# Rapeseed Protein Products

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## ABSTRACT

During recent years somewhat different methods of producing rapeseed protein concentrates (RPC) and isolates (RPI) have been developed. Texturizing of RPC has also been studied. Functional properties of RPC such as solubility, water-and fat-binding, emulsifying and foaming have been studied together with their organoleptic properties. Very bland RPC can be produced. How variables obtained in the instrumental analysis are related to those obtained in the sensory analysis has also been studied. Rapeseed flours are comparable to soy flours in water absorption and give higher fat absorption. Oil emulsification and whippability values depend on processing. Rapeseed protein concentrates and isolates show excellent water- and fat-holding capacity. The isolate is high in oil emulsification and whipping characteristics. Rapeseed protein products can therefore be used as extenders or binders in meat patties or sausages. Their use in bread and other food items also has been studied. Due to high contents of lysine, methionine and cysteine, rapeseed proteins have a higher nutritive value than any other known vegetable protein. Their nutritive value is as high as that of good animal proteins. This has been shown in growth studies on rats and in a nitrogen balance study on student volunteers. The safety of RPC has been tested through many years. With the exception of a negative effect on the zinc balance in rats, which can be compensated, no negative finding has been recorded.


## INTRODUCTION

Rapeseed and mustard *(Brassica napus, B. campestris* and *B. juncea)* rank number five among the oilseeds. They are the only oilseeds grown successfully in all parts of the world (Table II) (1).

The seeds contain 40-45% oil and 25% (Nx6.25) protein of a very high nutritive quality, but there are also about 4% of glucosinolates in the seeds of normal rapeseed varieties (Table II). Extensive breeding programs in Canada and Northern Europe have developed rapeseed varieties with low contents of glucosinolates.

During the 1970s somewhat different methods of producing rapeseed protein concentrates (RPC) for human consumption were developed in Canada, Sweden (Figure 1) (2), and Poland. The rapeseeds are first dehulled and the meats are then heat treated to inactivate the myrosinase. The glucosinolates are removed by water leaching, whereupon the material is dried. The oil is recovered by extraction. The by-products from the dehulling and water leaching steps can be used as cattle feed after further oil recovery.

A method to produce mustard seed protein has been developed in Mysore in India. Rapeseed protein isolates have also been prepared (3). Texturizing PRC has been studied in the US and Europe.

## COMPOSITION OF RPC

Composition of the rapeseed protein concentrate is shown in Table III. The crude protein content is 65% of dry matter, but as is usual with vegetable proteins, the true protein level is lower (57%). The RPC contains a relatively high level of phytic acid (inositol hexaphosphate), which will be discussed later. The residual glucosinolate content in RPC is very low, which means that more than 99% of the original glucosinolates can be removed. The water insoluble parts of the carbohydrates are left in the RPC. They consist of cell wall carbohydrates of the dietary fiber type. (4).

## NUTRITIONAL PROPERTIES OF RPC

The amino acid composition of RPC is shown in Table IV. Rapeseed protein has a substantially higher content of sulphur-containing amino acids than soy protein, as well as adequate amounts of the other essential amino acids.

This is well reflected in the nutritional value obtained in rat feeding trials (Table V). The results show conclusively that the nutritional value of RPC is equal to or better than that of a good animal protein. The variation in the PER values seems mainly to be depending on the laboratory. The importance of having a sufficiently high zinc level in the diet to obtain a normal PER value has been pointed out (5). Gorill et al. (6) supplemented RPC with methionine, lysine or isoleucine, but did not obtain increased PER

TABLE I

Production of Rapeseed
(1,000 tons)

| | 1970-71 | 1972-73 | 1975-76 | 1977-78 (forecast) |
|---|---|---|---|---|
| India | 1,944 | 1,800 | 1,936 | 1,600 |
| Canada | 1,612 | 1,279 | 1,749 | 1,900 |
| China | 975 | 925 | 1,350 | 1,350 |
| France | 576 | 703 | 532 | 421 |
| Poland | 573 | (450) | 726 | 672 |
| Sweden | 189 | 327 | 285 | 233 |
| Pakistan | 265 | 315 | 267 | ? |
| West Germany | 182 | 245 | 199 | 282 |

