HEMP SEED MEAL AS AN ALTERNATIVE PROTEIN SOURCE IN GROWING PIGS DIET: A PILOT STUDY

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by
Yuxin Zhang
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LIST OF ABBREVIATIONS

AA – Amino acid

ADF – Acid detergent fiber

ADFI – Average feed intake

ADG – Average daily gain

ALA – Alpha-linolenic acid

BW – Body weight

CBD – Cannabidiol

CP – Crude protein

HSM – Hempseed meal

LA – Linoleic acid

ME – Metabolize energy

NDF – Neutral detergent fiber

NE – Net energy

SBM – Soybean meal

SID – Standardized ileal digestibility

THC – Tetrahydrocannabinol

ABSTRACT

The overall goal of this pilot project was to assess the nutritional adequacy of hemp seed meal (HSM) for growing pigs. The objectives were to test the hypotheses that 1) voluntary feed intake in growing pigs fed diets containing 10 and 15% HSM will not differ compared to growing pigs fed diets containing soybean bean (SBM) as the main protein feed ingredient and 2) whole tract crude protein (CP) digestibility of a diet containing 10% HSM fed to growing pigs will not differ compared to pigs fed a diet containing SBM as the main protein feed ingredient. In the first study, six 54-kg barrows (Yorkshire × Landrace) were allocated to a repeated 3 x 3 Latin square design with 3 diets, 0% HSM (control), 10 and 15% HSM, and 3 periods. Feed intake did not differ between the HSM containing diets and control. Compared to control, ADG (1.35 kg/d) and gain:feed ratio (0.650) in pigs fed the 10% HSM diet did not differ and was greater ($P < 0.05$) compared to pigs fed 15% HSM (0.97 kg/d and 0.470). Compared to control, pigs fed the 15% HSM diet tended ($P \leq 0.1$) to have a lower ADG and gain:feed ratio (0.470). The results show that pigs voluntarily accept diets containing HSM at an inclusion rate of 15% but have reduced growth performance compared to pigs fed diets containing 10% HSM or 0% HSM. In the second study, eight 73-kg barrows (Yorkshire × Landrace) were allocated to a randomized complete block design with 2 diets containing 0 and 10% HSM, and 2 blocks [light body weight (BW) and heavy BW]. Whole tract CP digestibility was determined using the indicator method and Cr_2O_3 as the inert marker. Whole tract CP digestibility between 10% HSM and control diets did not differ, with digestibility values of 75.15 and 76.21%, respectively. Additionally, initial and final BW, daily feed intake, daily gain, and gain:feed ratio did not differ between 10% HSM and control diets. The results of this studies indicate that growing pigs accept diets containing HSM up to 15% with no change in their voluntary feed intake and that HSM included at 10% does not impact whole tract

CP digestibility of the diet, compared to conventional diets containing SBM as the main protein ingredient source.

INTRODUCTION

The increasing demand for sustainable animal feed has led to testing of alternative protein sources to replace conventional protein ingredients such as soybean meal. Soybean meal is widely used in animal feed and is facing several challenges including environmental concerns related to its cultivation, such as deforestation, high water usage, and pesticide application (Yano and Fu, 2023). This capstone project addressed whether hemp seed meal (HSM), a novel sustainable protein ingredient, can serve as a nutritionally adequate protein source for growing pigs. The two specific aims of this study were to 1) evaluate the acceptance of diets containing HSM at an inclusion rate of 10 and 15%, and 2) determine the effect of HSM on whole tract crude protein (CP) digestibility.

This document presents a brief literature review of HSM and its use in animal feed, the study methods, results, discussion, and a conclusion.

Hemp production and hemp seed meal definition and nutrient composition

Industrial and recreational hemp are both derived from the *Cannabis sativa* plant and differ in their tetrahydrocannabinol (THC) content and intended use. Industrial hemp is cultivated for its fibers, seeds, and cannabidiol (CBD), containing less than 0.3% THC (Cherney and Small, 2016). This low THC concentration is mandated by regulatory standards in various countries to ensure that industrial hemp is non-intoxicating. In contrast, recreational hemp, often referred to as marijuana, is bred to have high levels of THC, typically between 5% to 30%, to produce psychoactive effects (Cherney and Small, 2016). The difference in THC content and the resulting psychoactive potential distinguishes industrial hemp from its recreational counterpart. Hemp is more sustainable than soybean as it requires less water and fewer pesticides. Hemp also excels in carbon sequestration, absorbing more CO_2 than most crops, and its entire plant can be utilized for various industrial purposes, thus minimizing waste. These factors make hemp a more sustainable and versatile crop compared to soybean (Yano and Fu, 2023).

