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Effect of the insoluble dietary fibre from oil palm fat-free flour on digestibility in rats

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Abstract

This work shows the results of comparing the effects of the insoluble dietary fibre from oil palm fat-free flour and cellulose on the growth, weight, humidity and composition of faeces in adult rats (Sprague–Dawley). Five groups of rats were fed for 4 weeks. The control group was fed with a diet free of fibre, and the remaining four groups with diets containing 50 or 100 g of either oil palm fat-free flour or cellulose, respectively. The adaptation period was 4 days. The evolution of growth and food intake did not vary significantly $p < 0.05$ regardless of the type of diet. On the other hand, faeces excretion increased by 3.3–4.7 g/day in the groups of rats fed with oil palm fat-free flour, while it increased by only 3.1–4 g/day in diets based on cellulose. A higher content of water was observed in the faeces of rats fed with insoluble dietetic fibre from oil palm fat-free flour. The apparent digestibility of the insoluble dietary fibre of oil palm fat-free flour was low (35%), showing resistance to fermentation. The digestibility of the protein tended to decrease more with the insoluble dietary fibre of oil palm than with the cellulose, which may be related. © 1999 Elsevier Science Ltd. All rights reserved.

Keywords: Oil palm; Flour; Insoluble dietary fibre digestibility; Rat

1. Introduction

Previous research has shown that the absence of fibre in the diet contributes to the development of many gastrointestinal disorders and chronic cardiovascular diseases, diabetes mellitus, obesity and certain types of cancer (Burkitt, 1969; Trowell, 1976). These studies raised great interest in fibre and, after two decades of research, dietary fibre (DF) is considered an important component of food with different effects and functions in the gastrointestinal tract (Anderson, Deakins, Floore, Smith, & Whitis, 1990; Mendeloff, 1987). The physiological action of DF has been shown to depend on some physicochemical characteristics, which are not related directly to its chemical composition, so that DF chemical analysis is not a good indicator of its physiological behaviour (Eastwood, Brydon, & Anderson, 1986).

It has been demonstrated that soluble dietary fibre (SDF) increases the time of intestinal transit (Brow, Worldeng, Rumsey, & Read, 1988), delays gastric emptying (Rainbird & Low, 1986) and glucose absorption (Holt, Heading, Carter, Prescott, & Totlhill, 1979; Todd, Berfield & Goa, 1990) and can alter lipid assimilation (Pasquier et al., 1996). Insoluble dietary fibre (IDF) decreases intestinal transit time and increases faecal mass (Schneeman, 1990). The mechanism by which DF increases faecal mass has not been completely defined, but the study suggests that the main factors involved are related to the ability of the fibre itself to retain water in the faeces, possibly associated with the numerous free polar groups of the sugar fractions and the increase in faecal bacterial mass resulting from fibre fermentation (Stephen & Cummings, 1980; Robertson & Eastwood, 1981). The short chain fatty acids (SCF) can affect the water and salt homeostasis inside the colon (Adiotomre, Eastwood, Edwards, & Brydon, 1990; Eastwood & Morris, 1992). One of the consequences of fibre intake that has been associated with viscosity, is a decrease in protein digestibility and an increase in nitrogen faecal excretion (Stephen, 1987). This effect has been observed when large grain wheat bran, fruit fibre, legumes and pectin (Kelsay, 1978; Cummings et al., 1978) are used as a source of DF Nevertheless, growing rats fed with diets that had different viscosities adjusted with carboxymethyl cellulose did not show significant differences in the apparent

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ileac digestibility of nitrogen (Larsen, Wilson, & Moughan, 1994).

Studies on new sources of DF and its physiological effects are being published constantly. One of the sources of IDF is oil palm fat-free flour (OPFFF) which contains 70% of IDF and only 1.1% of SDF. It has been used to enrich breads and crackers with fibre, adding 2.5 and 3.5%, respectively (Pacheco-Delahaye, Cedres, Alvarado, & Cioccia, 1994).

