DIETARY FIBRES IN OILSEED RAPE: PROPERTIES AND EFFECTS ON THE DIGESTIBILITY OF RAPESEED MEAL

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INTRODUCTION

Rapeseed production has turned out to be important for many countries, after the introduction of double low rapeseed (Larsen and Sørensen, 1985). The high content in the seeds of oil (40-46%) and protein (22-28%) of a nutritional high quality has attracted special attention to rapeseed/rapeseed meal as a source to feed for poultry and monogastric animals (Jensen et al., 1991a & b; and refs. cited therein). Various rapeseed constituents present in too high concentration reduce, however, the rapeseed quality (Eggum et al., 1985). This is especially true for glucosinolates and degradation products thereof as reported by Sørensen (1988) & (1990) and Jensen et al. (1991b). Moreover, dietary fibres (DF) have been found to influence the rapeseed quality in a negative way (Bjergegaard et al., 1991a). This is caused by the hull fraction, high in DF (Bille et al., 1983; Bell and Keith, 1987) as well as DF in dehulled rapeseed (Bjergegaard et al., 1991a). Both of these DF sources reduce the digestibility of feed and food and have obviously various adverse effects (Bjergegaard et al., 1991a). This limits the possibilities of producing an optimal and high quality of rapeseed meal/protein for feed to young fast-growing animals as piglets, mink, poultry, and calves (Henriksen et al., 1987; Sørensen, 1988; Jensen et al., 1991a) and eventually as food protein constituent.

The effects of DF on digestive physiology and morphology have been observed in many studies (Kritchevsky, 1990, and refs. cited therein). Discussion of the result should, however, be extended to include not only recording of in vivo effects, but should also be systematically correlated to physicochemical properties of the individual DF and relevant analytical methods (Furda and Brine, 1990).

The objective of this investigation was to study and correlate physicochemical properties of DF and their physiological-antinutritional effects. Appreciable amounts of insoluble dietary fibres (IDF) and soluble dietary fibres (SDF) was isolated as powder. The sources of DF comprised different cultivar of double low oilseed rape (including a partly yellow seeded rape), rapeseed hulls and meal of dehulled rapeseeds. Chemical properties of the fibre fractions have been studied and found to be quite different for DF from different sources. Important properties of SDF and IDF studied comprise binding capacities for water, metals and proteins.

The work now described is apparently the first example of animal trials-chemical-biochemical studies based on IDF and SDF isolated from the plant material under consideration.

MATERIAL AND METHODS

Seeds of double low rapeseed (Brassica napus L., spring variety) were obtained from Maribo Frø, Holeby, Denmark. (**MRS**; partly yellow seeded variety) and from Novo Nordisk A/S, Copenhagen, Denmark (**NRS**; traditional brown seeded variety). Novo Nordisk A/S also contributed with dehulled extracted rapeseed meal (**NRM**) and rapeseed

hulls (NRH), obtained by aqueous enzymatic rapeseed processing (Jensen et al., 1991a).

The analytical methods used for the various compounds determined have been described elsewhere (Jensen et al., 1991a). In this connection, a new method of analysis for phenolics have been developed (Bjergegaard et al., 1991b). The procedures used for isolation of IDF and SDF from the various sources are described by Bjergegaard et al. (1991a). Details of the animal experiments and balance trials used as test for effects caused by IDF and SDF have been described previously (Jensen et al., 1991a; Bjergegaard et al., 1991a).

The isolated IDF and SDF were tested in balance trial with young growing rats, with a basal diet composed mainly of starch (80.6%), sucrose (9%) soybean oil (5.2%) and cellulose (5.2%) together with required vitamins and minerals. Casein + Met served as protein source. In the test diets, isolated DF replaced starch at a low level and a high level, corresponding to 2 and 6%, respectively, for IDF and 0.8 and 2.4%, respectively, for SDF. During the balance period, urine and faeces were collected seperately and digestible energy (DE), true protein digestibility (TD), biological value (BV) and protein utilization (NPU) were determined.

RESULTS

The chemical composition of the fibre sources are presented elsewhere (Arentoft et al., 1990; Bjergegaard et al., 1991a).

Table 1 shows the results from analyses performed on the IDF and SDF isolated from the plant materials, used as fibre sources.

Table 1. Concentration (% of DM) of protein, ash, IDF, SDF, and tannins in isolated fibre fractions.

