Animal Nutrition xxx (2018) 1–6

Contents lists available at ScienceDirect

Animal Nutrition

journal homepage: http://www.keaipublishing.com/en/journals/aninu/

Original Research Article

Digestible energy and metabolizable energy contents of konjac flour residues and ramie in growing pigs

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A R T I C L E I N F O

Article history:
Received 1 July 2017
Received in revised form
13 December 2017
Accepted 4 January 2018
Available online xxx

Keywords:
Apparent total tract digestibility
Digestible energy
Konjac flour residues
Metabolizable energy
Ramie

A B S T R A C T

The objectives of this study were to determine: 1) the effects of konjac flour residues and ramie on digestible energy (DE), metabolizable energy (ME) and apparent total tract digestibility (ATTD) of nutrients in diets fed to growing pigs, 2) the DE and ME contents of konjac flour residues and ramie. Thirty barrows were allotted to 1 of 5 treatments with 6 replicates per treatment. The 5 diets include a corn-soybean meal basal diet (CTL), konjac flour residues diets containing 15% konjac flour residues (LK) or 30% konjac flour residues (HK), and ramie diets containing 15% ramie (LR) or 30% ramie (HR). The experiment lasted 19 days, including 7 days for cage adaptation, 7 days for diet adaptation, and 5 days for total feces and urine collection. The energy values and ATTD of nutrients in each diet were determined, and DE and ME contents of konjac flour residues and ramie were calculated. The results showed that consumption of konjac flour residues significantly increased ($P < 0.01$) the fecal moisture content compared with the ramie treatment. The LK, HK and HR diets had lower ($P < 0.01$) DE values compared with the CTL diet. The HR diet had greater ($P < 0.01$) DE value compared with the HK diet. The LK and LR diets showed greater ($P < 0.01$) ATTD of DM, OM, GE and CP compared with the HK and HR diets. The HK diet had the lowest ($P < 0.01$) ATTD of ether extract (EE) among the 5 diets. No differences were observed for the ATTD of NDF and ADF among the 5 diets. Moreover, the DE and ME values of konjac flour residues under 2 inclusion levels (15% and 30%) were 11.66, 11.87 MJ/kg and 10.41, 10.03 MJ/kg, respectively. The corresponding values for ramie were 13.27, 13.16 MJ/kg and 13.07, 12.82 MJ/kg, respectively. In conclusion, the differences in fecal moisture content and the ATTD of EE among the 5 diets were mainly due to the different chemical compositions of konjac flour residues and ramie. Compared with konjac flour residues, ramie has greater DE and ME values under the same inclusion level.

1. Introduction

Increasing the inclusion proportion of fibre ingredients in swine diets can decrease the cost of feed for swine production and help to alleviate the supply and demand tension in grain market in the world (OECD-FAO, 2015). Also, fibre is required in swine diets to support normal physiological functions in digestive tract (Wenk, 2001; Yin et al., 2004). Nevertheless, dietary excess plant fibre impairs enzymatic digestion in the upper gastrointestinal tract (GIT) and increases microbial activity and digestion in the lower GIT, resulting in decreased digestibility of dietary components and dietary energy values (Noblet and Le Goff, 2001; Yin et al., 1993, Yin, 1994). However, the effect of fibre concentration on gut environment and nutrient digestibility differs with fibre properties (soluble vs. insoluble) (Högberg and Lindberg, 2006). Dietary insoluble fibre (IDF) can lead to higher flow rate of digesta, whereas dietary soluble fibre (SDF) may delay gastric emptying (Johansen et al., 1996; Guerin et al., 2001); both are important factors to influence nutrient digestion and absorption (Boudry et al., 2004).

Konjac flour has been consumed in forms of rubbery jelly, noodles, and other food products by humans for centuries, especially in Asia. Much of the recent interest in utilization of konjac

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Peer review under responsibility of Chinese Association of Animal Science and Veterinary Medicine.

Production and Hosting by Elsevier on behalf of KeAi

https://doi.org/10.1016/j.aninu.2018.01.001
2405-6545/

flour stems from its potential to use as SDF (Owusu-Asiedu et al., 2006). Ramie is also a traditionally grown crop, which has been mainly used as IDF, but proved to be palatable to domestic livestock. The nutritive value of ramie is reported to be similar to that of Lucerne (Kipriotis et al., 2015). However, to our knowledge, no literature has reported the energy values of konjac flour residues and ramie by now. Therefore, the objectives of this study were to: 1) evaluate the effects of konjac flour residues and ramie on digestible energy (DE), metabolizable energy (ME) and apparent total tract digestibility (ATTD) of nutrients in diets fed to growing pigs, 2) determine the DE and ME contents of konjac flour residues and ramie.

2. Materials and methods

The animal trial in this experiment was conducted in the Metabolism Laboratory of the Ministry of Agriculture Feed Industry Centre, China Agricultural University (Beijing, China). The Institutional Animal Care and Use Committee at China Agricultural University (Beijing, China) reviewed and approved the protocol of this experiment.

2.1. Sample preparation

Konjac flour residues (obtained during the production of konjac starch) used in this research were provided by New Hope Liuhe Group (Sichuan province, China). Ramie (feed-grade) used in this research was provided by Hunan Albert Animals Nutrition Group (Hunan province, China). The chemical compositions of konjac flour residues and ramie are shown in Table 1.

