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Nutritional value of rapeseed oil

(Rapsolja's näringsvärde)

by

Kerstin Borg

Näringsforskning 17, 147-163, (1973).

Summary

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Rapeseed oil has a growth retarding effect in animals. Some investigators claim that the high content of erucic acid in rapeseed oil alone causes this effect, while others consider the low ratio saturated/monounsaturated fatty acids in rapeseed oil to be a contributory factor.

Normally erucic acid does not occur in body fat, but when the diet contains rapeseed oil erucic acid is found in depot fat, organ fat and milk fat. Erucic acid is metabolized in vivo to oleic acid. The effects of rapeseed oil on adrenals, testes, ovaries, reproduction, liver, spleen, kidney, blood, heart and skeletal muscles have been investigated. Lipid infiltration in the heart has been observed in all species investigated. In long-term experiments in rats erucic acid produces fibrosis of the myocardium. Erucic acid and other docosenoic acids (C 22:1)

lower the respiratory capacity of the heart mitochondria. The reduction of respiratory capacity is roughly proportional to the content of erucic acid in the diet, and diminishes on continued administration of erucic acid.

The lifespan of rats is the same on corn oil, soybean oil, coconut oil, whale oil and rapeseed oil diet. Rats fed on a diet with erucic acid or other docosenoic acids showed a lowered tolerance to cold stress (+4°C).

In Sweden erucic acid constituted 3-4% of the average intake of energy up to 1970 compared with about 0.4% in 1972.

Introduction

About seven million tons of seed from rape, Brassica napus and closely related species are being produced today. Rape is in fifth place among oil producing plants following soybean, cotton, peanut and sunflower. The rapeseed contains about 40% oil and 25% protein. Rapeseed oil is characterized by a high content of long-chain monounsaturated fatty acids, especially erucic acid (C22:1 Δ 13, 30-50%)¹ and a low content of saturated fatty acids (table 1). Other long-chain monounsaturated fatty acids are eicosenoic acid (C20:1) and oleic acid (C18:1).

¹C22:1 Δ 13 indicates a fatty acid with 22 carbon atoms and one double bond in a position between carbon atoms 13-14 counting from the carboxyl group.

Photograph: Kirstin Borg has a M.Sc. and is an assistant at the hygienic department of the Swedish Government Food Research Laboratories.

Eicosenoic acid is like erucic acid characteristic for the family Cruciferae (mustard) and comprises 5-10% in rapeseed oil. Through hybridization experiments, a type of rapeseed has been developed in Canada with a very low content of erucic and eicosenoic acids (together less than 5%) and a high content of oleic acid (60%). This oil is called canbra oil.

A high content of oleic acid can also be found in olive oil (70-85%), peanut oil (35-60%), palm oil (40-50%), lard (40-50%) and tallow (40-50%). Fish oils contain varying amount of long-chain fatty acids. Herring oil contains large amounts of cetoleic acid (C22:1 Δ 11 an isomer of erucic acid, 10-30%) and eicosenoic acid (C20:1, 10-20%) while menhaden oil only contains a few percent of these fatty acids. Polyunsaturated fatty acids (for instance C20:5 and C22:6) occur in fish oils. Through hydrogenation of an oil the number of double bonds can be reduced. The degree of unsaturation in an oil will depend upon how complete the hydrogenation has been. Of the marine oils, hydrogenated menhaden oil is the type of oil chiefly used for margarine in Sweden (< 6% C22:1).

Rapeseed has been cultivated in India, China and Pakistan for centuries. Canada, Poland, France and Sweden started to grow rapeseed on a large scale during the Second World War when rapeseed oil became an important raw material for margarine. For about twenty years the nutritional value of rapeseed oil has been studied in feeding experiments with animals. These studies were intensified in 1970 when it was discovered that rapeseed oil caused changes in the myocardium. The same year the content of rapeseed oil was reduced drastically in margarine.

B = *U. Bailey's Industrial Oil and Fat Products*, 3rd ed., ed. D. Swern, Interscience Publishers, New York, 1964.
 S = *Småfett innehåller dessutom 2% mättade fettsyror med mer än C 18 och 15% omättade fettsyror C 20 och C 22.*

¹Butter fat contains in addition 2% saturated fatty acids with more than C18 and 1% unsaturated fatty acids C20 and C22.

The effects of rapeseed and canbra oils on the growth of experimental animals.

The nutritional value of rapeseed oil has been studied mostly with rats. A diet with 20% rapeseed oil or more retards the growth of young rats (83, 15, 76, 17, 13, 29). Rats eat less of a diet with 20% rapeseed oil than of one with for instance, 20% peanut oil. The decreased appetite is probably not caused by any organoleptic factors (87, 88) but rather by an effect on the hypothalamus (10). The degree of utilization of the consumed rapeseed oil is just as high as the control diet in Wistar rats (17, 13). The energy value of rapeseed oil is presumably the same as other oils (83, 88).