TABLE II

Composition of Rapeseed

| Component | % d.b. |
|---|---|
| Fat | 45 |
| Protein (N x 5.5) | 22 |
| Carbohydrates | 17 |
| Lignin and phenols | 7 |
| Glucosinolates | 4 |
| Phytic acid | 2 |
| Other ash components | 3 |

TABLE III

Analytical Data for Rapeseed Protein Concentrate (RPC)

| Compound | % d.b. |
|---|---|
| Protein (N x 5.5) | 57 |
| Protein (N x 6.25) | 65 |
| Fat | 3 |
| Crude fiber | 8 |
| Other carbohydrates | 23 |
| Total ash | 7.5 |
| Phytic acid | 6 |
| Other ash components | 2 |
| Other N-compounds | 1 |
| Moisture | 7.5 |
| Glucosinolates | <0.2 |

values, which shows that in practice there is no limiting amino acid in RPC.

A preliminary study has been made of the acceptability of RPC in the human diet as a nitrogen balance study on student volunteers (Figure 2). The results show that RPC has a less negative nitrogen balance than will milk protein or wheat protein.

In a recent study we determined the PER of different combinations of RPC and soy proteins in a ground meat mixture (7). As can be seen in Table VI combinations of RPC and textured soy flour and soy protein isolate (ISP) give a much higher PER value than do the soy proteins alone. ISP decreases and RPC increases the PER of the ground meat mixture, and the textured soy flour does not change it. If RPC is used in combination with soy proteins in the ground meat mixture, the PER value will not be lowered, as will be the case if soy protein isolate and textured soy flour are used together.

In another study (8) it was shown that the NPU and also the BV are increased if RPC is added to the ground meat mixture. On the other hand, the NPU and BV are lowered by textured soy flour and especially by soy protein isolate.

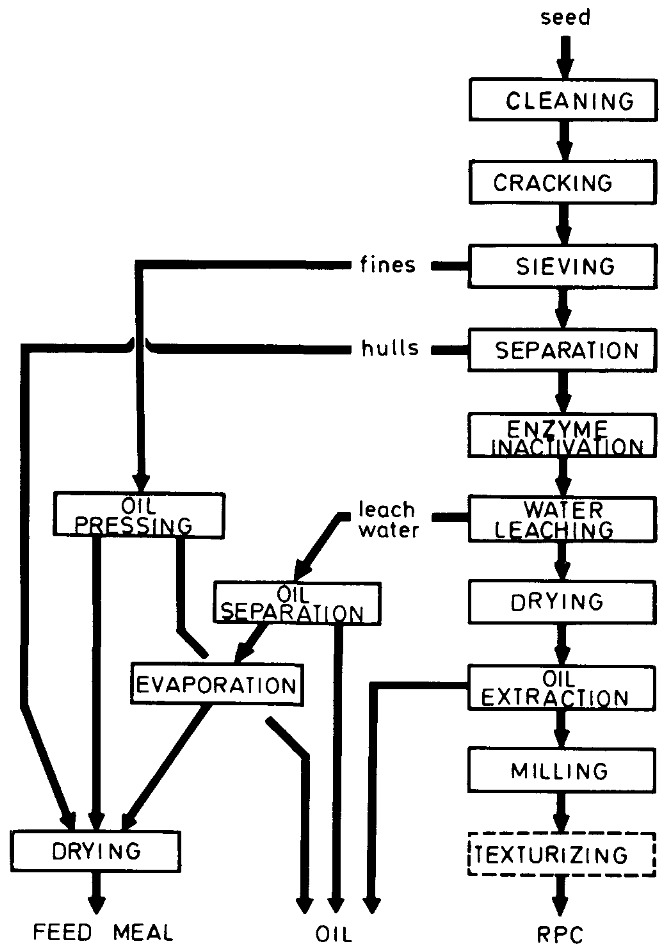


FIG. 1. Flow chart of the RPC process.

