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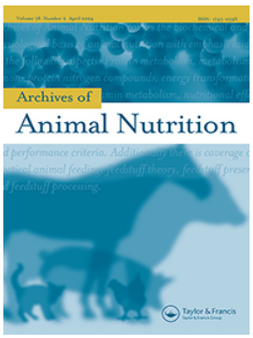

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Investigations into the chemical composition and nutritional value of different batches of rapeseed meals for turkey poults

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ABSTRACT

A study was conducted to investigate the chemical composition and feeding value of rapeseed meal (RSM) batches produced at the same plant when fed to turkey poults. In total, seven RSM samples were obtained from a single manufacturer within a period of 90 days. Although the manufacturer followed the same procedures during oil extraction and RSM production, different batches of rapeseed were used. A balancer feed (BF) was formulated to contain 11.85 MJ/kg ME and 265 g/kg crude protein. Seven nutritionally complete test mash diets were prepared by mixing 200 g/kg of each RSM batch sample with 800 g/kg of the BF, totalling 8 diets. Diets were fed to female B.U.T. Premium turkeys from 12 to 21 d of age. Each diet was fed to six raised floor pens, housing two birds, following randomisation. During the experiment, a nitrogen corrected apparent metabolisable energy (AMEn) assay was performed using a total collection technique. The AMEn in RSM samples was calculated based on the differences between the AMEn values of basal and test diets. Associations were examined between AMEn and the chemical composition of the RSM samples. The overall determined AMEn value of the RSM ranged from 5.50 MJ/kg DM to 8.53 MJ/kg DM, giving an average AMEn of 7.29 MJ/kg DM. There was no difference ($p > 0.05$) in AMEn content between batches. There was a negative correlation ($r = -0.864$; $p < 0.05$) between AMEn values and the neutral detergent fibre (NDF) content of the RSM samples. The results suggest that the NDF could be a good predictor of the AMEn of industry produced RSM. It may be inferred that processing rather than cultivar could be the main factor determining the feeding value of RSM for turkeys.

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Turkeys; nutrient composition; metabolisable energy; rapeseed meal; batch variability

1. Introduction

Oilseed rape (*Brassica napus*) is the third-largest source of vegetable oil in the world (Mielke 2018), with the highest production quantities being in Europe and Canada (USDA 2022). Rapeseed meal (RSM) is a by-product of oil production from oilseed rape and due to its relatively high well-balanced protein content (36–40%) is used in poultry nutrition (Watts et al. 2021). Compared to soya bean meal (SBM), RSM has

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a relatively low environmental footprint; thus, its use in poultry diets could be a viable tool for reducing the negative impact associated with global warming (Wilke et al. 2023). Both protein content and available energy values, e.g. nitrogen corrected apparent metabolisable energy (AMEn), are important characteristic in determining the feeding value of RSM. Understanding of AMEn content of RSM allows precise dietary formulation that meet the energy requirements of turkeys and optimise production outputs. However, there is limited data on RSM nutritive values for turkeys and the variability in AMEn that exists between RSM produced from modern rapeseed cultivars, leaving only tabulated data as the key source of information (Kasperzak et al. 2016; Olukosi et al. 2017). In addition, much of this data has been gathered over time from multiple locations outside of the UK and often using historical rather than modern rapeseed cultivars (Houdijk et al. 2017), limiting their value to UK feed formulators.

Chemical composition and nutrient availability of feed ingredients varies due to several major factors, including crop husbandry/crop nutrition, location, seasonal factors and genetics (Rodehutscord et al. 2016; Adewole et al. 2017; Azhar et al. 2019). In addition, by-products such as RSM are particularly prone to increased variability in nutritional values due to differences in primary processing (Oghbaei and Prakash 2016) and the manufacturing practices between crushing facilities (Adewole et al. 2016; Watts et al. 2020, 2021). These factors (agronomic and processing) may result in batch variation, even within the same processing plant, although information in the public domain is limited on this topic.