Hempseed meal is derived from industrial hemp, which is a nutrient-rich byproduct of the hemp seed oil extraction process, originating from the seeds of the hemp plant (Callaway, 2004). Hemp seeds are first harvested and cleaned to remove impurities. The seeds then undergo oil extraction through cold pressing or solvent extraction methods (Callaway, 2004). The solid material left after the oil is extracted, known as hemp seed cake, is subsequently milled into a fine powder to produce HSM (Callaway, 2004).

Hempseed meal consists of 28 - 32% crude protein, 9 - 12% crude fat, and 25 - 32% crude fiber (Kasula et al., 2021). Given its nutritional profile, HSM offers great potential not only as a protein source, but also as a source of fat and fiber, which may be desirable depending on the animal species and the stage of the life cycle of the animal. Also, it could be a safe animal feed ingredient that does not contain hemp cannabinoids (<0.005%) (Kasula et al., 2021), which is below the regulatory cannabinoids level (< 3%) (USDA., 2021).

Using HSM in animal diets shows potential as an environmentally sustainable and protein-abundant feed. Few studies have been conducted to assess its nutritional efficacy and palatability in livestock animals.

Hemp Seed Make Used in Domestic Animal Diets

Protein Digestibility

Cattle fed diets containing 20% HSM exhibited higher levels of ruminal and total tract nitrogen (N) digestibility, compared to cattle fed diet containing 75% dry-rolled corn, 20% corn silage, and 20% corn DDGS (Winders et al., 2023). In contrast, organic matter digestibility was reduced due to the greater acid detergent fiber (ADF) concentration in HSM.

In salmonid diets, in vitro protein digestibility of protein isolates derived from HSM was 91.1%, which is comparable to or higher than conventional protein-rich aqua-feed ingredients such as fish meals (83-95%), poultry by-product meal (74-94%), corn gluten meal (92%), and soybean meal (77-94%) (Banskota et al., 2022).

Standardized ileal digestibility (SID) of CP and amino acids (AA) in various alternative protein feed ingredients including HSM (inclusion rate of 24.5%), linseed cake, rapeseed cake, and faba bean, were determined in 22-kg Yorkshire barrows (Presto et al., 2011). While there were variations in the SID values across the different feed ingredients, the overall digestibility of CP and AA were found to be comparable to conventional protein feed ingredients (Table 1). This suggests that hemp seed cake could be effectively incorporated into pig diets due to its comparable SID values to other alternative protein feed ingredients.

Table 1. Standardized ileal digestibility (SID) [%] of crude protein, essential and non-essential amino acids in protein feed ingredients