2.2. Animals, housing and experimental design

Thirty barrows (Duroc × Landrace × Yorkshire; initial average BW of 42.23 ± 2.1 kg) were individually housed in stainless-steel metabolism crates (1.4 m × 0.7 m × 0.6 m) at the Fengning Animal Experimental Base of China Agricultural University (Hebei, China). Each crate was equipped with a feeder, a nipple drinker, a screened floor, 2 fecal collection trays, and a urine collection bucket. Pigs had free access to water and feed. The metabolism crates were located in an environmentally controlled room with a temperature of 22 ± 1 °C.

2.3. Diets, feeding and measurements

Pigs were allotted to 1 of 5 diets according to a completely randomized design ($n = 6$). The 5 diets include a corn-soybean meal basal diet (CTL), 2 konjac flour residues diets containing 15% konjac flour residues (LK) or 30% konjac flour residues (HK), and 2 ramie diets containing 15% ramie (LR) or 30% ramie (HR). All nutrients in diets including energy, crude protein, amino acids, vitamins and minerals were designed to meet or exceed the nutrient requirements of growing pigs (NRC, 2012). Ingredients and analyzed chemical compositions of the experimental diets are listed in Table 2.

The experiment lasted 19 days, including 7 days for cage adaptation, 7 days for diet adaptation, and 5 days for total feces and urine collection. During the adaptation period, the daily amount of feed was gradually increased until it was equivalent to 4% of the BW determined at the beginning of the experiment (Adeola, 2001). The daily intake was divided equally into 2 meals provided at 08:30 and 15:30.

Pigs were weighed individually at the beginning of the adaptation period and at the end of the collection period. The amount of feed added to the feeders was recorded each feeding time. Orts were removed and weighed after each meal and daily feed consumption was calculated. Water was available *ad libitum* for each pig.

2.4. Sample collection

The feces and urine collection and sample preparation were conducted following the methods described by Li et al. (2015).

Table 1
Analyzed nutrient components of the ingredients (%, as-fed basis).

Item	Konjac flour residues	Ramie
Dry matter	89.68	92.37
Crude protein	18.56	17.21
Gross energy, MJ/kg	15.25	18.86
Ether extract	1.00	6.96
Ash	8.12	3.96
Soluble dietary fibre	13.29	3.37
Insoluble dietary fibre	14.47	57.52
Total dietary fibre	27.76	60.89
Calcium	1.28	0.34
Phosphorus	0.32	0.60
Amino acids		
Alanine	0.77	0.65
Arginine	1.40	1.62
Aspartic acid	1.83	1.10
Cysteine	0.31	0.16
Glutamic acid	2.09	2.38
Glycine	0.74	0.65
Histidine	0.36	0.22
Isoleucine	0.50	0.44
Leucine	0.92	0.91
Lysine	0.64	0.38
Methionine	0.27	0.31
Pheylalanine	0.80	0.59
Proline	0.61	0.54
Serine	0.89	0.55
Threonine	0.64	0.43
Tryptophan	0.19	0.33
Tyrosine	0.48	0.31
Valine	0.95	0.72

Table 2
Ingredient compositions and analyzed nutrient components of the experimental diets (%, as-fed basis).

Item	Treatments[1]				
	CTL	LK	HK	LR	HR
Ingredients					
Corn	72.80	61.63	50.47	61.63	50.47
Soybean meal	25.00	21.17	17.33	21.17	17.33
Konjac flour residues		15.00	30.00		
Ramie				15.00	30.00
Dicalcium phosphate	0.60	0.60	0.60	0.60	0.60
Salt	0.35	0.35	0.35	0.35	0.35
Limestone	0.75	0.75	0.75	0.75	0.75
Premix[2]	0.50	0.50	0.50	0.50	0.50
Nutrient compositions					
Dry matter	87.55	87.71	88.09	88.44	89.21
Gross energy, MJ/kg	16.60	16.40	16.21	17.01	17.20
Ether extract	2.42	2.23	2.21	3.66	3.88
Crude protein	18.02	17.29	18.00	17.47	16.83
Soluble dietary fibre	4.54	8.55	10.01	4.10	2.00
Insoluble dietary fibre	9.43	10.15	11.01	16.47	23.51
Total dietary fibre	13.97	18.70	21.02	20.57	25.51

[1] CTL: corn-soybean basal diet; LK: diets containing 15% of konjac flour residues; HK: diets containing 30% of konjac flour residues; LR: diets containing 15% of ramie; HR: diets containing 30% of ramie.

[2] Premix provided the following per kg of complete diets for growing pigs: vitamin A, 5,512 IU; vitamin D_3, 2,200 IU; vitamin E, 30 IU; vitamin K_3, 2.2 mg; vitamin B_{12}, 27.6 μg; riboflavin, 4 mg; pantothenic acid, 14 mg; niacin, 30 mg; choline chloride, 400 mg; folacin, 0.7 mg; thiamine 1.5 mg; pyridoxine 3 mg; biotin, 44 μg; Mn, 40 mg (MnO); Fe, 75 mg ($FeSO_4 \cdot H_2O$); Zn, 75 mg (ZnO); Cu, 100 mg ($CuSO_4 \cdot 5H_2O$); I, 0.3 mg (KI); Se, 0.3 mg (Na_2SeO_3).

Please cite this article in press as: Li E, et al., Digestible energy and metabolizable energy contents of konjac flour residues and ramie in growing pigs, Animal Nutrition (2018), https://doi.org/10.1016/j.aninu.2018.01.001