The Feed Value of Rapeseed Meal[1]

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ABSTRACT

Rapeseed meal is a high protein-containing material that can be used as a feed for livestock and poultry. Typical meal contains a little less than 40% of protein; however it also contains about 12% crude fiber and glucosinolates, specific components of *Cruciferae* plants. Thus it is not very popular as a protein component of high quality feed mixtures for animals, and is used mostly in ruminant feeding. The protein value of rapeseed meal is higher than that of the majority of other vegetable proteins containing both lysine and sulphur amino acids. The amino acids of isolated rapeseed protein have been shown to be similar in composition to those of soybean protein, and present in higher concentrations. Rapeseed meal, in comparison with other vegetable oil seed meals, has a relatively high content of crude fiber, lowering its value as a feed component for nonruminants and especially for poultry. The amounts of minerals Ca and P of the vitamin niacin and of choline are rather high, exceeding the amounts of these components in other valuable oil meals, i.e., soybean or sunflower. Glucosinolate derivatives occurring in rapeseed meal are goitrogenic, causing considerable changes in thyroid from initial feeding. This has a negative effect on the biological value of rapeseed as a feed component and as evidenced, among other symptoms, by slower growth of young animals and their utilization of protein. These effects are especially evident in thein the feeding of growing chickens particularly when a protein deficiency exists in the diet. The presence of glucosinolates in feed has not as yet been demonstrated definitely to have a negative effect on the nutritive value of meat and eggs. Penetration and accumulation have not been found in those products. Glucosinolates and their derivatives such as L-5-vinyl-2-oxazolidinethione and isothiocyanates are not transmitted to the milk, although the thiocyanates content of milk evidently increases when cows are fed rapeseed meal. Goitrogenic symptoms have not been detected by consumption of this milk type. In the near future, the elimination of factors limiting the feeding value of rapeseed meal, such as glucosinolates and crude fiber, through breeding of new strains of rapeseeds, will permit their use in high quality protein mixtures not only for ruminant feeding but also in poultry and swine rations.

[1]One of nine papers presented at the Symposium, "Cruciferous Oilseeds," ISF-AOCS World Congress, Chicago, September 1970.

TABLE I

Estimated World Production of Oil Seed Cakes and Meals

Meal and cake	Million tons 1969	Million tons 1970	Per cent
Soybean	26.1	26.6	56
Cottonseed	7.2	7.0	15
Peanut	3.7	4.2	9
Sunflowerseed	3.1	3.6	8
Rapeseed and other cruciferous	2.8	3.7	6
Other	3.9	3.7	8
Total	46.8	48.0	100

INTRODUCTION

The meal which remains after extraction of oil from oilseeds represents, for the oilseed industry, a product of a value equal to that of the oil itself. This meal represents a very valuable protein component of feed mixes which are, in turn, indispensable in modern livestock raising for intensive production of meat, eggs and milk.

The principal representives of Cruciferae oilseeds in Europe and America are rape and turnip-rape and in Asia sarson and toria. The utilization of meals from these plants for forage purposes is beset with considerable difficulties (1,2). This causes a reduction in the price of the meal on the world market and adversely affects the economic position of rapeseed processing. This problem is particularly important in countries maintaining an intensive pig and poultry husbandry based on their rapeseed production as a domestic raw material source, as in Canada, France, Germany, Sweden and Poland. It can be foreseen that in the near future, with an increase in pig and poultry production, this problem will appear in other countries, i.e., India, Pakistan and China.

Soy meal occupies a leading position in the world production of oilseed meals. Rapeseed production yields are significant when compared to those of sunflower, cottonseed and peanut meals (Table I). Therefore rapeseed meal ranks with main sources of protein feed.

COMPOSITION

Protein

The basic component of feed, the protein, appears in rapeseed meal in substantial concentration (Table II). The average amount is 36 ± 2% with a maximum of 40%. Therefore in comparison the rapeseed meal is inferior to meals such as soy and peanut, but is very similar to cottonseed and sunflower.

Approximately 72% of rapeseed meal nitrogen occurs in the amino acid compounds; N-amide accounts for 12%, while nonsoluble nitrogen and products not precisely identifiable, such as those of SCN degradation, constitute 16% (5).

