Absorption from the alimentary tract of selected fatty acids of rapeseed oil

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Absorption from the alimentary tract of selected fatty acids of rapeseed oil by

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A comparison of intestinal absorption of erucic acid and that of oleic acid has been carried out on Wistar rats in various model systems. The deficiency in absorption of erucic acid was found. The presence of erucic acid in rapeseed oil may be considered as the main cause of its poor digestibility.

Fat digestion and its absorption from the small intestine depend first of all upon the kind of ingested fats and upon their fatty acid composition. In normal conditions, fats contained in the diet are almost fully absorbed. Therefore the digestibility coefficients of natural edible fats are very high, representing up to 98%. Lately, the biological and nutritional values of rapeseed oil were intensely studied in Poland and abroad. These values are lower than those of other oils like soybean,
sunflower or peanut oils /1, 5, 7, 9, 10, 11, 12/. Erucic acid (cis-13,decoenoic acid, C\textsubscript{22}) representing about 50\% of the total fatty acid content of rapeseed oil, is considered to be the main component which is responsible for the low biological and nutritional effects of rapeseed oil. The absorption of erucic acid is one of the less known aspects of this acid's biological and nutritional values /2, 5, 7, 8, 10/. The low digestibility coefficients of rapeseed oil are probably due to its poor digestion and absorption from the digestive tract. Following the research of Thomasson et al. /7/, absorption time of 50\% of the ingested butter and soybean oil is of 5 - 6 hours, whereas that of rapeseed oil is of about 9 hours. This is the highest absorption time of half of the ingested amount, among all known natural edible fats.

The aim of this research was to study the absorption from the digestive tract of erucic acid administrated per os as its ethyl ester or in its natural form as contained in rapeseed oil.

At the same time, absorption of oleic acid (C\textsubscript{18}) was determined for comparison.

Research method

The research was carried out on 130 Wistar rats bred by this institute. At the age of 10 weeks the rats were given ad libitum for two weeks a semi-synthetic diet without erucic acid (table I).
In a first experimentation series, on experimentation day, after 18 hours of fasting, during which the rats were kept in cages designed to prevent coprophagy, into their stomach were introduced with a probe 560 mg of erucic acid in the form of its ethyl ester and 1,5 ml of a test meal composed of 5 g of olive oil, 5 g of sodium caseinate and 40 g of a solution of physiological salt. The test meal was homogenized for 2 min. at 3000 rpm. Then, at 2, 4, 6 and 8 hours after administration of the test meal, the following samples were taken under ether anesthesia: blood from the portal vein and from the heart, content of the stomach and the small intestine (jointly) and of the large intestine. The content of the gastro-intestinal tract was rinsed with a 0,9% solution of sodium chloride at 37°C. For control purposes, the same samples were taken from rats, without feeding them, after 18 hours of fasting.

In a second experimentation series, the rats were divided into four experimentation groups with different forms and methods of erucic acid administration. The first group received 0,8 g of erucic acid ethyl ester per animal; the second - the same and 0,8 ml of soybean oil; the third - 1,6 ml of rapeseed oil; the fourth - 1,6 ml of rapeseed oil and 0,5 ml of soybean oil. The erucic acid content of each test meal was of about 560 mg. After a single administration of the test meal with a probe, the rats were put each in a metabolic cage where they were kept for 5 days. During all this time their feces were collected.
During this time, all rats were given 10 g per diem of a fatless diet shown in table II and water ad libitum. The absorption coefficients of the fatty acids under study were established in the first series after 8 hours and in the second during a period of 120 hours, by using the formula:

\[
\frac{I_i - I_c}{I_i} \times 100
\]

where \(I_i\) represents the ingested amount, \(I_c\) - the amount found in the content of the gastro-intestinal tract or in the feces. The chemical analysis was performed on samples taken from 4 rats. The fat was extracted from the samples by the method of Folch /4/. Afterwards, the fat was converted into methyl ester following the Stoffel method /6/ described by Endres /3/. The relative composition of the fatty acids was determined by gas-liquid chromatography. The determination was performed at the Institute of the Fermentative Industry with a Pye gas-chromatography apparatus with flame-ionization detector. The columns, 7 feet high and 4 mm wide, were packed with 10\% PEGA on Celite of 100 - 200 mesh. Column temperature was of 202° C. The resulted peaks were identified by comparing their relative retention time in relation to that on chromatograms of a standard mixture. The fatty acid content was expressed in relation to the total content or in mg.
Results and Discussion