The metabolisable energy (ME) system is widely used to describe the available energy in feeding stuffs for poultry. Although some other systems, e.g. net energy, theoretically may provide more accurate information on available energy, it is more challenging to obtain; thus, for a global comprehensive standardisation of the energetic feed evaluation, the ME system still has preference (Hoffmann 1998). Additivity of ME is a crucial consideration in poultry dietary formulations. It is assumed that the supply of ME in a complete diet is equal to the sum of the supply based on the ME values obtained from the single ingredients (Hong et al. 2002). Most importantly, when the dietary ME-level changes, the feed intake will also change, and the specifications for other nutrients must be modified to maintain the required intake. Therefore, the dietary ME level is often used as the starting point in the formulation of practical diets for poultry.

The main objective of the current study was to determine the AMEn of 7 batches of RSM produced at the same plant when fed to turkeys. The total tract dry matter retention (DMR) and nitrogen retention (NR) coefficients of all diets were also determined. The associations between AMEn and chemical and physical measurements of the RSM were also studied.

2. Materials and methods

2.1. Ethics and compliance

The study was performed at the National Institute of Poultry Husbandry (NIPH) and approved by the Research Ethics Committee of Harper Adams University, UK (Project

number 0197-201803-STAFF). The birds were reared in compliance with the UK Code of Practice for the welfare of meat chickens and meat breeding chickens (DEFRA 2018).

2.2. Rapeseed meal samples

Different samples of RSM were obtained from the same manufacturer (ADM, Liverpool, UK) following the same production procedures to investigate the variation among batches. The sampling interval was between 14 and 21 d during a period of 90 d from January to April 2018, yielding seven samples in total. All samples were stored in bags at ambient air temperature in a dry store. The stored RSM samples did not experience any freezing temperatures during storage. A representative sample was taken from each of the seven batches, and the major chemical components were measured. Although the manufacturer followed the same procedures during oil extraction and RSM production, different batches of rapeseed were used.

2.3. Dietary formulation

A wheat-based basal feed (BF) was prepared in a commercial feed mill (Target Feeds Ltd, Shropshire, SY13 2DX) to contain: wheat (477.6 g/kg), SBM (320 g/kg) and prairie meal (50 g/kg) as main ingredients (Table 1). Seven additional diets were then produced including 200 g/kg of one of the seven different batches of RSM and 800 g/kg of the BF. A total of eight experimental diets were compared, including the BF, with all diets fed as mash. All diets approximately met or exceeded the dietary specifications for BUT Premium turkeys (Aviagen, Turkeys Ltd, UK; Publication Number: NU22/EN Version 1; available from: https://www.aviagenturkeys.com/en-gb/documents). Diets did not contain any coccidiostat, antimicrobial growth promoters, prophylactic or other similar additives.

2.4. Experimental design

Female B.U.T. Premium turkeys were obtained from a commercial hatchery (Faccenda Foods Ltd., Dalton, UK) at day old and were placed in a single floor pen, bedded on wood shavings, and fed the BF until 12 d of age. Two birds were then randomly allocated to one of 48 raised floor pens with a wire mesh floor, providing 0.36 m^2 floor area, and presented with the experimental diets. Each diet was fed to six pens following randomisation. Each pen was equipped with a trough feeder and nipple drinker. Access to the feed and the water was *ad libitum*. The experimental house was equipped with a negative pressure ventilation system to meet commercial recommendations. Standard temperature (27°C to 25°C) and lighting programmes (8 h dark : 16 h light) for turkeys were used (Aviagen, Turkeys Ltd., UK; Publication Number: CL23/EN Version 3; available at: https://www.aviagenturkeys.com/en-gb/documents). At 17 d of age, after 5 d adjustment to the diets, the total excreta were collected for 4 d, at 24 h intervals, immediately frozen and pooled at the end of the study (21 d age). Following the last collection, samples were oven-dried at 60°C and then milled. Feed intake (FI) for the same period was recorded for the determination of dietary AMEn and total tract nutrient retention coefficients.

Table 1. Ingredients and composition of the experimental basal diet (on as-fed basis)*.