In one experiment the effects of twenty different oils and fats on rats were compared (83). Whale oil, herring oil and rapeseed oil resulted in slower growths than the other oils tested with the exception of kapok seed oil. Common to the three first-mentioned oils is a high content of long-chain unsaturated fatty acids. A number of later studies with rats have shown that erucic acid retards growth (86, 42, 13). The low content of saturated fatty acids in rapeseed oil could also have some effect. Rats grow best on a fat mixture with the same ratio of saturated/monounsaturated fatty acids as in the rat's own depot fat, circa 1:2 (58). In rats fed a diet with 20% rapeseed oil, the acceptance of the diet increased when the rapeseed oil was partly substituted by palm oil. In other rats that were fed oils with a chain length of maximum 18 carbon atoms the acceptance decreased as the degree of saturation of the oil decreased (11). Rocquelin et al feel that as the linoleic acid content of the diet is lowered to 10% or less of the total fatty acids, the growth of the animals is affected both by the content of erucic acid and by the ratio

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saturated/monounsaturated fatty acids in the diet (75). In one experiment with ducklings which were fed a diet with a constant amount of erucic acid, but varying amounts of palmitic acid (C16:0) a linear relationship was found between the ratio palmitic/erucic acids in the diet and the weight increases of the animals (90).

No growth retarding effects of canbra oil on rats have been found (73, 49, 4, 75) and the growth is not affected when saturated fat is added to a diet with canbra oil (49).

The growth retarding effects of rapeseed oil have chiefly been studied on rats, but have also been observed with pigs (70, 51), ducklings (88), guinea pigs (51, 37, 88), mice (37, 88), hamsters (88), turkeys (62, 79, 80) and broiler chickens (78). When chickens were fed 25% rapeseed oil in the diet the growth was retarded (37), but not when the diet contained 4 or 8% rapeseed oil (81). In some rabbit experiments rapeseed oil has retarded growth (5), but not in others (37, 97). No growth retarding effects have been observed in experiments with dogs (37, 51).

Absorption and digestion of rapeseed oil, canbra oil and their constituent fatty acids.

In rats rapeseed oil is absorbed at a slower rate than other fats and oils that normally form part of our food (52, 85). Absorption is considered to be the uptake from the digestive system as a function of time. The digestibility, however, is not dependent on time, but is defined as:

$$\frac{\text{Intake} - \text{excretion (corrected for metabolism)}}{\text{Intake}} \times 100$$

Apparent digestibility means that no correction is made for metabolic losses. The digestibility of rapeseed oil has been determined in a number of rat experiments with very variable results. Values between 58 and 95 have been obtained (table 2). Wistar rats digest rapeseed oil better than Sprague-Dawley rats.

The often low digestibility of rapeseed oil is chiefly due to the high content of erucic acid. In comparative experiments with "erucic acid free oils", the digestibility for canbra oil was as high as for peanut oil, 95% and 92% (74). p.150

The digestibility of rapeseed oil varies between 58 and 100% in various animals (table 2). Humans digest up to 99% of rapeseed oil (57, 53).

The digestibility of various fatty acids has also been studied by utilizing them as the sole source of fat in the diet (table 3). Rats absorb short-chain saturated fatty acids (up to 10 carbon atoms) completely while further increases in the chain length progressively decrease the digestion, so that very little of stearic acid (C18:0) is resorbed (38). A double bond in the middle of the carbon chain in the fatty acid means that it is digested to the same extent as a saturated fatty acid with six fewer carbon atoms (42, 38). Triglycerides of oleic acid, linoleic acid and erucic acid are digested to a greater degree than corresponding free fatty acids (44). Experiments with rapeseed oil when the digestibility for erucic acid was calculated gave generally higher values than in experiments with free erucic acid (74, 59).

TABLE 2. The digestibility of rapeseed oil.

