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NUTRITIVE VALUE OF HIGH-ERUCIC ACID AND LOW-ERUCIC ACID RAPESEED OIL

HRANIDBENA VRIJEDNOST REPIČINOG ULJA S VISOKIM I NISKIM SADRŽAJEM ERUKA KISELINE

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SUMMARY

In Poland rape is an oil plant grown on a large scale for food industry. It is the only oil plant giving good crops in climate and at soil of Poland. There is no doubt now that high-erucic acid rapeseed oil (30-50% of erucic acid) liquid or partly hardened exerts a harmful effect on the organism of many experimental animals (rats, rabbits, chickens, turkeys, guinea pigs, hamstars, mice, miniaturepigs, piglets and monkeys).

In view of this, in the countries where rape is grown including Poland varieties of rape with low erucic acid content and without erucic acid have been obtained by genetic selection methods. Presently low-erucic acid (1-5%) rape is grown in Poland, and rapeseed oil obtained from it is widely used in liquid form and also as fat base for the production of margarines.

A review of the world literature shows that high-erucic acid rapeseed oil produced pathological changes in many species of experimental animals. The experiments conducted for over 25 years at the National Institute of Food and Nutrition in Warsaw also demonstrated that administrataion of high-erucic acid rapeseed oil to experimental animals causes various functional and morphological changes in various organs.

The most pronounced pathological lesions were found in the myocardium where after initial transient fatty infiltration focal microcellular infiltrations developed in the form of granulomas followed by fibrosis development. These lesions were particularly evident in young animals.

After many experiments it was demonstrated that high-erucic acid rapeseed oil given to experimental animals in amount of 30% or more of the total energy intake stops weight gain in young animals, while the studies of the authors showed that low-erucic acid oil (1-3%) administered in the same amount has no harmful effect on weight gain. This effect on weight gain in young animals is probably due to lower consumption of food and poor assimilability and low energy value of this oil. It was found that high-erucic acid rapeseed oil is digested worse than other edible oils, while low-erucic acid rapeseed oil has the digestibility index similar to that of soybean oil or sunflower oil. One may assume, thus, that the degree of digestibility of rapeseed oil depends on its content of erucic acid. In high-erucic acid rapeseed oil erucic acid is situated nerly exclusively in positions 1 and 3 of triglyceride molecule, which probably determines the lowdigestibility index of this oil.

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It was shown in many experiments that administration of high- erucic acid rapeseed oil causes rapid and intense accumulation of lipids in the myocardium which is caused by erucic acid. Studies performed by Ziemlanski et al.,(1972-1989) confirmed by other authors, showed that fatty infiltration appeared in the myocardium already three hours after administration of high- erucic acid rapeseed oil with diet, with maximal infiltration after 3-4 days, which persists until the 7-8th day.With regression of fatty infiltration, that is after 6-7 weeks, microfocal histocytic infiltrations appeared, which with time were transformed into fibrosis.

Low-erucic acid rapeseed oil (1-5% erucic acid) caused no fatty infiltration in the myocardium, but after administration of this oil in amount exceeding 20% of the total energy intake it produced microfocal necrosis with histiocytic infiltrations ond microfocal fibrosis in the myocardium of some animals. It should be emphasized that the intensity of these lesions and their incidence were much lower than after high-erucic acid rapeseed oil. As yet it has not been explained whether a relationspip between myocardial fatty infiltration and the development of microfocal necrosis exists. The recent studies of Ziemlanski et al. (1989) showed that no-erucic acid rapeseed oil (i. e. double zero) caused practically no myocardial lesions.

Besides myocardial changes produced by high-erucic acid rapeseed oil adrenal changes were found. The authors demonstrated changes in the corticosterone content of adrenal glands, plasma and urine in the experimental animals proportional to the content of erucic acid in diet. Low-erucic acid rapeseed oil administered in amount equal even to 50% of the energy intake caused no such changes. In the light of these experiments the authors concluded that the content of low-erucic acid rapeseed oil (1-5% erucic acid) in diet should not exceed 10% of the energy value of the daily food ration.

The data on the effects of high-erucic acid and low-erucic acid oil on the human organism are rather scant, and are related mainly to the digestibility of rapeseed oil and erucic acid, and to the effect of one dose of this oil on the rate of utilization of fatty acids by the myocardium. The possibility of a cause-and-effect relataionship between the consumption of high-erucic acid rapeseed oil by humans and the development of myocardial fatty infiltration and microfocal necrosis has not yet been demonstrated. Nevertheless, the results of many experiments on various animal species indicate a need for caution, particularly with regard to high-erucic acid oil.

The studies of Canadian authors on young volunteers have shown that low-erucic acid rapeseed oil was more effective than soybean oil in reducing the blood cholesterol level. Our animal studies confirmed this observation; besides, we demonstrated a strong antiatherosclerotic effect of no-erucic acid rapeseed oil.

On the basis of the results of the studies carried out until now it may be assumed that no-erucic acid or low-erucic acid (1-5%) rapeseed oil is not a threat to health. Moreover, the oil contains large amouts of oleinic acid, approaching those found in olive oil, and this plays a beneficial role in human nutrition.

The present widely accepted opinion is that no-erucic acid or low-erucic acid (1-5% acid) are valuble edible oils and may be recommended to adults. Considering its antiatherosclerotic and hypocholesterolaemic effects it may be recommended to subjects with hypercholesterolaemia and in dietetic treatment of various disease. However, caution is suggested, as yet, in its administration to infants and babies.

Key words: low-erucic acid rapeseed oil - erucic acid metabolism - myocardial lipidosis - granulomas - myocardial fibrosis

In the last 25 years, in many countries, including Canada, France, The Netherlands, Sweden and Poland, studies have been conducted on the biological and nutritive values of liquid and hardened rapeseedoil. A considerable experimental body of data has been gathered concerning the effects of low-erucic acid and high-erucic acid rapeseed oil on the organism, accepting oil with 0,05% of erucic acid as low-erucic acid oil (Canbra, Primor, Canola, Oro, Janpol, Zephyr, Lesira, Beril etc).

The views on the usefulness of rapeseed oil for human nutrition have changed after the introduction of low-erucic acid varieties of rape and after studies of the nutritive value of these new varieties. The pressent discussion contains a summarizing review of these studies with the view of bringing order into often controversial opinions on these problems.

Rapsessed oil is obtained from the seeds of rape (Brassica napus v. oleifera D. C. Cruciferae). Dapending on climatic conditions the plant is sown in spring or autumn. Differences in the profile of fatty acids between these varieties are shown in Table 1.

High-erucic acid rapeseed oil has been in use as edible oil for several centuries in certain areas of China and India, and in Germany and Poland during World War II. Production of high- erucic acid oil increased greatly in Poland after 1946. reaching a peak in the 1960s. In Poland this is the only oil- producing plant cultivated on a large scale which under climatic and soil conditions in Poland can give satisfactory crops.

Table 1 Average per cent proportions of fatty acids in high-erucic acid rapeseed oil from plants sown in autumn and spring (Niewiadomski: Technology of Rapeseed. Warszawa, PWN 1983)
Tablica 1. Prosječni postotni odnos masnih kiselina u visoko eruka kiselini repičinom ulju iz biljki sijane u jesen i proljeće

Acid - Kiselina	Rape sown in Repica sijana u	
	autumn jesen	spring proljeće
Palmitic (hexadecanoic) - Palmitinska	3-4	3-5
Stearic (octadecanoic) - Stearinska	0.8 - 0.9	11-18
Oleic (octadecenoic) - Oleinska	8 - 14	12-17
Linolic (octadecadienoic) - Linolna	12 - 14	14-16
Linolenic (octadecatrienic) - Linoleinska	6 - 10	5-7
Eicosenoic - Eicosenska	6 - 8	9-16
Erucic (docosenoic) - Eruka	45 - 54	30-45

There is no doubt presently, that high-erucic acid rapeseed oil (with 30-50% of erucic acid), liquid or partly hardened, exerts a harmful effect on the organism of many animal species, as compared with sunflower oil, arachidic oil, soyabean oil etc. Particularly harmful biological and nutritional effects were visible in the experiments on young animals, e. g. rats, ducks, guinea pigs, and other animals, experimental and domestic (1,2,40,58).