Ingredients	Contents [g/kg]
Wheat	477.6
Prairie meal	50.0
Rye	20.0
Rapeseed meal	50.0
Soyabean meal (HiPro)	320.0
L-Lysine HCl	5.0
DL-methionine	4.0
L-threonine	1.4
Soya oil	20.0
Limestone flour	10.0
Dicalcium phosphate flour	35.0
Salt	3.0
Turkey premix†	4.0
Calculated nutrients	
Metabolizable energy [MJ/kg]	11.85
Ether extract [g/kg]	35.7
Crude protein [g/kg]	265.2
Lysine [g/kg]	16.8
Methionine + Cysteine [g/kg]	12.2
Ca [g/kg]	13.9
P available [g/kg]	7.8
Determined values‡	
Apparent metabolisable energy [MJ/kg]	12.21
Ether extract [g/kg]	34.8
Crude protein [g/kg]	243.0
Gross energy [MJ/kg]	16.81
Dry matter [g/kg]	885

*This basal diet was fed as a part of a complete diet comprising 200 g/kg of each experimental RSM sample and 800 g/kg of the balancer. Each experimental diet met or exceeded the diet specification for this strain of turkeys poults (Aviagen, Turkeys Ltd, UK); †contained vitamins and trace elements to meet breeder's recommendation (Aviagen, Turkeys Ltd, UK) and provided per kg diet: 50 mg nicotinic acid, 34 mg α-tocopherol, 15 mg pantothenic acid, 7 mg riboflavin, 5 mg pyridoxine, 3.6 mg retinol, 3 mg menadione, 2 mg thiamine, 1 mg folic acid, 200 µg biotin, 125 µg cholecalciferol, 15 µg cobalamin, 100 mg manganese, 80 mg iron, 80 mg zinc, 10 mg copper, 1 mg iodine, 0.5 mg cobalt, 0.5 mg molybdenum and 0.2 mg selenium; ‡laboratory analyses were performed in duplicate.

2.5. Laboratory analysis of rapeseed meal, feed and excreta samples

All samples were milled to pass through a 0.75-mm sieve (Cyclone mill twister, Retsch, GmbH, Haan, Germany). Dry matter (DM) in BF, RSM and excreta samples was determined by drying the samples overnight in a forced draft oven set at 105°C (AOAC 2006: Method 934.01). The Dumas, combustion method (Leco FP-528N, Leco Corp., St. Joseph, MI) was used to determine the total nitrogen content of BF, RSM and excreta with EDTA as a calibration standard (AOAC 2006: Method 968.06). Crude protein was calculated as nitrogen (N) x 6.25. The gross-energy (GE) of the BF, RSM and excreta samples were determined by isoperibol bomb-calorimeter (Model 6200, Parr Instrument Co., Moline, IL) with benzoic acid as an internal standard. Ether extract (EE) in BF and RSM was determined by Soxhlet extraction with petroleum ether (AOAC 2005). Neutral detergent insoluble N (NDIN) in RSM was measured according to Licitra et al. (1996) with results presented as g/kg DM. The neutral detergent fibre (NDF) in RSM were determined using FibertecTM apparatus (FOSS FT 122 Fibertec, Foss Analytical, Hilleroed, Denmark) following Van Soest et al. (1991) procedure. Samples

were assayed with a heat stable amylase and expressed exclusive of residual ash. Total glucosinolate (GLS) content of RSM was determined using high performance liquid chromatography (1992). Total (T), soluble (S) and insoluble (I) non-starch polysaccharides (NSP) in RSM were analysed as described by Englyst et al. (1994).

2.6. Calculations

The AMEn of the diets was calculated as described by Hill and Anderson (1958). The coefficients of total tract dry matter retention (DMR) and nitrogen retention (NR) were determined as the difference between intake and excretion of the nutrient, divided by their respective intake (Oduguwa et al. 2007).

The AMEn content of RSM batches was determined as follows:

$$AMEn(RSM) = \frac{\text{AMEn of RSM diet} - \text{AMEn of Basal feed} * 0.8}{0.2}$$

where 0.8 is the proportion of Basal feed diet in RSM diets and 0.2 is the proportion of RSM in the RSM diets, respectively.

2.7. Statistical analysis

Data were compared statistically using a randomised block one-way ANOVA (Genstat 23rd release 3.22 for Windows, IACR, Rothamsted, Hertfordshire, UK) with the following equation:

$$Y_{ijk} = X + B_i + T_i + e_{ijk}$$

where Y is any individual observations; X is the overall mean; B is the block effect (i = number of blocks in experiment was 6); T is the treatment group (j = number of treatments in the experiment was 8); e is the error term (residual variation). Treatment groups were the 8 diets (7 RSM-based diets and the BF). Correlation coefficients were also generated to determine the extent of any possible associations between the chemical composition and the AMEn of the 7 different RSM batches.

