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EXTRUSION OF RAPESEED INTENDED FOR ANIMAL FODDER. I. DETERMINATION OF PROCESS CONDITIONS

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Key words: rapeseed, pea, extrusion, energy consumption, extrudate.

The extrusion of rapeseed with pea enables the production of a concentrate which can be a partial substitute of soybean meal. A new method of evaluating the obtained extrudates was elaborated.

INTRODUCTION

Over the past years there were numerous studies aimed at improving the nutritive value of rapeseed and meal. The research concentrated either on genetical methods or on technological processes. Geneticists have by now obtained improved varieties of rape lacking erucic acid altogether (zero variety) or with greatly reduced erucic acid and glucosinolanes contents (double zero variety). The technological work was multidirectional, involving physical, chemical and biological methods, and concentrated mainly on inactivating or eliminating glucosinolanes; most of the developed procedures were not easily adaptable in the edible fats industry [1, 3-8, 10-12, 15-18, 20, 22-26]. The only techniques to find an increasingly wider application in the edible oil industry were husk removal from rapeseeds [9, 21] and rape meal fractionation [28] — both aimed at reducing fibre content — as well as thermal processing of meal or whole seeds [2, 13, 14, 19].

Given the increasing production of rape in Poland (1.1 milion tons in 1985 and 1.3 milion tons in 1986) and in other countries, there are plans to utilize part of the crop as fodder without deoiling. One of the ways of modifying rapeseed to suit fodder purposes involves their breaking up and texturing intended to inactivate harmful substances in the seeds and to improve the digestibility of nutritive components, especially protein. The practical utilization of this process requires the determination of process conditions. The lack of published data on this subject prompted us to investigate the selection of technological and technical parameters of the extrusion of full-oil rapeseed.

MATERIAL AND METHODS

The experiments were performed with rapeseed, pea as well as wheat and barley grain, all of which were broken up in a Rousselle beater mill prior to extrusion; the obtained granulation is given in Table 1. Mesh size in the mill was 3 mm, and worm rotation was 3000 r.p.m. In these conditions rapeseed yield was 168 kg/kWh, the figures for pea, wheat and barley being 120, 103 and 66 kg/kWh, respectively.

Table. 1 Granulation of raw materials used in the inwestigation

Raw material	Diameter D_{50} (mm)	Fraction (mm/%)			
		0.5	0.5-1.25	1.25-1.6	1.6
Rapeseed	0.46	53.6	40.9	3.1	2.4
Pea	0.60	49.9	40.9	7.5	1.7
Wheat	0.43	58.2	36.1	4.8	0.9
Barley	0.58	49.9	41.3	7.3	1.5

The broken up raw material was used to produce mixtures with rapeseed content ranging from 20 to 80%. The mixtures were subjected to texturing in a Clextral BC 45 (d. Creusot-Loire) extruder featuring two interlocking worms, 56 mm in diameter, and an inductively heated head. The outlet nozzle was 3 mm in diameter. The arrangement of the worms is illustrated in Fig. 1.

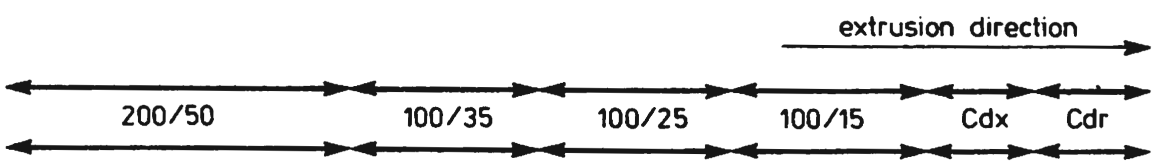

Fig. 1. Worms system in the extruder. The figure on the left of the virgule denotes the length of the worm module (mm) and the figure on the right — the worm's pitch (mm); Cdx denotes the so called "soft" worm module with opposite thread (50/15); Cdr denotes the so called "hard" worm module with opposite thread (50/15)

Humidity, specific gravity, bulk density, granulation degree, mean particle diameter were determined according to French standards (AFNOR).