## TOXICITY STUDIES ON RPC

Animal studies have shown that the low level of glucosinolates in RPC seems to be safe. Figure 3 shows a growth study with female rats given rapeseed protein products with various levels of glucosinolates. There is a growth-depressing effect, if the glucosinolate content is 10 times higher than that of RPC. When a nonheat-treated rapeseed meal with a

TABLE IV

Amino Acid Content of Rapeseed Protein Concentrate (RPC) and Soybean Flour (g/16 gN)

| Amino acid | RPC | Soybean flour | WHO/FAO scoring pattern 1973 |
|---|---|---|---|
| Isoleucine | 4.2 | 4.2 | 4.0 |
| Leucine | 7.3 | 7.0 | 7.0 |
| Lysine | 5.8 | 5.8 | 5.5 |
| Phenylalanine | 4.1 | 4.5 } | |
| Tyrosine | 3.1 | 3.1 } | 6.0 |
| Cystine | 2.6 | 0.7 } | |
| Methionine | 2.3 | 1.1 } | 3.5 |
| Treonine | 4.5 | 3.8 | 4.0 |
| Valine | 5.2 | 4.3 | 5.0 |
| Tryptophan | 1.4 | 1.3 | 1.0 |
| Histidine | 2.7 | 2.4 | |
| Arginine | 6.6 | 7.0 | |
| Aspartic acid | 7.1 | 10.2 | |
| Glutamic acid | 17.9 | 16.5 | |
| Serine | 4.7 | 5.0 | |
| Proline | 6.1 | 4.8 | |
| Glycine | 5.3 | 3.8 | |
| Alanine | 4.6 | 3.9 | |

TABLE V

Nutritional Values for RPC

| | | |
|---|---|---|
| Protein efficiency ratio | (PER) | 3.0 - 3.5[a] |
| Net protein utilization | (NPU) | 87 - 90 |
| Biological value | (BV) | 90 - 92 |
| True digestibility | (TD) | 95 - 100 |

[a]When adjusted to casein with a PER value of 2.5.

normal content of glucosinolates was given to the rats there was no growth at all.

Oxazolidinethiones and isothiocyanates from the glucosinolates cause the thyroid to increase in weight (the goitrogenic effect) as is shown in Figure 4. With the lowest level of glucosinolates there is no effect. Jones (9) has shown that it is the oxazolidinethione that has the strongest effect on the thyroid. He has also reported that if the glucosinolate content in the diet is 0.45 mg/g or lower, there will be no effect on rat growth or thyroid weight. The rats were given 20% protein in the diet, which means that the glucosinolate content of the RPC should be lower than 1.4 mg/g. This value is much higher than the normal value of < 0.2 mg/g for RPC. A glucosinolate content of this magnitude seems acceptable in RPC for food use. Cabbage, for example, can contain higher values (10).

Nitriles that can also be split products from glucosinolates have a higher toxicity than oxazolidinethiones and a different physiological effect. Van Etten et al. (11) have reported $LD_{50}$ values that are 5-10 times lower than for vinyloxazolidinethione. The nitriles are, however, not formed to any great extent in heat-treated materials. The content of nitriles in a well prepared RPC is below 1 mg/kg and will cause no problems.

Subacute toxicity studies have also been run for three months on rats and dogs with RPC (12). Another extended test for four months on rats with complete examination of blood, urine, organs etc., has recently been concluded. No detrimental effects on the animals has been found (13).

Another major problem with RPC has been the effect it can have on pregnant rats. Typically it causes anorexia (lack of appetite) and a weight loss during the last days of the pregnancy (14,15). In more severe cases, other toxic symptoms and a high fetal mortality was observed (16). Rat studies carried out during recent years connect this problem with the phytic acid in RPC and its effects on zinc absorption.

As stated earlier, the phytic acid content in RPC prepared in the usual way is rather high, about 5-6% (90 mg/g protein). In vitro experiments have shown that phytic acid forms very slightly soluble salts with zinc, especially in the

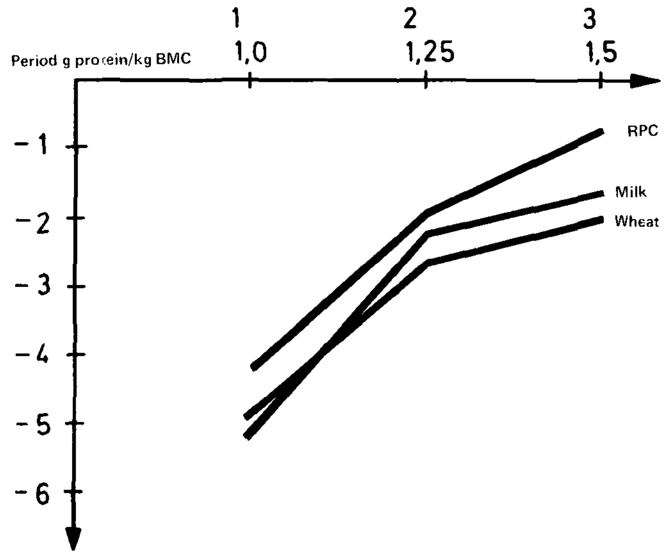


FIG. 2. Human nitrogen balance study.

presence of calcium (17). In rat studies a marked reduction in the zinc level in serum and femur can be seen in the animals given RPC (9,18,19). If, however, extra zinc is added to a RPC diet, no such reduction is observed.