3. Results

Tables 2 and 3 detail the chemical analyses of the experimental RSM batch samples. In brief, the average gross energy (GE) was 17.50 MJ/kg, with the lowest being 17.24 MJ/kg (batch A) and the highest being 17.87 MJ/kg (batch G; CV = 1.1%). The mean protein content was 344 g/kg (CV = 1.8%), as batch B had the lowest (335 g/kg) and batch C had the highest (353 g/kg) crude protein content. There was a range of EE contents, the lowest being 36 g/kg (batch C) and the highest being 48 g/kg (batch B and E; CV = 11.3%). The average NDIN was 16.61 g/kg, with the lowest being 15.98 g/kg (batch D) and the highest being 17.52 g/kg (batch B; CV = 2.8%). The mean NDF content was 353 g/kg (CV = 1.8%), as batch E had the lowest (342 g/kg) and batch B had the highest (364 g/kg) NDF content. The mean total NSP 224 g/kg (CV = 1.3%), with the lowest 218 g/kg (batch E) and highest 227 g/kg (batch C). The average soluble

Table 2. Chemical composition and gross energy (GE) content of experimental rapeseed meals (RSM).

RSM batch	DM [g/kg]	GE [MJ/kg]	CP [g/kg]	EE [g/kg]	NDIN [g/kg DM]	NDF [g/kg]	NSPs [g/kg]	NSPins [g/kg]	NSPt [g/kg]	GLS [umol/g]
A	880	17.24	336	40	16.63	355	62	163	225	4.48
B	880	17.42	335	48	17.52	364	56	171	226	4.20
C	880	17.50	353	36	16.20	354	58	169	227	6.50
D	880	17.33	346	38	15.98	354	56	166	222	4.00
E	890	17.58	344	48	16.86	342	57	162	218	3.30
F	880	17.56	349	37	16.50	347	57	169	226	5.14
G	890	17.87	346	44	16.61	353	51	174	225	5.57
Mean	883	17.50	344	42	16.61	353	57	168	224	4.74
CV%	0.5	1.1	1.8	11.3	2.8	1.8	5.3	2.4	1.3	21.0

DM, dry matter; CP, crude protein; EE, ether extract; NDIN, neutral detergent insoluble nitrogen; NDF, neutral detergent fibre; NSPs, soluble non-starch polysaccharides; NSPins, insoluble NSP; NSPt, total NSP; GLS, total glucosinolates; CV%, coefficient of variation; Mean and CV% are calculated for the 7 experimental RSM samples.

Table 3. Carbohydrate content of different sugar fractions of the rapeseed meal (RSM) samples (g/100 g)*.