The amino acid composition of rapeseed meal (Table III) is very similar to meals of other valuable oil plants (9,10) and is characterized by a relatively high metionine, cystine and lysine content (11).

For animal feeding, rapeseed meals are well-balanced sources of protein. However they are not able to compensate for the lysine deficiency typical of corn meal when used in mixtures (9). Nevertheless they constitute a valuable supplement for feeds, especially those deficient in sulphur amino acids (8). Lysine and isoleucine are among the limiting amino acids (12).

Qualitative indexes of protein established on the basis of the amino acids composition (Table III) are, for rapeseed meal, relatively high and similar to the values for soybean

TABLE II

Protein Content of Different Oil Seed Meals

Meal	Protein in meal, %
Peanut meal (1)	45-55
Soybean meal (4)	40-50
Cottonseed meal (1)	35-45
Sunflowerseed meal (3)	40-50
Rapeseed and other cruciferous meals (1)	30-40

TABLE III

Protein Value and Content of Essential Amino Acids (6) in Oil Seed Meals Protein (g) (16.0g N)

Amino acid composition and protein value	Peanut meal	Cottonseed meal	Rapeseed meal	Sunflower seed meal	Soybean meal
Amino acid					
Arginine	11.4	10.2	6.4	8.5	7.6
Cystine	1.2	1.6	2.7	1.5	1.4
Histidine	2.5	2.7	2.6	2.1	2.4
Leucine	6.9	5.7	5.1	6.2	7.7
Isoleucine	4.3	4.1	2.4	4.5	5.5
Lysine	3.3	4.3	6.4	3.3	6.3
Methionine	0.9	1.2	2.6	2.4	1.3
Phenylalanine	4.5	5.3	5.3	4.8	4.9
Threonine	2.8	3.2	3.4	3.6	3.9
Tryptophan	1.2	1.4	1.6	1.4	1.4
Tyrosine	3.2	2.0	2.5	2.2	2.6
Valine	5.2	4.8	3.1	5.1	5.3
EAA Index (Osser)(7,8)	64	68	74	67	77
NPU	43	---	56	54-67	49-60
Protein digistibility coefficient (peps+trip) (1,3,4)	82%	---	85%	94%	90%

meal. Bell et al. (13) defines the biological value of rapeseed meal protein as only 95% of the soy meal protein value. As a rule these indexes are distinctly higher for rapeseed meal than for cottonseed, sunflower or peanut meals, as well as for grain proteins. Protein of rapeseed meal with NPU value above 56 compares favorably with the value of soybean protein, 49-60, and sunflower, 54-67, and surpasses the peanut protein (11) (Table III).

These data verify the presence of some factors in rapeseed meal which negatively affect the utilization of protein by poultry. This has been previously indicated by Van Etten et al. (14) who proved that the protein of *Crambe abissinica* had a very high per cent, 2.55 and 2.75, after extraction with hydrated acetone, similar or higher than caseina, 2.50, or flour made of husked soybean, 2.15. Bock (15) indicated that the removal of goitrogenic compounds through methanol or water extraction increases the NPU value of rapeseed meal from 30 to 59-64. Thus it can be assumed that the protein of rapeseed meal has a valuable composition of amino acids of high biological value, but its effectiveness is decreased by the presence of glucosinolates.

Another qualitative index of protein, its digestibility in vitro (Table III) is less favorable in rapeseed meal than in soybean and sunflower meals. However, for rapeseed meal, these values are within the limits established for protein digestibility of other accepted oilseed meals. In experiments with feeding of ruminants, Bell et al. (13) obtained a similar index of digestibility in vivo, 82-86%. Our investigations on chickens (16) showed a 10% decrease of the protein digestibility index in relation to the determination in vitro. Similar observations were reported by Manns and Bowland (17).

It was also observed that the level of amino acids in blood plasma of chickens fed with rapeseed meal was lower than that in chickens fed with casein protein. The removal of glucosinolates and their derivatives from rapeseed meal was followed by the increase of amino acids in the blood (18).

Saccharides

The sacchrides content of rapeseed meal amounts on the average to 38%. These are mainly polysaccharides with only small amounts of mono-, di- and tri-sacchrides (10).

