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FEEDING TREATED WHEAT STRAW (BENEFICIAL FIBER) TO YOUNG PIGS

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Summary

This project investigated the effects of treated wheat straw (TWS) and untreated wheat straw (UWS) on weanling pig growth performance and systemic and localized immunological markers. One hundred and ninety-two crossbred (PIC 327 x Yorkshire) pigs were weaned at 27.1 ± 1.3 d old (8.0 ± 1 kg) and randomly allotted into 24 pens with 8 pigs per pen. Three dietary treatments were implemented over the course of the 28-d study, a basal control (CON), 5% untreated wheat straw (UWS), and 5% treated wheat straw (TWS). Diets were formulated to meet or exceed all nutrient requirements (NRC, 2012) and were manufactured on site. Growth performance data was recorded on a weekly basis. Blood samples were collected from one pig per pen on d 28 to evaluate systemic immune parameters. The same 24 pigs were euthanized on d 28 to evaluate localized immune parameters. Week 3 average daily gain of pigs fed UWS was less than those of pigs fed the control or TWS diets, but overall gains were similar. Pigs feed TWS were more efficient. Proinflammatory cytokine IL-6 decreased in the ileum and colon mucosa with the feeding of UWS and TWS. Ileal IL-12 was also decreased by feeding both straws. Feeding TWS increased plasma Ig-A. Treated wheat straw improved weanling pig performance, whereas feeding untreated wheat straw compromised early growth. Dietary wheat straw, treated or untreated, influenced systemic and localized immunological markers, indicating a beneficial effect on immune system development.

Background

A significant management challenge on swine farms is the successful weaning of piglets. Farmers manage a number of factors during this critical transition to avoid morbidity and mortality, including nutrition, housing, vaccinations, and transportation. Recently, the management of weaning has become more challenging with society's goal to diminish antimicrobial use. At Michigan State University we are focusing upon the use of beneficial or functional fibers for improving the gastro-intestinal development, function and health of the young pig and the growth performance of the pig. Ultimately, we seek to enhance the profitability of the farming enterprise.

Dietary fiber may benefit pig health by its positive effects on the microbiome and health of the mucosal barrier of the gastro-intestinal tract (Chase, 2018). The microbiome is the variety of microorganisms present in the gut. Dietary fiber is believed to beneficially-alter the mix of microorganisms or have a prebiotic effect. Martín-Peláez and others (2009) observed that in in vitro conditions, fermented sugar beet pulp did not produce an inhibitory effect on the growth of *S. Typhimurium*. However, Zhang and coworkers (2016) found that piglets provided creep feed with 1.3% dehydrated alfalfa included, had less *Streptococcus Suis* in the cecum and distal colon.

Wheat straw is another potential source of dietary fiber. Historically, swine nutritionists have recommended against feeding young swine (i.e. upon weaning in the nursery phase) wheat straw and other feedstuffs that have significant amounts of indigestible fiber, because of inferior growth performance. Research suggests that digestion and utilization of dietary fiber increases with age and physical maturity in pigs (Noblet and LeGoff, 2001). Ground wheat straw has mostly been included in the diets of gestating sows, and occasionally to growing-finishing swine. It has been fed more so in parts of the world where high-energy cereals are predominantly used only for humans.

Fiber is the combination of varied compounds (celluloses, hemicelluloses, pectin, and lignin) that have different physicochemical properties. Depending on the source of fiber, the amounts of these compounds differ; for example, wheat straw is known for greater amounts of lignin than alfalfa meal. During digestion and degradation by intestinal microflora these physicochemical properties change and have different impacts.

To enhance the nutritional value of straw, chemical and microbiological treatments have been studied. In the 70's it was Dr. H. Bergner and his students that studied the feeding of treated and untreated wheat straw for growing-finishing pigs from 60 to 220 pounds live weight. This research group treated wheat straw with hydrochloric acid, steam, and calcium hydroxide, and called it "partly hydrolyzed straw meal." Bergner (1981) summarized several of their studies by stating that the feeding value of straw was doubled after the treatment; containing approximately 20% utilizable carbohydrates (Bergner and Betzin, 1979). The nitrogen retention following intake of diets supplemented with partly hydrolyzed straw meal was similar to that in the control groups. Neither they nor any other research group studied the feeding of treated and untreated wheat straw to young pigs at weaning until our research group at Michigan State University did in 2018.

