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Effects of *Saccharomyces cerevisiae* fermentation product on the nutrient digestibility and ileal digesta characteristics of cannulated growing pigs fed corn- or barley-sorghum-based diets

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ABSTRACT

This study investigated the effects of *Saccharomyces cerevisiae* fermentation product (SCFP) on nutrient digestibility and ileal digesta characteristics of cannulated growing pigs fed corn- or barley-sorghum-based diets. Eight ileal-cannulated barrows randomized in a double 4 × 4 Latin square design were fed four diets in a 2 × 2 factorial arrangement, in which the first factor was diet type (corn- or barley-sorghum-based diet), and the second factor was dietary SCPF treatment (supplemented with or without 5 g/kg SCFP). The cannulated barrows (35.63 ± 0.76 kg) fitted with a T-cannula in the terminal ileum were housed in metabolism cages in an environmentally controlled room. The results show that compared with the corn-based diet, the barley-sorghum-based diet reduced the apparent total tract digestibility (ATTD) and apparent ileal digestibility (AID) of crude protein (CP), the AID of all amino acids, amylase activity, trypsin activity, and pH in the ileal digesta of growing pigs ($P < 0.05$). Dietary 5 g/kg SCFP supplementation increased the digestible energy (DE)/gross energy (GE) ratio ($P < 0.05$), and the metabolizable energy (ME)/GE ratio ($P < 0.10$) of growing pigs in comparison to the non-SCFP-supplemented diet. Additionally, dietary 5 g/kg SCFP supplementation tended to enhance the ATTD of acid detergent fiber (ADF) and the AID of lysine ($P < 0.10$) and elevated the AID of tryptophan in growing pigs ($P < 0.05$). However, the nutrient digestibility and ileal digesta characteristics were unaffected by diet type × SCFP interaction ($P > 0.05$). In conclusion, compared with the corn-based diet, the barley-sorghum-based diet reduced the activities of digestive enzymes and the digestive absorption of CP and amino acids in growing pigs. Dietary 5 k/kg SCPF supplementation had beneficial effects on the energy and ADF digestibility of

Abbreviations: ADF, acid detergent fiber; ADFI, average daily feed intake; ADG, average daily gain; AID, apparent ileal digestibility; ATTD, apparent total tract digestibility; Ca, calcium; CF, crude fiber; CP, crude protein; DE, digestible energy; DM, dry matter; FCR, feed conversion rate; GE, gross energy; ME, metabolizable energy; mPa*s, millipascal-seconds; NDF, neutral detergent fiber; P, Phosphorus; SCFP, *Saccharomyces cerevisiae* fermentation product.

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growing pigs. However, the nutrient digestibility and ileal digesta characteristics of the pigs were unaffected by diet type × SCFP interaction.

1. Introduction

Corn is the primary energy source in the swine feed industry of China, where people consume or produce more than 50 % of the world's pork supply (Chen and Yu, 2018). With soaring of maize prices in recent years in China, increasing attention has been devoted to various alternative energy feeds for swine production, such as barley and sorghum (Piao, 2018). Currently, less is known about the comparative effects of corn-based diets and barley-sorghum-based diets on the nutrient digestibility of pigs.

The use of barley and sorghum in swine feed may face a low digestibility problem because barley and sorghum are less easily digested than corn (Pan et al., 2016, 2017; Thacker et al., 1992). *Saccharomyces cerevisiae* fermentation product (SCFP) is a fermentation product using an unmodified strain of Saccharomyces cerevisiae, which includes fermentation products, residual yeast cells, fermentation media, and yeast cell wall components (Shen et al., 2011). Recently, maternal supplementation with SCFP was demonstrated to improve litter weight at weaning (Chen et al., 2020; Zhang et al., 2020) and individual pig weight at weaning (Zhang et al., 2020), which may be explained by the digestibility-enhanced characteristics of SCFP. It has been reported that dietary supplementation of 5 g/kg yeast culture improved the average daily gain (ADG), average daily feed intake (ADFI), and the apparent digestibility of gross energy (GE), dry matter (DM), crude protein (CP), as well as the villus height and villus height to crypt depth ratio in the ileum of weaning pigs (Shen et al., 2009). These references provide support for SCFP in enhancing the nutrient digestibility of pigs fed a barley-sorghum-based diet in place of a corn-based diet.