	Protein feed ingredient				p-value
	Hemp seed cake (n=5)	Linseed cake (n=5)	Rapeseed cake (n=6)	Faba bean (n=6)	
Crude protein	$85.2^{a} \pm 1.12$	$85.4^{a} \pm 1.17$	$81.7^{b} \pm 1.08$	$85.9^{a} \pm 1.03$	0.047
Lysine	$85.3^{ab} \pm 1.23$	$82.0^{a} \pm 1.29$	$87.3^{b} \pm 1.19$	$91.9^{c} \pm 1.13$	<0.001
Threonine	82.5 ± 1.37	79.7 ± 1.43	78.1 ± 1.30	81.4 ± 1.26	0.146
Methionine	$91.8^{a} \pm 1.23$	$87.8^{a} \pm 1.28$	$85.3^{b} \pm 1.16$	$61.9^{c} \pm 1.11$	<0.001
Isoleucine	$86.5^{a} \pm 1.25$	$85.7^{a} \pm 1.30$	$81.9^{b} \pm 1.23$	$86.5^{a} \pm 1.16$	0.019
Leucine	$87.8^{a} \pm 1.23$	$85.8^{ab} \pm 1.28$	$84.6^{a} \pm 1.19$	$89.1^{b} \pm 1.13$	0.041
Phenylalanine	86.9 ± 1.41	84.3 ± 1.36	83.4 ± 1.18	88.1 ± 1.09	0.054
Valine	85.8 ± 1.20	84.1 ± 1.25	83.5 ± 1.11	84.7 ± 1.11	0.051
Arginine	94.0 ± 0.78	91.8 ± 1.01	$88.5^{c} \pm 0.77$	$92.7^{ab} \pm 0.73$	<0.001
Histidine	$89.4^{a} \pm 0.98$	$82.3^{b} \pm 1.02$	$85.1^{b} \pm 0.96$	88.0 ± 0.91	<0.001
Alanine	85.1 ± 1.71	80.4 ± 1.79	82.5 ± 1.62	84.6 ± 1.57	0.300
Aspartic acid	$87.6^{a} \pm 1.09$	$81.7^{b} \pm 1.13$	$83.0^{bc} \pm 1.09$	$86.5^{ac} \pm 0.95$	0.030
Cysteine	78.7 ± 1.80	78.8 ± 1.87	75.7 ± 1.75	74.3 ± 1.66	0.106
Glutamic acid	$92.6^{a} \pm 0.97$	$90.5^{ab} \pm 1.14$	$91.1^{ab} \pm 0.97$	$89.9^{b} \pm 0.97$	0.040
Glycine	82.7 ± 2.21	81.8 ± 2.30	81.4 ± 1.91	81.5 ± 2.08	0.970
Proline	$77.3^{ab} \pm 1.68$	$72.4^{bc} \pm 1.70$	$75.9^{c} \pm 1.48$	$81.6^{a} \pm 1.46$	<0.001
Serine	$86.8^{a} \pm 1.14$	$81.4^{bc} \pm 1.25$	$82.5^{ac} \pm 1.05$	$85.3^{ab} \pm 1.04$	0.002
Tyrosine	$83.8^{a} \pm 1.40$	$80.8^{b} \pm 1.45$	$81.3^{ab} \pm 1.36$	82.7 ± 1.31	0.103

[abc]Means with different superscript letters within a row and diet differ (P <0.05). Adapted from Presto et al. (2011).

While HSM is a valuable protein source with CP and AA digestibility comparable and even superior to alternative protein ingredients, the presence and potential effects of anti-nutritional factors should be considered. Hempseed meal contains phytic acid, tannins, cyanogenic glycosides, trypsin inhibitors and saponins present in varying concentrations depending on the HSM extraction method and the plant cultivar. These same antinutritional factors in other feeds have been shown to cause the following effects: phytic acid binds essential minerals and reduces their bioavailability (Russo and Reggiani, 2015), and condensed tannins decrease protein digestibility and mineral absorption (Russo and Reggiani, 2015). Cyanogenic glycosides can release toxic hydrogen cyanide

(Russo and Reggiani, 2015), while trypsin inhibitors impede protein digestion by inhibiting the trypsin enzyme (Russo and Reggiani, 2015). Finally, saponins, which have bitter taste and hemolytic properties, can cause bloat in ruminants, and reduce feed intake (Russo and Reggiani, 2015). These compounds are generally more concentrated in monoecious hemp varieties compared to dioecious varieties (Russo and Reggiani, 2015). The processing method significantly affects the digestibility of HSM by altering its protein structure and mitigating the presence of antinutritional factors. Heat treatment, such as toasting or extruding, can improve digestibility by denaturing proteins, and thus increasing accessibility to digestive enzymes, and reducing the activity of antinutritional factors such as trypsin inhibitors and phytic acid (Russo and Reggiani, 2015). However, excessive heat can also degrade essential AA, reducing the overall nutritional quality of the protein. Mechanical processing methods, such as grinding or milling, can enhance digestibility by breaking down the seed's physical structure, increasing nutrient availability. Solvent extraction used to produce hempseed oil leaves behind a meal that retains high protein content but may still contain antinutritional factors that can affect digestibility if not further processed (Russo and Reggiani, 2015). Therefore, processing methods impact nutrient digestibility and thus increasing the variability in nutritional quality of HSM.