RSM batch	Carbohydrates	rha	fuc	ara	xyl	man	gal	glu	GlcA	GalA	g/100 g
A	Soluble	0.1	0.2	1.4	0.3	0.6	0.9	0.8	0.0	1.9	6.2
B	Soluble	0.1	0.2	1.3	0.3	0.5	0.7	0.7	0.0	1.8	5.6
C	Soluble	0.1	0.2	1.3	0.3	0.5	0.8	0.8	0.0	1.8	5.8
D	Soluble	0.0	0.2	1.2	0.2	0.6	0.7	0.8	0.0	1.8	5.6
E	Soluble	0.0	0.1	1.3	0.3	0.6	0.7	0.7	0.0	2.0	5.7
F	Soluble	0.0	0.1	1.4	0.4	0.6	0.6	0.6	0.0	2.1	5.7
G	Soluble	0.0	0.1	1.3	0.3	0.5	0.7	0.3	0.0	1.9	5.1
	Mean	0.04	0.16	1.31	0.30	0.56	0.73	0.67	0.00	1.90	5.67
	CV%	1.25	0.34	0.05	0.19	0.10	0.13	0.27	0.00	0.06	0.06
A	Insoluble	0.1	0.0	3.4	1.6	0.3	1.3	6.4	0.0	3.2	16.3
B	Insoluble	0.1	0.0	3.5	1.6	0.4	1.4	6.6	0.0	3.4	17.1
C	Insoluble	0.1	0.0	3.5	1.6	0.4	1.4	6.5	0.0	3.3	16.9
D	Insoluble	0.1	0.0	3.5	1.7	0.4	1.4	6.4	0.0	3.1	16.6
E	Insoluble	0.1	0.1	3.5	1.6	0.3	1.3	6.2	0.0	3.0	16.2
F	Insoluble	0.2	0.0	3.5	1.6	0.5	1.4	6.6	0.0	3.2	16.9
G	Insoluble	0.2	0.0	3.6	1.6	0.4	1.4	6.8	0.0	3.3	17.4
	Mean	0.13	0.01	3.50	1.61	0.39	1.37	6.50	0.00	3.21	16.77
	CV%	0.38	2.65	0.02	0.02	0.18	0.04	0.03	0.00	0.04	0.03
A	Total	0.2	0.2	4.9	1.9	0.9	2.1	7.2	0.0	5.1	22.5
B	Total	0.2	0.2	4.8	1.9	0.9	2.1	7.4	0.0	5.2	22.6
C	Total	0.2	0.2	4.8	1.9	0.9	2.2	7.3	0.0	5.1	22.7
D	Total	0.2	0.2	4.8	1.9	0.9	2.1	7.2	0.0	5.0	22.2
E	Total	0.2	0.1	4.8	1.9	0.9	2.0	6.9	0.0	5.0	21.8
F	Total	0.2	0.1	4.8	1.9	1.1	2.1	7.1	0.0	5.3	22.6
G	Total	0.2	0.1	5.0	1.9	0.9	2.1	7.1	0.0	5.2	22.5
	Mean	0.20	0.16	4.84	1.90	0.93	2.10	7.17	0.00	5.13	22.41
	CV%	0.00	0.34	0.02	0.00	0.08	0.03	0.02	0.00	0.02	0.01

*All data are the results of a chemical analysis conducted in duplicate; rha, rhamnose; fuc, fucose; ara, arabinose; xyl, xylose; man, mannose; gal, galactose, glu, glucose; GlcA, glucuronic acid; GalA, galacturonic acid; CV%, coefficient of variation.

NSP content was 57 g/kg (CV = 5.3%), as batch G had the lowest (51 g/kg) and batch A had the highest (62 g/kg) soluble NSP content. Batch G had the highest insoluble NSP content (174 g/kg) although batch E had the lowest one (162 g/kg, CV = 2.4%). There was a range of glycosylates (GLS) concentration with 3.3 g/kg the lowest (batch E) and 6.5 g/kg the highest (batch C; CV = 21.0%).

Detailed information on the carbohydrates in different sugar fractions of the RSM samples is presented in Table 3. The main soluble NSP sugar fraction was arabinoxylan

Table 4. Production performance, nutrient retention coefficients and metabolisable energy of diets and rapeseed meal samples (A–G) fed to young turkeys.

	FI [g/b/d]	WG [g/b/d]	FCR [g:g]	BW 21d [g]	DMR	NR	AMEn [MJ/kg DM]	AMEn RSM [MJ/kg DM]
Basal	48.1	33.6	1.433	522	0.645[a]	0.623[b]	13.63[a]	–
A	49.3	29.5	1.683	483	0.585[b]	0.546[a]	12.39[b]	7.36
B	49.6	29.5	1.740	486	0.555[b]	0.520[a]	12.01[b]	5.50
C	50.0	30.2	1.657	492	0.576[b]	0.539[a]	12.39[b]	7.44
D	50.3	30.4	1.659	499	0.569[b]	0.532[a]	12.20[b]	6.43
E	49.3	28.9	1.810	475	0.582[b]	0.540[a]	12.52[b]	8.09
F	48.2	29.9	1.629	483	0.588[b]	0.557[a]	12.60[b]	8.53
G	48.4	30.4	1.596	492	0.570[b]	0.539[a]	12.45[b]	7.69
Mean	49.2	30.3	1.651	491.5	0.584	0.550[a]	12.52	7.29
SEM	0.84	1.25	0.1158	11.4	0.0138	0.0158	0.223	1.023
CV%	4.2	10.1	17.2	5.7	5.8	7.1	4.4	34.4
p	0.481	0.292	0.512	0.174	0.004	0.003	<0.001	0.440

g, grams; b, bird; d, day; MJ, megajoules; FI, feed intake; WG, weight gain; FCR, feed conversion ratio; RSM, rapeseed meal; DMR, dry matter retention; NR, nitrogen retention; AMEn, nitrogen corrected apparent metabolisable energy; each value represents mean of eight replicate pens of two turkeys poults each; FI, WG and FCR were obtained during the entire study period; AMEn, DMR and NR coefficients were determined during the 4 last days of the study; SEM, pooled standard error of the mean; CV%, coefficient of variation; [a,b,c] Values within a column with different superscripts differ significantly at $p \leq 0.05$.