Therefore, this study was conducted to investigate the impacts of SCFP on nutrient digestibility and ileal digesta characteristics of cannulated growing pigs fed corn- or barley-sorghum-based diets.

Table 1
The composition and nutrient content of basal diets (as-fed basis).

Item	Corn-based diet	Barley-sorghum-based diet
Ingredients, g/kg		
Corn	706.0	0
Sorghum	0	499.6
Barley	0	240.5
Rice bran meal	0	40.0
Soybean meal	172.0	175.0
Soybean oil	0	12.4
Wheat bran	50.0	0
Wheat flour	40.0	0
Dicalcium phosphate	6.3	5.8
Limestone	7.5	6.0
Salt	3.8	3.8
L-lysine	4.3	5.0
D, L-methionine	1.2	1.4
L-threonine	1.4	1.8
L-tryptophan	0.1	0
Choline chloride	0.8	0.8
Vitamin and mineral premix [a]	1.4	1.4
Cr_2O_3	3.5	3.5
Mold inhibitor	1.0	1.0
Zeolite	0.7	2.5
Total	1000.0	1000.0
Calculated composition, unit		
Digestible energy, MJ/kg	13.51	13.51
Dry matter, g/kg	867.5	871.4
Crude protein, g/kg	155.6	155.6
Crude fat, g/kg	30.3	33.3
Neutral detergent fiber, g/kg	117.9	164.3
Acid detergent fiber, g/kg	45.2	77.5
Ash, g/kg	40.3	48.2
Calcium, g/kg	5.4	5.4
Available phosphorus, g/kg	2.4	2.4
Digestible lysine, g/kg	9.5	9.5
Digestible methionine + cysteine, g/kg	5.5	5.5
Digestible threonine, g/kg	5.9	5.9
Digestible tryptophan, g/kg	1.6	1.6

[a] Vitamin and mineral premix supplied per kilogram of complete diet: 96.46 mg Zn ($ZnSO_4 \cdot H_2O$), 172.70 mg Fe ($FeSO_4 \cdot H_2O$), 35.01 mg Mn ($MnSO_4 \cdot H_2O$), 17.83 mg Cu ($CuSO_4 \cdot 5H_2O$), 0.40 mg I (CaI_2O_6), 0.3 mg Se (Na_2SeO_3), 13,000 IU vitamin A, 4000 IU vitamin D_3, 41.08 IU vitamin E, 4 mg K, 0.034 mg vitamin B_{12}, 28.57 mg D-pantothenate, 75.77 mg niacin, 0.30 mg D-biotin, 2.31 mg folic acid.

2. Materials and methods

All animal protocols in this study were approved by the South China Agricultural University (Guangzhou city, Guangdong Province, China) Institutional Animal Care and Use Committee. The animal experiment was carried out at the swine metabolism laboratory at South China Agricultural University (Guangzhou city, Guangdong Province, China). This study was conducted between October 23, 2018 and December 26, 2018.

2.1. Animals, diets, and experimental design

Eight growing Duroc × (Landrace × Yorkshire) barrows (initial body weight, 31.06 ± 0.66 kg) were surgically quipped with a T-cannula in the distal ileum according to the procedure of Stein et al. (1998). On the 14th day after surgery, eight pigs (35.63 ± 0.76 kg) were randomly allotted to one of the four experimental diets according to a 4 × 4 Latin square design with 4 dietary treatments and 4 periods. Each period lasted for 10 days. The 4 diets were as follows: (1) corn-based diet (Table 1), (2) 5 g/kg SCFP supplementation in corn-based diet, (3) barley-sorghum-based diet, and (4) 5 g/kg SCFP supplementation in barley-sorghum-based diet. The SCFP was obtained from Beijing Enhalor Biotechnology Co., Ltd., Beijing, China. The SCFP was manufactured using patent yeast Sa-10 (*Saccharomyces cerevisiae*) fermentation technology that includes liquid and solid anaerobic fermentations, and dried with the media on which it was grown. The analysis of SCFP was not less than 150 g/kg CP, not less than 10 g/kg mannan, not more than 100 g/kg moisture and not more than 80 g/kg ash. All nutrients met or exceeded nutrient requirements of growing pigs recommended by the NRC (2012). All pigs were housed in individual stainless-steel metabolism crates (0.9 × 1.8 × 1.5 m) equipped with a nipple drinker and a feeder during the 40-day experimental period.