Table 2. Percentage of fatty acids in high- and low-erucic acid rapeseed oil according to various sources
Tablica 2. - Procentualno učešće masnih kiselina u repičinom ulju s visokim i niskim sadržajem eruka kiseline

Fatty acids - Masne kiseline	Rapeseed oil Repičino ulje	
	high-erucic visoka-eruka	low-erucic niska-eruka
Saturated - zasićene		
butyric (butanoic)	0	0
caproic (hexanoic)	0	0
caprylic (octanoic)	0	0
capric, (decanoic)	0	0
lauric (dodecanoic)	0	0
myristic (tetradecanoic)	0	0
pentadecanoic	0	0
palmitic (hexadecanoic)	3.34	4.30
heptadecanoic	0	0
stearic (octadecanoic)	0.96	1.15
arachidic (eicosanoic)	0.76	0.70
behenic (docosanoic)	0.19	0.29
lignoceric (tetracosanoic)	0.10	0.10
total	5.35	6.60
Monounsaturated - mononezasićene		
tetradecenoic	0	0
pentadecenoic	0	0
palmitoleic (hexadecenoic)	0.19	2.29
heptadecenoic	0	0
oleic (octadecenoic)	23.02	51.57
eicosenoic	9.55	1.43
erucic (docosenoic)	31.52	1.91
total	64.28	57.20
Polyunsaturated - Mnogostrukonezasićene		
linolic (octadecadienoic)	14.80	21.97
linolenic (octadecatrienoic)	10.03	9.55
arachidonic (eicosatetraenoic)	0	0
eicosapentaenoic	0	0
clupodonic (docosahexaenoic)	0	0
eicosenoic-eocosapentaneoic	0	0
docosapentaenoic-docosa-hexaenoic	0	0
total	24.83	31.52

Presently low-erucic aicd rape is grown widely in Poland.
Predstavljena repica s niskim sadržajem eruka kiseline uzgaja se u Poljskoj.

In view of this, in many countries where rape is grown (Canada, France, Germany Sweden etc) intensive studies have been conducted for obtaining rape varieties with lower or nil content of erucic acid. Through selection varieties with low- erucic acid content or even without it were obtained in Canada, Germany, Sweden, France, The Netherlands and also in Poland. The main difference between high-erucic acid and low- erucic acid oils was that in the low-erucic acid oil the erucic acid ($C_{22:1}$) was replaced byoleic acid ($C_{18:1}$). The fatty acids in high-erucic acid and low-erucic acid oil are shown in Table 2.

The low-erucic acid oil obtained from it is widely used in liquid form available in the market under the trade name of "universal oil" or as fat base in the production of margarines. In accordance with the accepted standard the universal oil can contain maximally 8% of erucic acid. Efforts are undertaken to reduce the content of this acid in low-erucic acid rapeseed oil produced in Poland to a maximal level of 5%, as accepted in the FAO/WHO standards. The studies carried out in our Institute have shown that the content of erucic acid in the "universal" oil is often below 5%. The maximal content of erucic acid in the margarines produced in Poland is regulated by the accepted norm, as presented in Table 3.

The world literature on the biological and nutritive values of rapeseed oils differing in the content of erucic acid is very extensive. Of particular value is the monograph "High and Low Erucic Acid Rapeseed Oils, Production, Usage, Chemistry and Toxicological Evaluation" published by Academic Press in 1983. in Toronto (Ed.: J. K. G. Kramer).

GENERAL CHARACTERISTICS OF THE BIOLOGICAL-NUTRITIVE VALUE OF RAPESEED OILS DIFFERING IN ERUCIC ACID CONTENT

It is thought now that the main cause of harmful biological- nutritive effects of rapeseed oil is erucic acid. Possibly, a certain role is also played by the unfavourable ratio of saturated to unsaturated fatty acids in rapeseed oil, and the presence of unknown components in the non-saponifialbe fraction of this oil.

After many studies (1,2,26,27,54,58,60,61) it was found, that high-erucic acid rapeseed oil given in various amounts (from 50 to 15 kcal %) with food to experimental animals produced a number of functional and anatomical changes in various organs. The most severe lesions were demonstrated in the myocardium where after preliminary fatty infiltration pathological changes appeared with focal small-cell infiltrations forming granulomas, followed by fibrosis. This was seen particularly in young animals.

High-erucic acid rapeseed oil also causes adrenal lesions and fatty degeneration of skeletal muscles in young rats. The studies in the recent decade (58,60,61,62,63) demonstrated that pathological changes in the myocardium also developed after feeding low-erucic acid oil to animals (Canbra, Primor and the Polish variety Janpol containing up to 2% of erucic acid) in amounts accounting for at least 20% of the energy value of the diet. However, the prevalence of these lesions and their intensity were much lower than after cousuming high- erucic acid oils. Lower amounts of this oil in diet caused nearly no pathological lesions.

The results of these experiments produce a problem for the dieteticians and for the producers of rapeseed oil since it is used in many countries for the production of salad oils, kitchen fats, margarines and shortenings (which are hardened fats used for improvement of bread and other baker's produsts). This problem is even more important considering the fact, that the experiments conducted in recent years on young rats demonstrated fatty infiltrations in the myocardium, with histiocytes and with focal fibrosis after intake of fish oil as well. Sea-fish oil, similar to rapeseed oils, contain considerable amounts of monounsaturated fatty acids (45-65%) but no erucic acid. The development of pathological lesions after fish oil is not quite understood, but is possibly an effect of cetoleic acid ($C_{22:1}n^{11}$) which accounts for up to 12% of all monounsaturated fatty acids. Sea-fish oil is recommended in the prevention of atherosclerosis. This is also true of low-erucic acid rapeseed oil which has a similar fatty acid profile as olive oil. The latter has a firm position in prophylactic diets. Thus, the pathological lesions observed in animals on low-erucic acid rapeseed oil and fish oil pose a dilemma of practical importance in the nutrition of healthy people as well those with diseases.

For over 25 years at the National Food and Nutrition Institute in Warsaw intensive studies have been conducted on the biological and nutritive value of rapeseed oil with different content of erucic acid, and margarines containing varying amounts of this acid (45,46,47,50-52-55). In these experiments it was found that addition to animal feed of high-erucic acid rapeseed oil produced a number of pathological changes.

THE EFFECT OF RAPESEED OIL ON WEIGHT GAIN IN ANIMALS

The first experiments demonstrating a harmful effect of rapeseed oil with high-erucic acid content were reported in 1940., after studies comparing the nutritive value of butter and margarine. In 1947 Beare et al.(quoted after 6) observed cessation of weight gain in young rats receiving high-erucic acid rapeseed oil. This observation was confirmed by the results reported by Deuel et al. (19,20) which demonstrated that after administration of high-erucic acid rapeseed oil the weight gain of the animals was lower than after consumption of butter and such plant oils as corn oil, soybean oil, arachidic oil, cottonseed oil and olive oil.

Deuel et al. (19,20) suggested that rapeseed oil was less well assimilated by rats, and that erucic acid was the main cause. This was confirmed in numerous studies carried out by Dutch scientists (1,2,3,42).

In the experiments carried out in the 1950s Thomasson and Boldingh demonstrated that the reduction of weight gain in young rats was proportional to the content of erucic acid in their diet. Addition of trierucate to arachidic acid produced the same effect as high-erucic acid rapeseed oil. The inhibition of weight gain of young animals as a result of administration of high-erucic acid rapeseed oil with diet was confirmed later on by many authors (1,3,40) as well as in our studies (45,46,50,54). Growth inhibition was very evident if the high-erucic acid oil accounted for 30% or more of the total energy value of the diet. Lower content of rapeseed oil, e. g. 20% or less, showed practically no inhibition of weight gain in the experimental animals. Our observations showed that the low-erurcic acid rapeseed oil Janpol given even in higher amounts, e. g. 30% of kcal, had no negative effect on weight gain as compared with sunflower oil or soybean oil (60,61,62).

Growth inhibition of the animals receiving rapeseed oil in diet was connected, in the first place, with poor assimilability and low energy production of this oil. Frequently, diet intake was also reduced, especially if rapeseed oil covered 40% or more of the energy value of the diet. Numerous studies showed that experimental animals as well as domestic animals (guinea pigs, mice, ducklings, turkeys, rabbits) receiving high-erucic acid rapeseed oil in diet required more feed per unit of weight gain than the animals on diet with soybean oil or sunflower oil. These observations suggest that lower weight gain of the experimental and domestic animals was the effect of erucic acid, and also of high amount of other monounsaturated fatty acids, with simultaneously present low level of saturated fatty acids in the diet. Addition of palmitic acid to the diet improved considerably the weight gain (1,44). It may be supposed that inhibition of weight gain of young animals receiving in the diet 30-60% of energy from high-erucic acid rapeseed oil was due to poor feed consumption and poor assimilability of this oil.