With an estimation of carbohydrate components appearing in feeds, special attention should be given to the crude fiber content (Table IV). The crude fiber content of rapeseed meal is considerably higher than in peanut or soy meals, but is similar to concentrations found in cottonseed and sunflower meals.

As crude fiber constitutes a ballast component of feed and is digested with the greatest difficulty among all essential components or organic feed, rapeseed breeders tend to decrease its concentration through seed selection. Canadian researchers (19) expect to decrease the concentration of crude fiber to approximately 8% through this selection.

Residue Fat

The content of residual oil in rapeseed meal, determined by conventional methods, does not usually surpass 1.5%. Therefore it does not play any essential role as an energetic

TABLE IV

Crude Fiber, Ash and Mineral Content of Oil Seed Meal

Component	Peanut meal (1)	Cottonseed meal (1)	Rapeseed meal (1)	Soybean meal (4)
Crude fiber, %	2.0-3.2	6.9-12.7	9.3-13.4	5.5-6.5
Ash, %	3.6-4.6	5.8- 7.5	7.0- 7.3	5.5-6.0
Minerals, ppm	(1)	(1)	(3)	(3)
Ca	70- 200	1800- 3300	3000-6000	2600
P	3500- 5700	11000-12600	9000-19000	6200
Na	50- 700	300- 2000	400	1400
K	11000-12000	12000-14600	15100	20600
Mg	2200- 5100	5400- 5900	---	3000
Mn	18- 550	23- 280	75	---
Fe	30- 100	80- 970	300	140
Cu	—	17- 19	10	—

TABLE V

Composition of Main Fatty Acids in Residual Fats and Rapeseed Oil (20)

Fatty acid	Residual fat, %	Rapeseed oil, %
16:0	5.8- 7.3	3-4
:1	0.4- 1.5	⟨ 0.3
18:0	0.9- 1.1	⟨ 1.0
:1	16.2-16.7	11-15
:2	18.8-23.2	11-13
:3	8.0- 9.9	6-10
20:0	0.4- 1.5	⟨ 1.0
:1	9.1-14.0	8-12
22:1	24.3-36.8	47-53

and biological component (below 0.3% C 18:2; C 18:3).

We are not considering the particulars of the composition of the residual oil where the content depends upon the method of oil extraction. If it appears in quantities exceeding 1%, its features are similar to rapeseed oil (20).

The composition of fatty acids in the residual oil in rapeseed meals (Table V) reveals a higher content of palmitic, oleic and linoleic acids than in the average composition of fatty acids in rapeseed oil, but a lower content of erucic acid. The contents of linolenic acid are not significantly different.

The mean content of unsaponifiable substances, including phosphates, in residual oil is 10 times and sterol 5 times higher than in the extracted oil. The main components of the unsaponifiable fraction are phosphatidyl choline, phosphatidyl ethanolamine and sterol glycoside. Phosphatidyl inositol, digalctosyl diglyceride, esterified sterol glycoside, and free sterols are also present (21).

Mineral Substances

Rapeseed meal, a typical protein component of feeds, cannot be considered a source of mineral substances whose composition and content can easily be controlled through the addition of the appropriate preparations.

The mineral content of rapeseed meal is relatively high compared to that of peanut meal but similar to that found in other oilseed meals with which it has been compared (Table IV). In addition, published data reveals that rapeseed meal is relatively rich in calcium and phosphorus. Among other components, the large content of manganese is worth mentioning. Regarding phosphorus content, the fact that about 40% appears in the form of phytin compounds should be considered (22).

Vitamins

In rapeseed meals as in other oilseed meals, the highest quantities of vitamins appear to be of the B-group (Table VI). In comparison with other oilseed meals, rapeseed meal is rich in cholin and niacin. However the content of panthotenic acid and thiamine is rather low.

The tocopherol content of rapeseed meal is about 45 mg/kg, including 12 mg of the alpha form (24,25).

