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The short-chain fatty acid content in the caecal digesta of rats fed diets with various sources of fibre*

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ABSTRACT

The contents of short-chain fatty acids (SCFA) in the caecal digesta of rats fed diets containing 4 or 10% cellulose (control diets) or 10% apple pulp (P), apple pulp (V), apple pectin, potato fibre or potato pulp were measured. The diets were fed for 27 days to 7 groups of 10 rats each. The animals were sacrificed and the caecum was removed, tissue and digesta weighed, and caecum analysed for SCFA. Caecal tissue and digesta weight, pool of acetic, and propionic acids were highest with pectin- and the lowest with cellulose diets, while potato fibre and apple pulp gave intermediate levels. The proportions of acetic acid were higher and butyric acid lower on pectin than on the other diets. It is concluded that fibre from plant by-products differs in ability to form short-chain fatty acids in the caecum of rats, which is reflected in the amount of fermentable material reaching the caecum.

KEY WORDS: dietary fibre, caecum, pH, SCFA, rat

INTRODUCTION

Fermentation of dietary fibre by the microorganisms in the large intestine leads to the production of short-chain fatty acids (SCFA), mainly acetic, propionic, butyric and valeric acid. Extensive fermentation of fibre decreases intraluminal pH and stimulates proliferation of caeco-colonic ephithelial cells. Lowering the pH in intestinal contents favours some bacterial species, which can reduce the growth of potentially harmful bacteria (Campbell et al., 1997).

The by-products of the vegetable and fruit industry are rich in dietary fibre that differs in its solubility and fermentability, as affected by its origin and technology. The purpose of this study was to investigate the effects of apple and potato by-products on caecal weight, pH and concentration of short-chain fatty acids in caecum digesta of rats.

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MATERIAL AND METHODS

Wistar rats, of initial mean body weight 60 g, were allotted to 7 groups of 10, and fed experimental diets for 27 days. The animals were housed in an environmentally controlled room, in individual plastic cages, with free access to water.

The diets contained, %: casein 12.3, maize starch 57, sugar 12, soyabean oil 4, mineral-vitamin mix 4.7, the control diets contained 4.0 or 10% cellulose, the experimental diets, 10% of the following fibre products: two different apple pulps (P and V), apple pectin, potato fibre, and potato pulp.

At the end of the experiment the animals were killed by overdosing CO_2. The caecum was removed and the empty caecum and its contents were weighed. The pH of the contents was measured and adjusted to 8.0. Caecal content was stored at -20ºC until analysed for SCFA by gas chromatography (Ziołecki and Kwiatkowska, 1973).

Statistical analysis of the results was performed using SPSS ver. 11.5.

RESULTS AND DISCUSSION

The type of fibre products did not affect feed intake. Caecum tissue and digesta weights ranged from 0.48 to 0.96 and 1.68 and 4.10 g, respectively, and

Table 1. Tissue and digesta weights of the caecum, content of acetic, propionic and butyric acids (μmol/caecum) and pH values of digesta in rats fed diets with various fibre sources

Diets	Tissue g	Digesta g	Acetic acid	Propionic acid	Butyric acid	pH
Cellulose, 4%	0.48^{B}	1.68^{B}	43.2^{B}	13.8^{B}	9.4^{b}	7.59^{A}
Cellulose, 10%	0.55^{B}	2.67^{B}	93.6^{BC}	22.2^{B}	27.4	7.25^{Ba}
Apple pulp (P)	0.51^{B}	2.20^{B}	98.0^{BC}	19.5^{B}	27.0	7.11^{Bb}
Apple pulp (V)	0.54^{B}	2.02^{B}	110.8^{BC}	19.9^{B}	29.2	6.96^{C}
Pectin	0.96^{A}	4.10^{A}	275.6^{A}	54.1^{A}	20.2	6.73^{D}
Potato fibre	0.56^{B}	2.66^{B}	179.3^{AC}	26.3^{B}	44.3^{a}	6.81^{CD}
Potato pulp	0.57^{B}	2.36^{B}	159.1^{C}	23.1^{B}	39.7	6.91^{C}

^{A,B,C}- $P<0.01$, ^{a,b}- $P<0.05$

were higher ($P\leq0.01$) in rats consuming pectin compared with the other treatments (Table 1). The content of acetic and propionic acids, expressed as μmol/caecum, were also greater ($P\leq0.01$) in rats fed the pectin diet. The ceacal content of butyric acid was the smallest in rats consuming the 4% cellulose diet and the highest in rats given the diet with potato fibre; the differences were significant ($P\leq0.05$).The pH values of caecal digesta in rats given the low-cellulose diet was slightly alkaline, (7.6) and higher ($P\leq0.01$) than on the other diets. The caecal digesta

of rats fed on the pectin diet had a lower pH (P≤0.01) than of those fed the other diets.

