUR2: survival rate during lactation.

[a,b] Means in the same row with different superscripts differ significantly ($P < 0.05$).

Table 4. The effect of dietary Almond hull additive supplementation on nutrient digestibility in lactating sow[1]

Items	CON	TRT1	TRT2	SEM2	P-value
Weaning					
Dry matter	59.86	60.55	61.30	1.52	0.4310
Nitrogen	58.29	59.39	60.56	2.18	0.6427
Energy	59.89	61.20	61.56	2.23	0.7419

[1] Abbreviation: CON, basal diet; TRT1, CON + 3% almond hull; TRT2, CON + 6% almond hull.

[2] Standard error of means.

Table 5. The effect of dietary Almond hull additive supplementation on fecal score in lactating sow[1]

Items	CON	TRT1	TRT2	SEM2	P-value
Fecal score[3]					
Pregnancy					
Day 100–107	3.32	3.26	3.27	0.05	0.4021
Lactation					
Week 3	3.44	3.39	3.34	0.05	0.7787

1 Abbreviation: CON, basal diet; TRT1, CON + 3% almond hull; TRT2, CON + 6% almond hull

[2] Standard error of means.

[3]Fecal score = 1 hard, dry pellet; 2 firm, formed stool; 3 soft, moist stool that retains shape; 4 soft, unformed stool that assumes shape of container; 5 watery liquid that can be poured.

Table 6. The effect of dietary Almond hull additive supplementation on milk contents in lactating sow[1]

Items	**CON**	**TRT1**	**TRT2**	**SEM2**	**P-value**
Colostrum					
Fat, %	10.55	10.62	10.56	0.19	0.9267
Protein, %	5.12	5.19	5.17	0.04	0.7916
Lactose, %	5.68	5.70	5.52	0.12	0.5917
Solids not fat, %	10.76	10.42	10.82	0.25	0.8677
Total-solids, %	20.66	20.77	20.86	0.10	0.4920
Frozen point, ℃	-0.55	-0.55	-0.55	0.00	-
Milk					
Fat, %	12.39	13.31	13.48	0.44	0.4303
Protein, %	2.56	2.67	2.59	0.14	0.7232
Lactose, %	6.61	6.61	6.66	0.15	0.8408
Solids not fat, %	7.08	7.35	7.47	0.25	0.4680
Total-solids, %	17.84	17.92	17.84	0.10	0.7836
Frozen point, ℃	-0.62	-0.62	-0.62	0.00	-

[1] Abbreviation: CON, basal diet; TRT1, CON + 3% almond hull; TRT2, CON + 6% almond hull.

[2] Standard error of means.