Nutrition 31 (2015) 1141–1147

Contents lists available at ScienceDirect

Nutrition

journal homepage: www.nutritionjrnl.com

Basic nutritional investigation

Soluble arabinoxylan alters digesta flow and protein digestion of red meat-containing diets in pigs

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ARTICLE INFO

Article history:
Received 12 December 2014
Accepted 15 March 2015

Keywords:
Arabinoxylan
Intestinal retention time
Protein digestion
Microbial biomass
Water-holding capacity
Pig model

ABSTRACT

Objectives: The aim of this study was to investigate how a moderate increase in dietary meat content combined (or not) with soluble fibre would influence protein digestion as well as digesta characteristics and flow.
Methods: Four groups of pigs were fed Western-style diets (high-protein/high-fat) containing two types of barbecued red meat, one with and one without a wheat arabinoxylan-rich fraction. After 4 wk, digesta samples were collected from small and large intestinal sites and analyzed for protein, amino acids, dry matter, and acid-insoluble ash. Tissue samples were also collected from each site.
Results: Arabinoxylan consumption led to somewhat lower apparent protein digestibility within the small and large intestines as well as shorter mean retention times. This suggests that the lowered protein digestibility is due, at least partly, to shorter access time to digestive proteases and absorptive surfaces. Additionally, digesta mass was higher in pigs fed arabinoxylan while dry matter (%) was lower, indicating an increased digesta water-holding capacity due to the presence of a soluble dietary fiber.
Conclusion: Data showed that solubilized wheat arabinoxylan provides potential health benefits through decreased protein digestibility, increased digesta mass, and reduced mean retention time, even for diets with a moderately higher protein content. These factors are associated with efficiency of digestion and satiety, both of which have implications for prevention of obesity and other health disorders.

Introduction

There is great interest in the effect of dietary fiber (DF) and protein on human health. Protein is known to increase satiety, leading to improved weight control and body composition [1]. However, concerns also have been expressed for its various negative effects on health, such as its effects on colonic health [2] and the increase in weight gain in the case of long-term high levels of meat consumption [3].

Epidemiologic studies have shown that consumption of DF is associated with a lowered risk for diseases including colorectal cancer [4], cardiovascular disease [5], and diabetes [6]. However, these are mainly associations, and research is needed to elucidate the mechanisms by which specific fiber components (or their combinations) lead to physiological effects, particularly for diets varying in other macronutrients, such as protein.

Cereal grain DF consists largely of nonstarch polysaccharides (NSP) including arabinoxylan, (1,3;1,4)-β-glucans, and resistant starch. Little work has been done to investigate the effects,

The present study was supported by a grant from the CSIRO Flagship Collaboration Fund to the High Fibre Grains Cluster via the Food Futures Flagship.
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http://dx.doi.org/10.1016/j.nut.2015.03.006
0899-9007/

benefits, or both of arabinoxylan, the major soluble fiber present in wheat, particularly in relation to diets with differences in meat content. Until now, focus has been on grain insoluble fibers, especially for their fecal bulking action [7].

Potentially soluble arabinoxylan occurs in the cell walls of the endosperm and aleurone layers of wheat grains, comprising ~60% to 70% of the wall and ~3% of the whole grain [8]. Wheat-flour arabinoxylan consists of a β-(1,4)-linked D-xylose backbone with mono- and di-substitutions by α-l-arabinosyl residues [9]. Arabinoxylans exhibit natural variations in the arabinose-to-xylose ratio (A/X) and the pattern of substitution of the xylan backbone, which may influence solubility [10]. This distinguishes soluble arabinoxylan from the largely insoluble arabinoxylan in wheat bran.

Small intestinal benefits of NSP include slower carbohydrate digestion and uptake [11], reduced bile salt reabsorption [12], and enhanced feelings of satiety [13], although none of these effects has been investigated for arabinoxylan. NSP intake in the form of pectin is associated with decreased apparent protein digestibility, which is attributed partly to endogenous losses, such as increased secretions of saliva, mucus, or both [14,15]. Slower and more distal digestion is also associated with prolonged satiety, an effect referred to as the ileal brake. It has been proposed that these effects of soluble NSP result from their polymeric hydrocolloid nature [5].

With increased dietary meat protein intake, the presence of soluble DF might obviate some negative effects of red meat (RM) as it would enhance small intestinal water-holding effects, leading to other digestive changes. Our hypothesis was that addition of solubilized, well-defined arabinoxylan to a diet would increase the water-holding capacity of small intestine digesta and digesta flow (decreased retention times), leading to reduced protein digestion. A Western-style (high-protein/high-fat) diet was fed to pigs, building on data examining the effects of a range of DFs in similar diets [16,17], because the pig digestive system more closely resembles that of humans than the rodent digestive system [17–19]. Our aim was to quantify the effects of wheat arabinoxylan in high- and low-RM diets, in terms of both amino acid and protein digestibility, mean retention time, and other digesta characteristics of the small and large intestines.