I. Amount of erucic and oleic acids found

in the content of the gastro-intestinal tract

The erucic and oleic acid content of the studied
samples is shown in fig.1 and 2.

The obtained results show that the erucic acid
content of samples taken from the stomach and the small
intestine of rats after fasting was of 6.3% of the total
fatty acid content. Two hours after 560 mg of erucic acid
ethyl ester were introduced, this content went up to an
average of 72.2%, to diminish after 4 hours to 68.9%,
and then to 49.5% after 6 hours and to 38.8% after 8 hours.

The amount in mg of erucic acid found jointly in
the stomach and the small intestine, sampled after fasting,
was of 0.3 mg. Two hours after introduction of 560 mg of
erucic acid, this amount increased to an average of 384.3 mg
(about 68% of the introduced quantity). After 4 hours it
decreased to an average of 216.3 mg (about 40% of the
introduced quantity); after 6 hours it decreased to an
average of 70.6 mg (about 12%) and after 8 hours to 46.8 mg
(about 8%). The amount of erucic acid found in the content
of the large intestine represented 10.7% of the total
fatty acid content after fasting. Two hours after intro-
duction of 560 mg of erucic acid, its content in the large
intestine increased to 31.6%, after 4 hours to 68.0% and
after 6 and 8 hours to 77.0%. The erucic acid content
expressed in mg presented the same variation. Two hours
after administration of the applied dose of erucic acid ester, its amount found in the content of the large intestine increased to 37.5 mg (6.5% of the introduced quantity), after 4 hours to 119.1 mg (about 20%), after 6 hours to 258.7 mg (about 45%), and after 8 hours to 231.3 mg (50% of the introduced quantity). The high erucic acid content of the samples taken from the large intestine 3 hours after introduction of the test meal proves a low absorption rate of erucic acid administered in the form of ethyl ester.

The determination of the oleic acid content of the samples taken after fasting showed that in the stomach and in the small intestine contents this acid represented 20.3% of the total fatty acid content. Two hours after administration of the test meal, the relative oleic acid content was of 9.1%, after 4 hours it was of 11.8%, after 6 hours of 13.7%, and after 8 hours it was of 19.4%. Following contents were found in the large intestine: 20.2% after fasting; 12.9% after 2 hours; 6.7% after 4 hours; 4.0% after 6 hours and 4.3% after 8 hours. The amounts in mg of oleic acid found in the contents of the stomach and the small intestine were: 18 mg after fasting; 45.7 mg after 2 hours; 31.7 mg after 4 hours; 21.4 mg after 6 hours and 20.9 mg after 8 hours. Similarly, in the large intestine content the following amounts were found: 15.2 mg after fasting; 16.1 mg after 2 hours; 13.3 mg after 4 hours; 14.0 mg after 6 hours and 17.3 mg after 8 hours. Contrary to the erucic acid, the amount of oleic acid found in the
considered period in the large intestine content practically
did not vary, which proves that oleic acid is well absorbed
from the small intestine. The obtained data are shown in
fig. 1 and 2.

Analysis of the "absorption" coefficients established
after 8 hours shows that these coefficients are 45% for
erucic acid and 96% for oleic acid.