(13.1 g/kg; CV = 0.05%) with the lowest 12 g/kg (batch D) and highest 14 g/kg (batch A and F). Glucose was the main carbohydrate constituent determined in the insoluble (average 65 g/kg, CV = 0.03%; with the lowest 62 g/kg, batch E; highest 68 g/kg, batch G) and in the total (average 71.7 g/kg, CV = 0.02%; batch E lowest 69 g/kg and batch B highest 74 g/kg) fractions.

The results of feed intake (FI), AMEn of RSM and diets and dietary nutrient retention coefficients are shown in Table 4. There were no differences ($p > 0.05$) in FI, weight gain (WG), feed conversion ratio (FCR) and body weight (BW) of the turkeys fed different diets. The AMEn value of the RSM containing diets varied from 12.01 MJ/kg DM (batch B) to 12.60 MJ/kg DM (batch F; $p > 0.05$). The overall dietary DMR, including basal feed, was 0.584, as DMR of basal feed was higher ($p < 0.05$) compared to diets based on RSM batches. There were no differences in NR between the diets ($p > 0.05$). The mean determined AMEn value of the RSM batches was 7.29 MJ/kg.

Table 5. Selected correlation coefficients between the determined AMEn and compositional profile of rapeseed meal (RSM) samples when fed to turkeys.

	AMEn	N	EE	GLS	NDF	NSP s	NSP ins	NSP t
N	0.549							
EE	−0.285	−0.601						
GLS	0.231	0.589	−0.588					
NDF	**−0.864**	−0.511	0.067	0.165				
NSPs	0.038	−0.279	−0.310	−0.154	0.015			
NSP ins	−0.189	0.208	0.001	0.610	0.434	−0.732		
NSP t	−0.169	0.072	−0.455	**0.777**	0.608	0.037	0.646	
NDIN	−0.355	−0.709	**0.824**	−0.359	0.339	−0.063	0.151	0.019

Differences between treatments are statistically significant when $p \leq 0.05$. $p < 0.1$ ($r \geq 0.669$; $0.753 \leq r$); $p < 0.05$ ($r \geq 0.754$; $0.873 \leq r$); $p < 0.01$ ($r \geq 0.874$).

AMEn, nitrogen corrected apparent metabolisable energy (MJ/kg DM) in RSM; N, nitrogen in RSM (g/kg DM); Fat, as ether extract (EE) in RSM (g/kg DM); GLS, glycosylates in RSM (umol/g); NDF, neutral detergent fibres in RSM (g/kg DM); NSP tot, NSP ins and NSP sol, is respectively total, non-soluble and soluble non-starch polysaccharide contents in RSM (g/kg DM); NDIN, neutral detergent insoluble nitrogen (g/kg DM).

Table 5 shows the correlation coefficients between the determined AMEn and the compositional profile of the experimental RSM samples, when fed to turkeys. There was a negative correlation ($r = -0.864$; $p < 0.05$) between AMEn and NDF content of the RSM samples. A negative correlation existed between N and NDIN ($r = -0.709$; $p < 0.1$). There was a positive correlation between EE and NDIN ($r = 0.824$; $p < 0.05$) and GLS and NSPt ($r = 0.777$; $p < 0.05$).

4. Discussion

The feeding value of rapeseed can be influenced by genotype, climate, agronomic practices, and their interactions (Abbadi and Leckband 2011; Hu et al. 2013; Nowosad et al. 2017). However, the rapeseed cultivars used to produce the studied RSM samples and the conditions of cultivation were unknown, but obtained from commercial farm. The chemical composition of the RSM samples used in this study was within the range that is generally reported in the literature (Woyengo et al. 2010; Adewole et al. 2016; Olukosi et al. 2017). Watts et al. (2021) also reported a similar chemical composition and AMEn of industry produced RSM samples, but the composition of a laboratory obtained single-cultivar RSM was different. However, there was no difference within the AMEn values of laboratory produced single-cultivar RSM (Watts et al. 2021), suggesting that processing may equalise the feeding value due to neutralisation of most of the antinutrients and equally diluting fat content.