DIGESTIBILITY AND ASSIMILABILITY OF RAPESEED OILS

In numerous animal experiments it has been shown that high- erucic acid rapeseed oil is less well digested than other edible fats and oils such as soybean oil, sunflower oil, butter or lard. The lower digestibility index of rapeseed oil is due mainly to the presence of erucic acid in it. Rocquelin and Leclerc (33) and ourselves (46,47,48) have demonstrated experimentally thaat erucic acid accounts for 75-77% of all fatty acids recovered from faeces. It is excreted as free acid or as monoglyceride, or diglycerides. Our experiments showed (48) that after oral administration of 560 mg of erucic acid in the form of rapeseed oil or ethyl ester of this acid it was eliminated with faeces during 5 successive days. The digestibility index of the Janpol low-erucic acid oil was 97,5%, thus it was similar to that of soybean and sunflower oil (56). These results were confirmed by Rocquelin and Leclerc (39) and Farnworth (quoted after 21). The digestibility index for high-erucic acid rapeseed oil ranged in various studies from 73% to 91% depending on the amount of oil in the diet and on the diet type. It is known that the digestibility index decreases with decreasing length of fatty acid chain. According to Caroll (15), the digestibility index of monounsaturated fatty acids decreases dramatically with the increasing molecular mass.

After a series of experiments (1,48,49) it was found that the digestibility index decreased with the increasing length of the chain of saturated as well as monounsaturated fatty acids. After feeding fatty acids as methyl or ethyl esters to rats it was noted that the esters were absorbed better than free fatty acids (19,41). But in the case of triglycerides a significant difference was noted between the digestion and absorption of saturated and monounsaturated fatty acids. Triglycerides containing saturated fatty acids were digested and absorbed less well than unsaturated fatty acids while triglycerides with monounsaturated fatty acids were absorbed better than fatty acids alone.

The studies of the authors (47,48,49) demonstrated that the digestibility index of erucic acid rose from 72% to 80% after mixing of the ethyl ester or erucic acid with soybean oil. It was noted that absorption of erucic acid highly present in rapeseed oil also (from 73% to 80%) after mixing of this oil with soybean oil.

In the light of these results it may be supposed that high concentration of polyunsaturated fatty acids makes easier the formation of micelles and facilitates the transport of the products of the hydrolysis of dietary fats by enterocytes and thus may improve the absorption of less well absorbed fatty acids from the digestive tract.

Apart from the type of fatty acid, its position in the triglyceride molecule also affects the rate of digestion of tiglycerides and the absorption of hydrolysis products. It should be accepted that the absorption of the acids in position 2 in the triglyceride molecule is maximal (21).

The poor digestibility of high-erucic acid rapeseed oil, particularly in Sprague-Dawley rats usually used for the experiments, is due, probably, to several factors. In the first place, pancreatic lipase hydrolyses esters of eicosenoic and erucic acids at a lower rate, 62% and 72% respectively than the rate of oleic acid hydrolysis whose absorption rate has been accepted as 100%. Moreover, erucic acid (22:1) present in high-erucic acid rapeseed oil is nearly always situated in positions 1 and 3 of triglyceride molecule, and only 5% of this acid takes position 2 of the molecule. Position 2 is occupied mainly by acids 18:1, 18:2 or 18:3. Possibly this factor determines the low digestibility index of high-erucic acid rapeseed oil.

Monoglycerides containing mainly $C_{18:1}$, $C_{18:2}$, and $C_{18:3}$acids are easily absorbed, while erucic acid and cis $C_{20:1}$, n 9 acid are absorbed less easily. Considering these facts it may be supposed that the esterification of triglycerides containing high-erucic acid in which the 22:1 acid is shifted to position 2 of the triglyceride molecule could increase the digestibility of this oil.

Intramolecular esterification change of high-erucic acid rapeseed oil containing 45% of erucic acid improves the digestibility of that oil probably due to increased amount in the mixture of 2-monoerucin which is better digested and absorbed than free erucic acid. This could also explain better digestion and absorption of trierucin and high-erucic acid rapeseed oil (21) than the absorption of free erucic acid. It may be assumed, thus, that the digestibility degree of rapeseed oil depends on its content of erucic acid. This is indicated by the results of studies in which rapeseed oils with different erucic acid content were used.

Low-wrucic acid rapeseed oil, containing 5% of erucic acid, is well digested by rats (digestibility index 96%), similarly to arachidic acid (33).

It is worth stressing that erucic acid can damage the small intestine mucosa. The studies of the authors (45) demonstrated that in all animals receiving high-erucic acid rapeseed oil (with about 50% of erucic acid) enlargement and flattening of intestinal villi was noted, and the distances between them were increased. Such changes were more pronounced in the animals receiving partly hardened high-erucic acid rapeseed oil. The experiment showed (45) that in rats receiving high- erucic acid rapeseed oil accounting for 30-40% of the energy in diet the digestibility index of other components, e. g. proteins, was not reduced. In the experimental diets used protein accounted for 20% and mineral components for 4-5%.

It is worth stressing that in humans the digestibility of high- erucic acid rapeseed oil is high, as demonstrated by Deuel et al.(19) in 1949, and confirmed in 1972 by McDonald.

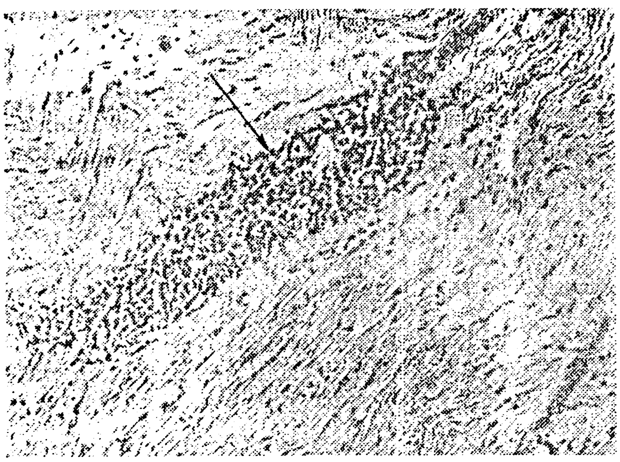
The energy efficiency of rats receiving high-erucic acid oil was lower than that of rats receiving sunflower oil.Hornstra (23) found that the energy efficiency of rats receiving 60% of energy from rapeseed oil was lower than that of rats receiving 60% of energy from sunflower oil.

In the experiments of the authors (57) in which rats were given 40% of energy as sunflower oil, lard or higherucic acid rapeseed oil (50% of erucic acid) the lowest index of energy efficiency was found in the group receiving rapeseed oil (94.5%), and the highest index was in the group receiving sunflower oil (97.5%). These values were higher than those repported by Hornstra for diets containing 60% of energy from rapeseed oil (88%) and sunflower oil (92%). These results confirm the general conclusion that the energy efficiency of the diets with high-erucic acid rapeseed oil is lower.

In the experiments on rats given high-erucic acid rapeseed oil in diet (57) the graduated exercise on electric-driven track (25 rpm, inclination angle 5,5% during 50 minutes daily for 7 weeks)raised the energy efficiency index to 97.5%.

ERUCIC ACID METABOLISM WITH PARTICULAR REFERENCE TO THE HEART

The results of the studies of Abdelatif and Vles (1) demonstrated that feeding high-erucic acid rapeseed oil containing 49% of erucic acid covering 50% of kcal% of the diet to rats caused rapid and great accumulation of lipids in the myocardium. The myocardium became pale already on the first day of the diet, and after 3-6 days on this diet the colour changed to creamy-white. Examination of myocardial tissue revealed that the colour change was caused by fatty degeneration of the myocardial fibres. Similar myocardial fatty degeneration was observed after also administration to animals of trierucin in amounts corresponding to its content in high-erucic acid rapeseed oil. The conclusion was that erucic acid was the cause of the fatty degeneration of the myocardium, and this was confirmed by other authors (5,24,27,35). Myocardial fatty degeneration was connected with increased content of triglycerides in the myocardium, while the content of phospholipids and cholesterol was unchanged (13,46,51,53,58).