Goitrogens

The presence of goitrogens is a yet unsolved problem in the utilization of rapeseed meal proves to be a considerable difficulty. Plants of the genus *Brassica*, to which rape belongs, distinguish themselves by the presence of specific sulphuric compounds, repressing the activity of the thyroid gland (26). These substances can be found in seeds in considerably extraction of oil from the seed, the goitrogenic substances remain in the meal, almost in the initial quantities.

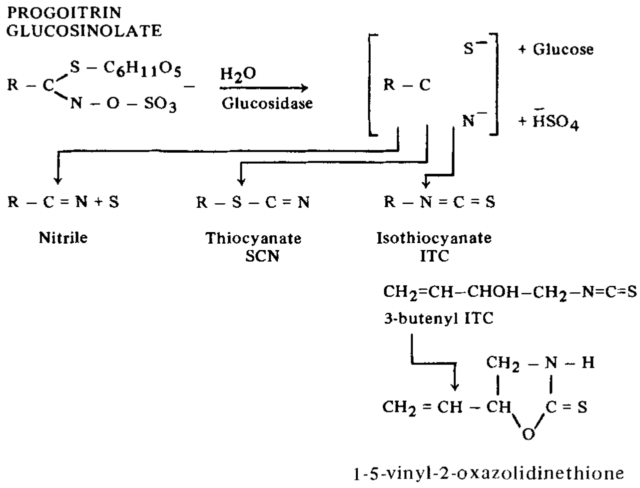

FIG. 1.

Goitrogenic substances appear in seed in the form of glucosinolates, also called thioglucosides, which are biologically inactive.

The destruction of the cellular structure allows the glucosinolates to come into contact with the enzyme thioglucosidase (myrosinase), which is present in special plant cells. This enzyme (or these enzymes) hydrolizes the glucosinolates liberating glucose and bisulphate, while biologically activating the compounds generally divided into three groups: goitrin and related nitryles; organic isothiocyanates; inorganic thiocyanate.

Goitrin and nitriles: These compounds are formed from the glucosinates, progoitrin or epi-progoitrin. Under the influence of thioglucosidase 2-hydroxy-3-buthenyl-isothiocyanate is set free and cyclic thioxaolidinethion is formed (27) (Fig. 1). Kjaer et al. and Astwood et al. (27,28) have shown in seeds of rape and turnip-rape, the presence of L-5-vinyl-2-oxazolidinethione (OZT), earlier called L-5-vinyl-2-thiooksazolidone (VTO), a compound ranking high in antithyroidal activity.

Van Etten (29) has recently shown that when rapeseed meals are allowed to autolyze, the hydrolysis products include nitriles which contain an episulfide group. In most cases hydrolysis that proceeds at a faster rate to give the cyano compounds is favored in freshly harvested seed.

The mechanism of OZT influence on the thyroid gland is not completely understood. However it is known that OZT blocks the irreversible mechanism connected with the organic binding of iodine in the thyroid, and thus a partial suppression of tiroksine synthesis follows.

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TABLE VI

Vitamin Content of Oil Seed Meals, mg/kg

Vitamin	Peanut meal (1)	Cottonseed meal (1)	Rapeseed meal (23)	Sunflower meal (3)	Soybean meal (4)
Choline	1800-2400	3200-3500	7000	---	---
Pantothenic acid	15-53	7-14	9.9	33-58	13.0
Thiamine	1.6-17.2	3.9-14.2	1.9	3.6	12.3
Riboflavin	2.0- 5.3	5.3- 9.0	4.2	3.6	3.4
Niacin	---	28.6-45.0	167	90-415	23

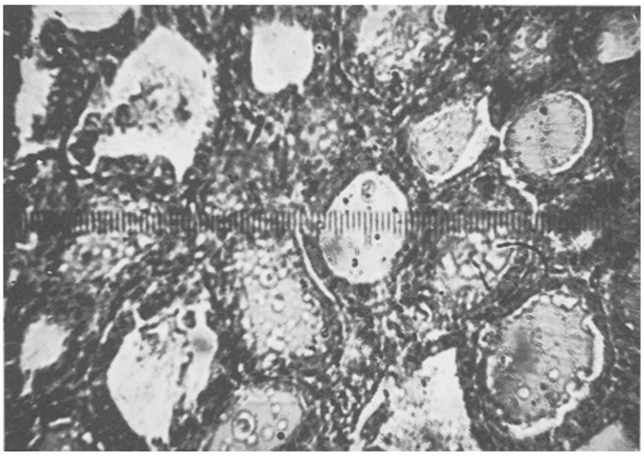

FIG. 2. Thyroid of a normal adult chicken.