Fibre source	Fibre type	Protein[1)]	Ash	IDF[2)]	SDF[2)]	Tannins
MRS	IDF	27.8	14.1	35.2	9.6	0.74
NRS	IDF	24.9	11.8	49.2	7.5	0.79
NRH	IDF	20.2	5.3	66.7	3.6	0.25
NRM	IDF	61.7	6.0	26.5	1.8	0.80
NRS	SDF	22.3	54.6	0.2	14.4	0.47

[1)] Calculated as N x 6.25
[2)] Corrected for protein and ash

NRM appeared to be interesting by containing 2-3 times more protein than the other DF. From the results presented elsewhere (Bjergegaard et al., 1991a) it have been revealed, that rapeseed DF have a strong binding capacity for protein, which could explain appreciable parts of the relative low TD of rapeseed/rapeseed meal (Jensen et al., 1991a; Michaelsen et al., 1991).

Results obtained with respect to effects from DF on DE, TD, BV, and NPU are shown in Figure 1.

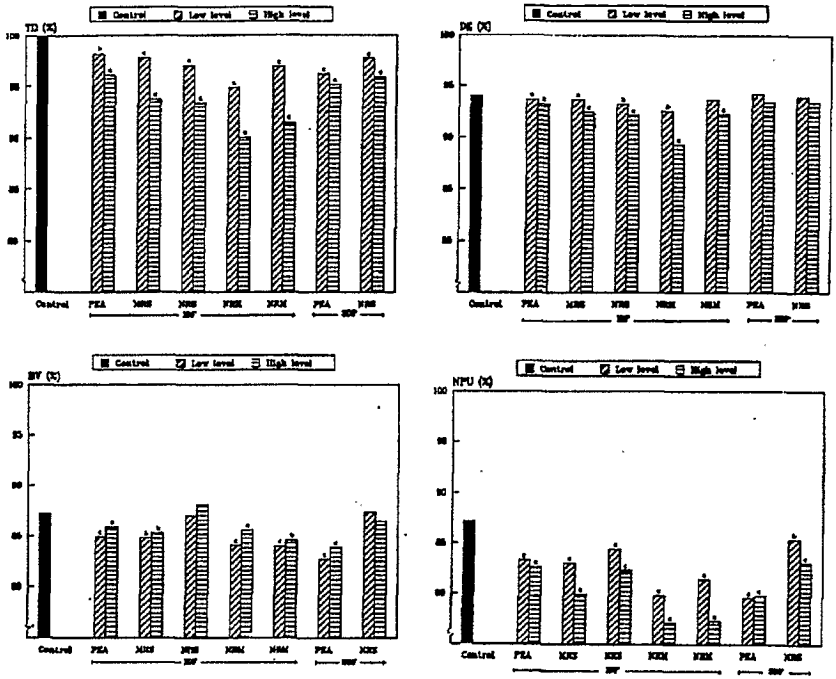

Fig. 1. The effect of IDF and SDF on utilization of energy (DE) and protein (TD, BV, NPU) compared to a diet with no addition of isolated DF. Significant effect are showed as a: $0.01 < P \leq 0,05$, b: $0.001 < P \leq 0.01$, and c: $P \leq 0.001$.

DE was significantly reduced, when increasing IDF in the diets, whereas the effect of SDF was negligible. TD decreased significantly when IDF as well as IDF was increased. DF from all sources except NRS fibres had a marked negative on BV. The reduction in TD and BV was reflected in NPU.

Measurements of internal organ weights revealed only small effects of DF. However, a tendency of increased pancreas weight, being significant for diets including NRS (IDF) and PEA (SDF) was observed. The pH in digest was generally lowered by DF, although in most cases not significant.

Water binding capacity (WBC) (Michaelsen et al., 1991), the possibilities and efficiency with respect to binding of various metals have been determined recently for DF isolated from the different sources. Moreover, titration as a measure of "uronic acid content" in DF has been performed. Data from these experiments will be presented with details elsewhere. Selected data are shown in Tables 2 and 3.

Table 2. Water binding capacity (WBC) and swelling of IDF presented together with % free uronic acids in SDF and IDF (calculated values).