Studies have been made on growth and diet consumption of pregnant rats with different protein sources in the diet (Table VII) (20). If the phytic acid content in the rapeseed material was reduced either by acid leaching, by using rapeseed with low phosphorus content or by preparing a rapeseed isolate, no effects were found. The anorexia can also be overcome by an extra addition of zinc (80 mg/kg) or iron (270 mg/kg) to the diet. If the calcium content of the diet is strongly reduced, the effect on the pregnant rats will also disappear. For comparison, cottonseed protein and soybean flour were included in the test. The cottonseed protein , with a high phytic acid content, also caused anorexia, but no effect could be observed after the inclusion of soybean flour with a low phytic acid content.

These and other results show that it is the phytic acid in RPC that strongly binds zinc and makes it unavailable for the pregnant rat, which has an increased demand of dietary zinc during the last days of pregnancy. The results also clearly show that there are ways to solve this problem by adding extra zinc or by lowering the phytic acid content.

## FUNCTIONAL PROPERTIES

Functional properties of protein preparations can pro-

TABLE VI

PER Values for Protein Mixtures

| Protein source or mixtures | | % Veg. protein in corresp. meat patty[a] | PER (adjusted) |
|---|---|---|---|
| RPC | | | 3.5 |
| Textured soy flour | (TSF) | | 2.2 |
| Soy protein isolate | (ISP) | | 1.9 |
| Ground meat mixture | (GMM)[b] | | 3.0 |
| RPC + TSF (55+45 of protein) | | | 3.3 |
| RPC + TSF + ISP (42+42+17 of protein) | | | 3.1 |
| RPC + GMM | | 6.8 | 3.3 |
| TSF + GMM | | 8.1 | 3.0 |
| ISP + GMM | | 4.7 | 2.7 |
| RPC + TSF + GMM | | 3.7 + 3.7 | 3.1 |
| RPC + ISP + GMM | | 4.6 + 1.5 | 3.1 |
| TSF + ISP + GMM | | 5.2 + 1.7 | 2.6 |
| RPC + TSF + ISP + GMM | | 5 + 5 + 2 | 3.1 |

[a]33% of the protein from soy or rapeseed.
[b]Mixture of beef and pork trimmings, skimmilk powder, potato flakes and bread crumbs.

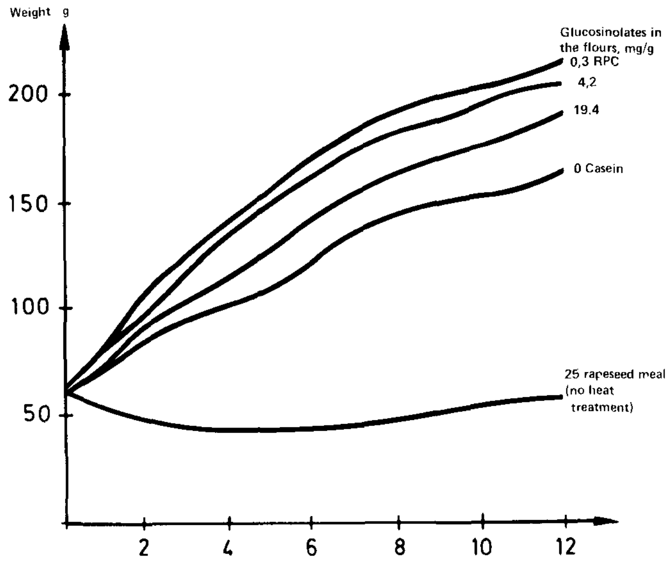


FIG. 3. The effect of glucosinolates on growth of female rats given rapeseed flours.