Growth Performance

Dietary supplementation with HSM at an inclusion level of up to 10% did not negatively affect the growth performance of slow-growing broilers (Tufarelli et al., 2023). Inclusion of HSM at 5 and 10% did not affect final body weight (BW), average daily gain (ADG), feed conversion ratio (FCR) (feed:gain) and mortality rate and tended to decrease average daily feed intake (ADFI) (Table 2)

Table 2. Effect of dietary treatments on growth performance of slow-growing broiler chickens.

	Diet				
	HSM0	HSM5	HSM10	SEM	P-value
Final BW, g	2119	2148	2155	38.4	0.197
ADG, g/d	53.1	53.3	53.5	0.75	0.212
ADFI, g/d	126.0	125.2	124.8	2.04	0.063
FCR, g/g	2.37	2.35	2.33	0.04	0.167
Mortality, %	1.31	1.29	1.33	0.221	0.598

Adapted from Tufarelli et al. 2023.

In finishing heifer diets, substituting 20% hempseed cake for dried corn DDGS resulted in lower BW, ADG, and gain efficiency (gain:feed), with no impact on feed intake (Table 3) (Winders et al., 2022). This reduction in growth performance may be attributed to the higher insoluble fiber concentration, higher acid detergent fiber content, and lower digestibility of rumen undegradable protein. In addition, the dietary net energy (NE) for maintenance and NE for gain was reduced in the 20% HSM diet, resulting in reduced available energy.

Inclusion of HSM up to 5% in diets of lactating sows improved the nutritional profile of milk, with greater n-3 fatty acid concentration, and greater litter ADG, compared to sows fed diets formulation with 5% soybean meal (SBM) (Lanzoni et al., 2024). The feasibility of HSM as an alternative protein source to SBM in swine diets was evaluated by Kemp (2022). Barrows fed diets containing HSM (5.1%) or SBM (6.1%) diet did not differ in their feed intake, feed:gain, or ADG suggesting that HSM could be a viable alternative protein source without negatively impacting the growth metrics of pigs when fed at this low inclusion rate.

Further work is needed to determine how barrows respond to higher inclusion rates of HSM.

Table 3. Performance of heifers fed hemp seed meal (HSM) and DDGS based diets

Item	Control (DDGS)	HSM	SEM	P-value
Initial BW, kg	492.6	496.7	25	0.80
Final BW, kg	698.1	682.7	16	0.05
Dry matter intake, kg	14.2	14.1	0.6	0.94
ADG, kg	1.83	1.69	0.15	0.05
Feed:gain	7.76	8.37	0.26	0.02
NEm, Mcal/kg	1.92	1.83	0.02	0.02
NEg, Mcal/kg	1.28	1.19	0.02	0.02

Adapted from Winders et al. (2022).

Carcass Characteristics

In the previously mentioned study done by Tufarelli et al. (2023), the inclusion of HSM at 10% positively influenced the fatty acid profile of broilers meat and oxidative status. Specifically, the HSM diets led to an increase in long-chain fatty acids of the n-3 series and a decrease in the n-6/n-3 ratio in the thigh and breast muscles. Additionally, the HSM diets lowered the concentration of malondialdehyde (MDA) and lipid hydroperoxides in the breast meat, indicating improved oxidative stability.

Marbling score, loin eye area and fat thickness were unaffected by feeding diets containing 20% HSM compared to DDGS in heifers (Winders et al., 2022).

Animal Health

Hemp seed proteins have been shown to have functional properties such as anti-inflammatory activities, immunomodulatory effects, and regulatory effects on lipid metabolism, highlighting their potential as nutraceutical ingredients (Chen et al., 2023).

Hempseed meal is rich in essential fatty acids, particularly linoleic acid (LA) and alpha-linolenic acid (ALA) (Vastolo et al., 2021). These fatty acids can be converted to longer chain polyunsaturated fatty acids, such as EPA and DHA. Hens fed with HSM showed an improved fatty acid profile in their eggs, with an increase in n-3 fatty acids and a reduction in the n-6 to n-3 ratio. The n-6 to n-3 ratio decreased with an increase in inclusion levels of HSM. This change in ratio is attributed to the high levels of ALA present in the HSM, which contributed to the increased n-3 content in the eggs (Kasula et al., 2021).