2.2. Feeding and sample collection

Pigs had *ad libitum* access to water and were fed a daily amount of feed equivalent to 4% of their body weight, which was divided into two equal meals provided at 0800 and 1700 h. Each 10-day experimental period consisted of 5-days of acclimatization to diets followed by a 3-day collection of feces and urine samples and a 2-day collection of ileal digesta.

2.3. Laboratory analysis

2.3.1. Conventional nutrients in diet, feces, and urine

The energy values of diet, feces, and urine samples were analyzed by the IKA C200 bomb calorimeter (IKA Analysetechnik, Heitersheim, Germany). The DM content was tested according to the standard method (GB6435-1986; People's Republic of China 1986). The CP content was analyzed with an automatic Kjeldahl nitrogen analyzer (Kjeltec® 2300 Analyzer Unit, Foss Tecator AB, Höganäs, Sweden). The acid detergent fiber (ADF) and neutral detergent fiber (NDF) contents were analyzed using an A200i automatic cellulose analyzer (Ankom Technology, NY, USA). The calcium and phosphorus contents were analyzed according to standard methods (GB/T6436-2018 and GB/T6437-2018; Republic of China 2018). The chromium content was measured using a Thermo Scientific ICE3500 (USA) atomic absorption spectrometer according to the standard method (GB/T13088-2006; Republic of China 2016).

2.3.2. Amino acids contents of diets and digesta

The amino acid contents of the diets and digesta were analyzed using an automatic amino acid analyzer using nor-leucine as the internal standard (LP-8900, Hitachi, Tokyo, Japan), which was described in our previous study (Zhang et al., 2017). Before analysis, samples were hydrolyzed using 6 mol/L HCl for 24 h at 110 °C except for tryptophan, methionine, and cystine. Tryptophan was determined after 4 mol/L LiOH hydrolysis for 22 h at 110°C. For methionine and cystine, samples were treated by cold performic acid oxidation overnight and hydrolysis (Zhang et al., 2017).

2.3.3. pH, viscosity, and digestive enzyme activity of digesta

The pH value of digesta was analyzed using a PB-10 digital pH meter (Sartorius, Göttingen, Germany). The viscosity of digesta was tested using a rheometer (MCR 502, Anton paar, Austria), and readings were expressed in millipascal-seconds (mPa*s). The digestive enzyme activities (trypsin, amylase, and lipase) were analyzed by commercial kits (Nanjing Jiancheng Bioengineering Institute, Nanjing, China).

2.4. Calculations

The digestible energy (DE), metabolizable energy (ME), the apparent total tract digestibility (ATTD) of nutrients, and the apparent ileal digestibility (AID) of nutrients (including amino acids) were calculated using the following equations:

$$DE\left(\frac{MJ}{kg}\right) = \frac{Feed\ inta\ ke\left(\frac{kg}{d}\right) \times Feed\ gross\ energy\left(\frac{MJ}{kg}\right) - Feces\ output\left(\frac{kg}{d}\right) \times Feces\ gross\ energy\left(\frac{MJ}{kg}\right)}{\text{Feed intake}\left(\frac{kg}{d}\right)};$$

Table 2
Effects of *Saccharomyces cerevisiae* fermentation product (SCFP) on the digestible energy and metabolizable energy of cannulated growing pigs fed corn- or barley-sorghum-based diets.