Animal		Rapeseed oil in diet %	% erucic acid in oil	Digestibility	Reference
Djurart		Rapsolja i kosten %	Rapsoljans erukasyrahalt vikts-%	Digestionskoefficient	Referens
Rats	Råttor W	20		92 AD	17
	Råttor S-D	25		58	37
	Råttor W	20	37	83 AD	16
	Råttor S-D	20	37	65 AD	
	Råttor W	15	45	81 AD	74
	Råttor W	15	2	95 AD	
Broiler	Råttor W	32	52	90-95	59
	Broiler	11		92	47
	Chicken	10		90	82
	Broilerkycklingar	10		90	82
Rabbit	Kanin	25		58	37
	Kanin	8		94	97
Lamb	Lamm	50 energi-%	41	62	96
Pig	Svin	100 el. 200 g/dag		ca 100	69
Baby Pigs	Svin	300 g/dag		95	
	Svin (baby pigs)	20		78 AD	51
Dog Puppies	Hundvalpar	20		94 AD	51
Guinea Pigs	Marsvin	20		72 AD	51
	Marsvin	25		61	37
Humans	Homo	ca 82 g/dag		99	57
	Homo	ca 52 g/dag		99	53

W = Wistar rats
S-D = Sprague-Dawley rats
AD = Apparent digestibility

TABLE 3. Digestibility of various fatty acids.

Animal	Fatty acid or ester	F. A. or ester in diet wt. %	Digestibility	Comments	References
Djurart	Fettsyra eller ester	Fettsyrans eller esters halt i kosten vikts-%	Digestionskoefficient	Anm.	Referens
Rats	Råttor S-D	Kaprinsyra C 10:0	100		38
		Laurinsyra C 12:0	86		
		Palmitinsyra C 16:0	48		
		Stearinsyra C 18:0	12		
		Oljesyra C 18:1	84		
		Erukasyra C 22:1	53		
		Metylterukat	62		
		Etylterukat	59		
	Råttor S-D	Erukasyra C 22:1	52		42
		Metylterukat	55		
		Etylterukat	59		
		Ficosensyra C 20:1	64		
		Oljesyra C 18:1	85		
	Råttor	Metylterukat	90		68
		Metyleicosenoat	96	Utsöndrad fettsyra analyserades för beräkning av fettsyrens digerbarhet. I alla övriga experiment bestämdes fettsyran i utsöndrade totalipider.	
	Råttor	Erukasyra C 22:1	92	Kalciumfri diet	44
		Erukasyra C 22:1	48	2% Hubbel-Mendel-Wakemans saltblandning	
		Erukasyra C 22:1	21	5% Hubbel-Mendel-Wakemans saltblandning	
Råttor W	Erukasyra C 22:1	6.7	73 AD	15% rapsolja	74
	Erukasyra C 22:1	0.3	91 AD	15% canbraolja	
Råttor W	Erukasyra C 22:1	17	86 AD	32% rapsolja	59

Förkortningar se tabell 2.

Comments

Excreted fatty acids were analyzed for the calculation of the digestibility of the fatty acid. In all other experiments the fatty acids were determined in excreted total lipids.

Calcium-free diet
 2% Hubbel-Mendel-Wakemans salt mixture
 5% Hubbel-Mendel-Wakemans salt mixture
 15% rapeseed oil
 15% canbra oil
 32% rapeseed oil

The metabolism of erucic acid.

Erucic acid normally does not occur at all, or in very small amounts, in body fats. In animals that have been fed rapeseed oil, the body fat contains less erucic acid (22:1) and more oleic acid (18:1) than the feed. It has therefore been assumed that the long chain monounsaturated fatty acids in rapeseed oil are metabolized in vivo to oleic acid (39, 50, 48). This has been demonstrated experimentally by Carreau et. al. (33, 34).

In rat experiments with radioactive tracers Carrol (40) found p.151 that nervonic acid (C24:1) and to a lesser extent erucic acid (C22:1) are deposited in the liver as free fatty acids and are metabolized at a slower rate than oleic acid (C18:1). In another experiment the incorporation of radioactively tagged erucic acid in various rat tissues was studied (liver, spleen, kidneys, heart, testes and sperm glands). The erucic acid disappeared quickly (2 hours) from all these tissues with the exception of the spleen (65).

In experiments with C¹⁴ tagged oleic acid and erucic acid both were oxidized at the same rate, but erucic acid yielded less oxidation product; i.e., a lower ratio between C¹⁴ measured in the exhaled air over 8 hours and the amount of C¹⁴ added (8). The total oxidation rate of erucic acid is higher in rats which have received a high-fat diet than in those having received fat-free food. In the last mentioned animals the two carbon units from the β -oxidation were to a large extent used for the synthesis of fatty acids. Only small quantities of two-carbon units were oxidized completely which resulted in a low C¹⁴ content in the exhaled carbon dioxide (8).

THE EFFECTS OF RAPESEED OIL ON ORGANS AND TISSUES

Effect on composition of body fat and milk fat.

The fat in the diet influences the composition of the body fat. The erucic acid content in organ and depot fat following feeding with rapeseed oil or a mixture of corn oil and ethyl erucate to newly weaned rats are shown in table 4. In adult rats on a diet of rapeseed oil for 6 months there were no continuous accumulation of erucic acid in depot fat and other organs studied. The biological half-life for erucic acid in organ lipids and depot fat has been calculated to be 18-31 days (92).

