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APPARENT METABOLIZABLE ENERGY OF SWEET POTATO BY-PRODUCTS FOR BROILER CHICKENS

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ABSTRACT

Sweet potato by-products have the potential to be energy feed ingredient for poultry, but limited nutrient digestibility data exists. This study determined the nitrogen corrected apparent metabolizable energy (AMEn) of raw sweet potato (SP), cooked sweet potato (CSP) and sweet potato fries (SPF) for broiler chickens. The experiment had a completely randomized design with 120 Ross-308 male broiler chickens distributed to 20 battery cages having six birds per cage and five replicate cages per treatment. Dietary treatments were a basal grower diet and three sweet potato meal SP, CSP and SPF substituted diets. Birds were fed a common starter diet with 3050 Kcal per kg DM metabolizable energy and 23% protein for the first 14 days then birds were given the test diets for seven days. No differences (P>0.05) existed in gross energy digestibility coefficients among test ingredients. The SPF had the highest DM, CP and AMEn digestibility coefficients. The AMEn for SPF, CSP, and SP were 4721, 3640 and 3263 kcal per kg DM respectively. In conclusion, AME of sweet potato by-products can vary, and some of this variation may be due to the processing methods used to create the ingredient.

Keywords: Sweet potato by-products, AMEn, digestibility, broiler chicken

Introduction

Sweet potato is a root tuber crop which can be grown year-round in tropical and subtropical countries. Boiled, baked or fried sweet potato tubers are commonly used as carbohydrate sources in human diets. On a DM basis, sweet potato tubers have 70 % starch, 10 % total sugars, 5% protein, 1 % lipid, 10 % total fiber and less than 1 % vitamins [1].

By-products like dehydrated raw sweet potato (SP), dehydrated cooked sweet potato (CSP) and dehydrated sweet potato fries (SPF) could be potential poultry feed ingredients since they contain very low levels of NSP and other anti-nutritional factors [2]. The average time for crop maturity after plating is only three months which provides six harvest annually.

Research suggested that dehydrated sweet potato could be used to replace some of the corn used in poultry diets [3]-[4]. Digestibility data for most sweet potato by-products originating from human food industries have not been determined for broilers. The digestibility data currently available for some sweet potato by-products were obtained using adult roster assays which might have overestimated the actual digestibility in younger growing broilers. Apart from the effects of age on the digestibility of ingredient by chickens, substantial genetic improvement has been made to currently available commercial broiler lines. The extent to which they digest feed ingredients and the nutrient requirements have changed. The objective of this study was to identify the digestibility nutrients present in SP, CSP, and SPF for Ross 308 broilers. It was hypothesized that SPF would yield more digestible energy than CSP and SP.

2. Materials and methods

In this study, all the birds were cared for according to the Canadian Council on Animal Care guidelines [5] and the experimental protocol was approved by the animal care committee at Dalhousie University Faculty of Agriculture.

2.1 Preparation of ingredients

Centennial variety sweet potato tubers were purchased from a local supplier in Truro, Nova Scotia, Canada. To make SP and CSP, the potatoes were sliced into 1 cm thick pieces. One batch of sliced potato was placed in an aluminium boiling pot with strainer basket (RiverGrille® 42 qt.). The potatoes were cooked at 80 °C for 30 minutes in boiling water then the strainer basket removed from the pot and allowed to drain for one hour. The cooked and uncooked potatoes were placed in a drying oven at 55 °C for 18 hours to make SP and CSP which had approximately 8 % moister.

The SPF tubers were sliced into 1 x 0.2 x 0.2 cm pieces, place in a commercial deep fryer (AT Cooker®, Model FCDTT-A14) with canola oil heated to 190 °C for 3-4 minutes. Fries were allowed to drain for 30 minutes on 4 layer of paper towel (Cascades Premium 6 RL™) then passed through a meat grinder. The ground fries were placed in an oven to dry at 55 °C for 18 hours. The 18 hours at 55 °C drying procedure was selected because it produced consistent dry matter across all ingredients and the lowest dry matter for the ground fries. All dried samples were ground to pass through a 0.5 screen using a hammer mill.