The present study evaluated the effect of IDF from OPFFF on the growth, faecal mass and humidity, IDF and protein digestibility in rats, as compared with rats fed with a diet free of fibre and those fed with cellulose as a source of IDF.

2. Materials and methods

The oil palm fat-free flour OPFFF, a gift from 'La Bananera Venezolana C.A.' (extraction by presser and hexane), was ground to 60 mesh and the cellulose (60 mesh) was purchased from 'Purina de Venezuela'.

Three-month-old adult male Sprague–Dawley rats were obtained from the rat colony of the Universidad Central de Venezuela (School of Medicine). The average weight of the animals was 230 g. They were randomly divided into five groups of eight rats each. The animals were located in individual cages with a normal cycle of 12 h light–darkness with constant air circulation. The temperature of the room was kept at 24–25°C with free access to food and water. Five different diets were prepared, one free of insoluble dietary fibre, two diets with 5 and 10% of IDF from OPFFF, and two diets with 5 and 101% of IDF from cellulose, an experimental procedure described by Bravo, Saura-Calixto, and Goni (1992). The composition of each diet is shown in Table 1. The food was prepared in the laboratory. The protein sources, minerals and vitamins were purchased from 'Purmia de Venezuela'. The corn oil and the starch were purchased from 'Maicina C.A.' The starch was substituted by IDF (5–10%). All five flour mixes were sifted through a 0.4-mm fine sieve. The adaption period to the diet was 4 days and the experimentation period lasted 21 days. Records of animal weight, ingestion of diets, water drunk and faecal weight were taken daily. To obtain their weight, faeces were dried (105°C), ground, and sifted to 0.4 mm.

2.1. Analytical methods

The IDF in diets and faeces was measured following the official method of AOAC (1990) according to the Prosky, Asp, Schweizer, De Vries, and Furda (1988), using the Sigma C.A. kit. The humidity and the protein (N×6.25) in diets and faeces were analysed according to the techniques of AOAC (1990). AB reagents were analytical grade.

The apparent digestibility of the protein, as well as of IDF, was calculated as the difference between the intake and the excretion in faeces and are expressed as a percentage of the intake:

$$[(\text{intake} - \text{excretion})/\text{intake}] \times 100.$$

This calculation was done during the second, third and fourth weeks of the experiment.

2.2. Statistical methods

The mean and standard deviation for each group were calculated and were compared using the one-way ANOVA, with the Turkey–Kramer test to evaluate differences among the groups. The results were considered statistically significant when $p < 0.05$.

3. Results and discussion

The addition of IDF did not have any effect on the weight of growing rats, nor the median of the food

Table 1
Composition of diets (g/100 g dry diet)

Ingredients	Fibre-free diet	IDE–OPFFF 5%	IDF–OPFFF 10%	IDF–cellulose 5%	IDF–cellulose 10%
Protein	20	20	20	20	20
DL-Methionine	0.3	0.3	0.3	0.3	0.3
Corn oil	5.0	5.0	5.0	5.0	5.0
IDF–OPFFF	–	5.0	10.0	–	–
IDF–cellulose	–	–	–	5.0	10.0
Mineral mixture (AIN 76)	3.5	3.5	3.5	3.5	3.5
Vitamin mixture (AIN 76)	1.0	1.0	1.0	1.0	1.0
Choline bitartrate	0.2	0.2	0.2	0.2	0.2
Corn starch	70	65	60	65	60

AIN, American Institute of Nutrition (1977); IDF, insoluble dietary fibre; OPFFF, oil palm fat-free flour.

ingested during the observation period of the experiment (Table 2). The weight gain was similar in all the groups receiving IDF when compared to the fibre-free diet group. These results were close to those reported by Bravo et al. (1992) with apple pulp dietetic fibre and by Nyman, Schweizer, Tyren, Reiman, and Asp (1990) with high fibre content vegetables (carrots, peas, Brussels sprouts and green beans). Nevertheless, it has been reported that diets supplemented with dietetic fibre reduce the density of metabolizable energy so that the voluntary intake of food increases to adjust to the caloric requirements (Lopez-Guisa, Harned, Dibielzig, Rao, & Marlett, 1988).