Item	Corn-based diet		Barley-sorghum-based diet		SEM	P-value		
	0 g/kg SCFP[1]	5 g/kg SCFP	0 g/kg SCFP	5 g/kg SCFP		Diet type	SCFP	Diet type × SCFP
N[2]	8	8	8	8				
Average daily feed intake, kg	1.74	1.73	1.72	1.76	0.061	0.976	0.897	0.858
Average daily feces output, g	255.12	245.31	242.74	246.25	8.576	0.752	0.862	0.714
Average daily urine output, L	2.68	2.65	2.00	2.12	0.143	0.032	0.873	0.790
Digestible energy, MJ/kg	13.87	14.05	13.80	13.80	0.069	0.293	0.531	0.558
Metabolizable energy, MJ/kg	13.55	13.66	13.49	13.54	0.076	0.589	0.633	0.826
Digestible energy/Gross energy	0.828	0.856	0.841	0.855	0.004	0.463	0.013	0.391
Metabolizable energy/Gross energy	0.816	0.836	0.812	0.836	0.005	0.869	0.081	0.821

[1] SCFP, *Saccharomyces cerevisiae* fermentation product.
[2] Pig was the experimental unit for all determined parameters, and the number of replicates per treatment was 8.

Table 3
Effects of *Saccharomyces cerevisiae* fermentation product (SCFP) on apparent total tract digestibility and apparent ileal digestibility of nutrients of cannulated growing pigs fed corn- or barley-sorghum-based diets.

Item	Corn-based diet		Barley-sorghum-based diet		SEM	P-value		
	0 g/kg SCFP[1]	5 g/kg SCFP	0 g/kg SCFP	5 g/kg SCFP		Diet type	SCFP	Diet type × SCFP
N[2]	8	8	8	8				
Apparent total tract digestibility								
Dry matter	0.821	0.847	0.825	0.831	0.0048	0.526	0.113	0.310
Crude protein	0.858	0.876	0.814	0.805	0.0064	< 0.001	0.582	0.083
Calcium	0.525	0.542	0.540	0.545	0.0054	0.423	0.307	0.614
Phosphorus	0.425	0.433	0.408	0.415	0.0075	0.266	0.623	0.972
Ash	0.534	0.539	0.507	0.503	0.0094	0.112	0.977	0.817
Crude fiber	0.329	0.340	0.322	0.342	0.0059	0.841	0.209	0.684
Neutral detergent fiber	0.437	0.431	0.423	0.443	0.0149	0.977	0.806	0.683
Acid detergent fiber	0.368	0.386	0.397	0.429	0.0080	0.020	0.098	0.614
Apparent ileal digestibility								
Dry matter	0.767	0.801	0.776	0.760	0.0055	0.131	0.382	0.020
Crude protein	0.848	0.861	0.776	0.780	0.0095	< 0.001	0.540	0.751
Calcium	0.497	0.512	0.510	0.511	0.0060	0.606	0.540	0.590
Phosphorus	0.416	0.426	0.407	0.422	0.0073	0.674	0.414	0.877
Ash	0.511	0.528	0.496	0.505	0.0070	0.196	0.372	0.791
Crude fiber	0.284	0.285	0.292	0.299	0.0089	0.573	0.819	0.883
Neutral detergent fiber	0.387	0.390	0.403	0.419	0.0199	0.588	0.816	0.883
Acid detergent fiber	0.332	0.327	0.343	0.338	0.0140	0.713	0.855	0.986

[1] SCFP, *Saccharomyces cerevisiae* fermentation product.
[2] Pig was the experimental unit for all determined parameters, and the number of replicates per treatment was 8.

$$ME\left(\frac{MJ}{kg}\right) = \frac{Feed\ intake\left(\frac{kg}{d}\right)\times Feed\ gross\ energy\left(\frac{MJ}{kg}\right) - Feces\ output\left(\frac{kg}{d}\right)\times Feces\ gross\ energy\left(\frac{MJ}{kg}\right) - Urine\ output\ (mL)\times Urine\ gross\ energy\left(\frac{MJ}{mL}\right)}{\text{Feed intake}\left(\frac{\text{kg}}{\text{d}}\right)};$$