Fibre source	Fibre type	WBC pH ~ 7 (g water/g IDF)	WBC pH ~ 2 (g water/g IDF)	Swelling (cm)		Swelling (cm)	% of "free uronic acids"
MRS		4.5	3.2	1.9[1)]	1.1	-[2)1)]	22.4
NRS	IDF	5.0	5.0	1.9	2.0	2.0	24.4
NRH		3.2	2.9	0.9	0.8	1.0	16.2
NRM		3.1	2.8	1.9	1.4	1.9	21.0
NRS	SDF	-	-	-	-	-	41.0

[1)] Columns to be compared
[2)] Not determined

Table 3. Binding of metals. Data obtained by AAS

Fibre source	Metal added before eluating	Metal restrained (1)	Metals liberated (2) mequi. metal/ 160 mg fibre	Metals measured
MRS		0.140	0.064	(1): Ca^{++}
NRS	Ca^{++}	0.108	0.072	(2): Na^{+}
NRH		0.108	0.069	
NRM		0.112	0.024	
MRS		0.039	0.061	(1): Mn^{++}
NRS	Mn^{++}	0.030	0.029	(2): Ca^{++}
NRH		0.025	0.021	
NRM		-0.004	0.021	
MRS		0.077	0.011	(1): Zn^{++}
NRS	Zn^{++}	0.071	0.017	(2): Mn^{++}
NRH		0.077	0.020	
NRM		-0.021	0.002	
MRS		0.172	0.018	(1): Fe^{+++}
NRS	Fe^{+++}	0.177	0.032	(2): Zn^{++}
NRH		0.197	0.058	
NRM		0.086	0.004	
MRS		0.098	0.021	(1): Ca^{++}
NRS	Ca^{++}	0.055	0.050	(2): Fe^{+++}
NRH		0.066	0.047	
NRM		0.073	0.044	

IDF from NRH was interesting by binding water with only minor swelling compared to NRM-IDF. Variations in binding capacity exist, depending on the metals as well as the isolated fiber involved. However, the highest binding capacity was in general toward Fe^{+++}, whereas only little affinity for Mn^{++} seemed to exist: IDF from NRM did deviate a little from this typical pattern.

DISCUSSION

DF are quantitatively dominating rapeseed constituents (approx. 15-20% of DM) with IDF in much higher concentration than SDF. Of the two varieties used for isolation of appreciable amounts of DF for the present investigations, the partly yellow-seeded variety had a higher SDF content than the dark seeded variety. As expected the hulls had the highest concentration of DF, but also content of DF in dehulled rapeseed meal was considerable.

DF isolated from the different sources exhibited several differences in physico-chemical properties. However, further investigation will be nessesary to reveal any correlations to physiological effects. So, the observed effects of DF on WBC, mineral - and metal binding (Frölich, 1990) calls for more detailed studies of the isolated fibres - their structure and properties - in relation to eventual effects on intestinal microflora, xenobiotics and flatulence (DeBethizy and Goldstein, 1985; Hidaka et al., 1990; Edwards, 1990).

Concerning rapeseed quality, the apparently strong association of N/protein to DF is of special interest (Bjergegaard et al., 1991a), as low digestibity of rapeseed protein are one of the main problems in use of double low rapeseed meal in animal feed. The possible association between DF and lipids (Furda, 1990; Behall, 1990) call also for attention in relation to the relative high lipid content in dehulled rapeseed meal obtained from the aqueous enzymatic extraction procedure (Jensen et al., 1991a).

A possibility of chemical changes in the properties of DF by the isolation procedure do exist. This risk has been evaluated (Bjergegaard et al., 1991a) and did not seem to be a serious problem in the present experiments. However, this is an area which calls for further atttention.

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REFERENCES

ARENTOFT, A.M., BJERGEGAARD, C and SØRENSEN, H. 1990. Pea quality depending on varieties and growth conditions. Växtodling 23, 182-197.

BEHALL, K.M. 1990. Effect of soluble fibres on plasma lipids , glucose tolerance and mineral balance. In: New developments in dietary fiber. Physiological, Physicochemical, and Analytical Aspects (Eds. I. Furda and C.J. Brine). Plenum Press. New York and London. 1-5.

BELL, J.M. and KEITH, M.O. 1987. The digestibility of canola meal by pigs as affected by age of pig and characteristics of the diet. In: Proc. 7.th Int. Rapeseed Cong., Poznan, Poland. Vol. 7, 1647-1656.

BILLE, N., EGGUM, B.O., JACOBSEN, I., OLSEN, O. and SØRENSEN, H. 1983a. The effects of processing on antinutritional rape constituents and the nutritive value of double low rapeseed meal. Z. Tierphysiol. Tierernähr. u. Futtermittelkd. 49, 148-163.

BJERGEGAARD, C., EGGUM, B.O., JENSEN, S.K. and SØRENSEN, H. 1991a. Dietary fibres in oilseed rape: Physiological and antinutritional effects in rats of isolated IDF and SDF added to a standard diet (1). J. Anim. Physiol. a. Anim. Nutr. submitted.