We fed treated wheat straw (with acid, heat, and calcium carbonate) to weaned pigs (Lewton et al., 2019). No antibiotic was fed, and neither were pharmacologic amounts of copper or zinc. Piglet growth was maintained with up-to 10% treated wheat straw in the diet. We observed that inclusion of treated wheat straw influenced systemic and gut mucosal immunological parameters. Pigs fed diets containing 5% and 10% treated wheat straw had higher levels of MHC class II expression in peripheral circulating monocytes (an index of enhanced antigen presentation to the immune system) which may reflect an enhanced development of immune function. Serum IgA levels (marker of mucosal immunity) were higher in pigs fed 10% treated wheat straw. Intestinal mucosal gene expression of the pro-inflammatory cytokine IL12 was reduced with increasing concentrations of treated wheat straw.

We did not study untreated wheat straw. Recognizing that there is a cost to treating the straw and not knowing if the benefit to gut health may be a result of the straw alone, or if it may also be a result of the treatment of the straw, our next research goal was to determine the effect of untreated wheat straw in nursery diets on growth performance, intestinal development, and intestinal microbiota of weaned pigs.

Methods

All research was conducted in one of four mechanically-ventilated nursery rooms at Michigan State University Swine Farm. One hundred ninety-two crossbred (PIC 359 x Yorkshire), mixed sex pigs were weaned at 28 d of age, weighing 8.0 ±1.0 kg. They were randomly allotted based on litter and sex to cohorts of 8 pigs per pen (4 barrows and 4 gilts) and randomly placed in 24 pens (1.22 x 1.83 m). Pens were randomly assigned to one of three treatments:

- Basal (control)
- 5% untreated wheat straw (UWS)
- 5% treated wheat straw (TWS)

Per kg of wheat straw (Lauwers Alfalfa & Straw Farms, Capac, Michigan), treatment involved soaking with 1750 mL of water and 250 mL of phosphoric acid, followed by a heating process performed by placing the mixture in a pressure cooker and heating to 100^{o} C under pressure for thirty minutes. After cooling, the solution was buffered with 125 g of calcium carbonate. Wet straw was then moved to aluminum drying pans and placed in a drying oven that was set to 75^{o} C. Straw was confirmed dry by using a weight comparison system, for an average of 24-30 hours of total drying time. Dry straw was then finely ground through a 1 mm screen using a Wiley mill micro grinder (name, location). Ground straw was then stored until being mixed into the diet.

Dietary treatments were imposed over three nursery phases (I, II, and III; 7, 7 and 14 days, respectively). Diet formulations were similar to those commonly used by the industry using corn, processed soybeans, animal products, minerals and vitamins, and met or exceeded nutrient requirements of NRC (2012). Pharmacological concentrations Cu or Zn were not used. No antimicrobials were fed. Diets within phase were kept isocaloric using dextrose in order to keep supplemental fat content similar across treatments.

Gain, feed intake, feed efficiency were determined weekly. Nursery mortality and morbidity were recorded. Blood samples (5 mL) were collected by jugular venipuncture on d 28 from one pig randomly selected from each pen, with consideration of sex. Pigs were sacrificed for collection of ileal and colonic mucosa samples. Blood samples were analyzed for systemic immune marker IgA and intestinal samples were analyzed for mucosal cytokines TNFα, IL-12, IL-6, IL-10.

Project Timeline Alterations

- January 1, 2019 to December 31, 2019
    - Original grant dates
- July 9, 2019
    - No-cost extension granted through December 31, 2020
        - Because of smaller than anticipated farrowing groups at MSUSF and because of other studies that were slated ahead of our study
- April 13 – May 11, 2020
    - Granted “Essential” status by MSU, so that study could be conducted at MSUSF
- July 1, 2020
    - MSU approved Individual Lab Safety Plans and laboratories were reopened

Results and Discussion

In Table 1 are the analyzed composition values for treated and untreated straw. Prior to our work with wheat straw, there were no analyzed values for either ingredient. With treatment of the straw, GE decreased, however crude fat increased, which most likely indicates a release of fat (fiber bound) from the wheat straw in addition to sugars during the treatment process. Ca and P and ash increased with treatment, likely due to phosphoric acid and calcium carbonate additions as part of the treatment methodology.

In week 3, the gains of pigs fed untreated wheat straw were less than those of pigs fed the control or treated wheat straw diets (Table 2). Overall gains were similar. Pigs fed the treated wheat straw were more efficient in weekly, and overall. Analyzed lipid content is increased by treating the straw, which may be resulting in greater net energy that contributes to more efficient pig growth.