Grafikon 2. Fotografija histološkog preparata srčanog mišića štakora, koji su dobivali u hrani razne količine repičinog ulja. Strelica pokazuje zrnasto tkivo. (Ziemlanski i sur., 1974 / / 52)

The results we obtained show that myocardial fatty degeneration occurred already 3 hours after administration of high-erucic acid rapeseed oil with diet (51,53). In the following hours considerable infiltration of the myocardium by lipids was observed. In the analysis of the degree of the fatty infiltration in successive days on the diet with erucic acid it was concluded that the highest degree of the infiltration occured after 3-4 days, and it persisted for 7-8 days (fig 1.). In the following days, despite continued intake of high-erucic acid rapeseed oil the fatty infiltration decreased gradually. After 2-4 months the myocardial lipid level was similar to that in the animals receiving soybean oil or sunflower oil.

The degree of fatty degeneration of rat myocardium depended on the length of the chain of the monounsaturated fatty acids with 20 or more carbon atoms in the chain. For instance, decosenoic acid (22:1) is more haarmful than eicosenoic acid (20:1). With regression of myocardial fatty degeneration, that is after 6-8 weeks, small focal infiltration by histiocytes appeared, which later underwent fibrotic changes.

The results of numerous experiments (5,8,13,27,46,47,50,55) show that considerable amounts of erucic acid are deposited in tissue lipids of the experimental or domestic animals receiving high-erucic oil with diet. In short-lasting experiments (1-56 days) the greatest accumulation of erucic acid was noted in the myocardium. It was present there at the time of the highest fatty infiltration of the myocardium. The amount of erucic acid in the myocardium was proportional to its amount in diet. At the same time, some fatty infiltrations were found in the skeletal muscles.

After long-term feeding of high-erucic acid rapeseed oil to animals the amount of erucic acid in myocardial lipids decreased gradually. Our studies (46) showed that in an experiment with diet containing 30% of kcal from rapeseed oil (the amount of erucic acid in the fat in the diet was 40%) after 7 months only 4.8% of erucic acid was found in myocardial lipids, and after 12 months - 4.2%. In these animals the content of erucic acid in perirenal fat was twice as high, amounting to 9.8% after 7 months of the experiment. In the subcutaneous tissue these values were 9.1% and 6.4% respectively (46). In hepatic lipids only small amounts of erucic acid were found, that is 2.1% after 7 months, and 1.9% after 12 months. In hepatic mitochondria only 0.4% and 0.7% was found after 7 and 12 months respectively. These results show that erucic is readily metabolized in liver cells.

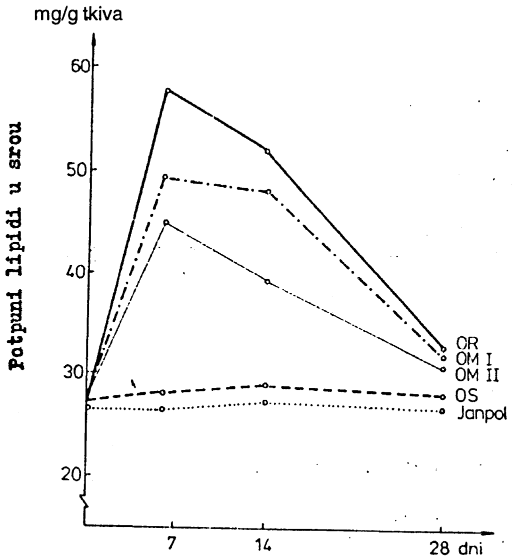
Our experiments (51) as well as those of other authors showed that the amount of oleic acid was increasing in liver lipids. In animals on standard diet the content of $C_{18:1}$ acids in liver lipids was 9.8% while in the group on high-erucic acid rapeseed oil it was 24%.

In short-term experiments (56) it was noted that erucic acid was deposited not only in myocardial lipids, but also in the adrenals, e. g. after 7, 14 and 28 days on the diet containing 30% of kcal from high-erucic acid rapeseed oil (46% of erucic acid) the content of this acid in the adrenals was 8.6%, 5.8% and 9.9% respectively. Similar levels were found in blood - 8.5%, 5.0% and 5.8% respectively. In short-term experiments the greatest deposition of erucic acid (apart from the myocardium) was found in the reserve fatty tissue.

In the perirenal fat after 7, 14 and 28 days on a diet with 30% of kcal from high-erucic acid rapeseed oil (47% of erucic acid)this acid was found in the amounts of 8.2%, 9.7% and 11.8% respectively, and in the same experiment erucic acid in myocardial lipids was 34.3%, 27.0% ond 19.8% respectively (56).

Numerous reports in the vorld literature (1,2,5,6,7,17,24,28,34) and the results of our studies (51-54) show that the myocardium is the organ most sensitive to the action of high-erucic acid rapeseed oil.

It is worth stressing that myocardial fatty degeneration and the development of granulomas was caused by crude and refined high-erucic acid rapeseed oil. Feeding low-erucic acid rapeseed oil (containing 0.1-0.5% of erucic acid), such as Janpol or Winiary, failed to produce myocardial fatty degeneration as show in Fig 1.



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_._._ OM I repičino ulje + sojino ulje 3:1
_____ OM II repičino ulje + sojino ulje 1:1
____ OS sojino ulje
..... Janpol uljna repica Janpol 0,1 % eruka kiseline

Grafikon 1. Omašćenje srčanog mišića nakon primjene u hrani repičinog ulja u usporedbi s drugim vrstama ulja (Ziemlanski, 1977/ /58)

Numerous experiments (5,6,7) in which animals were given various fatty acids (oleic, eicosenoic, erucic and cetolic) demonstrated that the main factor responsible for myocardial fatty degeneration was docosenoic acid i. e. erucic acid. Similar but less pronounced myocardial fatty degeneration was observed in various young animals kept on diets with fish oil, particularly herring oil (7,17,39).

Many authors believe that myocardial fatty degeneration is due mainly to erucic acid present in rapeseed oil and regard this acid as toxic for animals in experiments (quoted after 18). It would be more justified to regard erucic acid as one of the fatty acids less well metabolized by rats and other laboratory animals with consequent pathological changes developing in the myocardium.

As mentioned already, after about 20 weeks on a diet with high-erucic acid rapeseed oil fatty degeneration of the myocardium regressed. Similar lesions were noted in skeletal muscles (20).

This shows that long-term administration of high-erucic acid rapeseed oil leads to metabolic adaptation of the myocardium and skeletal muscles. The initial fatty infiltration of the skeletal muscles regresses completely without leaving traces. On the other hand, in the myocardium it leaves persistent changes in the form of small focal infiltrations of granuloma type with focal fibrosis. It may be concluded that high-erucic acid rapeseed oil is metabolized by the myocardium selectively worse. This is particularly true of erucic acid present in high amounts (45-55%) in rapeseed oil.

In the light of our experiments (61-63) with administration of low-erucic acid rapeseed oil it may be supposed that erucic acid, although being only one of the factors producing these myocardial changes, is among them the most important one. On the basis of the observations of other authors studying the development of granulomas in the myocardium after feeding the animals with large amounts of cocoa fat or its substitute, or fish oils (e. g. herring oil) we could supoose that these lesions are produced by fats less well metabolized by the myocardium. This leads to morphotic changes with the appearance of histiocytic infiltrations changing later into microfocal fibrosis (50,55).

The question arises, whether there is a connection between myocardial fatty infiltration and the development of microfocal necrosis.Many observations suggest that there is no direct cause-and-effect relationship between them. Until now it has been accepted that myocardial necrosis is always preceded by myocardial fatty degeneration. This view is based on the results of experiments on rats give high amounts of high-erucic acid rapeseed oil. Our observations point out that microfocal myocardial fibrosis can develop without previous fatty infiltration.

Our studies (60-62) and those of Framer et al. (quoted after 27) demonstrated that in male rats receiving low-erucic acid rapeseed oil fatty infiltration of the myocardium was slight or completely absent, but in certain animals microfocal necrosis developed following histiocytic infiltrations and microfocal fibrosis. The degree of the lesions and their incidence were, however, much lower than after administration of high-erucic acid rapeseed oil. It may be supposed that in rats myocardial necrosis can be caused by many metalolic factors and differences in nutrition conditions. Such factors as age, sex, strain or species of the experimental animals used may also be important in this respect. All these factors should be considered in the interpretation of the results of the experiments.