BJERGEGAARD, C., MICHAELSEN, S., MØLLER, P. AND SØRENSEN, H. 1991b.

High performance capillary electrophoresis: Determination of individual anions, carboxylates, intact- and desulfoglucosinolates. In: This Proc.

DeBETHIZY, J.D. and GOLDSTEIN, R.S. 1985. The influence of fermentable dietary fiber on the disposition and toxity or xenobiotics. In: Xenobiotics metabolisms: Nutritional effects. (Eds. Finley and Schavass, D.E.) Am. Chem. Soc., Washington.

EDWARDS, C. 1990. Mechanisms of action on dietary fiber on small intestinal absorption and motility. In: New developments in dietary fiber. Physiological, Physicochemical, and Analytical Aspects (Eds. I. Furda and C.J. Brine). Plenum Press. New York and London. 1-5.

EGGUM, B.O., LARSEN, L.M., POULSEN, M.H. and SØRENSEN, H. 1985. Conclusion and recommandations. In: Advances in the production and utilization of cruciferous crops (Ed. Sørensen, H.). Martinus Nijhoff/Dr. W. Junk Publ., Dordrecht, 11, 304-311.

FURDA, I. 1990. Interaction of dietary fiber with lipids-mechanistic theories and their limitations. In: New developments in dietary fiber. Physiological, Physicochemical, and Analytical Aspects (Eds. I. Furda and C.J. Brine). Plenum Press. New York and London. 1-5.

FURDA, I. and BRINE, C.J. 1990. New developments in dietary fiber. Physilogical, physicochemical, and Analytical Aspects. Plenum Press. New York and London.

FROLICH, W. 1990.Chelating properties of dietary fiber and phytate. The role for mineral availability. In: New developments in dietary fiber. Physiological, Physicochemical, and Analytical Aspects (Eds. I. Furda and C.J. Brine). Plenum Press. New York and London. 1-5.

HENRIKSEN, P., HILLEMANN, G., MORTENSEN, K. and SØRENSEN, H. 1987. Requirements to the quality of oilseed rape which can be used without problems in diets to mink (Mustela vison Screb.). In: Proc. 7th Int. Rapeseed Cong., Poznan, Poland. Vol. 7, 1817-1824.

HIDAKA, H., HIRAYAMA, M. TOKUNAGAT, T. and EIDA, T. 1990. The effects of undigestible fructooligosaccharides on estestinal mikroflora and various physiological functions on human health. In: New developments in dietary fiber. Physiological, Physicochemical, and Analytical Aspects (Eds. I. Furda and C.J. Brine). Plenum Press. New York and London. 105-117.

JENSEN, S.K., OLSEN, H.S. and SØRENSEN, H. 1991a. Processing of oilseed rape at gentle conditions resulting in limited glucosinolate degradation and fractionation into hulls, oil, syrup and protein rich meal. In: This Proc.

JENSEN, S.K., MICHAELSEN, S., KACHLICKI, P. and SØRENSEN, H. 1991b. 4-Hydroxyglucobrassicin and degradation products of glucosinolates in relation to unsolved problems with the quality of double low oilseed rape. In: This Proc.

KRITCHEVSKY, D. 1990. Dietary fiber: A glance into future. In: New developments in dietary fiber. Physiological, Physicochemical, and Analytical Aspects (Eds. I. Furda and C.J. Brine). Plenum Press. New York and London. 1-5.

LARSEN, L.M. and SØRENSEN, H. 1985. The value of oilseed rape production in Denmark and the EEC. In: Advances in the production and utilization of cruciferous crops. (Ed. Sørensen, H.) Martinus Nijhoff/Dr. W. Junk Publ. Dordrecht, 11, 1-18.

MICHAELSEN, S., MORTENSEN, K. and SØRENSEN, H. 1991. Heat and microwave processing of oilseed rape: Effects on product quality. In: This Proc.

SØRENSEN, H. 1988. Analysis of glucosinolates and acceptable concentrations of glucosinolates in oilseed rape and products thereof used as feed to different animals. Bulletin-GCIRC, 4, 17-19.

SØRENSEN, H. 1990. Glucosinolates: Structure - Properties - Function. In: Canola and Rapeseed: Production, Chemistry, Nutrition and Processing Technology. (Ed. Shahidi, F.). Van Nostrand Reinhold Publ., 115 Fifth Avenue, New York, 9, 149-172.