Hardness and plasticity of the extrudate were determined in a specially adapted texture meter manufactured by Zenken (Japan). This apparatus was equipped with a table on which the analysed material was placed, a replaceable pressure shoe, and a sensitive lever arm coupled with a sensor converting torsional force into electric current which then flowed through a registering device and an integrator computing the curve area.

Each sample was subjected to two crushing tests, A_1 and A_2 (Fig. 2), where A_1 is the curve area of the first test, and A_2 the curve area of the second test.

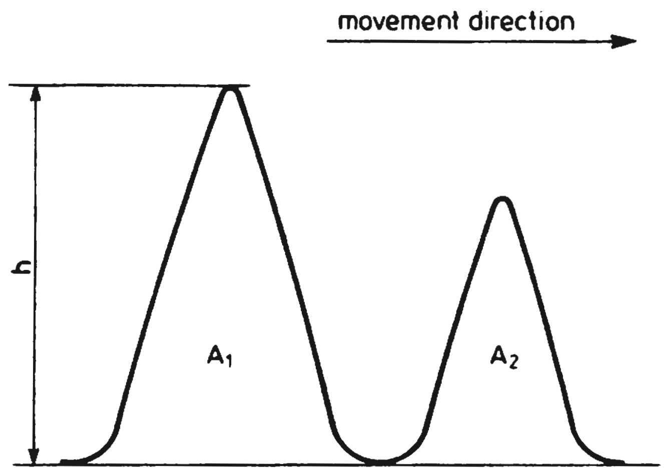

Fig. 2. Double crushing curve of extrudate intended for determinations of hardness and plasticity

Hardness D is expressed in kG and was calculated from the formula

$$D = \frac{h\ (\text{cm})}{2.5\ V\ (\text{volts})};$$

plasticity P (in %) was calculated from

$$P = \frac{A_2}{A_1} \cdot 100.$$

The development of this method of extrudate evaluation led to the assumptions of the lowest hardness and plasticity values at which the product satisfies technological requirements [29]: 3.5 kG hardness and 70-75% plasticity.

RESULTS AND DISCUSSION

Preliminary extrusion tests with broken up rapeseed alone did not give satisfactory results because of the slip of the extruded mass due to high fat content. In order to bring down the fat content and to increase friction, and thus to obtain a product with the desirable structure, the rapeseed material was diluted with 20-80% of wheat, barley or pea.

When breaking up the various raw materials, care was exercised to produce mixture components of similar grain size in order to ensure comparable heat flow in the extruded mass. The rate of heat transfer during extrusion increases with the decrease of broken up particles' size and the increase of their homogeneity. Moreover, in a homogeneous mixture heat flow is uniform in all parts of the product. However, due to chemically conditioned physical properties of the seeds it was not possible to obtain identical particle dimensions, although the dominant fractions occurred in similar proportions (Tabl. 1). After breaking up, the mean particle dimensions D_{50} were 0.46 mm for rapeseed, 0.60 mm for pea, 0.58 mm for barley, and 0.43 mm for wheat.

During experimental extrusions of rapeseed-wheat mixtures we attempted to determine process conditions ensuring adequate physical properties of the finished product. To this end, we varied water additions, extrusion temperature and worm rotation speed (Tabl. 2). Assuming that harness and plasticity are the

Table 2. Conditions of rapeseed-wheat mixture extrusion

Extruder technological parameters	Rapeseed proportion in the mixture (%)						
	20	30	40	50	60	70	80
Extrusion temperature (°C)	130	130	180	180	180	176	166
Rotation speed (r.p.m.)	250	250	100	100	150	150	300
Water added (kg/h)	13	13	16	20	13	9	9
Extrudate yield (kg/h)	91	92	101	116	102	103	104
Power consumed (kWh/t)	121	109	109	77	88	97	106

most important characteristics defining the technological usefulness of extrudates, it was found that products with 20 and 30% rapeseed contents display near-satisfactory hardness (3.1 kG) and plasticity (85 and 73%, respectively) (Tab. 3).