TABLE 4. The erucic acid content in organ-and depot fat of rats after feeding with rapeseed oil.

Type of fat in diet	Fat content of diet %		Duration of experiment, weeks												
	Kostens fetthalt %	Försökets längd veckor	Erukasyrhalten (% av totala fettsyror)					Erucic acid content (% of total F.A.)							
			Bi-Adrenal	Heart	Spleen	Kidney	Erythro-	Brain		Depot fat	Referens				
			njurar Plasma	Hjärta	Mjälte	Testes	Njurar	cyter	Lever	Hjärna		Prostata-	Depåfett		
Corn oil &	12	12	20	10	8		1	4	5	3	0,2	1		95	
Me-erucate	12	18	15	8	6	5	5	4	3	2	1				
Rape	12	18	12	3	3	5	2	2	2	1	0,7				
Canbra	12	18	1	1	0,4	0,7	0,2	0,3	0,6	0,2	0,2				
Olive	12	18	1	-	-	-	-	-	-	-	0,5				
Rape	10	3								4			8	91	
	20	21											7	50	

Erucic acid is chiefly incorporated in triglycerides and to a lesser extent in phospholipids (26, 9, 50). In ovaries and adrenal glands the erucic acid was to a large extent deposited in the cholesterol fraction (35, 41, 36, 37, 39, 93). In ovaries and adrenal the erucic acid comprised 23 and 30% respectively of the total fatty acids in the cholesterol fraction following 10 weeks feeding with a 1:5 mixture of corn oil and ethyl erucate (93).

In rats that had been on a rapeseed oil diet for 3 days (50 energy-%), Blomstrand (27) found that all phospholipids isolated (lecithin, phosphatidylethanolamine and cardiolipin) in homogenate and mitochondria from heart contained erucic acid. The most noteworthy finding was the heavy incorporation of erucic acid in cardiolipin. These contained also eicosenoic acid (C20:1).

In female rats fed rapeseed oil, the milk contained eicosenoic acid (C20:1) and erucic acid. The milk from rats which had been fed rapeseed oil for several generations contained 6-energy-% erucic acid (14). The milk contained approximately twice as much erucic acid in another experiment when the rats were given a diet of rapeseed oil at the start of lactation (9). Any publications that compare the fatty acid composition in milk and in the mothers depot fat have not been encountered.

Effects on adrenals

In rats which were fed a diet with rapeseed oil, the adrenal glands were larger and contained more fat than the control animals (35, 36, 41, 2, 4, 5). It has been found that erucic acid causes both of these changes (36). The fat was deposited in the cells of the ectodermal medulla of the adrenal gland and these cells were enlarged (4). Changes in these tissues caused by rapeseed oil did not diminish in the 64 weeks the rat experiments were carried out using 60-energy-% rapeseed oil (45% erucic acid) in the diet (4, 5).

Rapeseed oil caused a significant increase in the cholesterol content of the adrenal glands in Sprague - Dawley rats (37), but causes little or no increase in Wistar rats (16), rabbits, Guinea pigs, chicks p.153 or dogs (37). In addition to the increase in the cholesterol content in

the adrenal gland and liver, the excretion of endogenously formed cholesterol in the faeces increased in Sprague - Dawley rats (42). Adrenocorticotrophin-induced synthesis of prostaglandins in vitro was considerably lower in adrenal gland homogenate from rats on a rapeseed oil diet, than from rats on a corn oil diet (32).

During exposure to stress (cold), cholesterol erucate was poorly utilized for steroid formation and the corticosterone-level in plasma was significantly lower than in control animals (94). When rats were exposed to cold (+4°C) the mortality was higher for animals on a rapeseed oil diet than those on a corn oil diet (20% fat in diet). All animals on a rapeseed oil diet died within 38 days with an average life span of 15 days, while half of the animals on a corn oil diet died within 34 days with an average life span of 20 days (18). Beare-Rogers (20) has shown that docosenoic acid¹ (C22:1) in the diet resulted in a poorer survival following exposure to cold (+4°C). The animals were fed 5% corn oil and 15% test oil in the diet for four (4) weeks. The mortality was 3/15 with lard, 6/15 with canbra oil, 13/15 with rapeseed oil and 10/15 with hydrogenated herring oil. If the effect depends on insufficiencies in the adrenals or the heart could not be determined.

¹Docosenoic acid is the systematic name for fatty acids with 22 carbon atoms and 1 double bond.

Testicles, ovaries, reproduction and milk secretion.