MATERIALS AND METHODS

Animals and experimental design

In the first study, six growing barrows (Yorkshire × Landrace) were used to determine the acceptability of diets containing HSM. Pigs were assigned to three dietary treatments [0% HSM (control), 10% HSM and 15% HSM] in a repeated 3 × 3 Latin square design with three pigs per square and three periods. Pigs were blocked by BW, with a light (46.6 to 49.2 kg) and heavy (49.4 to 51.8 kg) BW group respectively assigned to the two squares. Within each square, pigs were randomly assigned to treatments at each of the three periods (Appendix A). In the second study, eight growing barrows were used in a randomized complete block design, with pigs blocked by BW, with a light (71 to 72.6 kg) and a heavy (71.2 to 75.4 kg) BW group.

Diets

The analyzed nutrient concentration of HSM is presented in table 4 and the ingredient and nutrient composition of the three experimental diets are presented in table 5 for study 1 and table 6 for study 2. The HSM used for both studies contained 30.7% crude protein, 1.06% lysine, 12.14% crude fat (ether extract), and 47.2% neutral detergent fiber (table 4).

Diets were formulated to meet the NRC (2012) nutrient requirements for growing pigs ranging from 25-50 kg. Diets were formulated to meet the minimum SID Lys requirement of 0.98%. The SID Lys concentration of HSM was estimated based on the analyzed Lys concentration in HSM of 1.31% and the SID Lys digestibility of 83.3% (Presto *et al.* 2011). The 15% HSM diet was formulated first. Because of the high NDF concentration in HSM (49.8%), the dietary NDF concentration in the 15% HSM diet ended up being 12.6%. Therefore, the 10% HSM and control diets were formulated to include wheat bran to maintain as close as possible a similar NDF across all 3 diets. Corn oil was used to achieve a similar ME across all 3 diets. For the second study, chromic oxide (Cr_2O_3) (Thermo Fisher, Waltham, MA. cat # 192085000) was included at 0.25% in both control and 10% HSM diets at the expense of 0.25% corn.

Feeding and data collection

The first study consisted of three periods, with four days per period. Pigs were switched to a new diet at each period and BW was recorded (Appendix A). The daily amount of feed was calculated as follows: the daily ME requirement was calculated based on 3.2 × ME maintenance requirement, where maintenance ME requirement = 197 × $BW^{0.6}$ (NRC, 2012) and the daily amount of feed was calculated based on the ME content of 3,300 kcal/kg. The 3.2 factor was based on NRC feed intake and growth model averaging an energy intake of 2.8 × ME maintenance requirement. Using a factor of 3.2 allowed for maximizing energy intake while minimizing orts. Individual feed allocation was calculated at the beginning of each 4-day period according to the pig's BW. Pigs were fed at 0800 and 1600 in equal proportions and any orts were recorded daily.

In the second study, pigs were assigned to two blocks according to their BW as described earlier. Pigs were fed the control and 10% HSM diets for 6 days of adaptation followed by fresh fecal samples collection over a 2-day period. A total of approximately 880 g of fresh feces were collected and frozen until analysis. Fresh fecal samples were pooled and manually homogenized. A sub-sample was used to determine dry matter (DM) and the remainder was dried for 48 hours. For DM analysis, 5 grams were weighed in duplicates onto aluminum weigh boats and dried at 105 ◦C for 24 hours in a forced air oven. These results are presented in Appendix D. The remainder of dried feces (48 hours) were ground using a Wiley mill and a 1-2 mm particle size wire mesh. Approximately 15 g of ground fecal samples and diet samples (control and 10% HSM diets) were submitted to the University of Missouri Agricultural Experimental Station Chemical Laboratory for chromium and N analysis.

Whole tract N (CP) digestibility was determined based on the indicator method as follows:

First, the total daily DM fecal production was estimated using the daily DM intake of Cr_2O_3 and the concentration of Cr_2O_3 in feces using the following equations:

1) $Cr2O3\ intake\ \left(\frac{g}{day}\right) = \%\ Cr2O3\ in\ diet\ \times daily\ DM\ intake, \frac{g}{day}$

2) $Fecal\ DM\ output\ \left(\frac{g}{day}\right) = \frac{Cr2O3\ intake\ \left(\frac{g}{day}\right)}{Fecal\ Cr2O3,\%}$