The humidity of the extrudates was similar, amounting to ca. 16%. This low figure was the result of the relatively low temperature (130°C) during extrusion (Tab. 2). Extrusion at higher temperatures (e.g. 180°C) required larger water additions (up to 16-20 kg/h) which led to increases of extrudate humidity up to 17-23%. When less water was added during extrusion, there was no expansion, starch gelatinization and protein texturing, and this gave the obtained products a sawdust consistence. As rapeseed content in the mixture increased from 40 to 80%, the extrudates hardness gradually decreased from 1.9 to 0.8 kG, and there was a similar drop in plasticity. All these physical disadvantages of the products discouraged further research with wheat as a component in mixtures with rapeseed.

When wheat was replaced in the mixture with barley, the results were even worse. For this reason, we included in Table 4 only those process conditions at which the obtained product retained a coherent consistence. A change of any of the four parameters given in this table led to loss of extrudate cohesiveness. The results of the experiments ruled out barley as a vehicle for rapeseed during extrusion.

The remaining experiments involved rapeseed-pea mixtures. The conditions of extrusion are given in Table 5. It is easily seen that the number of variable

Table 3. Physical characteristics of extruded rapeseed-wheat mixture

Physical characteristics	Rapeseed proportion in the extruded mixture (%)						
	20	30	40	50	60	70	80
Mixture humidity (%)	11.6	11.3	10.8	10.3	9.7	9.5	8.9
Extrudate humidity (%)	16.3	16.7	17.2	22.9	14.5	9.0	9.6
Bulk density (g/l)	398	482	460	403	474	438	447
Mass density (g/cm^3)	0.94	1.11	1.04	1.09	1.06	0.91	0.92
Expansion rate (Se/So)	2.5	2.0	1.9	1.8	1.8	2.4	2.1
Hardness (kg)	3.1	3.1	1.9	1.3	1.5	1.0	0.8
Plasticity (%)	84.6	72.5	52.0	57.2	49.0	25.6	26.3

Table 4. Conditions of rapeseed-barley (30—70%) mixture extrusion

Extrusion temperature (°C)	Rotation speed (r.p.m.)	Water added (kg/h)	Extrude yield (kg/h)	Power consumed (kWh/h)
200	100	19	115	92

Physical characteristics of the extruded rapeseed-barley mixture

Mixture humidity (%)	11.6
Extrudate humidity (%)	22.0
Bulk density (g/l)	387
Mass density (g/cm^3)	1.16
Expansion rate (S_e/S_o)	1.8
Hardness (kG)	0.7
Plasticity (%)	53.4

Table 5. Conditions of rapeseed-pea mixture extrusion

Extruder techlonogical parameters	Rapeseed proportion in the mixture (%)						
	20	30	40	50	60	70	80
Extrusion temperature (°C)	180	200	210	200	200	200	200
Rotation speed (r.p.m.)	200	100	100	100	100	100	100
Water added (kg/h)	18	11	13	13	13	13	13
Extrudate yield (kg/h)	126	125	118	120	120	120	119
Power consumed (kWh/h)	92	80	92	90	75	75	76

parameters of the process was small compared to the conditions selected for the extrusion of rapeseed-wheat mixtures. The following process conditions were determined experimentally: temperature — 200°C, worm rotation — 100 r.p.m., water addition — 11-13-kg/h. Given the high energy consumption during extrusion, the water addition was such as to ensure maximum extrudate humidity of 13-14% without additional drying, and sufficient water at the beginning of the process to produce starch gelatinization (the volume of water required in the mixture amounts to at least 20-25% of starch content). The extrusion of the mixture with 30% of rapeseed in the given conditions gave a product with satisfactory hardness (3.9 kG) and plasticity (ca. 73%). Higher proportions of rapeseed in the mixture led to lower hardness and plasticity of the extrudate.