In male rats, mainly Sprague - Dawley, which were fed an adequate basic diet with addition of 10% erucic acid or more, degeneration of the tubuli in the testes was demonstrated after about 3 months and sterility after 5 months. When erucic acid was eliminated from the diet, the spermatogenesis was restored if the degenerative changes of the testes had not proceeded too far. The changes resembled some of the defects that are caused by lack of essential fatty acids or Vitamin E. The abovementioned effects did not occur when equivalent amounts of rapeseed oil were added to the diet (25% rapeseed oil with 50% erucic acid). This can possibly be explained by the presence of other fatty acids in the rapeseed oil, among other essential fatty acids (43). Wistar rats on a 20% rapeseed oil diet had significantly lower testes weight and smaller tubuli than the control animals after 5 weeks on the diet, but exhibited no cell changes (17). Following six weeks on a diet with 20% rapeseed oil, the Sprague - Dawley rats had the same testes weight, but Wistar rats had lower testes weight as compared to control animals (16). In a 7-month experiment with a rapeseed oil diet, no harmful effects on the sexual organs of male rats (Wistar) were observed (28). In one experiment with pigs, the testes and epididymis weighed much less in relation to the body weight in animals that had received rapeseed oil, than in the control animals (89).

Female rats on a rapeseed oil diet became sexually mature later than control rats (63,41). No disturbances in the function of the ovaries could be detected (41, 13). The ovaries weighed less than those in the control group (41) and contained more cholesterol (41, 93). p. 154

Reproduction studies with rats have shown that erucic acid and oleic acid in the diet can result in decreased fertility. In most cases the rats became pregnant and the young were born alive, but the mortalities of the litters were high due to failing development of milk glands and milk production in the mother (43). In a reproduction study with three litters from a generation Wistar rats, there was no statistical difference in the question of litter size and the number of weaned young between groups that were given rapeseed oil (8.5% erucic acid) or corn oil. The weight of the just weaned young was lower in the rapeseed oil group. No disturbance in the spermatogenesis of the male rats (F_6) could be demonstrated (13). In a reproduction study over four generations with Wistar rats on various diets, fewer young were born and they had lower weights at weaning in the group which had received 20% rapeseed oil in the diet (14).

Effect on liver.

The effect of rapeseed oil on the liver has primarily been studied with regard to weight, cholesterol content, fat content and morphology.

In certain experiments, but not in others, the weight of the livers increased. In rat experiments with 25% rapeseed oil in the diet the cholesterol content of the liver increased to 0.5% as compared to 0.2% for the control animals (35, 37). Erucic acid in the feed had the same effect (42). The total lipid content of the liver (6-8%) did not increase on a rapeseed oil diet as compared to a corn oil diet (16, 12) and a peanut oil diet (75, 72).

Two months on a 15% rapeseed oil diet (45% erucic acid) did not cause any histological damage in the liver of rats (75). In long-term experiments (1-2 years) with rats with 50-60 energy-% rapeseed oil in the feed there was an indication of fat-deposition and degeneration in the central parts of the lobes of the liver (84, 4, 5).

Ducklings are more sensitive than rats with regards to the liver. In a three-week experiment with ducklings in which the rapeseed content was varied, 30 energy-% rapeseed oil was the lowest content causing cirrhotic changes in the liver. When the rapeseed content of the feed was increased from 10 to 30 energy-%, the liver weight increased (hypertrophic cirrhosis) and then later decreased (atrophic cirrhosis) with a further increase in the amount of rapeseed oil. The same type of changes were induced by glyceryl trierucate (3). In experiments with ducklings and guinea pigs, the effects of isocaloric oil mixtures containing a constant amount of erucic acid were studied. An increase in the palmitic acid content of the feed decreased the number of cases of liver cirrhosis (90, 6). The effect of the rapeseed oil on the morphology of the liver is counteracted through addition of tallow to

the feed (6), is not affected by olive, safflower or soybean oils (6, 1) and is made worse by glyceryltrilaurate (C12:0) (6). Increased erythropoiesis in the liver has been observed with ducklings and guinea pigs which have received rapeseed oil in the diet (88, 90, 1).

Effects on spleen.

The effect of rapeseed oil on the weight and morphology of the spleen has been studied with rats, ducklings and guinea pigs.

In rats experiments the spleen has not been affected by rapeseed oil (77, 7, 2, 4, 75, 5) except in a study where an increase in weight of the spleen was reported (73). Ducklings, however, exhibited changes in the spleen when rapeseed oil is included in the diet. Ducklings with 30 energy-% rapeseed oil or more in the diet exhibited atrophy of the red pulp, lipidosis and increased erythropoiesis of the spleen (3). Increased saturation of the fat in the diet (rapeseed oil) through addition of hydrogenated palm oil or tallow lessened the effect on the morphology of the milt (90, 6, 1).