$$ATTD = \frac{Feed\ intake\left(\frac{kg}{d}\right)\times Nutrient\ in\ feed\ (\%) - Feces\ output\left(\frac{kg}{d}\right)\times Nutrient\ in\ feces\ (\%)}{\text{Feed intake}\left(\frac{\text{kg}}{\text{d}}\right)\times \text{Nutrient in feed}\ (\%)}$$

$$AID = \left(1 - \frac{\text{Nutrient content in digesta}\left(\frac{\text{g}}{\text{kg}}\text{DM}\right)}{\text{Nutrient content in diet}\left(\frac{\text{g}}{\text{kg}}\text{DM}\right)}\times\frac{Chromium\ content\ in\ diet\left(\frac{g}{kg}DM\right)}{Chromium\ content\ in\ digesta\left(\frac{g}{kg}DM\right)}\right)$$

Table 4
Effects of *Saccharomyces cerevisiae* fermentation (SCFP) product on apparent ileal digestibility of amino acids of cannulated growing pigs fed corn- or barley-sorghum-based diets.

Item	Corn-based diet		Barley-sorghum-based diet		SEM	P-value		
	0 g/kg SCFP[1]	5 g/kg SCFP	0 g/kg SCFP	5 g/kg SCFP		Diet type	SCFP	Diet type × SCFP
N[2]	8	8	8	8				
Indispensable amino acids								
Lysine	0.904	0.916	0.890	0.898	0.0032	0.008	0.099	0.713
Phenylalanine	0.880	0.893	0.826	0.821	0.0067	< 0.001	0.567	0.226
Threonine	0.869	0.885	0.843	0.848	0.0047	< 0.001	0.184	0.436
Isoleucine	0.889	0.899	0.817	0.814	0.0079	< 0.001	0.697	0.382
Leucine	0.883	0.898	0.818	0.800	0.0085	< 0.001	0.803	0.055
Valine	0.859	0.872	0.792	0.790	0.0080	< 0.001	0.510	0.415
Arginine	0.920	0.929	0.882	0.883	0.0044	< 0.001	0.286	0.375
Methionine	0.915	0.920	0.881	0.899	0.0042	< 0.001	0.115	0.330
Histidine	0.879	0.899	0.824	0.820	0.0071	< 0.001	0.285	0.122
Tryptophan	0.879	0.908	0.871	0.881	0.0039	0.011	0.005	0.129
Dispensable amino acids								
Aspartic acid	0.874	0.890	0.822	0.824	0.0064	< 0.001	0.218	0.342
Serine	0.871	0.887	0.817	0.811	0.0069	< 0.001	0.555	0.162
Glutamic acid	0.903	0.914	0.863	0.849	0.0058	< 0.001	0.815	0.082
Glycine	0.809	0.839	0.755	0.756	0.0086	< 0.001	0.208	0.239
Alanine	0.846	0.865	0.787	0.768	0.0088	< 0.001	0.990	0.074
Tyrosine	0.864	0.883	0.825	0.804	0.0066	< 0.001	0.915	0.013
Proline	0.861	0.889	0.804	0.801	0.0096	< 0.001	0.397	0.272
Cystine	0.904	0.910	0.864	0.857	0.0060	< 0.001	0.939	0.466

[1] SCFP, *Saccharomyces cerevisiae* fermentation product.
[2] Pig was the experimental unit for all determined parameters, and the number of replicates per treatment was 8.

2.5. Statistical analysis

Statistical analysis was conducted using the General Linear Model procedure of SPSS 22.0 version (IBM Corp, 2013), arranged as a 2 × 2 factorial design with the diet type and dietary SCFP treatment being the main factors. Pig was the experimental unit for all determined parameters. The following model was used: $Y_{ijk} = \mu + A_i + B_j + (AB)_{ij} + e_{ijk}$, in which Y_{ijk} = dependent variable, μ = mean, A_i = diet type (i = corn-based diet or barley-sorghum-based diet), B_j = dietary SCFP treatment (j = yes or no), AB_{ij} = interaction effect between diet type and dietary SCFP treatment, e_{ijk} = random error. The results are expressed as the mean and SEM. Probabilities < 0.05 were regarded as significant, and probabilities > 0.05 and < 0.10 were regarded as tendencies among treatments.