MORPHOLOGICAL AND FUNCTIONAL ADRENAL CHANGES AFTER RAPESEED OIL DIET

Besides myocardial lesions of interest are also changes in the adrenals. Already in 1951 Caroll (14) observed adrenal enlargement in rats receiving rapeseed oil in diet. He also noted that the adrenals were pale as compared to normal ones. Increased mass of the adrenals was associated with increased cholesterol content in them (14).

In recent studies on the adrenal function Walker and Corney (44) found lower plasma corticosterone level in response to stress in the animals receiving ethylerucate as compared to rats receiving olive oil in diet. We found (9-11) that in rats receiving high-erucic acid oil in diet the amount of corticosterone increased in the adrenals and also in plasma and urine. Corticosterone changes were proportional to erucic acid level in diet, that is, with increasing erucic acid consumption the amount of corticosterone rose in the adrenals. Administration of low-erucic acid oil in proportion of 50% of kcal in diet during 6-9 weeks caused no change of corticosterone content in the adrenals, and the determined values were the same as those found in the group receiving sunflower oil (9,10,60,61,62).

In the earlier studies of the authors (11) it was observed that when the rats were kept at low temperature the amount of corticosterone decreased in the group receiving rapeseed oil while in the group on sunflower oil this amount remained unchanged.

METABOLIC AND MORPHOLOGICAL TOLERANCE OF RAPESEED OIL BY OTHER ANIMAL SPECIES

The studies conducted for 30 years in various scientific centres have provided evidence that high-erucic acid rapeseed oil has lower nutritive and biological value than soybean oil, sunflower oil, arachidic oil etc. The studies were conducted on various animal species under various conditions. The obtained results, as well as their interpratation, often varied quite considerably.

STUDIES ON PIGS

Pigs responded to diets with high-erucic acid rapeseed oil in a different way than rats. In pigs myocardial fatty infiltration was less pronounced than in rats. In rats high- erucic acid oil could cause triglyceride accumulation in the myocardium even six times greater than in control animals. In young piglets only slight fatty infiltration was sometimes observed using very sensitive histological methods (oil red O) after feeding to them high amounts of high-erucic acid rapeseed oil or oil from sea fish.

Similar results were reported in experiments on miniature pigs (5,6). Myocardial fatty infiltration was also noted in normal pigs (aged 76-80 days) receiving high-erucic acid oil (43). The authors found ultrastructural changes in the hearts of pigs after 45 days on this diet. The changes included the appearance of giant mitochondria, 2-4 times bigger in size. They were called "megamitochondria."

At the same time in Canada long-term studies were begun on pigs receiving high- and low-erucic acid rapeseed oil, and various other edible oils serving for control. The Yorkshire pig breed was used, and the work of Friend et al. (quoted after 27) on a large group of animals failed to demonstrate any significat myocardial changes in groups receiving control diet, without fat enrichment, and groups receiving diets with 20% per weight of corn oil, high-erucic acid and low-erucic acid rapeseed oils.

Similar results were reported from the Alberta University (quoted after 27) where no differences in myocardial changes were found between pigs kept on diet without fat or diets containing soybean oil, high-erucic acid and low-erucic acid rapeseed oils availabale ad libitum.

In the German-Danish studies (quoted after 27,42) conducted on pigs of German-Landrance breed receiving in diet soybean oil, low-erucic acid rapeseed oil (Lesina) or a mixture of rapeseed oils, that is low-erucic acid oil "Primor" (5% 22:1) and high- erucic acid oil (48% 22:1) no differnces were noted in the incidence and intensity of myocardial lesions.

In summary, it may be said that the results of studies on pigs were rather unequivocal. No significat changes were found in the myocardium of pigs kept on no-fat diet or diets containing various proportions of high-erucic acid or low-erucic acid rapeseed oils.

The changes found in pigs by certain authors were, as a rule, less pronounced than in rats.

STUDIES ON MONKEYS

Relatively a small number of studies have beeen done on monkeys. Schiefer et al. (quoted in 27) experimented on 11 Macaca fascucularis monkeys (born in laboratory). They were given, during 120 days, diets with added 25% of a mixture 3:1 of lard and corn oil or high-erucic acid rapeseed oil (23% of erucic acid), or partly hardened herring oil (23% of cetoleic acid). All diets containing long-chain monounsaturated fatty acids (22:1) produced evident fatty infiltration in the myocardium (+++), while the diet containing lard and corn oil caused only moderate (O to ++) fatty infiltration in the four grade infiltration scale. Similar changes were found in skeletal muscles.

The experiments were repeated by Schiefer in 1982 (36). The monkeys were killed 6,12,18,24 and 30 months after the beginning of the diets. The results were similar to those reported previously, however, in the groups receiving herring oil or corn oil with lard the degree of fatty infiltration was ++ to +++ after 3 months.

Electron microscopic studies of the myocardium of the monkeys receiving in diet long-chain monounsaturated fatty acids (22:1) showed enlarged mitochondria with irregular shapes and changes in the matrix. Some damage was also noted in the mitochondrial structure. No similar ultrastructural changes were reported in the monkeys kept on the diet with corn oil and lard, with myocardial fatty infiltration scoring +++.

Earlier studies of Beare-Rogers and Nera (5,6) on monkeys revealed presence of lipid droplets in the myocardium after 1 or 10 weeks on diet with high-erucic acid rapeseed oil.

The studies carried out by Gopalan et al. (quoted after 27) in 1974. on Macaca radiata monkeys receiving 20 g of mustard oil per 100 g of diet during 1 year failed to reveal any significant changes in the general health of the animals, but autopsy and histological examination of the myocardium revealed fatty infiltration.

Certain concluions can be drawn from the studies on monkeys reported in literature. It seems that high-fat diets, especially those containing long-chain monounsaturated fatty acids, produce a more intense fatty infiltration of the myocardium in monkeys than in pigs but much lower than in rats.Moreover, in the myocardium of monkeys fatty infiltration was noted after high-fat diets, even without docosaenoic acids. Myocardial fatty infiltration in monkeys was never as intense as in rats.

A separate problem is the development of small foci of necrosis or granulomas in the myocardium of monkeys after diet with rapeseed oil. The available data are insufficient for claiming a correlation between the content of high-erucic acid rapeseed oil or other oils containing docosaenoic acid and focal pathological changes in the myocardium. Thesse changes very in their appearance from slight microfocal necrosis to focal infiltrations composed of lymphocytes, mononuclear cells, plasma cells and eosinophils. These changes can be regarded as diffuse myocarditis. A detailed analysis of the obtained data suggests that these lesions should probably not be linked with infections but rather with stress (quoted after 27). Similar changes were noted in monkeys on high-fat diets without rapeseed oil.

In the experiments with diets containing 25% of high-erucic acid rapeseed oil (25% of 22:1, n 9) and partly hydrogenated herring oil (25% of 22:1, n 11) or a mixture of corn oil with lard given to monkeys, myocardial changes, particularly in the form of focal infiltrations, were found in all the three groups of animals (quoted after 26 and 27).

In the available literature only one paper was found on diet with low-erucic acid rapeseed oil given to monkeys. The study was reported by Kramer et al. (quoted after 27). In their study no myocardial necrosis or fibrosis was noted in monkeys receiving 20% per weight of low-erucic acid oil. A similaar finding was reported from studies on rats. No significant differences were observed between the group on low-erucic acid oil and the control group receiving soybean oil. Certain pathological changes were found in the myocardium but the authors considered that they were not related to the type of dietary fat. It is worth reminding that monkeys are herbivorous animals and in their natural environment they consume very small amounts of fat.

STUDIES ON POULTRY

Only few experiments were done on poultry. Adbelafit and Vles (1,3)carried out first experiments on ducklings giving them high-erucic acid rapeseed oil. It was found that administration of high-erucic acid oil (50%, 22:1) in amounts covering 40% of kcal volue of the diet or more killed the ducklings. Autopsy revealed effusions in pericardial sac. The hearts were pale and showed high-grade atty degeneration. Fatty degeneration was also found in the liver associated with fibrosis.