2.2 Diet preparation

Each by-product was incorporated at 45% of total diet at the expense of corn starch, corn, soybean meal, and soy oil. The meals were included at 45% within the basal diet instead of the standard 30% in order to mimic the potential levels it would be included in a diet if it was considered as the main energy source. Test diets contained 1% celite as an indigestible marker.

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The starter and basal grower diets (Table 1) were formulated to meet or exceeded [6] recommendations for broiler chickens.

2.3 Experimental design

The experiment was a completely randomized design with 120 Ross-308 male broiler chickens of one day of age. Birds were weighed and assigned to dietary treatments having six birds per cage with five replicate cages per treatment. Birds were housed in battery cages for the experimental period in a room with negative pressure ventilation and in floor heating. The initial temperature was 35 °C on day one with a step-down program of 2 °C per week. Dietary treatments included a standard basal grower diet as the control and three sweet potato meal SP, CSP and SPF substituted diets. From hatch to 14 days all birds were fed a common starter diet with 3050 Kcal per kg DM metabolizable energy and 23% crude protein ad libitum. Birds were given the test diets on day 15 and excreta collected on day 20 and 21. Samples were stored in individual containers at -20 °C until analyzed.

Table 1. Experimental diets compositions as fed basis

Item	Starter	Basal grower	Gower test diets
Ingredient as fed basis (g/kg)			
Corn	542.2	502	264.9
Corn starch		23.4	9.8
Soybean meal	360	382	201.6
Soybean oil	50	40	21.1
Sweet potato by-products*		0	450
Mono-dicalcium phosphate	20	17.5	17.5
Limestone (38% Ca)	13	14	14
Iodized Salt	4	4	4
Vitamin-mineral premix•	3	3	3
DL-Methionine	3.8	3	3
L-Lysine, HCL	2.9	1.1	1.1
L-Threonine	1.1	0	0
Celite		10	10
Total	1000	1000	1000
Calculated nutrient content			
Crude protein (%0	22.6	22.8	
ME kcal/kg	3192	3100	
Calcium (%)	1	1	
Phosphorus (%)	0.75	0.70	

Non-phytate Phosphorus (%)	0.46	0.42	
Amino acids (%)			
ARG	1.5	1.52	
HIS	0.59	0.6	
ILE	0.92	0.96	
LEU	1.89	1.93	
LYS	1.43	1.35	
MET	0.72	0.65	
MET+CYS	1.08	1.01	
PHE	1.05	1.08	
THR	9.4	0.86	
VAL	1.02	1.05	

*sweet potato (SP), cooked sweet potato (CSP) or sweet potato fries (SPF).

•Vitamin-mineral premix provided the following per kilogram of complete diet: vitamin B12, 4 mg ;vitamin D, 440,000 IU; vitamin A, 2,200,000 IU; vitamin E, 6000 IU; menadione, 400 mg; thiamine, 300 mg; riboflavin, 1200 mg; pyridoxine, 800 mg; niacin, 12,000 mg; pantothenic acid, 2000 mg; folic acid, 120 mg; biotin 30 mg; copper, 2000 mg; iron, 16,000 mg; manganese 16,000 mg; iodine, 160 mg; zinc, 16,000 mg; selenium, 60 mg; calcium carbonate 100,000 mg; Ethoxyquin 125 mg; wheat middlings 754,546 mg.

2.4 Chemical analysis

Excreta samples were freeze-dried while diets and ingredient oven dried according to [7] method no. 934.01 for dry matter (DM). Samples were ground using a coffee grinder (Proctor Silex E160B, Picton, Ontario) and feed and excreta were ash by [7] method no. 942.05. Nitrogen was determined using the combustion method (Leco model FP-2000 N analyzer, Leco Corporation, St. Joseph, MI), with EDTA as a calibration standard and crude protein (CP) calculated as N x 6.12 following [7] method no. 990.30. Gross energy was (GE) measured with a Parr adiabatic bomb calorimeter (Parr Instrument Co., Moline, Illinois).