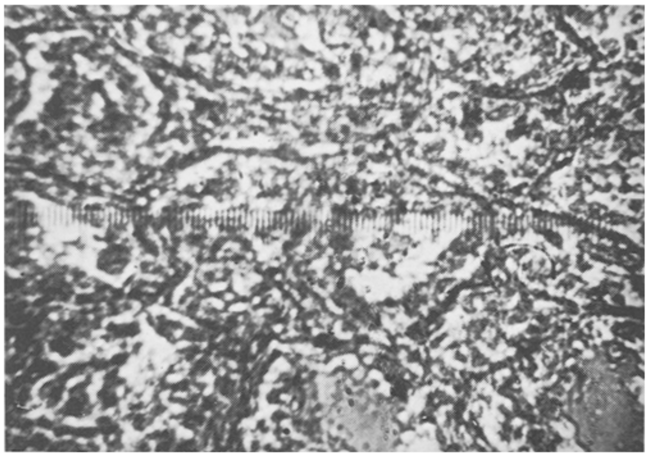

FIG. 3. Thyroid of a chicken after 4 weeks feeding a ration containing rapeseed meal.

resulting from this partial suppression, stimulates the hypophysis to secrete excessive amounts of thyrotropine affecting the thyroid gland, stimulating its growth (30). The histopathological investigations indicate a considerable hypertrophy and hyperplasia of parenchymatic elements and almost complete loss of foliculare coloid. The observations of the adrenal gland indicated hyperemia and expansion of blood vessels of marrow as well as considerable hydration of cortex (31).

Two pictures show the results of microscopical examination of chicken thyroid glands. Figure 2 is a photomicrograph of the thyroid of a normal adult chicken and Figure 3 of the glands of a chicken after 4 weeks feeding a ration containing rapeseed meal. Desquamation of ephitelium, compressed follicules in small restricted areas, and decrease in colloid can be readily observed.

The goiter caused by addition of these compounds to the diet cannot be alleviated by increasing the iodine intake. Thus damage can occur when meal containing these compounds is used in the feeding of nonruminants. The feeding effects obtained are worse than by application of other feeds. On the other hand, cattle fed with extracted meal show no changes in thyroid glands.

According to Clandinin (32) and our work (Table VII), after prolonged feeding of chickens these functions of the gland approached normal, indicating the attainment of a physiological equilibrium at increased thyroid to body weight.

Nitriles formed from the glucosinolates may act as goitrogens, but several workers were not always able to confirm the reported goitrogenic properties of organic nitriles (29).

Isothiocyanate and thiocyanate: Isothiocyanates found in rape and turnip-rape seeds can be divided into volatile and nonvolatile compounds (33). The volatile isothiocyanates, principally 3-butenyl- and 4-pentenyl-isothiocyanates, are the most common occurring in seeds (Table VIII).

The main sources of thiocyanates are glucobrasicine and sinalbine which are present in rape and turnip-rape seeds. The isothiocyanates obtained from these compounds can be transformed in thiocyanates (34).

The isothiocyanates have a considerably lower goitgogenic activity than the oxazolidinethiones. The thiocyanates are characterized by the weaker goitrogenic activity (35,36).

The influence of isothiocyanates and thiocyanates is similar. They block the capture of iodine by the thyroid gland and set free the iodine accumulated in it. In this way they check the first phase of the thyroid hormones biosynthesis, but they do not damage any of the thyroid gland mechanisms. The goitrogenic effect of these compounds can be removed by the addition of iodine to the ration.

Special attention should be given to the latest investigations of Langer (37) on the synergetic influence of the goitrogenes compounds. These investigations were carried out on rats receiving in their diets, oxazolidinethion, alliloisothiocyanataes and thiocyanates individual or all together. The goitrogenic effect of the mixture of goitrogenic compounds was considerably higher than the sum of results obtained in groups receiving those compounds individually.