Ratanasethkul et al. (quoted after 26) gave to chicken, ducks and turkeys diets containing high-erucic acid rapeseed oil, soybean oil, and to the control group a mixture of corn oil and lard. In all the ducks and some chicken on high-erucic acid oil (36%, 22:1) hydropericardium was present. In al the birds receiving that oil myocardial fatty degeneration was noted which decreased despite continuation of the diets. These changes resembled those found in rats. In ducks the thickness of myocardial wall was increased and myocardial fibrosis was present. Typical granulomas were noted in the myocardium of some turkeys.

SUMMARY OF THE RESULTS OF ANIMAL EXPERIMENTS

Summarizing the available reports in world literature it can be said that the occurrence of tatty degeneration of the myocardium after diets containing docosaenoic acid was found in many animal species (rats, rabbits, ducks, chicken, turkeys, guinea pigs, hamsters, mice, miniature pigs, piglets and monkeys). The intensity of these changes varied but no animal species was resistant to the effects of high-erucic acid rapeseed oil in diet or to administration of erucic acid.

The works of Houstmuller et al. (24). Christophersen and Bremer (16), Lemarchal et al. (28), Pinson and Padieu (32), Bezard et al. (8) show that in all enzymatic reactions occurring in the process of tatty acid oxidation in the myocardium the degree of erucate metabolism was lower than that of palmitate or oleate. Although it is difficult to transfer the results of these in vitro experiments to the living organism of animals, it may be supposed that the cumulation of lipids in the myocardium may be due to reduced rate of beta-oxidation and lower binding to carrier proteins.

The experiments of Bezard et al. (8) demonstrate that erucic acid is removed from the circulation of animals more slowly than oleic acid. In our Department of Nutrition Physiology and Biochemistry experiments were carried out on carnitine determination in the hearts and livers of male rats which, were given after a 20-hour fast rapeseed oil, methyl ester of erucic acid or soybean oil. Erucic acid increased the content of acylcarnitines in the myocardium but had no effect on the content in the liver. The effect of erucic acid on myocardial acylcarnitine content was particularly evident during graded exercise.This may indicate that myocardial fatty degeneration produced by dietary rapeseed oil is due to impairment of erucic acid oxidation. Struijk et al. demonstrated that administration of a diet with 50% of kcal from rapeseed oil to rats during 1-14 days increased heparin-induced activity of lipoprotein lipase in plasma by about 45% after 3-6 days.

Of interest are the results reported by Slinger et al. (37) who observed that myocardial fatty degeneration in rats receiving high-erucic acid rapeseed oil was associated with reduction of glycogen in the myocardium where it replaces fat as an energy source. The glycogen content in the myocardium remained low throughout the whole period of the diet with high-erucic acid rapeseed oil.

It is worth stressing that transient fatty degeneration of the myocardium in the animals receiving high-erucic acid rapeseed oil is not so dangerous as later degenerative changes wich can develop even though the animals are given higher amounts of low-erucic acid rapeseed oil such as Cambra, Primor or Janpol. These changes are difficult to understand from the standpoint of myocardial biochemistry.

Another interesting observation is that administration with diet of low-erucic acid rapeseed oil Janpol in amounts over 20% of the total energy of the diet caused in some animals myocardial changes with the development of scant focal granulomas not preceded by fatty infiltration. The frequency and intensity of these changes were lower in relation to the animals receiving high-erucic acid rapeseed oil (60-62). This observation was confirmed by many authors (17,43) who used in experiments various low-erucic acid rapeseed oils, e. g. Cambra or Primor etc.

Our studies (60-63) demonstrated that low-erucic acid rapeseed oil (2.8% of erucic acid) given to animals in amounts covering 10% of kcal in the diet gave practically identical results as soabean oil. The practical conclusion is that the content of no-erucic acid rapeseed oil in diet should not exceed 10% of its energy value. This conclusion is based on the results of studies in which it was found that myocardial degenerative changes developed after diets containing higher amounts of low-erucic acid rapeseed oil or fish oil. However, the role of other components of these oils should not be disregarded in the mechanism of myocardial damage development. It seems as yet that the main cause is erucic acid or other long-chain polyunsaturated fatty acids. We carried out a number of experiments giving the animals various amounts of liquid or partly hydrogenated rapeseed oil together with other fats. The content of erucic acid in these diets ranged from 0.2 % to 40 %, and the total amount of energy derived from these oils was not exceeding 20%. An evident correlation was demonstrated between the amount of fatty acids with 20 and more carbon atoms and the incidence and intensity of myocardial changes (56,57).

A separate problem are the differences in the effects of liquid and partly hydrogenated rapeseed oils. Many years of experience (52,54) have demonstrated that the incidence and intensity of changes in rat hearts, after they had been given hardened rapeseed oil in diet in the form of various margarines with various amounts of erucic acid, were lower in rats receiving the same amounts of liguid oil. This has been confirmed by other authors.

EFFECT OF HIGH-ERUCIC ACID RAPESEED OIL ON HUMAN ORGANISM

Studies on this problem are rather scant and have been carried out mainly for establishing the digestibility of rapeseed oil or erucic acid, and the effect of a single dose of rapeseed oil on the respiratory system and on the rate of utilization of low-erucic acid rapeseed oil by the myocardium. In recent years the effect of rapeseed oil on plasma lipids has been investigated.

Of interest were the results reported by Clouet et al.(quoted after 22) on the oxidation rate of erucic acid by isolated human myocardium in vitro, and the observations of Swaar (39) on the cumulation of erucic acid in the myocardium of people dying in traffic accidents.

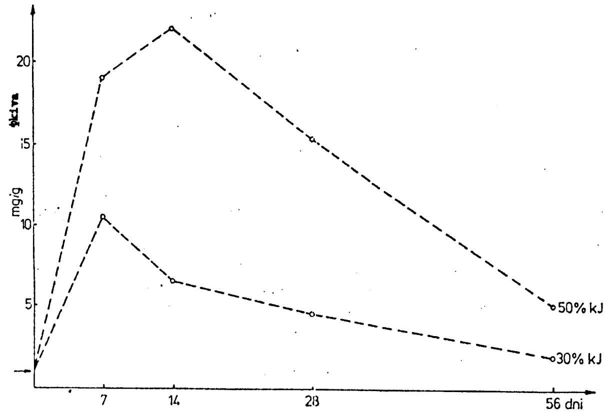
Deuel et al. (19) demonstrated in 1949. that rapeseed oil is well digested in human digestive tract. This was confirmed later on in 1972-1973 by McDonald (29) and Vaisey et al. (41). In these studies the digestibility of erucic acid was determined in adults receiving diets containing 20-22% of energy derived from high- and low-erucic acid rapeseed oil, and margarines and shortenings (hardened fats used for improving the quality of baker's products) containing high- erucic acid rapeseed oil. The apparent digestibility of erucic acid was high, reaching 98-100%.

In the studies of Vaisey et al. (41) the overall consumption of dietary fat from the diet containing high-erucic acid rapeseed oil was 128 g daily, and 120g from the diet containing low-erecic acid oil. In the diets 38% of energy was derived from fats and the studied oils accounted for 50 % of total fat.

The mean consumption of high-erucic acid rapeseed oil was 72 g and that of low-erucic acid oil - 70 g daily. Fat digestibility from both diets was nearly identical, the apparent digestibility of high-erucic acid rapeseed oil was 96%, that of low-erucic acid oil was 96.5%. The mean digestibility index of erucic acid was 99.5%, in agreement with the results obtained by Deuel et al. (19.20).

In the last two decades the interest of doctors and nutritionists in the possibility of lowering plasma lipids by consumption of plant oils has increased. Particularly important has been lowering plasma cholesterol level. In many studies it was found that increasing the amount of polyunsaturated acids in diet decreased plasma cholesterol level, while increasing the consumption of saturated fatty acids raised this level.

Previous reports (30) indicated that monounsaturated fatty acids had no evident effect on plasma cholesterol level. The view was widely accepted that fluctuations in the dietary monounsaturated acid level had only a slight effect on plasma cholesterol level.



Grafikon 3. Sadržaj eruka kiseline u lipidima srčanog mišića u štakora, koji su dobivali razne količine repičinog ulja u hrani. (Ziemlanski, Budzynska - Topolowska i sur., 1975 / 54)

In the light of recent experimental and clinical studies this view had to be revised. It is known that olive oil containing small amounts of polyunsaturated fatty acids (about 7-10%) and a high amount of oleic acid is effective in decreasing the human plasma cholesterol level.