3. Results

3.1. The DE and ME

As shown in Table 2, the average daily fecal output, DE, and ME of growing pigs were unaffected by dietary treatments ($P > 0.10$). The average daily urine output of growing pigs was decreased when pigs were fed barley-sorghum vs. corn-based diet ($P < 0.05$). In addition, dietary supplementation with 5 g/kg SCFP increased the DE/GE ratio ($P < 0.05$), and the ME/GE ratio ($P = 0.081$) compared with the non-SCFP-supplemented group. No diet type × SCFP interaction was found ($P > 0.10$).

3.2. The ATTD and AID of conventional nutrients

As displayed in Table 3, pigs fed the barley-sorghum-based diet had lower ATTD of CP and higher ATTD of ADF compared to those fed the corn-based diet ($P < 0.05$). Dietary SCFP supplementation tended to increase the ATTD of ADF ($P = 0.098$). The ATTD of CP tended to be affected by diet type × SCFP interaction ($P = 0.083$). Pigs fed the barley-sorghum-based diet had lower AID of crude protein than those fed the corn-based diet ($P < 0.05$). Dietary SCFP supplementation did not affect the AID of conventional nutrients, including DM, CP, calcium (Ca), Phosphorus (P), ash, crude fiber (CF), NDF and ADF ($P > 0.10$). The AID of dry matter was affected by diet type × SCFP interaction ($P < 0.05$).

3.3. The AID of amino acids

As described in Table 4, pigs had decreased AID of all amino acids when they were fed the barley-sorghum-based diet vs. the corn-based diet ($P < 0.05$). Dietary SCFP supplementation increased the AIDs of lysine ($P = 0.099$) and tryptophan ($P < 0.05$). The AIDs of glutamic acid ($P = 0.082$), alanine ($P = 0.074$), and tyrosine ($P < 0.05$) were affected by the diet type × SCFP interaction.

Table 5
Effects of *Saccharomyces cerevisiae* fermentation product (SCFP) on digestive enzyme activities, viscosity, and pH of ileal digesta of cannulated growing pigs fed corn- or barley-sorghum-based diets.

Item	Corn-based diet		Barley-sorghum-based diet		SEM	P-value		
	0 g/kg SCFP[1]	5 g/kg SCFP	0 g/kg SCFP	5 g/kg SCFP		Diet type	SCFP	Diet type × SCFP
N[2]	8	8	8	8				
Amylase (U/dL)	69.34	73.35	67.82	67.84	0.896	0.047	0.245	0.249
Lipase (U/L)	276.15	275.60	265.62	274.30	12.556	0.824	0.879	0.862
Trypsin (U/mL)	88.02	90.05	84.57	85.55	1.084	0.073	0.488	0.806
Digesta viscosity (mPa*s)[3]	2.23	2.20	2.22	2.22	0.012	0.979	0.651	0.651
Digesta pH	7.27	7.07	6.52	6.57	0.121	< 0.001	0.578	0.341

[1] SCFP, *Saccharomyces cerevisiae* fermentation product.
[2] Pig was the experimental unit for all determined parameters, and the number of replicates per treatment was 8.
[3] mPa*s, millipascal-seconds.

3.4. Digestive enzyme activities, viscosity, and pH of ileal digesta

As depicted in Table 5, pigs fed the barley-sorghum-based diet had lower amylase activity ($P < 0.05$), trypsin activity ($P = 0.073$), and pH ($P < 0.05$) than those fed the corn-based diet. The digestive enzyme activities, viscosity, and pH of ileal digesta were unaffected by SCFP supplementation or diet type × SCFP interaction ($P > 0.10$).