Materials and methods

Animal procedures were approved by the Animal Ethics Committees of the University of Queensland and CSIRO Food and Nutritional Sciences (Animal Ethics Committee Approval Number: SAS/181/09/CSIRO-NF).

Animals and housing

Eight-week-old, Large White male pigs were housed in a temperature-controlled room (22°C ± 2°C), at the university (Gatton campus). Pigs were matched by weight and introduced to their experimental diet over a 7-d period with 10 pigs per diet. Pigs were housed in pens (five pigs per pen) according to diet, and moved to individual pens for feeding. They were monitored twice daily.

Experimental design

The experiment was split into two time periods, 6 wk apart, with 20 pigs per period. Four experimental diets were fed twice daily to pigs in each period (five pigs per diet per period), and the pigs had free access to water. Samples were collected after 4 wk on the diet.

Ingredients, diets, and feeding

An aqueous arabinoxylan-rich fraction (AXRF: Penfords, Tamworth, Australia), was dried using a low-temperature belt-drying process (NutraDry, Brisbane, Australia). This AXRF product was analyzed and found to comprise ~360 g/kg arabinoxylan, 320 g/kg starch, 110 g/kg protein, and 160 g/kg other components. Specific information related to NSP composition is shown in Table 1. The starch content of AXRF was accounted for in the diet formulation. Wheat bran (4%) was added to all diets to maintain laxation. The RM was rump steak, trimmed of fat and cooked on a hotplate until lightly browned. The meat was dried (NutraDry) as follows: after mincing (4 mm mincing plate), water was added (70 kg water/100 kg minced meat), and the resulting slurry was heat treated at 80°C for 2 min to avoid bacterial contamination and dried at 80°C. The dried product was milled through a 2- to 3-mm screen and packed into vacuum-sealed bags. The product contained 830 g/kg dry matter (DM) crude protein, 166 g/kg DM crude fat, and 915 g/kg DM.

Table 2 shows the composition of experimental diets. There were four experimental diets: low meat (LM) with and without added AXRF, and high meat (HM) with and without added AXRF. Celite (Celite Corporation, Lompoc, CA, USA) was added to each diet (20 g/kg) during the last week of feeding as the acid-insoluble ash (AIA) component, an indigestible marker. Daily feed allocation increased weekly, based on body weight.

Table 1
Arabinoxylan and (1:3;1:4)-β-D-glucan analysis of wheat bran and AXRF

	Wheat bran*	AXRF*
AX (% w/w)	21.9 ± 0.3	35.9 ± 0.8
Arabinose/xylose ratio	0.63 ± 0.011	0.61 ± 0.002
(1:3;1:4)-β-D-glucan (% w/w)	1.6 ± 0.04	1.7 ± 0.25

AX, arabinoxylan; AXRF, arabinoxylan-rich fraction
* Mean three replicates ± SD

Anesthesia

Each pig was sedated with an intramuscular injection of zolazepam/tiletamine (Zoletil; Virbac Pty. Ltd, Milperra, Australia) at 5 mg/kg combined drug, and methadone (Parnell Laboratories Pty. Ltd., Sydney, Australia) at 0.25 mg/kg. When sedated (~10 min), the pigs were masked with 2% isoflurane/oxygen. Thiopentone was administered intravenously, for tracheal intubation (50–150 mg total dose). Isoflurane maintained anesthesia until removal of the gastrointestinal tract (GIT). This regimen maintained GIT blood supply, until sacrifice by overdose of pentobarbitone sodium.

Sampling protocol

Pigs were fed 4 and 2 h before anesthesia to standardize collection time with feeding. After a midline laparotomy, the GIT (from pyloric sphincter to ~3 cm preanus) was ligated regularly using cable ties, to avoid digesta mixing. After removal, the cecum was isolated and the remaining large intestine (LI) subdivided into three parts: proximal, middle and distal colon (PC, MC, and DC). The small intestine (SI) was divided into four parts, 1 m from each end (SI-1 and SI-4, representing duodenum and ileum), whereas the remaining jejunum was halved (SI-2 and SI-3). All sections were measured and weighed (full and rinsed tissue). Digesta was removed per site. Samples for protein analysis were freeze-dried.

Table 2
Ingredients and composition of experimental diets (g/kg)

Ingredients (g/kg)	LM	LMAX	HM	HMAX
Meat	236	236	300	300
Tallow	49.9	49.9	40	40
Sunflower oil	88.5	88.5	88.5	88.5
AXRF	—	255	—	255
Wheat bran	40	40	40	40
Starch	511	256	457	202
Sucrose	70	70	70	70
NaCl	3	3	3	3
Vitamin/mineral premix	2	2	2	2
Determined composition (g/kg air-dry)				
Dry matter	928	941	935	949
Crude protein	168	205	215	235
Crude fat	202	198	192	198
Starch	444	301	414	250
Dietary fiber	15	138	13	141
Ash	34	40	35	45

AXRF, arabinoxylan-rich fraction; HM, high meat; HMAX, high meat with AXRF; LM, low meat; LMAX, low meat with AXRF