II. Variation of the erucic and oleic acid
content of the blood plasma

While determining the erucic and oleic acid content
of the intestine contents, the variation of the amounts
of these acids in the blood plasma was also examined, after
introduction of one test meal containing erucic acid and
olive oil. The variation of the relative content of these
acids is shown graphically in fig. 3. It was found that in
rats after fasting, even if they were fed in the last two
weeks with a diet without erucic acid, the blood plasma
contained about 1.3% of this acid. Two hours after intro-
duction of the test meal, the erucic acid content of the
blood taken from the portal vein increased to 6.2% and
stayed at that level with a slight increase only, for other
4 hours. After 8 hours, the erucic acid content of the
portal blood slowly increased. Similarly, the values for
the oleic acid were: 18.3% after fasting; 22.4% after
2 hours; 21.0% after 4 hours; 22.0% after 6 hours and
18.7% after 8 hours.
The variation of the erucic acid content of the peripheral blood taken from the heart was different. As soon as 2 hours after administration of the test meal, the erucic acid content of the blood plasma was of about 14. This variation is shown in fig. 3. Similarly, the values for the oleic acid were: 15.0\% after fasting; 17.2\% after 2 hours; 18.9\% after 4 hours; 17.1\% after 6 hours; 18.3\% after 8 hours. The maximum values for the erucic acid content were higher than those in the portal blood. The slightly different variation of erucemia in the heart blood as compared to the portal blood is due to the fact that the long-chain fatty acids pass principally into the thoracic duct and then indirectly into the peripheral blood. The higher relative increase of the erucic acid as compared to the oleic acid is due to the fact that normally the erucic acid is not contained in the tissues and body fluids.

III. "Absorption" coefficients of erucic and oleic acids in the 5-day experiment.

Table III shows the relative fatty acid content of feces collected during 120 hours. We can see that the relative erucic acid content is important in several rat groups. The absorption coefficients computed for the erucic and oleic acids are shown in table IV. These data prove that in the first group fed with erucic acid ester only, the absorption coefficient of erucic acid was low, representing 69\% only. In the second group fed with erucic acid ethyl ester and soybean oil, the absorption coefficient of erucic
acid was higher, representing 80%. The corresponding value for oleic acid in this group was of 85%. The third group fed with rapeseed oil only had a lower absorption coefficient of the fatty acids under study.

Conclusions

Our research leads to the following conclusions:

1. 8 hours after introduction of a single dose of erucic acid with the test meal, the erucic acid found in the content of the stomach and the small intestine still represented about 40% of the total fatty acid content. At the same time, the amount of erucic acid found in the content of the large intestine increased, this amount representing 50% of the ingested quantity.

2. Elimination of the single dose of erucic acid from the gastro-intestinal tract lasted about 5 days.

3. Contrary to the erucic acid, the oleic acid was absorbed from the gastro-intestinal tract almost completely in less than 8 hours.

4. The absorption coefficients of erucic acid were substantially lower than those of oleic acid.

5. Erucic acid should be considered as the main cause of the lower digestibility of rapeseed oil.
Table I

Composition of the diet used in the period preceding the proper experiment

<table>
<thead>
<tr>
<th>Components</th>
<th>Quantity in g</th>
<th>kcal in g</th>
<th>kcal</th>
</tr>
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<tr>
<td>Soybean oil</td>
<td>5</td>
<td>45</td>
<td>11.3</td>
</tr>
<tr>
<td>Casein</td>
<td>23</td>
<td>92</td>
<td>23.1</td>
</tr>
<tr>
<td>Succharose</td>
<td>20</td>
<td>80</td>
<td>20.0</td>
</tr>
<tr>
<td>Wheat starch</td>
<td>41</td>
<td>164</td>
<td>41.1</td>
</tr>
<tr>
<td>Potato starch</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mixture of mineral saltsx)</td>
<td>4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Group B vitaminsxx)</td>
<td>1</td>
<td>18</td>
<td>4.5</td>
</tr>
<tr>
<td>Fish-liver oil</td>
<td>2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>100.0</td>
<td>399</td>
<td>100.0</td>
</tr>
</tbody>
</table>

x) Mineral salt mixture II following Hawk, Ph.B. et al. and micro-elements in the De Luca modification. Practical physiological chemistry, Philadelphia 1947


