Determination and prediction of the amino acid digestibility of sunflower seed meals in growing pigs

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This article's featured experiment was conducted to evaluate the chemical composition and amino acid (AA) digestibility of sunflower seed meal (SFSM), and to use this data to develop prediction equations for estimating AA digestibility for growing pigs.

Ten SFSM samples were collected from five provinces in China. Twelve barrows (38,8±4,6kg) fitted with ileal T-cannula were allotted into two 6x6 Latin square designs. Each of six experimental periods comprised a five day adaption period followed by a two day collection of ileal digesta.

The ten test diets contained 50% SFSM as the sole source of AA. Another nitrogen-free diet was used to measure the basal endogenous losses of crude protein (CP) and AA. Chromic oxide (0,3%) was used as an inert marker in each diet.

There was considerable variation (CV >10%) among the ten SFSM in chemical composition (dry matter [DM]).

Test results

The concentration of CP and ether extract (EE) ranged from 29,33% to 39,09% and 0,88% to 11,33%, respectively. Crude fibre (CF), neutral detergent fibre (NDF) and acid detergent fibre (ADF) ranged from 21,46% to 36,42%, 38,15% to 55,40%, and 24,59% to 37,34%, respectively.

There was variation among the ten SFSM in apparent ileal digestibility (AID) and standardised ileal digestibility (SID) for lysine (Lys) and threonine, which ranged from 63,16% to 79,21% and 55,19% to 72,04% for AID and 67,03% to 82,07% and 61,97% to 77,01% for SID, respectively. The variation in CP and methionine (Met) ranged from 60,13% to 74,72% and 74,79% to 88,60% for AID and 66,70% to 79,31% and 77,16% to 90,27% for SID, respectively.

Met was a good indicator to predict AA digestibility. These results indicate that conventional chemical composition of SFSM was variable (CV >10%) among the ten SFSM (DM). The results of AID, SID and prediction equations could be used to evaluate the digestibility of SFSM in growing pigs.

Sunflower (*Helianthus annuus, Asteraceae*) is one of the most widely cultivated oil crops in the world (Flagella *et al.*, 2002). The worldwide production of sunflower seed reached 37,08 million tons and subsequently produced 15,22 million tons of oil (FAO, 2012). Together with soya beans, cottonseed and canola (rapeseed), sunflower seeds are one of the major oilseeds produced in the world (Salunkhe *et al.*, 1992).

Oilseed byproducts play an important role in supplying plant protein (Church and Kellems, 1998). Soya bean meal (SBM) is often referred to as the gold standard compared to other protein sources (Cromwell, 2000; Zhang *et al.*, 2013). The demand for soya bean is increasing due to its inclusion in livestock feed and its use for human consumption (Sasipriya and Siddhuraju, 2013).

In order to satisfy the need for protein resources, other materials such as rapeseed meal (Baidoo *et al.*, 1987; Brand *et al.*, 2001; Opalkal *et al.*, 2001; Zhang *et al.*, 2012), cottonseed meal (Noland *et al.*, 1968; Tanksley *et al.*, 1981) and peanut meal (Batal *et al.*, 2005; Sulabo *et al.*, 2013) are used to replace SBM in the feed industry.

Potential protein source

SFSM is a byproduct of the oil extraction of sunflowers and could be an important protein resource for use in animal diets. Solvent extracted sunflower seed meal has an average CP concentration of 30,7% and a higher concentration of Met than solvent extracted SBM, but has less Lys than SBM (NRC, 2012). Another characteristic of SFSM is that it is not known to have antinutritional factors such as those found in soya

Table 1: Analysed chemical composition of sunflower seed meal (% DM).

Item	Sunflower seed meal number[1]													
	1	2	3	4	5	6	7	8	9	10	Min	Max	Mean	CV
DM	90,91	91,37	92,51	90,76	92,15	92,91	91,27	91,85	90,79	90,31	90,31	92,91	91,48	0,92
Composition														
CP	34,91	38,00	29,33	32,02	31,68	29,47	35,19	34,63	39,09	30,87	29,33	39,09	33,52	10,13
Ether extract	2,19	2,08	5,23	0,93	1,23	3,47	2,02	0,88	1,73	11,33	0,88	11,33	3,11	101,99
NDF	41,65	38,15	55,40	45,93	47,32	43,97	40,96	42,67	40,72	51,90	38,15	55,40	44,87	12,01
ADF	25,85	24,59	37,34	31,31	31,42	28,04	25,89	27,99	26,07	30,52	24,59	37,34	28,90	13,28
Crude fibre	21,83	23,11	36,42	30,54	29,87	27,25	21,46	25,66	22,47	33,69	21,46	36,42	27,23	19,31
Ash	6,86	7,15	5,45	6,32	6,82	7,75	8,30	6,40	6,76	6,71	5,45	8,30	6,85	11,37
Calcium	0,27	0,32	0,17	0,34	0,33	0,45	0,44	0,30	0,30	0,31	0,17	0,45	0,32	25,07
Phosphorous	1,04	1,15	0,63	0,81	0,94	0,84	1,02	0,98	1,06	0,92	0,63	1,15	0,94	15,89

DM, dry matter**; Min,** minimum**; Max,** maximum**; CV,** coefficient of variation**; CP,** crude protein**; NDF,** neutral detergent fibre**; ADF,** acid detergent fibre.