2.5 Calculations

The nutrient digestibility coefficients of diets = NDCD (1), ingredients = NDCI (2), digestible nutrients in ingredients = DNI (3) and energy (4) and (5) were calculated using the calculation adapted from [8]. Where AIA is acid insoluble ash and diet is either (B) = basal or (T) = test, gross energy = GE, apparent digestible energy of ingredients = AME, Nitrogen corrected apparent digestible energy of ingredients = AMEn and N=nitrogen.

$$\mathrm{NDCD} = \left[100 \times \frac{\%\,\mathrm{AIA\,in\,diet}}{\%\,\mathrm{AIA\,in\,excreta}} \times \frac{\%\,\mathrm{nutrient\ in\ excreta}}{\%\,\mathrm{nutrient\ in\ diet}}\right] (1)$$

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$$\text{NDCI} = \left[100 \times \frac{(\text{T})\,\text{NDCD} - (\text{B})\,\text{NDCD}}{45}\right] + (\text{B})\,\text{NDCD}\ (2)$$

DNI = NDCI x nutrient content of ingredients (3)

AME =GE digestibility of ingredients x ingredients GE (4)

$$\text{AMEn} = \text{AME} - 8.22 \times \text{diet N}\left[\frac{\text{excreta N} \times \text{diet AIA}}{\text{excreta AIA}}\right] (5)$$

2.6 Statistical analysis

All data were subjected to a one-way analysis of variance using Proc Mixed procedure of SAS. Means of significantly different treatments were separated using Pdiff α at p≤0.05 (SAS Version 9.2; SAS Institute, Inc., Cary, NC) [9].

3. Results and discussion

The ingredients DM content varied from 93 to 87% (Table 2), but all values except for SPF 87% fell in the 90 to 93% range reported by [2]. The highest GE 5093 kcal per kg DM was observed for SPF meal (Table 2). The GE of SP meal 3859 kcal per kg DM was approximately 661 kcal lower than the 4520 kcal per kg DM reported by [10] but similar to the 3945 kcal per kg DM for sun dried meal reported by [11].

The wide range reported for sweet potato GE in the literature suggested that Sweet potato by-products GE values are variable. This variability in GE might be related to how the by-products were prepared or their total starch and oil content. The starch content of the SP and CSP would be the major source of energy during digestion but SPF may contain residual oil from the deep frying process which could contribute a substantial amount of energy due to the large caloric value of oils. Unfortunately, this study did not analyzed the starch content of the meals but [12] reported starch values ranging from 63 to 77% of sweet potato DM. It is likely that differences in starch and fat contents of the sweet potato by-products of this study and those of other studies could have led to the some of the discrepancy between GE values for the by-products.

The CP of SP at 8% was higher than [10] 2.8% but lower than the range of 8.7 to 13.9% for Bosbok and Cormel varieties oven dried at 40, 60 and 80 °C [2]. The ash content of SP at 6% was higher than those reported by [10] but identical to [2] 6%. The variations in CP and ash composition of sweet potato is known to be influenced by many factors such as processing technique used to obtained the by-products, environmental conditions during plant growing

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season and plant varieties [1]. Drying temperature is known to influence ash content of sweet potatoes [2]. The less moisture present in the final product, the higher the ash content will be.

Table 2. Digestible and analyzed nutrients of sweet potato by products on a DM basis

Item	Nutrient analysed				Digestibility coefficient				Digestible nutrients				
	DM	CP	Ash	GE	GE	DM	CP	Ash	AMEn	AME	DM	CP	Ash
SP•	92	8	6	3859	89	94^{b}	73^{b}	15^{b}	3263^{c}	3279^{c}	86^{b}	6^{b}	0.9
CSP‡	93	10	5	4100	89	95^{c}	69^{b}	16^{b}	3640^{b}	3656^{b}	88^{a}	7^{a}	0.8
SPF†	87	7	4	5093	93	96^{a}	87^{a}	35^{a}	4721^{a}	4736^{a}	83^{c}	6^{b}	1
SEMɸ					1.3	0.3	4	5	43.3	53.2	0.3	0.3	0.2

GE = Gross energy in (kcal per kg DM), AMEn = nitrogen corrected apparent metabolizable energy in (kcal per kg DM) and AME = apparent metabolizable energy in (kcal per kg DM)

•SP, sweet potato meal.