Second, apparent whole tract N (CP) digestibility (%) was calculated using the following equation:

$$100\ \times\ \frac{\left[\left(Diet\ DM\ intake\ \left(\frac{g}{day}\right) \times \%\ N\ in\ diet\right) - \left(Fecal\ DM\ output\ \left(\frac{g}{day}\right) \times \%\ N\ in\ feces\right)\right]}{Diet\ DM\ intake\ \left(\frac{g}{day}\right) \times \%\ N\ in\ diet}$$

Statistical analysis

For the first study, the data were tested for normality using Shapiro-Wilk test in RStudio followed by ANOVA. The response variables included initial BW, final BW, ADG, feed intake and gain:feed. The full model included diet, period, square and all 2 and 3-way interactions as fixed classification effects. Square and its interaction with the other factors were not significant. Therefore, the reduced model included diet, period, and diet × period as fixed classification effects. The reduced model simplifies the full model by excluding the square factor and its interactions, focusing only on diet and period, and their interaction. Response variables were tested for significant differences by ANOVA between HSM 15 and Control, HSM 10 and Control, and HSM 15 and HSM 10.

For the second study, the response variables include digestibility, initial BW, final BW, ADG, feed intake and gain:feed. The model included diet as fixed classification effect and block as random effect. A Welch two sample t-test was used to determine the difference in CP digestibility and performance between the 10% HSM diet and control diets.

Differences were accepted at $P < 0.05$ and tendencies at $P \leq 0.10$.

RESULTS

Study 1: Acceptability of Diets Containing HSM

In the first study, the acceptability of diets containing HSM was evaluated by feeding growing pigs with diets containing 0% (control), 10%, and 15% HSM. Daily feed intake remained consistent across all dietary treatments (Table 7), suggesting that the acceptability of HSM-containing diets was similar to the control diet. Compared to control, ADG (1.35 kg/d) and gain:feed ratio (0.650) in pigs fed the 10% HSM diet did not differ and was greater ($P < 0.05$) compared to pigs fed 15% HSM (0.97 kg/d and 0.470). Compared to control, pigs fed the 15% HSM diet tended ($P \leq 0.1$) to have a lower ADG and gain:feed ratio (0.470), suggesting a potential negative impact on growth performance at this higher inclusion rate (Table 7).

Study 2: Whole Tract Digestibility and Growth Performance

In the second study, the whole tract crude protein (CP) digestibility and growth performance of pigs fed control and 10% HSM diets were evaluated. Whole tract CP digestibility between the 10% HSM and control diets did not differ, with digestibility values of 75.15 and

76.21%, respectively (Table 8). This indicates that the inclusion of 10% HSM in the diet did not adversely affect whole tract digestibility of CP.

Growth performance parameters, including final BW, daily feed intake, ADG, and gain:feed ratio, were also not different between the two dietary treatments. These results suggest that the inclusion of 10% HSM in the diet did not negatively impact the overall growth performance of the pigs (Table 8).

Table 7. Feed intake and performance of growing pigs fed control, 10% HSM and 15% HSM diets

Item	Control	10% HSM	15% HSM	SEM	P-value
n	6	6	6		
Initial body weight, kg	54.5	53.8	53.8	1.084	0.987
Final body weight, kg	63.4	64.7	62.2	1.047	0.915
Daily feed intake, kg	2.09	2.09	2.08	0.025	0.987
Daily gain, kg	1.26^{a}	1.35^{a}	0.97^{bc}	0.068	0.044
Gain:feed	0.60^{ac}	0.65^{a}	0.47^{c}	0.034	0.068

[a vs b] Differ at P = 0.044.
[a vs c] Tend to differ at P = 0.082 for daily gain and P = 0.107 for gain:feed.

Table 8. Whole tract (fecal) crude protein digestibility of control and 10% HSM diets fed to growing pigs, and growth performance.

Item	Control	10% HSM	SEM	P-value
n	4	4		
Whole tract CP digestibility, %	76.21	75.15	0.753	0.525
Initial body weight, kg	64.5	65.3	1.132	0.768
Final body weight, kg	73.4	73.7	0.902	0.883
Daily feed intake, kg	2.51	2.52	0.018	0.890
Daily gain, kg	1.48	1.40	0.070	0.634
Gain:feed	0.59	0.56	0.030	0.648

Discussion

The findings of this study indicate that HSM can be included in the diets of growing pigs without negatively affecting feed intake and CP digestibility. The acceptability study demonstrated that pigs could accept diets containing up to 15% HSM. However, while growth performance was unaffected at the 10% inclusion level, the 15% HSM diet reduced ADG and gain:feed. The reduced growth performance in pigs fed the 15% HSM diet may possibly be due to the presence of anti-nutritional factors. The NDF concentration of the 15% HSM diet was nearly equal across all diets, therefore it is unlikely that the high NDF concentration resulted in the difference in ADG and gain:feed.