The caecal concentration (mmol/100 g digesta) of acetate was the highest (P≤0.01) on diets with pectin, potato fibre and potato pulp and lowest on cellulose diets, but butyrate was the lowest on pectin and cellulose diets (P<0.05) and the highest on potato fibre and pulp. Differences in concentrations of propionate were much less pronounced (Table 2).

Table 2. Concentrations (mmol/100g digesta) and proportions (% of sum) of acetic, propionic and butyric acids in caecal content of rats fed diets with various fibre sources

	Concentrations			Proportions		
Diets	acetate	propionate	butyrate	acetate	propionate	butyrate
Cellulose, 4%	2.58^{B}	0.83^{b}	0.56^{B}	62.4^{Bb}	20.0^{Aac}	13.6^{a}
Cellulose, 10%	3.43^{b}	0.83^{b}	1.01	62.8^{Bb}	15.8	18.9^{A}
Apple pulp (P)	4.55	0.91	1.24	66.1^{B}	14.2^{bc}	17.6^{A}
Apple pulp (V)	5.31	0.99	1.38	68.0^{B}	13.0^{B}	17.3^{A}
Pectin	6.73^{A}	1.31^{a}	0.49^{B}	77.8^{A}	16.1^{ab}	5.8^{Bb}
Potato fibre	6.72^{A}	1.01	1.64^{A}	70.5^{a}	10.7^{Bc}	17.2^{A}
Potato pulp	7.00^{Aa}	0.99	1.62^{A}	70.9^{a}	10.5^{Bc}	16.5^{A}

^{A,B,C,D} - P<0.01; ^{a,b,c} - P<0.05

Acetic acid formed the major metabolite with all of the fibre sources. Pectin gave the highest (P≤0.01) production of acetic acid (77.8%) and the lowest of (P≤0.01) butyric acid (5.8%), whereas apple pulp fibre resulted in the proportion of butyric acid being similar to the other fibre preparations. The proportion of propionic acid was the lowest (P≤0.01) with potato fibre, potato pulp and apple pulp and the highest (P≤0.01) in rats given the 4% cellulose diet.

The large production of acetic acid and low production of butyric acid with apple pectin were in agreement with earlier studies by Berggren et al. (1993) who showed similar proportions of these acids in the caecum of rats fed a diet containing pectin. The high caecal proportion of butyric acid on the apple pulp diets may be due to the differences in fibre matrix (Henningsson et al., 2002).

The products used in this experiment originated from apple and potato processing. With the exception of the apple pectin, which was 99% soluble, the other tested materials contained 42 to 63% insoluble and 6 to 18% DM of soluble fibre. The cellulose used in the control diets was mostly insoluble. The potato products gave high concentrations of butyric acid. This may be explained by the fact that some resistant starch could be present in those products and was fermented to butyric acid, as was shown in pigs (Martin et al., 1998; Henningsson et al., 2002). One of the most important properties of the SCFA is their trophic effect on the intestinal epithelium, with butyric acid considered to be the most effective and propionic acid, the least. Acetic, propionic and butyric acids are all

taken up by the colonic mucosa, though butyric acid is transported preferentially and appears to be the preferred energy source for the colonocytes, and may have a protective effect in the colon. The smallest content and proportion of butyric acids in the caecal digesta after feeding rats the pectin diet could indicate that this product may have a less protective effect in the colon.

CONCLUSIONS

It can be concluded that in rats, the extent of fermentation and the pattern of individual acids is dependent on the by-products fed. Potato fibre and potato pulp produced high amounts of butyric acid and may have greater trophic effect in the colon than other fibre sources.

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STRESZCZENIE

Lotne kwasy tłuszczowe w treści jelita ślepego szczurów żywionych dietami zawierającymi różne źródła włókna

Oznaczono zawartość i proporcje lotnych kwasów tłuszczowych (SCFA) w treści jelita ślepego szczurów żywionych dietami zawierającymi 4 lub 10% celulozy (diety kontrolne) oraz po 10% wytłoków jabłecznych P i V, pektyny jabłecznej, włókna lub pulpy ziemniaczanej. Siedem grup szczurów, po 10 sztuk w każdej, żywiono badanymi dietami przez 27 dni. Następnie szczury uśpiono, wypreparowano i zważono puste jelito ślepe i znajdującą się w nim treść. W treści oznaczono pH i zawartość SCFA. Masa jelita, masa treści i zawarte w niej kwasy octowy, propionowy i masłowy były największe u szczurów żywionych dietą z pektyną, najmniejsze przy podawaniu diety z 4% celulozy, a pośrednie przy żywieniu dietami zawierającymi włókno ziemniaczane i wytłoki jabłeczne. Stężenie i udział procentowy kwasu octowego był największy, a kwasu masłowego najmniejszy przy skarmianiu diety z pektyną. Wyniki te wskazują, że produkty odpadowe z przemysłu owocowego i ziemniaczanego różnią się podatnością na fermentację w jelicie ślepym szczura.