Many isothiocyanates are easily recognized by their pungency, a characteristic of mustard oils. For this reason rapeseed meal should not be fed wet, as the liberated mustard-flavored extracts produce unpleasant odors discouraging the animals from eating it (38).

ANIMAL FEEDING

Independent of progress in the debittering of rapeseed

TABLE VII

Relative Weight of Thyroid Glands in Relation to Their Sizes in Control Chickens, Considered as 100 (53)

Goitrogens	Group of diet, in feed, mg/kg: Control	Control + crystaline OZT[a]	Rapeseed meal	Day of Experiment	Size of Thyroid Gland		
OZT	0	150	742	0	100	100	100
ITC[b]	0	—	154	5	100	125	127
				10	100	136	161
				16	100	137	171
				22	100	130	163

[a]OZT = L-5-vinyl-2-oxazolidinethione
[b]ITC = isothiocyanate.

TABLE VIII

Glucosinolates and Mustard Oils in Rapeseed

Thioglucoside	Isothiocyanate	Property	Magnitude
Glucoiberin	3-Me sulfinylpropyl	Nonvolatile	+
Sinalbin	p-OH benzyl-	Volatile	+
Gluconapin	3-butenyl-	Volatile	+++
Glucobrassiconapin	4-pentyl-	Volatile	+++
Gluconasturtiin	2-phenyl ethyl	Volatile	+
Progoitrin	2-OH-3-butenyl-	Nonvolatile	+++

meal, of the application of the methods elaborated in industrial practice, and of the attempts to grow varieties with a low content of goitrogenic substances, any means should be examined if it can be used for animal feeding in the actual qualitative state. This problem has a dual character. On one hand, the influence of meal on animal health and production yields should be considered; on the other, the possibility of penetration of goitrogenic substances through animal products into human foods must be recognized.

RUMINANTS

Asplund (39), Asplund and McElroy (40) and Bunger et al. (41,42) have shown that ruminants have the highest resistance to rapeseed meal influence. These animals have not been so adversely affected by goitrogenic factors. Only the fact that rapeseed meal was less palatable and less readily digested than many of the other high protein oilseed meals has been considered. Generally no marked goitrogenic influence of rapeseed meal on cattle can be shown. Our investigations have shown that OZT is partly destroyed in the animal's rumen.

Also, in the feeding of sheep with rapeseed meal, no detrimental influrnce on the wool was found. Therefore the sole factor, limiting the dosage of rapeseed meal in the feeding of ruminants, is its taste and the actual feeding needs. Ten per cent rapeseed meal is the generally recommended level for use in feeding mixture (43).

SWINE

The amino acid composition of rapeseed meal like soybean meal satisfies the requirements of the young pigs, but results in the appearance of goitrogenic compounds.

The application of high level rapeseed meal in the feeding of pigs causes negative effects such as increase of the size of thyroid gland, decrease of sucking pig growth, reduction of feeding indexes and slaughtering effects, and negative influence on maturation rapidity, reproducitivity and lactation. It is generally assumed (43) that the share of rapeseed meal in the diet for these animals should not exceed 4%.

POULTRY

The most extensive investigations of rapeseed meal utilization as a feed were carried out on chickens. The fundamental contributions of Clandinin and Tajcnar (30), Clandinin et al. (44) and Clandinin and Bayly (45) and other Canadian research workers deserve particular mention. Their work was concerned with a search for high protein components for industrial feeding mixes for use in industrial production of broilers, with due consideration for the special susceptibility of chickens to goitrogenic factors. The latter were evaluated as unusually rapid changes of the thyroid gand size and, as a consequence, a rapid influence on the function of this organism. The feeding experiments conducted thus far have produced a negative influence of the goitrogenic substances of rapeseed meal on the rate of growth of chickens, on egg production of mature hens, and on the repression of thyroid gland activity. It appears from investigations of Clandinin (32) and ours that only after 2-3 weeks of feeding can the growth of chickens be established. After this period the normal amount of tyroksine is discharged and further growth is continued without any disorders.

Therefore it would appear that by application of moderate quantities of rapeseed meal and skilled feeding, and after allowing for a depression period, satisfactory production results may be obtainable.