The described experimental extrusion of full-oil rapeseed, commenced in 1984 at the Institut National de la Recherche Agronomique in France, was aimed at improving the nutritive value of this fodder raw material. Similar studies have recently been launched at the University of Newcastle upon Tyne in Great Britain [30]. In order to improve the nutritive value of rapeseed with a high

Table 6. Physical characteristics of extruded rapeseed-pea mixture

Physical characteristics	Rapeseed proportion in the extruded mixture (%)						
	20	30	40	50	60	70	80
Mixture humidity (%)	12.7	12.3	11.8	10.7	10.2	9.7	9.3
Extrudate humidity (%)	20.7	11.7	14.3	12.8	12.6	12.6	13.2
Bulk density (g/l)	418	432	473	479	478	473	463
Mass density (g/cm³)	1.15	1.03	1.09	1.06	1.03	1.02	1.09
Expansion rate (S_e/S_o)	1.9	1.8	1.9	2.0	1.9	1.9	1.9
Hardness (kG)	2.8	3.9	3.3	1.5	1.2	1.0	0.8
Plasticity (%)	70.1	72.7	64.6	42.9	52.1	47.9	52.9

glucosinolanes content, it was extruded with barley and sunflower meal. In experiments with rats an increase of dry mass consumption, increased of live weight, improved biological value of protein, and decreased thyroid activity were observed.

CONCLUSIONS

1. The most effective carrier of rapeseed during extrusion was pea. In the specified extrusion conditions the extrudate containing 30% rapeseed displays suitable technological characteristics: 11.7% humidity, 3.9 kG hardness and 73% plasticity.
2. Parallel research with cereals (wheat, barley) showed them to be ineffective carriers of rapeseed.
3. Energy consumption by the extruder is inversely proportional to the content of liquid substances (oil, water) in the initial mixture.
4. Hardness and plasticity, the factors determining the quality of the obtained extrudate, decrease with the increase of rapeseed proportion in the mixture for extrusion.
5. It was established [29] that the results of hardness and plasticity measurements performed for the extrudates with the devised method employing the Zenken texture meter are significantly convergent with analogous hardness results obtained with the classical method using a Lhomargy compression meter (test for determining the hardness of pelleted industrial feeds described in [31]).

LITERATURE

1. Afzalpurkar A. B., Mukherjee K. D., Mangold H. K.: 4-th Int. Rapeseed Conf., Giessen 1974, 609.
2. Ballester D. et al.: J. Sci. Food Agr. 1970, 21, 143.
3. Bell J. M., Youngs C. G., Sallans H. B.: Canada patent nr 839653