Hypertrophic spleen with enlarged fat-infiltrated red pulp and intensive erythropoeises was demonstrated in guinea pigs which had p.155 received rapeseed oil in the diet (50 energy %) for six weeks (88). At least 25 energy-% rapeseed oil in the feed is required to cause changes in the spleen in guinea pigs (90). As in ducklings, the addition of hydrogenated palm oil led to a lessening of the effect on the morphology of the spleen (90).

Effect on kidneys.

The weights of the kidneys increased in rats which had received rapeseed or canbra oil in the diet for two months (73). This effect was not observed in a similar experiment carried out some years later by the same researchers (75). Abdellatif and Vles (2) observed that some kidney tubuli were dilated and contained protein after four and eight weeks on a rapeseed oil diet. In rat experiments lasting sixteen weeks or longer, kidney changes were noted and these became more pronounced the longer the experiment lasted. The changes consisted of increased kidney weights and of nephrosis characterized by vacuolation in the tubulus epithelium, tubulus dilation and focal connective tissue proliferation (2, 4, 5). In female rats the concentration capacity of the kidneys after nine and nineteen weeks on a rapeseed oil diet (40%) was significantly lower than in control rats that received the same quantity peanut oil in the feed (25).

Effects on blood.

The effects of various fats and oils on the content of blood lipids, especially the cholesterol fraction, have been investigated in a number of studies.

In rats, mice and dogs no effect of rapeseed oil on the cholesterol content of the blood has been observed while a tendency for hypercholesteremia has been reported for guinea pigs and chickens (37). Rabbit experiments with 6-8% rapeseed oil in the diet did not affect the cholesterol content of the blood (97, 64). Results of rabbit

experiments with higher rapeseed oil levels were contradictory. No effects on the cholesterol content of the blood were demonstrated after 4 weeks on a rapeseed oil diet (25% rapeseed oil) in one experiment (37) while 40 energy-% rapeseed oil caused a sharp increase in the cholesterol content of the blood in another (5).

Rapeseed oil in the feed increased hematocrite and reticulocyte values in ducklings (3). In guinea pigs, rapeseed oil in the diet caused haemolytic anemia. When the rapeseed oil diet was supplemented with hydrogenated palm oil, the hemoglobin level, the PVC value (packed cell volume) and the value for non-electrolytic hemolysis of erythrocytes were improved (90).

Effect on the heart.

In the early 1960's, Roine et al (77) showed that rats on a rapeseed oil diet got "myocarditis". This was confirmed by Rocquelin and Cluzan (73) in rat experiments which lasted for six months. Following these experiments, the effect of rapeseed oil on the heart was studied more systematically. The pathological changes in the rat heart induced by rapeseed oil can be divided into three stages: pronounced lipidosis, histocyte infiltration, and finally fibriosis (2, 4, 5, 29).

Intracellular fat infiltration starts already a few hours after giving rapeseed oil and reaches a maximum after 3-6 days after which it decreases rapidly (60, 21). The fat deposit in the heart

never disappears completely (4, 60, 21, 29). The lipidosis is milder in adults than in young animals (4, 19, 24). Lipidosis in the heart, caused by rapeseed oil has also been observed in ducklings, guinea pigs, rabbits, desert rats, mini pigs, piglets and squirrel monkeys (3, 90, 5, 24). In ducklings rapeseed oil produced in addition a serious hydropericardium (3). In feeding experiments with 40 energy-% rapeseed oil, three of ten animals died within 3 weeks and with 60 energy-% rapeseed oil eight of ten animals died within 2 weeks. As mentioned earlier, the animals also had liver damage. In the control group (butter fat), no animals died during the experiments (3). When tallow or hydrogenated palm oil (20 energy-%) was added to a rapeseed oil diet (ca 40 energy-% rapeseed oil) all ducklings lived after 3 weeks. However, if glyceryltrilaurate (C12:0) was added, the mortality increased in this group (6). Additions of palmitic acid to an erucic acid rich diet lowered the mortality in the ducklings over a 3 week period (90). p.156

After four and eight weeks on a rapeseed oil diet (60 energy-%) infiltration of mononuclear cell and histocytes and in addition proliferation of fibroblasts was observed. These changes increased in seriousness and became less cellular and more fibriotic with time (4). Beare-Rogers feels that lipidosis and fibriosis are independent of each other (19).