A statistically significant increase of faecal mass, produced as a consequence of the IDF quantity, is clearly observed (Table 3). The OPFFF–IDF increased the dried faecal mass from 3.3 to 4.7 g/day, when the IDF was raised in the diets from 5 to 10%, respectively. This increase was less (3.1–4 g/day) in the animals that had diets with 5–10% of cellulose IDF when compared to the results of fibre-free diets. Rats fed with 10% of wheat or rice bran dietetic fibre for 21 days, showed an increase in the faecal mass of 258 and 217%, respectively (Gestel, Besancon, & Rovanet, 1994). Linear correlations between the intake of dietetic fibre and faecal mass have been reported (Cummings, Bingham, Heaton, & Eastwood, 1992; Hansen, Bach, Knudsen, & Eggum, 1992; Hillman, Peters, Fischer, & Pomare, 1981; Prynne & Southgate, 1979) even though this increment can depend on the type of diet and the origin of the dietetic fibre (Edwards & Eastwood, 1995). The average daily intake of water was similar in all the groups ($p < 0.05$) but the humidity of the faeces showed significant differences according to the type of diet and increased with the quantity of insoluble dietetic fibre in the food. The faecal mass increase could be due to several factors. IDF from OPFFF produced a major increase in water content in faeces, from 0.82 to 1.51 g/day for the rats that were on diets with 5 and 10% IDF, respectively, compared with the fibre-free diet (0.29 g/day). Rats fed with cellulose had less water content in their faeces (0.69–1.08 g/day), showing that cellulose has a very low affinity for water, as had been previously demonstrated. This study corroborates previous observations which suggest that the greater the retention of water (caused by IDF intake), the greater the increase in the faeces weight (Robertson & Eastwood, 1981). Faecal mass increase could also be linked to the presence of IDF in the faeces. The diets with more IDF presented in significantly higher contents of IDF in the faeces (Table 4). The apparent digestibility of IDF from OPFFF (34.5%) was greater than that of cellulose (22.5%) and it does not seem to be related to the level of IDF. Analysis of the data indicates a great resistance to bacterial fermentation in the colon of rats fed with both insoluble fibres studied. Previous publications explain that low fermentation fibres like wheat bran, increase the faecal mass and that more fibre is found in the

Table 2
Effect of oil palm fat-free flour (OPFFF), insoluble dietetary fibre (IDF), and cellulose IDF on growth and food intake in rats

Dietary group	Initial weight[a]	Weight increase (g)[a]	Food intake (g day^{-1})[a]
Fibre-free	235 ± 20	38.5 ± 3.7	14.8 ± 1.2
OPFFF–IDF 5%	228 ± 25	38.8 ± 4.2	14.6 ± 1.8
OPFFF–IDF 10%	230 ± 22	39.3 ± 4.3	15.0 ± 1.6
Cellulose IDF 5%	237 ± 21	38.1 ± 3.3	14.5 ± 1.4
Cellulose IDF 10%	232 ± 27	38.9 ± 4.4	15.3 ± 1.7

Values represent mean ± standard deviation; $n = 8$ rats/group.
[a] Not significantly different.