It is known that high- and low-erucic acid rapeseed oils have low content of saturated fatty acids and relatively high content of monounsaturated fatty acids. The main difference between them is that in low-erucic acid oil the erucic acid (22:1) is replaced by oleic acid (18:1). Both oils contain about 20-35% of polyunsaturated fatty acids (18:2 + 18:3). This shows that high- and low-erucic acid rapeseed oils are not a very rich source of polyunsaturated fatty acids but it can be supposed that the use in diets of low-erucic acid rapeseed oil replacing animal fats could reduce total plasma cholesterol level.

It was noted that reduction of dietary saturated fatty acids was twice as effective in the reduction of plasma cholesterol level as the equivalent increase of polyunsaturated fatty acids (25). In the Food and Nutrition Institute of the Manitoba University a series of metabolic studies were carried out in 1974-1980 on the effects of high- and low-erucic acid rapeseed oils on plasma lipids of young healthy individuals (quoted after 22), and it was found that the plasma cholesterol level decreased significantly after intake of low- erucic acid oil Lear.

Similar changes were observed in the plasma levels of phospholipid phosphorus which was significantly decreased. The study of the profile of fatty acids in plasma phospholipids showed that the acids changed parallel with the changes in the profile of fatty acids in high- and low-erucic acid rapeseed oils given in diet.

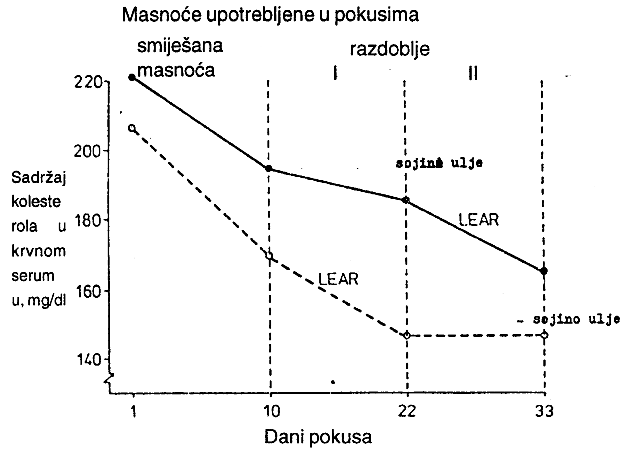
In the analysis of the studies on plasma cholesterol level of people consuming high- or low-erucic acid rapeseed oils it was revealed that low-erucic acid oil was more effective in the reduction of plasma cholesterol level. Blood samples taken on days 1,10,18,25 and 32 of the diet containing the studied oils demonstrated that in the individuals taking high-erucic acid rapeseed oil the plasma cholesterol level was initially decreased but on the 32nd day it rose evidently, while in the group receiving low-erucic acid oil a permanent decrease of cholesterol level was obtained.

In other investigations on young individuals Bruce et al. (quoted after 22) demonstrated that low-erucic acid rapeseed oil had even a more prononced hypocholesterolaemic effect than soybean oil. In these studies a reduction was also obtained of palmitic acid in plasma lipids while its level was high in control groups. Reduced palmitic acid level was associated with increased level of oleic acid which was in agreement with the profile of fatty acids in diet. This could suggest that erucic acid is metabolized in man to oleic acid, as demonstrated previously in animal experiments (50,54,55,56).

The study of the profile of fatty acids in reserves of fatty tissue obtained by biopsy from the subcutaneous epigastric tissue of two persons consuming high-erucic acid repeseed oil in diet showed that erucic acid was accumulated in reserves of fat in small amounts. Fatty tissue samples were taken on days 10 and 32 of high-erucic acid rapeseed oil diet. The content of erucic acid was o.4% and 2% of all fatty acids.

The low content of erucic acid in phospholipids and triglicerydes in human fatty tissue may be an evidence of its rapid conversion into other fatty acids, particularly oleic acid. These observations contradict the studies on rats in which the authors demonstrated high accumulation (up to 15%) of erucic acid in triglycerides in reserves of fatty tissue, which was proportional to the content of this acid in diet.

The energy processes in man after consumption of high-erucic acid rapeseed oil were studied by Tremolieres et al.(quoted after 22). A single dose of rapeseed oil 0.5 g/kg body weight (accounting for 13% of fat-derived energy) added to the diet of adult man caused after 150 minutes a rise of the oxidation of fatty acids in the organism, probably mainly in the liver. The maximal content of erucic acid and eicosaenoic acids in plasma lipids was observed 150-210 minutes after rapeseed oil ingestion. No accumulation of erucic acid in the erythrocytes was observed after one dose of rapeseed oil. Tremolieres and Carre (quoted after 22) demonstrated in man increased oxidation of fatty acids from rapeseed oil in comparison with arachidic oil. After 4 hours from rapeseed oil ingestion the oxygen uptake rose by 24% obove the resting value, i. e. before oil ingestion. These authors concluded that the ingested fat caused no inhibition of mitochondrial function.



Grafikon 4. Utjecaj sojinog ulja i ulja od niskoglukozidne repice LEAR na sadržaj kolesterola u krvnom serumu mladih ljudi - (Mc Donald, 1983/ /29)

This conclusion was not confirmed by the results obtained by Clouet et al. (quoted after 22) with incubated human myocardial mitochondria taken for examination within 15 hours after death in a traffic accident. The metabolization rate of erucic acid was significantly lower than e. g. that of oleic acid. This was confirmed in other studies, in which human myocardial mitochondria were obtained by intraoperative cardiac biopsy (quoted after 22). The problem of possible harmful influence of rapeseed oil on human cardiovascular system remains to be explained. Particularly important would be explanation of whether granulomas develop in human myocardium, as this is the cases e. g. with rats, or whether consumption of rapeseed oil and other oils containing high amounts of erucic acid (mustard oil) could be harmful for man.

Microfocal lesions in human myocardium, similar to those found in rats, are observed but their cause is different. Many drugs or toxins can produce disseminated focal myocardial lesions but these lesions cannot be connected with fat consumption (22).

The possibility of a cause and effect relationship between the consumption of high-erucic acid rapeseed oil and accumulation of erucic acid in human myocardial lipids, on the one hand, and the development of microfocal myocardial necroses was the subject of careful studies initiated by the Indian Council of Medical Research and published by Anonymous in the years 1976- 1977 in the Annual Report of the National Institute of Nutrition, Hyderabad, India (4). For that study the area of Calcutta was chosen, where the consumption of erucic acid was particularly high. It was found that the content of erucic acid in myocardial lipids was a consequence of mustard oil consumption. The mean content of erucic acid in myocardial lipids was 5.6%, ranging from 0.9 to 9.9%. That study failed, however, to establish the connection of heart diseases with erucic acid consumption. For that purpose over 100 hearts were examined histologically to find granulomas or focal myocardial fibrosis.

The data concerning erucic acid accumulation in human myocardium and consumption of fats containing fatty acids from the C22:1 group were published by Svaar in 1982 (39). His study was based on autopsy examinations of individuals aged 20 to 69 years dying in accidents. No focal lesions were found. Slight fatty infiltration was demonstrated in 50% of the examined hearts but this was without any relation to the concentration of C22:1 acids in myocardial lipids.

In the light of thesse studies and the present state of knowledge, as suggested by Grice and Heggtveit, the conclusion can be drawn that there are no sufficient data indicating that the consumption of C22:1 fatty acids present in rapeseed oils and sea-fish oils can exert a haramful effect on human heart. Nevertheless, many observations made in various animal spacies call for caution in respect to high-erucic acid rapeseed oil in diet, especially in food taken by children and adolescents.

In summary, it can be said that low-erucic acid, or better no- erucic acid rapeseed oil in human food is not harmful to adults. No-erucic acid rapeseed oil is presently used all over the world in liquid form as salad oil, or partly hardened for the production of margarines.

In this place, it is worth stressing that no-erucic acid rapeseed oil contains high amounts of oleic acid being in this respect at the top, besides olive oil, of all edible oils. This is of importance, since the view on the role of monounsaturated fatty acids, especially oleic acid, has changed recently. Oleic acid reduces eqaually effectively cholesterol level in low density lipoprotein (LDL) fraction as linolic acid, without reducing the level of cholesterol in the high density lipoprotein (HDL) fraction, which is known to be an unfavourable effect.