Including 10% HSM in the diet did not affect whole tract CP digestibility. This aligns with previous research indicating that HSM has a comparable digestibility profile to other alternative protein sources. It is possible that CP digestibility could be reduced in the 15% HSM since growth performance was reduced. Additional studies should be conducted to determine nutrient digestibility of diets containing at least 15% HSM compared to diets formulated with SBM. Factors such as the type of fibers in HSM and the potential anti-nutritional components like phytic acid and tannins could play a role in reducing nutrient availability and growth performance at higher inclusion rates. Processing methods that reduce anti-nutritional factors and improve nutrient availability, such as heat treatment or extrusion, should be explored to optimize the use of HSM in pig diets.

Conclusion and Implication

Overall, this study supports the potential of HSM as an alternative protein source in pig diets at an inclusion rate of 10%. An inclusion rate of 10% HSM was found to be optimal, supporting good growth performance and crude protein digestibility. While the 15% HSM diet was fully acceptable, it resulted in reduced growth performance. The sustainable nature of hemp production, combined with the nutritional benefits of HSM, makes it a promising ingredient for animal feed. Further research is needed to determine the optimum inclusion rate and the long-term effects of its inclusion in pig diets, to address potential factors limiting the efficacy of higher inclusion rates and to assess the abundance of anti-nutritional factors. We acknowledge that this study was limited in its scope, in particular the number of animals. Nonetheless, this pilot study does contribute to the limited body of knowledge on the nutritional adequacy of HSM in swine diets.

Table 4. Nutrient composition of HSM[1]

Item, %	As Fed	DM
Dry matter	94.7	100
Crude protein	30.7	32.5
Lysine[2]	1.06	1.13
ADF	37.8	40.0
NDF	47.2	49.8
Lignin	14.9	15.7
Crude fat	12.14	12.82
Ash	4.62	4.88

[1]Dairy One Lab, Ithaca, NY.

[2]Cumberland Valley Analytical Services, Waynesboro, PA.

Table 5. Ingredient and nutrient composition of experimental diets (as-fed)

Ingredient composition, %	Control	10% HSM	15% HSM
Corn, yellow dent	44.25	43.63	48.05
Soybean meal, 48 % CP	26.00	29.42	28.70
Hemp seed meal	0.00	10.00	15.00
Wheat bran	20.00	8.00	0.00
Corn oil	6.50	5.70	5.00
Premix[1]	3.25	3.25	3.25
Nutrient concentration (calculated)[2]			
ME, kcal/kg	3293	3298	3299.8
CP, %	19.1	21.9	22.3
NDF, %	12.6	13.7	13.8
CF, %	3.4	6.4	7.7
EE, %	9.4	9.2	8.8
Lys[3], %	1.12	1.27	1.13
SID[4] Lys, %	0.98	0.98	0.98
Total Ca, %	0.70	0.64	0.63
Total P, %	0.75	0.66	0.59
STTD P[5], %	N/A	N/A	N/A
Nutrient concentration (analyzed)[6]			
CP, %	22.4	23.6	23.2
NDF, %	10.5	12.1	12.6
ADF, %	5.5	7.8	7.9
CF, %	2.9	4.7	6.3
Lignin, %	1.2	2.0	2.0
EE, %	8.16	8.65	8.80

[1]Key Natura Pork Base 65.
[2]Based on nutrient concentrations in feed ingredients according to NRC (2012) and analyzed values for HSM.
[3]Lysine value for HSM was an analyzed value.
[4]SID = standardized ileal digestible (NRC, 2012).
[5]STTD P % in HSM is not available.
[6]Values were analyzed by Dairy One Lab, Ithaca, NY.