In experiments with various amounts of rapeseed oil in the diet an attempt was made to find the highest dosage that will not cause fat deposition in the heart. Abdellatif and Vles (4) mean that a dosage as low as 5 energy-% rapeseed oil (ca 1.2% erucic acid in the diet) can cause fat deposition in the heart, while Beare-Rogers et. al. (21) feel that

10 energy-% rapeseed oil (ca 1.5% erucic acid in the diet) will not cause any abnormal fat deposition. Engfeldt (29) found that it is not possible with certainty to demonstrate drops of fat with a light microscope when the feed contains around 1% erucic acid. Positive results were in general obtained with contents above or around 2% erucic acid in the diet. Preliminary electron microscopic studies of heart muscle fiber showed occurrences of single fat droplets when erucic acid was given (1-2%) and also a few single fat droplets in control rats which had been given peanut oil.

There are many indications that it is the long-chain monoenoic acids, and especially erucic acid, which are the cause of the pathologic changes induced by rapeseed oil. Rats and ducklings that had been given a diet with glyceryltri-erucate exhibited injuries similar to those caused by rapeseed oil (2, 3, 4). Hydrogenated herring oil contains a high percentage of docosenoic acid (C22:1). Beare-Rogers et. al. (21, 23) have shown that hydrogenated herring oil caused fat deposition and later degenerative injuries to the rat heart. In rat experiments with synthetic oils it has been found that a high content of eicosenoate (C20:1) caused histologically distinguishable fat droplets in the heart in one week, but erucate (C22:1 Δ 13) and cetoleate (C22:1 Δ 11) caused considerable greater fat deposition in the heart (22).

Experiments with canbra oil with a very low content of erucic acid and eicosenoic acid (ca 2% of each) have also been carried out. Rocquelin et. al. (73, 75) have observed myocarditis in rats that had

received canbra oil in the diet for two or six months. The injuries occurred, however, less often and were less serious than in the rapeseed oil group. Abdellatif and Vles (4) repeated Rocquelin's experiment (six months) but could not demonstrate pathological changes with canbra oil in that length of time or over shorter periods, (3 days and 2 weeks).

The effect of supplementing a rapeseed oil diet with saturated fat has been studied with ducklings (90, 6, 1). Addition of hydrogenated palm oil or tallow has had a lessening effect on the hydropericarditis, but the injuries to the heart muscle were unchanged. Addition of glyceryltrilaurate (C12:0) enhanced all injuries caused by a rapeseed oil diet.

In order to find out if the intestinal flora was of any importance, Gustafsson (56) added rapeseed oil to the diet (10% C22:1) to five bacteria-free and five conventional male rats for ten days. The control groups were given peanut oil in the feed. The myocardium showed extensive fat deposition both in bacteria-free and in conventional animals that had been given rapeseed oil, while none could be found in the control groups.

Sprague-Dawley rats, ten males and ten females were given a rapeseed oil diet (10% C22:1). Control animals were given the same amount of peanut oil in the diet. Electrocardiograms every seventh day for eight weeks showed no differences between groups (25). p.157

The fat deposition in the rat heart caused by rapeseed oil is accompanied by a decrease in the respiration ability of the heart mitochondria (60). Ernster and Heijkskjold have confirmed this and found that the degree of inhibition is largely proportional to the erucic acid content

and that it decreases after erucic acid has been administered over a long period of time. This also applied to the fat deposition. The primary cause of both the fat deposition and the respiration inhibition is an inhibition of the metabolism of other fatty acids normally occurring in the food (45, 46, 54). Erucic acid while being metabolized should therefore exhibit an inhibiting effect on the oxidative metabolism of the principal 16-18 carbon chain fatty acids normally occurring in the feed. Since these fatty acids constitute an important substrate for the heart and are taken up in liberal amounts from the blood, an inhibition of their oxidation can lead to an accumulation of fat. This in turn affects the mitochondria, especially through disturbing the substrate transport which will lower the respiration ability.

Effect on skeletal muscles.

In rats, rapeseed causes a reversible fat infiltration in the skeletal muscles. In animals given rapeseed oil in the diet (60 energy-%) the muscles were pale after 2-4 weeks due to the fat deposition. In eight weeks or more the muscle had normal color and the morphology was normal after sixteen weeks on a rapeseed oil diet (2, 4, 5). In two-week experiments, 20 energy-% rapeseed oil in the diet was the lowest amount that caused light fat infiltration in the heart and skeletal muscle (2).

Three weeks on a rapeseed oil diet has caused changes in the skeletal muscle of ducklings in the form of fat infiltration with edema and dissolution of muscle fiber, and in some cases with cell infiltration. These changes occurred with diets containing ca 30 energy-% rapeseed oil (15 energy-% erucic acid) or more (3). The changes in the skeletal muscle in ducklings did not improve if the rapeseed oil diet was supplemented with saturated fat (90, 6, 1).

Effect of various fats on lifespan.