1 Sources of sunflower seed meal: 1, 4, and 8 were from Xinjiang; 2, 7, and 9 were from Hebei; 3 was from Liaoning; 5 was from Shanxi; 6 and 10 were from Inner Mongolia.

bean, cottonseed and rapeseed meals.

Although sunflower seed contains 1,56% chlorogenic acid (Milic *et al*., 1968), its concentration in SFSM does not lead to toxicity effects (Senkoylu and Dale, 1999). Sunflower seed meal diets supplemented with Lys can be used as a replacement for SBM in growing pigs (Seerley *et al*., 1974). However, the digestibility of these nutrients may vary considerably, resulting in rather inaccurate measures for the nutritional value of actual batches of feed (Just *et al*., 1983).

Therefore, the objective of this study was to compare the chemical composition of different SFSM and determine the AID and SID of CP and AA of SFSM fed to growing pigs. In addition, the results of the chemical analysis were used to establish prediction equations for AID and SID that could be applied in future commercial practice.

Materials and methods

This experiment was conducted at the China Agricultural University (Beijing, China). The institutional animal care and use committee at the university approved the protocol for the experiment. All the pigs had been used in another experiment before being placed in this experiment.

The experiment was conducted in the metabolism laboratory of the Ministry of Agriculture Feed Industry Centre, Beijing. The temperature and humidity of the room were automatically controlled and kept at 18°C to 21°C and 50% to 65%.

Twelve barrows (Duroc x Landrace x Yorkshire) with an initial body weight (BW) of 38,8±4,6kg were fitted with a simple T-cannula in the distal ileum (Stein *et al*., 1998). The barrows were individually placed in stainless steel metabolism crates (1,4 x 0,45 x 0,6m^3). Each crate was installed with a one-hole feeder and a nipple drinker.

Ten sunflower seed meals were collected from five provinces in China, which are representative of more than 80% of the country's output. The chemical composition of the ten SFSM differed from each other (*Table 1* and *2*).

The diets used in this experiment were prepared based on the chemical composition of the feed ingredients. All diets were fed in mash form.

Composition of ingredient

According to the reports, SFSM is a valuable ingredient for swine because of its high energy concentration and ease of handling in feed mills (Thacker, 1998). It is also a good ingredient because it is free of most antinutritional factors (Wahlstrom, 1990).

The results of the chemical analysis of SFSM conducted in this experiment varied greatly. The CV of CP, NDF, ADF, CF, Ash, Ca, and P were higher (CV >10%) due to the selection of samples before the official experiment.

Preparations for collecting samples from the major provinces that cultivate SFSM in China involved contacting the representative plants, acquiring basic information on the chemical concentration of SFSM in each plant and collecting typical samples in person.

In addition, the variation of SFSM might result from different growth conditions, such as climate and soil conditions (Alpaslan and Gündüz, 2000). Although, most SFSM underwent a similar production process of a pre-pressing extraction method (Fick and Miller, 1997). The differences, such as temperature, pressure and time during the production process, might lead to the changes in chemical concentration in SFSM (Clandinin and Robblee, 1950; Parrado *et al*., 1991). The large variation of EE (0,88% to 11,33%) was mainly related to the different extraction processes.

The average concentration of CP (sources 1, 2, 7, 8 and 9) was higher than other sources and NRC (2012), probably because of genetic improvement (Robertson, 1972). The concentrations of EE among the ten SFSM sources varied from 0,88% to 11,33%, depending on the extraction process and the amount of residual oil left after extraction (Dinusson, 1990).

The EE in source 4 and 8 SFSM were lower than the others, which means the oil had been extracted according to the Association of American Feed Control Officials (AAFCO, 2011). The ten SFSM sources had a higher average value of NDF but lower ADF than González-Vega *et al*. (2012), which was similar to the value reported in NRC (2012).

Digestibility of CP and AA

Waldroup *et al*. (1970) reported that SFSM can be effectively used to replace up to 50% of SBM in broiler diets. The AID and SID values for CP in this experiment were lower than NRC (2012), because of the lower concentration of CP in the ten SFSM.

Table 2: Analysed AA composition of sunflower seed meal (% DM).