Table II

Composition of the fat-free diet used during experimentation

<table>
<thead>
<tr>
<th>Components</th>
<th>Quantity in g</th>
</tr>
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<tbody>
<tr>
<td>Casein</td>
<td>23</td>
</tr>
<tr>
<td>Succharose</td>
<td>20</td>
</tr>
<tr>
<td>Wheat starch</td>
<td>18</td>
</tr>
<tr>
<td>Potato starch</td>
<td>4</td>
</tr>
<tr>
<td>Mixture of mineral saltsx)</td>
<td>4</td>
</tr>
<tr>
<td>Group B vitaminsxx)</td>
<td>1</td>
</tr>
</tbody>
</table>

100 g

x) Mineral salt mixture II following Hawk, Ph.B. et al. and micro-elements in the modification of De Luca. Practical physiological chemistry, Philadelphia 1947

Fig. 1 Variation of the amount of erucic acid (I) and oleic acid (II) found in the content of the stomach and the small intestine (—) and in the content of the large intestine (---).

Fig. 2 Variation of the amount in mg of erucic acid (I) and oleic acid found in the content of the stomach and the small intestine (—) and in the content of the large intestine (---).
Fig. 3 Variation of the relative amount of erucic acid (I) and oleic acid (II) in the blood plasma from the portal vein (A) and from the heart (B)
# Table III

Relative content of some fatty acids in feces collected from rats following 4 test meals

<table>
<thead>
<tr>
<th>Time in hours</th>
<th>Diet I</th>
<th>Diet II</th>
<th>Diet III</th>
<th>Diet IV</th>
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<tbody>
<tr>
<td>0-12</td>
<td>5.5</td>
<td>6.5</td>
<td>5.1</td>
<td>6.8</td>
</tr>
<tr>
<td>12-24</td>
<td>5.5</td>
<td>6.5</td>
<td>5.1</td>
<td>6.8</td>
</tr>
<tr>
<td>24-48</td>
<td>5.5</td>
<td>6.5</td>
<td>5.1</td>
<td>6.8</td>
</tr>
<tr>
<td>48-60</td>
<td>5.5</td>
<td>6.5</td>
<td>5.1</td>
<td>6.8</td>
</tr>
<tr>
<td>60-72</td>
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<td>6.5</td>
<td>5.1</td>
<td>6.8</td>
</tr>
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<td>72-84</td>
<td>5.5</td>
<td>6.5</td>
<td>5.1</td>
<td>6.8</td>
</tr>
<tr>
<td>84-96</td>
<td>5.5</td>
<td>6.5</td>
<td>5.1</td>
<td>6.8</td>
</tr>
<tr>
<td>96-108</td>
<td>5.5</td>
<td>6.5</td>
<td>5.1</td>
<td>6.8</td>
</tr>
<tr>
<td>108-120</td>
<td>5.5</td>
<td>6.5</td>
<td>5.1</td>
<td>6.8</td>
</tr>
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Table IV

Absorption coefficients of oleic and erucic acids after administration of various test meals

<table>
<thead>
<tr>
<th>Meals</th>
<th>Oleic acid, %</th>
<th>Erucic acid, %</th>
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<tbody>
<tr>
<td>I Erucic acid ethyl ester</td>
<td>85</td>
<td>69</td>
</tr>
<tr>
<td>II Erucic acid ethyl ester &amp; soybean oil</td>
<td>81</td>
<td>80</td>
</tr>
<tr>
<td>III Rapeseed oil</td>
<td>87</td>
<td>72</td>
</tr>
<tr>
<td>IV Rapeseed oil and soybean oil</td>
<td>87</td>
<td>79</td>
</tr>
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Bibliography


2. Bartnik, J.: Wyniki doswiadczenia nad wchlanialnostcia kwasu erukowego u szczurów (result of experimentation on the digestibility of erucic acid in rats), Roczniki PZH, 1961, 12, 425


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