It is known that the lifespan of animals can be increased by lowering the food intake. In some studies the animals were given a limited amount of food (66, 67, 71) in others food ad libidum for some days followed by fasting for a few days (30, 31). Lifespan has also been studied in relation to various feed components. In one study rats were given only a basic diet or 80% basic diet mixed with 20% sucrose or 20% corn oil. The animals grew very well on the diet with a high fat content, but the lifespan was shortened, which was most pronounced for the males (55).

A rapeseed oil diet results in lower food intake. This led Thomasson (84) to study the influence of rapeseed oil on the lifespan of male rats. The diet contained 50 energy-% fat, and butter fat was used as control fat. The animals that were given rapeseed oil lived 20-25% longer than the control animals. Pathological investigations gave no clear information on the cause of death. Rate of growth and daily food intake was lowest for the rapeseed oil group. A later experiment with various contents of rapeseed oil or butter fat in the diet (10-72 energy-%) verified that rapeseed oil did not shorten the lifespan of rats (88). In a study with SPF-rats (specific pathogen free), groups that were given butter fat, rapeseed oil, corn-, soybean-, coconut- and whale oils in the diets were also included. The effect of the oils on growth was: butter fat = corn oil = soybean oil > coconut oil > whale oil > rapeseed oil. The mortality p.158 was the same for all groups with the exception of the butter fat group which had a shorter lifespan (88). Thomasson et. al. (88) also studied the

effects of rapeseed oil and butter fat on the lifespan of mice. The diets contained 10-72 energy-% fat. The experiment lasted for 89 weeks. Animals with 40 energy-% or more in the diet reached 50% mortality in the rapeseed oil group considerably later than in the butter fat group.

Improvements in oil plants with special reference to the oil quality.

Many oil producing plants have been tried with respect to their suitability as an agricultural crop in Sweden. Superior properties have been shown by rapeseed (Brassica napus) and Brassica campestris. These together with Sinapis alba are the only oil plants that are now cultivated in this country. The oil from all three of these plants has a high content (30-55%) of erucic acid.

For a number of years cultivation has been carried out with rapeseed and Brassica campestris with the aim of developing types free of erucic acid.

Since the consumption of margarine with a high content of linoleic acid has increased and is expected to increase further and the prices for imported linoleic acid - rich raw materials are increasing, it is desirable to increase the production of linoleic acid. The oils of the erucic acid group have unfortunately all a low content of linoleic acid. As a rule the linoleic acid content in oils from the conventional rapeseed varieties is about 15% and in oils from the new erucic acid-free varieties 20-25%. A very active program is under way with the purpose of increasing the linoleic acid content in rapeseed oils. The aim is to develop types with about 40% linoleic acid.

Other possibilities for increasing the linoleic acid production in this country are to reintroduce the poppy and to take up sunflower cultivation in Swedish agriculture.

Measures implemented.

From a nutritional point of view it would be desirable to have the erucic acid content of the diet lowered or eliminated. The Canadian canbra oil can contain less than 1% erucic acid. It should be remembered that fish oils contain a high percentage of long-chain mono- and poly-unsaturated fatty acids and that docosenoic acid (C22:1) both from rapeseed oil and from hydrogenated herring oil give fat infiltration in rat hearts and later degenerative injuries.

In Sweden rapeseed oil is chiefly consumed as one of several fat components in margarine. Hydrogenated fish oils can also be found in the diet in certain makes of margarine. When the Association of Swedish margarine manufacturers in 1970 was given the information that was available on the effect of rapeseed oil on animals, the Association decided that margarine produced in Sweden should contain at most 15% of the fat as rapeseed oil. Since 1971 the rule was changed so that margarine can contain at most 7.5% docosenoic acid (C22:1, as erucic acid or isomers) calculated on the total amount of fatty acids. The result of this restriction is that erucic acid contributes on the average ca 0.4% of the total energy intake as compared to 3-4% earlier. Analyses of margarine carried out by the Swedish Food Department in the spring of 1973 showed that docosenoic acid comprised at most 4% of the total quantity of fatty acids. About one third of the Swedish margarine consumption is at present so-called refrigerator margarine which does not contain rapeseed oil.

Canada has announced that C22:1 fatty acids should not exceed 5% of the total fatty acids in the following foods produced after 30/11 1973: margarine and margarine-like products, shortening, salad oils, food oils, salad dressings and mayonaise.

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26. (in German) The distribution of foreign fatty acids in animal bodies: The participation of erucic acid in the accumulation of organ- and depot fat following extended feeding with rapeseed oil.
87. (in Dutch) A comparison of the food value of butter and margarine.
91. (in German) Evidence of participation of fatty acids from dietary or depot fat on the accumulation of liver fat and on the liver lipidosis occurring as a result of choline deficiency.
92. (in German) The distribution and half-life of erucic acid following feeding of rats with rapeseed oil.