Item	Sunflower seed meal number[1]													
	1	2	3	4	5	6	7	8	9	10	Min[2]	Max[3]	Mean	CV[4]
Indispensable AA														
Arginine	2,70	3,03	2,22	2,52	2,48	2,35	2,91	2,60	3,06	2,34	2,22	3,06	2,62	11,36
Histidine	0,89	1,11	0,87	0,86	0,85	0,80	0,97	0,88	1,18	0,83	0,80	1,18	0,93	13,67
Isoleucine	1,36	1,55	1,20	1,29	1,25	1,15	1,45	1,34	1,62	1,23	1,15	1,62	1,34	11,45
Leucine	2,18	2,38	1,78	2,04	1,99	1,92	2,29	2,07	2,46	1,81	1,78	2,46	2,09	11,06
Lysine	1,56	1,63	1,22	1,52	1,45	1,31	1,56	1,51	1,67	1,36	1,22	1,67	1,48	9,61
Methionine	0,80	0,86	0,61	0,74	0,76	0,65	0,80	0,77	0,89	0,66	0,61	0,89	0,75	12,00
Phenylalanine	1,45	1,67	1,22	1,23	1,30	1,17	1,45	1,42	1,71	1,28	1,17	1,71	1,39	13,39
Threonine	1,33	1,42	1,09	1,15	1,14	1,08	1,35	1,29	1,45	1,17	1,08	1,45	1,25	11,04
Tryptophan	0,37	0,43	0,33	0,34	0,35	0,32	0,40	0,34	0,44	0,35	0,32	0,44	0,37	11,64
Valine	1,85	2,02	1,57	1,60	1,62	1,52	1,83	1,76	2,05	1,80	1,52	2,05	1,76	10,47
Dispensable AA														
Alanine	1,70	1,76	1,41	1,55	1,54	1,49	1,74	1,66	1,79	1,52	1,41	1,79	1,62	8,10
Aspartate	3,08	3,50	2,66	2,88	2,68	2,71	3,23	3,03	3,56	2,77	2,66	3,56	3,01	11,04
Cystine	0,64	0,62	0,39	0,52	0,53	0,47	0,60	0,60	0,71	0,48	0,39	0,71	0,56	17,15
Glutamine	7,02	7,62	5,97	6,56	6,28	6,20	7,51	6,89	7,86	6,12	5,97	7,86	6,80	10,05
Glycine	2,05	2,32	1,70	1,93	1,91	1,69	2,12	2,01	2,35	1,92	1,69	2,35	2,00	11,22
Proline	1,19	1,30	1,12	1,16	1,17	1,11	1,28	1,17	1,33	1,16	1,11	1,33	1,20	6,58
Serine	1,45	1,64	1,14	1,38	1,37	1,29	1,53	1,41	1,66	1,36	1,14	1,66	1,42	11,00
Tyrosine	0,78	0,93	0,66	0,68	0,63	0,70	0,88	0,75	0,97	0,59	0,59	0,97	0,76	17,58

DM, dry matter**; Min,** minimum**; Max,** maximum**; CV,** coefficient of variation**; AA,** amino acid**.**

1 Sources of sunflower seed meal: 1, 4, and 8 were from Xinjiang; 2, 7, and 9 were from Hebei; 3 was from Liaoning; 5 was from Shanxi; 6 and 10 were from Inner Mongolia.

The results of AID and SID of CP and AA in source 3 SFSM resulted from the highest concentration of NDF, ADF and CF, which had a depressive effect on AA digestibility (Sauer *et al*., 1980; Lenis *et al*., 1996).

The SFSM with a relatively higher concentration of EE, associated with lower NDF and ADF (source 2), had higher AID and SID values ($p<0,05$). The different content of EE in the diets also affected the digestibility of source 10 SFSM (Noblet and Perez, 1993). The relatively higher concentration of NDF and CF may contribute to a decreased AA digestibility (Sauer *et al*., 1980; Lenis *et al*., 1996).

Jørgensen *et al*. (1984) reported that the digestibility of sunflower seed products is lower than SBM. Sunflower seed meal has a lower content of Lys than SBM (Smith, 1968; Sosulski and Sarwar, 1973). Sources 2 and 9 SFSM had a higher concentration of Lys. However, the average AID and SID values of Lys among all SFSM were lower than NRC (2012).

Differences in the heating temperature could also have caused the variation in the AID and SID values of CP, resulting in a Maillard reaction that decreased the concentration and digestibility of Lys in corn distillers dried grains with solubles (Pahm *et al*., 2008). In addition, the concentration of Met was relatively higher in SFSM than SBM (Olvera-Novoa *et al*., 2002).

For most indispensable AA, the AID was lower than the value shown in NRC (2012). However, the SID of those AA had less variation. This means that endogenous loss of AA cannot be ignored for evaluation of AA. In addition, the SID value had greater accuracy than AID (González-Vega *et al*., 2012).

Correlations and prediction equation

The results of the study indicated that the variability of chemical composition in SFSM could contribute to the difference of AID and SID values. The AID and SID of CP could be accurately predicted by Met, which means that Met was highly correlated with CP. The concentration of reactive Lys was a good predictor for the concentration of Lys in distillers dried grains with solubles and canola meal, respectively (Almeida *et al*., 2014).

The Lys concentration per unit CP could be an acceptable predictor of Lys SID in wheat distillers dried grains with solubles (Cozannet *et al*., 2010). Other factors such as CP, Trp and Ca were also essential for estimating the digestibility of AA.

In conclusion, the digestibility of SFSM has great variation resulting from differences in chemical composition. The concentration of Met was the factor most affected in the equations established in this experiment. In order to improve SFSM as an alternative to SBM for use in swine diets, more SFSM samples should be collected and further research should be conducted to increase the accuracy of the equations.

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