The return to replacement of saturated fatty acids with oleic acid is justified in the light of 15 years of epidemiological observations conducted in 7 countries which demonstrated that oleic acid consumption reduced the mortality from ischaemic heart disease.It was also observed that the incidence of coronary heart disease, that is coronary arteriosclerosis, is low in Mediterranean countries where olive oil is widely used in diet.

The results of our recent studies (65) on the antiatherosclerotic action of the so called no-erucic rapeseed oil (o.0-0.5% of erucic acid) are worth reporting. In this study it has been shown that no-erucic acid oil effectively reduce the total plasma cholesterol level and LDL cholesterol level, increasing at the same time the HDL cholesterol level. The degree of inhibition of atheroma development induced by high cholesterol consumption is similar in the group of animals receiving sunflower oil in diet and that recciving no- erucic acid rapeseed oil.

In the light of these data it can be said that no-erucic acid rapeseed oil is a valuable edible oil.

Considering the evident action of rapeseed oil containing practically no erucic acid which reduces the plasma cholesterol level and prevents atherosclerosis this oil can be recommended in the diet of hypercholesterolaemic patients and in other diseases. However, caution is recommended in using it for children and adolescents.

This opinion is also true of food products containing no- erucic acid or low-erucic acid rapeseed oil, the latter with erucic acid content about 5%.

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SAŽETAK

U Poljskoj repica je uljarica što se ugaja na širokoj osnovi za prehranbenu industriju. To je jedina uljarica koja daje dobar urod u klimi i na tlu Poljske. Sada nema sumnje da repičino ulje s visokim sadržajem eruka kiseline (30-50% eruka kiseline), tekuće ili djelomično stvrdnute, izaziva štetno djelovanje na organizam mnogih pokusnih životinja (štakora, kunića, pilića, purana, zamoraca, hrčaka, miševa, malih papigica, mladih svinja i majmuna).

U svezi s time, u zemljama gdje se repica uzgaja, uključujući Poljsku, genetskim metodama selekcije dobivene su sorte repice s niskim sadržajem eruka kiseline i bez eruka kiseline. Trenutačno se u Poljskoj uzgaja repica s niskim sadržajem eruka kiseline (1-5%) a repičino ulje što se od nje dobiva uvelike se upotrebljava u tekućem obliku, a isto tako i kao masna osnova, za proizvodnju margarina.

Pregled svjetske literature pokazuje da je repičino ulje s visokim sadržajem eruka kiseline prouzročilo patološke promjene u mnogih vrsta pokusnih životinja. Pokusi što su se provodili preko 25 godina u Nacionalnom institutu za hranu i prehranu u Varšavi isto tako je pokazao da davanje repičinog ulja s visokim sadržajem eruka kiseline pokusnim životinjama uzrokuje razne funkcionalne i morfološke promjene u raznim organima.

Vrlo izrazite patološke lezije nađene su u miokardu gdje su se nakon početne kratkotrajne masne infiltracije razvile fokalne mikrostanične infiltracije u obliku granuloma, nakon čega se razvila fibroza. Te su lezije bile osobito očite u mladih životinja.

Nakon mnogih pokusa pokazalo se da repičino ulje s visokim sadržajem eruka kiseline davano pokusnim životinjama u količini od 30% ili više od ukupnog unošenja energije zaustavlja porast težine u mladih životinja, dok su proučavanja pokazala da ulje s niskim sadržajem eruka kiseline (1-3%) davano u istoj količini nije imalo štetnog učinka na porast težine. Ovaj se učinak na dobivanje težine vjerojatno može pripisati manjoj potrošnji hrane i slaboj probavljivosti, te niskoj energetskoj vrijednosti toga ulja. Nađeno je da se repičino ulje s visokim sadržajem eruka kiseline lošije probavlja nego druga jestiva ulja, dok repičino ulje s niskim sadržajem eruka kiseline ima indeks probavljivosti sličan indeksu sojinog ulja ili ulja suncokreta. Prema tome, može se pretpostaviti da stupanj probavljivosti repičinog ulja ovisi o sadržaju eruka kiseline. U repičinom ulju s visokim sadržajem eruka kiseline eruka kiselina je gotovo isključivo smještena na položajima 1 i 2 trigliceridne molekule, što vjerojatno određuje niski indeks probavljivosti tog ulja.

U mnogim je pokusima pokazano da davanje repičinog ulja s visokim sadržajem eruka kiseline uzrokuje naglo i intenzivno nakupljanje lipida u miokardu što je prouzrokovano eruka kiselinom.Proučavanja koja je proveo Ziemlanski i sur. (1972-1989), a što su potvrdili i drugi autori, pokazala su da se u miokardu pojavila masna infiltracija već tri sata nakon davanja repičinog ulja s visokim sadržajem eruka kiseline u hrani, s najvišom infiltracijom nakon 3-4 dana, što je trajalo do7.-8. dana. S regresijom masne infiltracije, tj. nakon 6-7 tjedana pojavile su se mikrofokalne infiltracije koje su se nakon nekog vremena pretvorile u fibrozu.

Repičino ulje s niskim sadržajem eruka kiseline (1-5% eruka kiseline) nije prouzročilo nikakve masne infiltracije u miokardu, ali nakon davanja toga ulja u količini od preko 20% ukupnog uzimanja energije ono je proizvelo mikrofokalnu nekrozu s histiocitičnim infiltracijama i mikrofokalnom fibrozom miokarda nekih životinja. Potrebno je naglasiti da je intenzitet i ovih lezija i njihova pojava mnogo niža nego nakon repičinog ulja s visokim sadržajem eruka kiseline. Još nije protumačeno da li postoji veza između masne infiltracije miokarda i razvoja mikrofokalne nekroze. Novija proučavanja Ziemlanski i sur. (1989) pokazuju da repičino ulje bez eruka kiseline (tj. dvostruko 0) nije prouzročilo gotovo niti jedne lezije miokarda.

Osim promjena miokarda zbog repičinog ulja s visokim sadržajem eruka kiseline nadjene su i nadbubrežne promjene. Autori su prikazali promjene u sadržaju kortikosterona nadbubrežnih žlijezda, plazme i urina u pokusnih životinja razmjerno sadržaju eruka kiseline u hrani. Davanje repičinog ulja s niskim sadržajem eruka kiseline u iznosu čak i do 50% primljene energije nije prouzročilo nikakve takve promjene. U smislu tih pokusa autori su zaključili da niski sadržaj eruka kiseline u repičinom ulju (1-5% eruka kiseline) u hrani ne bi smio preći 10% vrijednosti energije dnevnog obroka.

Podaci o djelovanju ulja s visokim i niskim sadržajem eruka kiseline na ljudski organizam prilično su oskudni i uglavnom se odnose na probavljivost repičinog ulja i eruka kiseline i na djelovanje jedne doze toga ulja na stopu iskorištenja masnih kiselina od miokarda. Mogućnost odnosa uzrok - posljedica između potrošnje repičinog ulja s visokim sadržajem eruka kiseline u ljudi i razvoja masnih infiltracija miokarda i mikrofokalne nekroze još nije prikazana. Pa ipak, rezultati mnogih istraživanja na raznim vrstama životinja upućuju na potrebu opreza, osobito u svezi s uljem s visokim sadržajem eruka kiseline.

Proučavanja kanadskih autora na mladim dobrovoljcima pokazala su da je repičino ulje s niskim sadržajem eruka kiseline djelotvornije od ulja soje u smanjenju razine kolesterola u krvi. Naša su istraživanja na životinjama potvrdila to zapažanje; osim toga, mi smo prikazali snažno antiaterosklerotično djelovanje repičinog ulja bez eruka kiseline.

Temeljem rezultata dosadašnjih proučavanja može se pretpostaviti da repičino ulje s niskim sadržajem eruka kiseline ili bez nje (1-5%) nije prijetnja zdravlju. Osim toga, ulje sadrži velike količine oleinske kiseline, skoro iste kao u maslinovom ulju i to igra korisnu ulogu u ljudskoj prehrani.

Danas je široko prihvaćeno mišljenje da su ulja bez eruka kiseline ili s niskim sadržajem eruka kiseline vrijedna jestiva ulja (1-5% kiseline) i mogu se preporučiti odraslima. S obzirom na njegovo antiaterosklerozno i hipokolesterolično djelovanje može se preporučiti bolesnicima s prevelikom količinom kolesterola te u liječenju raznih bolesti dijetom. Međutim, predlaže se oprez, za sada, u primjeni kod novorođenčadi i male djece.