The impact of dietary wheat straw on immune function is shown in Table 3. Proinflammatory cytokine IL-6 decreased in the ileum and colon mucosa with the feeding of treated and untreated straw. Ileal IL-12 was also decreased by feeding straw. TNF-a in colon mucosa did not differ in the second study, as it did in the previous study (Lewton et al, 2019). Feeding 5% treated wheat straw increased plasma Ig-A in our second study, but it had not changed this immunoglobin in our first study. The impact of wheat straw on immune development has now been assessed in two studies at Michigan State University. Both studies have showed benefits of feeding wheat straw on immunity and health, with different cytokines impacted differently. The results indicate the need for further study.

Conclusions

This research provides additional proof that wheat straw benefits pig health. The growth performance of pigs fed treated wheat straw may be improved over typical nursery diets currently being fed. The cost of straw treatment must be evaluated before a conclusion about swine farm profitability may be drawn. Possibly the most important outcome of this work, is that the feeding of wheat straw may be an alternative to the feeding of feed-grade antimicrobials. Antimicrobial resistance in our environment could be reduced, and consumer trust in pork quality and safety increased.

Acknowledgements

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Reference

Lewton, J.R., M.A. Michael, Mrigendra Rajput, K.M. Thelen, A.J. Moeser, D.W. Rozeboom. 2019. Feeding treated wheat straw to weaned pigs improves feed efficiency and impacts mucosal and system immune parameters. J. Anim. Sci. Vol. 97, Suppl. 3:123–124, https://doi.org/10.1093/jas/skz258.255

Table 1. Analyzed composition of treated and untreated wheat straw		
Item	Untreated wheat straw	Treated wheat straw
Moisture, %	4.47	5.68
Crude protein, %	2.12	1.66
Crude fat, %	1.03	4.05
Ash, %	6.67	28.73
Calcium, %	0.249	4.55
Phosphorus, %	0.077	9.09
Lys, %	0.1	0.07
Met, %	0.04	0.03
Thr, %	0.08	0.05
Crude fiber, %	42.92	29.84
NDF	78.66	42.41
ADF	54.63	39.75
Hemi-cellulose	24.03	2.66
Total dietary fiber	90.12	49.85

Table 2. Growth performance of nursery pigs fed untreated wheat straw (UWS) and treated wheat straw (TWS).				
Item	Control	5% UWS	5% TWS	SEM
BW, kg				
Initial	8.30	8.30	8.31	0.21
Final	19.83	19.26	19.81	0.21
ADG, kg				
week 1	0.17	0.17	0.18	0.01
week 2	0.34	0.32	0.32	0.01
week 3	0.50^{a}	0.45^{b}	0.51^{a}	0.02
week 4	0.64	0.63	0.63	0.02
Overall	0.41	0.39	0.41	0.01
ADFI, kg				
week 1	0.27	0.26	0.26	0.01
week 2	0.45	0.44	0.44	0.02
week 3	0.74	0.69	0.70	0.02
week 4	0.98	0.96	0.96	0.02
Overall	0.61	0.59	0.59	0.02
G:F				
week 1	0.62^{a}	0.63^{a}	0.71^{b}	0.02
week 2	0.76	0.72	0.73	0.01
week 3	0.69^{a}	0.66^{a}	0.72^{b}	0.01
week 4	0.65	0.66	0.65	0.01
Overall	0.68^{abx}	0.67^{b}	0.70^{ay}	0.01

[ab]Values in a common row lacking a common superscript differ ($P < 0.05$)
[xy]Values in a common row lacking a common superscript differ ($P < 0.10$)

Table 3. Systemic and gut mucosal immunological parameters.						
	2018			2020		
Item	Control	Treated wheat straw 5%	Treated wheat straw 10%	Control	Untreated wheat straw	Treated wheat straw
Plasma Ig-A	0.468[ab]	0.525[a]	0.351[b]	0.482[a]	0.478[a]	0.728[b]
Ileum						
TNF-a				1.0	0.69	0.80
IL-6				1.0[a]	0.12[b]	0.27[b]
IL-12				1.0[a]	0.64[b]	0.78[b]
IL-10				1.0	0.81	0.96
Colon						
TNF-a	1.0[a]	0.84[ab]	0.20[b]	1.0	1.12	1.24
IL-6	1.0	0.67	0.49	1.0[a]	0.41[b]	0.65[e]
IL-12	1.0[a]	0.37[ab]	0.22[b]	1.0	1.19	1.10
IL-10	1.0	1.10	1.50	1.0	1.02	0.81[f]

[abc]$P < 0.05$ With in study year, values with different superscripts differ $P < 0.05$.

[e]$P = 0.18$ TWS compared to Control.

[f]$P = 0.05$ TWS compared to Control.