‡CSP, cooked sweet potato meal.

†SPF, deep fried sweet potato meal

ɸPooled standard error of means

a-c Means within a column with different superscripts differ significantly (P<0.05)

The moisture content of the by-products in this study were not the same as those reported by previous studies [2]-[12]. The variety and growing location of the sweet potato were different among studies. The coefficient of variation for the mineral and CP content of various varieties of sweet potato grown at different locations can be as high as 39% and 31% respectively [12].

The GE digestibility coefficient was 89, 89 and 93 for SP, CSP, and SPF respectively. There was no difference (P<0.05) in GE digestibility coefficient of the three ingredients. However, there were significant (P<0.05) difference in DM digestibility coefficient between the ingredients in which SPF had higher values than SP and CSP who's values were not significantly different. Ash and CP digestibility coefficient for CSP and SP were similar, and both were significantly lower than SPF. Frying enhanced the DM, ash and CP digestibility coefficient of the sweet potato. One theory is that this could be related to the ability of oils to enhance the palatability of food, unfortunately, no feed intake data were collected and as such this theory could not be confirmed in this study.The CSP had the highest DM 88% and CP 7% retention when compared to the other test ingredients. The SP and SPF CP retention did not differ but SP had significantly higher retention of DM than SPF. There was no (P<0.05) difference in the ash retention between the ingredients.

Sweet potato fries had the highest AMEn 4721 kcal per kg DM and AME 4733 kcal per kg DM. The high AMEn of SPF might be related to the high GE 5093kcal per kg DM of the ingredient possible due to the addition of extra calories from deep frying in canola oil. Unfortunately, fat analysis of the test ingredient was not done in this study. The AMEn of SP was 3263 and its AME 3279 kcal per kg DM was lower than 3468 and 3886 kcal per kg DM reported by [4] and [10] when 40% sun dried meal or 40% oven dried sweet potato meals were substituted in a basal diet. The AME values reported by those authors were lower than that of SPF.

The method used to process the meals in the present study could have resulted in the AME variations since frying and cooking increased the AME compared to just oven drying. It is possible that the oil from frying might be a source of extra calories for the SPF meal thus increasing its AME value. Cooking and frying may have gelatinized the starch which would increase the accessibility to digestive enzymes resulting in the release of more glucose calories which would increase the CSP and SPF AME values.

Raw diet sweet potato has been reported to contain trypsin inhibitors ranging from 32 to 2.8 TIU per gram of sample [12]. It is highly probable that the SP by-product contained more trypsin inhibitors which could reduce the animal’s ability to release the starch from the storage vacuole composed of a protein membrane which must first be hydrolyzed before the starch can be release. The application of heat and moisture during the cooking and frying process may have inactivated the trypsin inhibitors present in CSP and SPF which enhanced their digestibility values. Raw sweet potato has also been reported to contain oxalate in a water soluble form which tends to leach out upon cooking [12]. Sweet potatoes that were sun dried have been reported to be a good energy source and feeding it to broiler at 30% of the diet hand no negative effects on performce and digestive tract physiology [3]. This may indicate that oxalate and trypsin inhibitors levels in sweet potatoes varieties available in North America might be too low to cause any adverse effects when sun dried tubers were fed the broilers chicken.

4. Conclusion

Digestibility AMEn values were developed for SP, CSP, and SPF using a current boiler line. It was clear from this study that not all sweet potato by-products had the same nutritive value. The method of processing had a significant impact on the nutritive value of the meals. Future research is needed to identifying the best inclusion levels for each meal. Diet can be formulated for starter, grower and finisher phase using the AMEn values established in this study.

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