Table 6. Ingredient and nutrient composition of experimental diets (as-fed)

Ingredient composition, %	Control	10% HSM
Corn, yellow dent	44.00	43.38
Soybean meal, 48 % CP	26.00	29.42
Hemp seed meal	0.00	10.00
Wheat bran	20.00	8.00
Corn oil	6.50	5.70
Premix[1]	3.25	3.25
Cr_2O_3	0.25	0.25
Nutrient concentration (calculated)[2]		
ME, kcal/kg	3293	3298
CP, %	19.1	21.9
NDF, %	12.6	13.7
CF, %	3.4	6.4
EE, %	9.38	9.19
Lys[3], %	1.12	1.27
SID[4] Lys, %	0.98	0.98
Total Ca, %	0.70	0.64
Total P, %	0.75	0.66
STTD P[5], %	N/A	N/A
Nutrient concentration (analyzed)[6]		
CP, %	19.0	22.8
NDF, %	13.6	14.2
ADF, %	5.0	7.0
CF, %	3.7	6.0
Lignin, %	0.9	1.8
EE, %	9.14	9.00

[1]Key Natura Pork Base 65.
[2]Based on nutrient concentrations in feed ingredients according to NRC (2012) and analyzed values for hemp seed meal.
[3]Lysine value for HSM was an analyzed value.
[4]SID = Standardized ileal digestible (NRC, 2012).
[5]STTD P % in HSM is not available.
[6]Dairy One Lab, Ithaca, NY.

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APPENDICES

Appendix A. Repeated Latin square design arrangement

Heavy group

Period / Diet	Control	HSM 10%	HSM 15%
1 (3/7-3/11)	Pig 1	Pig 3	Pig 4
2 (3/11-3/15)	Pig 4	Pig 1	Pig 3
3 (3/15-3/19)	Pig 3	Pig 4	Pig1

Light group

Period / Diet	Control	HSM 10%	HSM 15%
1 (3/7-3/11)	Pig 5	Pig 7	Pig 8
2 (3/11-3/15)	Pig 8	Pig 5	Pig 7
3 (3/15-3/19)	Pig 7	Pig 8	Pig 5

Appendix B. Individual pig performance in the first study

Pig ID	Treatment	Period	Square	Weight (kg)	Total gain (kg)	ADG (kg)	Gain:feed
1	C	1	H	57.2	5.4	1.35	0.662
3	HSM 10	1	H	56.4	7	1.75	0.883
4	HSM 15	1	H	53.4	3	0.75	0.374
5	C	1	L	51.8	4.4	1.1	0.568
7	HSM 10	1	L	51.2	4.6	1.15	0.601
8	HSM 15	1	L	54.2	5	1.25	0.632
1	HSM 10	2	H	61.8	4.6	1.15	0.531
3	HSM 15	2	H	60.6	4.2	1.05	0.489
4	C	2	H	59.4	6	1.5	0.722
5	HSM 10	2	L	56.8	5	1.25	0.613
7	HSM 15	2	L	56.4	5.2	1.3	0.642
8	C	2	L	58.8	4.6	1.15	0.548
1	HSM 15	3	H	63.4	1.6	0.4	0.176
3	C	3	H	65.6	5	1.25	0.558
4	HSM 10	3	H	65	5.6	1.4	0.632
5	HSM 15	3	L	61	4.2	1.05	0.487
7	C	3	L	61.2	4.8	1.2	0.559
8	HSM 10	3	L	64.4	5.6	1.4	0.636

Appendix C. Individual pig performance in the second study

Pig ID	Treatment	Initial weight (kg)	Final weight (kg)	Total gain (kg)	ADG (kg)	Gain/feed
1	Control	63.4	71.2	7.8	1.30	0.527
2	Control	68.0	75.8	7.8	1.30	0.507
3	Control	65.6	74.4	8.8	1.47	0.579
4	HSM 10	65.0	72.6	7.6	1.27	0.507
5	Control	61.0	72	11	1.83	0.737
6	HSM 10	70.4	78.4	8	1.33	0.510
7	HSM 10	61.2	71	9.8	1.63	0.663
8	HSM 10	64.4	72.6	8.2	1.37	0.547

Appendix D. Fecal dry matter of individual pig

Pig ID	Diet	Dry Matter
1	C	23.98
2	C	24.77
3	C	25.14
4	10	28.21
5	C	23.58
6	10	29.84
7	10	26.83
8	10	30.56