4. Bell J. M., Keith M. O.: 6-th. Int. Rapeseed Conf., Paris 1983, 1432.
5. Chanet M.: Rev. francaise de corps gras 1970, 17, 309.
6. Frolich A.: Kgl. Lantbruks-Hogskal. Ann., 1983, 20, 105.
7. Gabriel M., Vancikova O., Simunek Z.: Prumysl Potr., 1980, **31** (2), 117.
8. Gregor Mc D. I., Blake J. A., Pickard M. D.: 6-th Int. Rapeseed Conf., Paris 1983, 1426.
9. Greilsamer B.: 6-th Int. Rapeseed Conf., Paris 1983, 1496.
10. Kirk L. D., Mustacas G. C., Griffin E.L., Booth A. N.: J. Am. Oil Chem. Soc., 1971, 48, 845.
11. Kozłowska H., Sosulski F. W., Youngs C. G.: Can. Inst. Food Sci. Technol. J., 1972, 149.
12. Króliczek A., Wartenberg L., Rebusiewicz B., Kinal S.: Przem. Ferm. i Rolny 1977, **21** (6), 13.
13. Maheshwari P. N., Stanley D. W., Vort van de F. R.: J.A.O.C.S., 1980, 57, 194
14. Medeiros H., Kirleis A. W., Vetter R. J.: J.A.O.C.S., 1978, 55, 679.
15. Megen van W. H.: USA patent nr 244973.
16. Mukherjee K. D., Afzapurkar A.B., El-Nockrashy A. S.: Fette, Seifen, Austrichm., 1976, 78, 306.
17. Perlyoth L., Ballester D., Sanchez F.: Oil, Grassi, Dervati 1976, **12** (6), 47.
18. Sallans H. R., et al.: Pr. Reg. Lab., NRC Review 1967.
19. Shen H., Summers J. D., Leeson S.: Anim. Feed Sci. Technol., 1983, 8, 303.
20. Sosulski F. W., Saliman F. S., Bhatty R. S.: Conf. Int. Food Sci. Technol. J., 1972, 5 (2), 101.
21. Stanley D. W., Man de J. M.: 4-th Int. Rapessed Conf., Giessen, 1974, 633.
22. Staron T.: 4-th. Int. Rapeseed Conf., Giessen 1974.
23. Staron T.: Journées int. sur le colza. Paris 1970, 482.
24. Szewczuk A., Masztalerz P., Nadwyczawski W.: Zesz. Nauk. Wyższ. Szk. Roln., Wrocław 1970, 27, 151.
25. Toreson H., Andersson R.: Livsmedelstechnik 1979, **25** (2), 73.
26. Vaccacino C. et al.: 6-th Int. Rapeseed Conf., Paris 1983, 1508.
27. Youngs C. G., Perlin A. S.: can. J. Chem., 1967, 45, 1801.
28. Żernicki W.: Zesz. nauk. ART Olsztyn. 1982, 17, 163.
29. Żernicki W.: Extrusion de colza graine entiére en vue de son utilisation en alimentation animale. Compte rendu INRA-LTAA Nantes 1985.
30. Żernicki W.: Biul. Informacyjny Przem. Paszowego 1979, 3, 33.
31. Smithnard R. R., Eyre M. D.: J. Sci. Food Agric., 1986, 37, 136.

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EKSTRUDOWANIE NASION RZEPAKU NA CELE PASZOWE. I. PRÓBY USTALANIA WARUNKÓW PROWADZENIA PROCESU

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Streszczenie

Zbadano możliwości wytłaczania ziarna rzepaku z nośnikiem energetyczno-białkowym (tab. 2, 4, 5) w celu otrzymania częściowego zamiennika śruty sojowej w żywieniu zwierząt. W I części przedstawiono wyniki wstępnych badań nad wytłaczaniem rzepaku z pszenicą, grochem i jęczmieniem (tab. 3, 4, 6). Proces wytłaczania prowadzono w ekstruderze firmy Clextral typ BC 45 (d. Creusot-Loire) charakteryzującym się posiadaniem dwóch ślimaków wytłaczających, współprzeni-

kających się i zbudowanych modułowo z możliwością różnego umiejscowienia poszczególnych elementów, zwłaszcza ze zwojami przeciwnymi i elementami zagniatającymi.

Najefektowniejszym nośnikiem dla rzepaku okazał się groch. W określonych warunkach ekstrudowania produkt zawierający 30% rzepaku ma odpowiednią charakterystyk technologiczną: wilgotność 11,7%, twardość 3,9 kG oraz plastyczność 73% (tab. 6). Otrzymane wyniki twardości i plastyczności ekstrudatu, wg nowo opracowanej metody ich oznaczania za pomocą teksturometru Zenken wykazały istotną zależność z wynikami twardości otrzymanymi metodą klasyczną za pomocą kompresometru Lhomargy (test dla oznaczania twardości pasz granulowanych). Różnice wyników obydwu metod są rzędu kilku procent [29]. Ustalono, że najniższe wartości twardości i plastyczności, oznaczane nową metodą, wynoszą odpowiednio 3,5 kG oraz 70-75%.