It is recommended (43) that levels as high as 10-15% of rapeseed meal may be included in starting and growing chickens, as much as 10% for laying and breeding chickens and turkeys, but only 5% in feeding of starting and growing broilers.

TRANSMITTAL OF GOITROGENS TO FOOD

The problem of the transfer of goitrogenic substances from rapeseed meal through meat or milk into human food has been the object of only a few investigations. For many reasons it is essential to establish the fact that goitrogenic substances are not concentrated in an edible product. Most information has been obtained on milk.

Cows' Milk

Investigations carried out by Clandinin and Bayly (45) and by Virtanen and coworkers (46-48) showed a rapid increase in OZT content in milk after the administration of feed with rapeseed meal. However the quantities entering the milk were very small, amounting to 0.05% of the quantity administered with the feed. In our (49,50) investigations the transfer of OZT to milk was not found. The spots of similar character which appear on thin layer chromatography reveal differences in ultraviolet absorption.

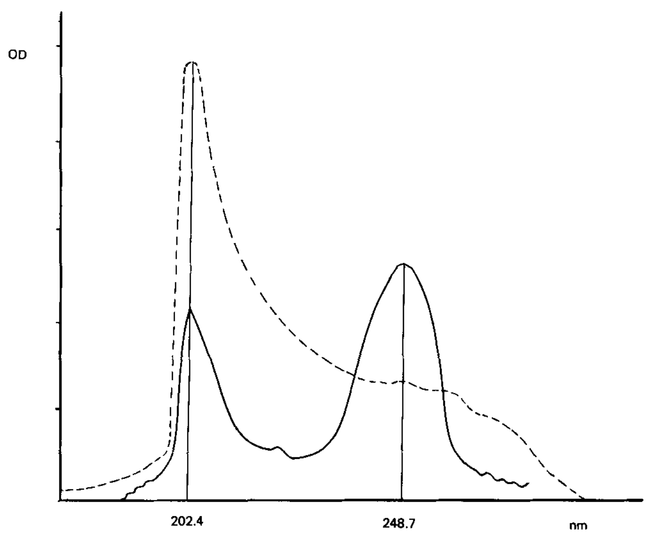

FIG. 4. UV Spectral absorption curve of L-5-vinyl-2-oxazolidine thion (OZT– and spot from milk cows rapeseed meal. Key: ——OZT; --- spot qualified as OZT.

TABLE IX

Evaluation of Leaven Activity of Raw Milk (51), 5 Breedings, 42 Transplantations

Number	Group of Milk	Type of feeding	Activity according to Kurmann			
			Very good	Good	Satisfactory	Poor
Hansen leaven						
R	regenerated	?	35	3	4	—
C	control	peanut	32	8	1	1
E	experimental	rapeseed meal	26	12	3	1
Polish starter B_4						
R	regenerated	?	42	—	—	—
C	control	peanut	38	2	—	2
E	experimental	rapeseed meal	31	11	—	—

The milk from cows fed rapeseed meal exhibit maximum absorption at 202.4 nm but not at 248 nm as revealed in the spectrum of OZT (51) (Fig. 4). This difference is supported by biological studies which reveal that milk of animals fed larger doses of Brassica plants does not disturb the accumulation of radioactive iodine in the human thyroid gland (46). Rats fed on milk containing OZT have not shown any changes of goitrogenic type. Therefore no negative influence of rapeseed meal application in cattle feeding nor any decrease of the nutritional value of milk has been established.

In milk from cows fed rapeseed meal, however, considerable increase in the thiocyanides content was found (49,50) and a negative effect on leaven bacteria activity and on the ripening of cheese has been established (Table IX). This decreases the value of milk as a raw material for hard cheese production (52).

Meat and Eggs

Investigations have not revealed, even in trace quantities, the presence of OZT in meat. No information has been obtained concerning the penetration of OZT from feed into eggs, but similar effects may be postulated.

Therefore it can be concluded that the presence of goitrogenic substances in rapeseed meal do not influence the nutritional value of animal products, and that the main problem remaining is to establish the optimal utilization of rapeseed meal as a feed component.

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