Table 3
Effect of OPFFF–IDF and cellulose IDF on the faecal weight, humidity in faeces and water intake in rats

Dietary group	Faecal weight (dry) (g/day)	Humidity of faeces (g/day)	Water intake (ml/day)[a]
Fibre-free	1.5 ± 0.18d[b]	0.29 ± 0.05e[b]	31.5 ± 3.2
OPFFF–IDF 5%	3.34 ± 0.31c	0.82 ± 0.14c	31.8 ± 3.5
OPFFF–IDF 10%	4.78 ± 0.45a	1.51 ± 0.21a	32.2 ± 4.1
Cellulose IDF 5%	3.14 ± 0.22c	0.69 ± 0.15d	32.0 ± 3.8
Cellulose IDF 10%	4.05 ± 0.27b	1.08 ± 0.20b	32.4 ± 3.7

Values represent means ± standard deviation; $n = 8$ rats/group. OPFFF, oil palm fat-free flour; IDF, insoluble dietary fibre.
[a] Values not statistically different.
[b] Values with different letters are significantly different at $p < 0.05$.

Table 4
Apparent digestibility coefficient (ADC) of OPFFF–IDF, cellulose–IDF and protein

Dietary group	IDF intake (g/day)	IDF excreted (g/day)	ADC–IDF (%)	Protein intake (g/day)[a]	Protein excreted (g/day)	ADC–protein (%)
OPFFF–IDF 5%	83 ± 0.02b[b]	0.55 ± 0.02d	34.10 ± 2.6a	2.92 ± 0.41	0.3 ± 0.02c	88.7 ± 1.5a
OPFF–IDF 10%	1.61 ± 0.08a	1.00 ± 0.09b	35.40 ± 2.3a	3.00 ± 0.25	0.44 ± 0.09a	85.4 ± 2.5cb
Cellulose IDF 5%	0.85 ± 0.12b	0.67 ± 0.02c	22.20 ± 1.8b	2.90 ± 0.37	0.29 ± 0.04c	90.0 ± 2.3a
Cellulose IDF 10%	1.58 ± 0.05a	1.24 ± 0.10a	21.50 ± 2.0b	3.06 ± 0.32	0.40 ± 0.05b	87.0 ± 2.1b

Values represent mean ± standard deviation of 8 rats/group. OPFF, oil palm fat-free flour; IDF, insoluble dietary fibre.
[a] Values not statistically different.
[b] Values with different letters are significantly different at $p < 0.05$.

faeces (Wrick et al., 1983). On the other hand, highly fermented fibres increase the faecal mass because there is an increase in the bacterial mass (Cummings et al., 1978; Stephen, 1987). A correlation between fibre digestibility and the capacity of increasing the faecal mass has been observed (Hansen et al., 1992). When the apparent digestibility coefficient (ADC) of the protein was studied, significant differences were shown among the groups. As the level of IDF from OPFFF increased from 5 to 10%, the apparent digestibility of the protein decreased from 88.7 to 85.4%, respectively, and for the cellulose IDF it decreased from 90% at 5% to 87% at 10%. Compared to the OPFFF 5% diet, the cellulose IDF 5% does not significantly affect the digestibility of the protein. This effect has been observed with other types of dietetic fibre and many explanations have been offered. For some researchers it is due to the nitrogen indigestibility of the dietetic fibre (Van Soest, 1985) while others think it is caused by the increase of bacterial nitrogen in the faeces (Stephen, 1987; Stephen & Cummings, 1980). Other studies suggest that fibre blocks the access of digestive enzymes to absorbable compounds (Onning & Asp, 1995). In this study, the increase of nitrogen that was excreted might be caused by some compound associated with the OPFFF–IDF, and it might also be said that this IDF could decrease the activity of proteolytic enzymes, therefore decreasing the apparent digestibility of the protein. The absence of trypsin inhibitors in defatted oil palm flour (Pacheco-Delahaye, 1996) has been reported.

The main conclusions in this study are that OPFFF–IDF does not affect the growth or food and water intake in adult rats, but it causes a considerable increase in the mass, water content, and insoluble fibre of the faeces. Therefore, it has little fermentation and low apparent digestibility. The apparent digestibility of the protein tended to decrease with the oil palm fat-free flour insoluble dietary fibre than with the cellulose which may be related.

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