The GLS content of the RSM samples had the greatest variability within the parameters analysed but were within the ranges reported for other commercially produced RSM (Adewole et al. 2016; Olukosi et al. 2017; Watts et al. 2021). All of the studied RSM samples had a GLS content of <30 umol/g, suggesting that they were produced from "00" cultivars (Canola Council of Canada 2009). Variations in the GLS contents of batches did not have an impact on the energy value of the RSM, a finding which supports that of Olukosi et al. (2017) and Watts et al. (2021).

Pre-press solvent extraction is the most widely used commercial oil recovery method (Canola council of Canada 2015), where the rapeseed is exposed to high temperature, high pressure and processed with hexane. Prolonged exposure to high temperatures can damage the protein fraction of the RSM and increase the levels of indigestible fibre, which may increase binding of nitrogenous components to fibre and phenolic constituents (Mosenthin et al. 2016; Salazar-Villanea et al. 2016). Heat damaged protein in RSM may produce a similar amount of NDIN, however the N proportion between batches may remain, thus possibly explaining the negative correlation observed. Eklund et al. (2015) found that during desolventizer/toaster phase the level of NDF and NDIN increased but the reactive lysine and lysine:CP ratios decreased. The same authors (Eklund et al. 2015) suggested that the feed industry would most likely benefit from a rapid and accurate prediction of amino acid digestibility based on the content of NDIN in different batches of RSM used for feed manufacturing. Although amino acid content/digestibility of RSM samples were not determined, those finding suggest that lysine is unlikely to be involved in the prediction of the metabolisable energy values in the current report.

The average AMEn content of the 7 batches of commercially produced RSM used in the current study was 7.29 MJ/kg DM, which is a similar value as previously reported with turkeys (Kozlowski et al. 2018) and with chickens (Jia et al. 2013; Olukosi et al. 2017; Watts

et al. 2021). The metabolisable energy in feedstuffs is a measurement of the available energy in carbohydrates, fats and proteins (Leeson and Summers 2001). However, Abdollahi et al. (2021) report that in protein sources, correcting AME for nitrogen may lead to an underestimation of energy values. In addition, their results (Abdollahi et al. 2021) identified inconsistencies in metabolisable energy based on differences in methodologies used. Regarding RSM, it has been suggested that the main predictors of metabolisable energy are the contents of EE (Olukosi et al. 2017) and fibre (Adewole et al. 2017; Watts et al. 2021). Newkirk et al. (2003) also suggested that the relatively low AMEn content of industry produced RSM may be due to its lower protein digestibility and higher NDF content. In the present study, applying the substitution method increased the variability in AMEn values obtained for the different RSM samples and likely reduced the sensitivity of the statistical analysis.

Based on the results of the correlation analysis in our study, there is some suggestion that NDF could be a good predictor of the AMEn of RSM. It is widely accepted that the anti-nutritional effect of high fibre diets is due to raised viscosity of gut contents and modulated microflora (Amerah et al. 2009). An increase in intestinal digestive viscosity is associated with enhanced bacterial fermentation, reduced digestion and absorption of nutrients by the host (Bedford 2018). High dietary fibre content may also be a reason for increased endogenous losses and encapsulation of nutrients, which makes them less accessible to digestive enzymes (Bedford et al. 2024). All of the mentioned factors may decrease the AMEn content of RSM samples. In support, research by Clark et al. (2001) reported higher AMEn values for dehulled RSM compared to standardly produced RSM suggesting that lower fibre content can improve the energy utilisation of the RSM.

5. Conclusion

The range of variation in the AMEn of industry-produced rapeseed meal batches was low, as were differences in their chemical compositions and GE content. There was no significant difference in AMEn content between batches. This suggests that processing, rather than cultivar could be the main driver of variation in nutritional value of RSM when fed to turkeys. There was a negative correlation between AMEn values and NDF content in RSM. Experiments involving more samples and obtained from different crushing plants may provide wider and robust data set.

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