4. Discussion

The aim of this study was to evaluate the effects of SCFP on nutrient digestibility and ileal digesta characteristics of cannulated growing pigs fed corn- or barley-sorghum- based diets. It is generally believed that soluble β-glucan and tannin in barley-sorghum-based diets are the main factors affecting the feeding values of barley and sorghum (Pan et al., 2016). β-glucan and tannin are easily combined with proteins, carbohydrates, and minerals to form a complex that is not easily digested by monogastric animals, which reduces the absorption efficiency of nutrients (Pan et al., 2016). β-glucans are the main cell wall component of barley endosperm, and a high content of β-glucan has been reported to decrease the nutritional value of barley (Thacker et al., 1992). Tannins are the primary antinutritional factor affecting the feeding value of sorghum (Pan et al., 2017). Although the chemical contents of sorghum are similar to those of corn, the nutritional value of sorghum is normally considered to be 95 % of the nutritional value in corn (Pan et al., 2017). In the present study, pigs fed the barley-sorghum-based diet had lower amylase activity, trypsin activity, and pH in ileal digesta than those fed the corn-based diet, which indicates that barley-sorghum based diet reduced the nutrient digestive capability of growing pigs. Pigs fed the barley-sorghum-based diet had lower ATTD and AID of CP and higher ATTD of ADF compared to those fed the corn-based diet. Growing pigs have poor digestibility of lignin and cellulose included in the ADF of barley, which was digested in small quantities by intestinal microbes (Fairbairn et al., 1999). Consistent with our results, Pan et al. (2017) found that sorghum in place of corn in growing pigs decreased the feed conversion ratio (FCR), and increased nitrogen output by 27.9 % and the crude protein apparent digestive ratio by 7.2 %. Sorghum partially or totally in place of corn also reduced the FCR and the apparent digestive ratio of weaned pigs (Pan et al., 2017). Consistent with the decreased crude protein digestibility, pigs had decreased AID of all amino acids when pigs were fed barley-sorghum based diet vs. corn-based diet. It has been demonstrated that the amino acid digestibility of sorghum is adversely affected by many factors, such as tannin (Liu et al., 2013) and fiber (Jaworski et al., 2015), which partially explains the decreased AID of amino acids in pigs fed the barley-sorghum based diet in place of the corn-based diet.

In the current study, dietary supplementation with 5 g/kg SCFP did not affect the AID of conventional nutrients. In agreement with our results, Yang et al. (2018) reported that dietary addition with 1 g/kg yeast culture did not influence the ATTD of nitrogen and DM of weaning piglets. However, dietary SCFP supplementation tended to increase the ATTD of ADF in the present study. Consistent with our results, Plata et al. (1994) found that dietary addition with yeast culture (*Saccharomyces cerevisiae*) improved NDF digestibility and ruminal protozoan populations of steers fed oat straw based diets. Jouany et al. (2008) also found that live yeast culture supplementation increased the ADF digestibility of horses fed a high-starch or high-fiber diet. In addition, dietary SCFP supplementation increased the DE/GE ratio, and the ME/GE ratio, as well as the AID of lysine and tryptophan. However, the digestive enzyme activities, viscosity, and pH of ileal digesta were unaffected by SCFP supplementation or diet type × SCFP interaction, which suggests that the beneficial effects of SCFP on nutrient digestibility may be attributed to microbiota modulation, not physical or chemical digestion. Further research on this topic is warranted and may include a role of the microbiota when feeding SCFP.

5. Conclusions

Compared with corn-based diet, barley-sorghum based diet reduced the activities of digestive enzymes and the digestive absorption of crude protein and amino acids in growing pigs. Dietary supplementation with 5 g/kg *Saccharomyces cerevisiae* fermentation product had beneficial effects on the energy and acid detergent fiber digestibility of growing pigs. However, the nutrient digestibility and ileal digesta characteristics were unaffected by diet type × *Saccharomyces cerevisiae* fermentation product interaction.

CRediT authorship contribution statement

Jun Chen: Writing - original draft. **Yijiang Wang:** Writing - review & editing. **Jinming You:** Methodology. **Jiaming Chen:** . **Min Tian:** Validation. **Fang Chen:** Methodology. **Shihai Zhang:** Conceptualization. **Wutai Guan:** Conceptualization, Writing - review & editing, Funding acquisition.

Declaration of Competing Interest

We declare that we have no financial and personal relationships with other people or organizations that can inappropriately influence our work, there is no professional or other personal interest of any nature or kind in any product, service and/or company that could be construed as influencing the position presented in, or the review of, the manuscript entitled.

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