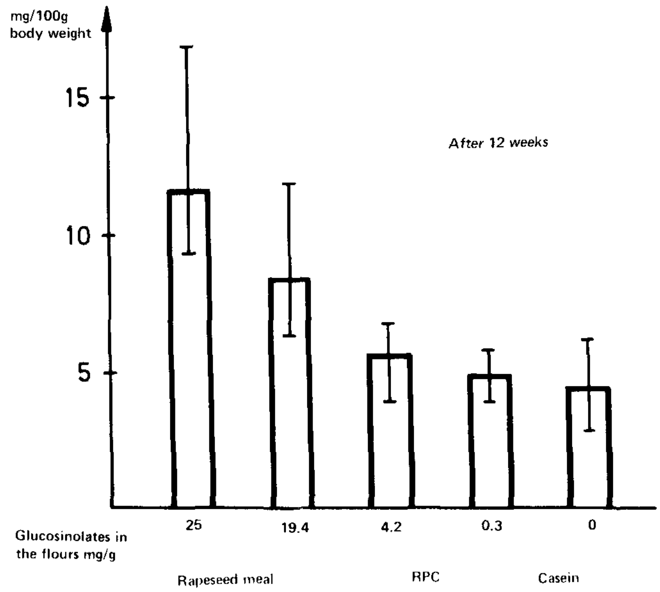


FIG. 4. The effect of glucosinolates on thyroid weight of female rats given rapeseed protein products.

vide information about the action of the protein when incorporated into a food. Solubility, water- and fat-binding, emulsifying and foaming of RPC have, therefore, been studied together with their organoleptic properties. Very bland RPC can be produced. The relation of variables obtained in the instrumental analysis to those obtained in the sensory analysis has also been studied.

Solubility is normally the first property to be tested when a new protein product is to be studied. Radwan and Lu (21) determined the solubility at different temperatures from 25-55 C in the whole pH range. It was found that the points of minimum nitrogen solubility occur at pH values from 4.5 to 7.2.

Gillberg and Törnell (3) studied the dissolution of nitrogen and phosphorus-containing substances from defatted rapeseed (and the subsequent precipitation of these substances by acid). The dissolution of the substances was found to vary in a complicated manner with the pH of extraction (Figure 5). The curves in the figure are from the extraction of a meal that was defatted without heating.

Rapeseed protein concentrate produced in a technical process on a pilot-plant scale has a rather limited solubility due to the heat treatments. Modifications of rapeseed protein concentrate of limited solubility have been made. Alkali, acid, and enzymes were used in the solubilization procedures (22). All modified products had higher values of solubility, emulsifying, and foaming indices, and three of the seven modified preparations had a better swelling ability than the original RPC-sample; however, the taste of the products was too strong, and the functional properties were still too poor to be of practical interest.

The water absorption (swelling) of rapeseed protein products is very high. That this property compares favorably with those of soybean products has also been shown by Sosulski (23). Water absorption and water-holding capacity of rapeseed and soy proteins are shown in Figure 6. When the protein products are texturized, the water absorption decreases.

Rapeseed protein products are also superior to soybean flour and concentrate in fat absorption, with rapeseed protein concentrate showing the highest value.

Whippability, foam stability and gelation of rapeseed products have also been studied, with poor results for RPC and good for rapeseed protein isolate.

The color of RPC is light with a tendency to turn darker during heat treatments, especially extrusion cooking. Rapeseed protein isolates are usually greyish.

## TASTE AND FLAVOR

Characteristic flavors of textured rapeseed and soy proteins have been analyzed organoleptically (24). Very bland rapeseed protein products can be produced. Quist has made an extensive study of unconventional proteins as aroma precursors (25,26). Over 110 compounds were identified by GLC-MS from the head space gas of a low temperature distillate from more or less heated RPC. The odor of rapeseed protein samples depends on the presence of low

TABLE VII

Growth Study of Pregnant Rats Given Different Protein Sources in the Diet

| Diet | Growth day 19-21, g[a] | Diet consumption on day 21, g[a] |
|---|---|---|
| Casein | 23.3 | 15 |
| RPC (Standard) | -3.8 | 4 |
| RPC (Phytic acid reduced) | 35.6 | 18 |
| RPC (Low-P-seeds) | 30.7 | 19 |
| RPI | 31.0 | 15 |
| RPC + extra Zn | 22.8 | 14 |
| RPC + extra Fe | 18.8 | 14 |
| RPC lox Ca diet | 22.1 | 16 |
| Cottonseed protein (LCP) | 10.8 | 11 |
| Soybean flour | 20.8 | 18 |

[a]Parturition on day 22.

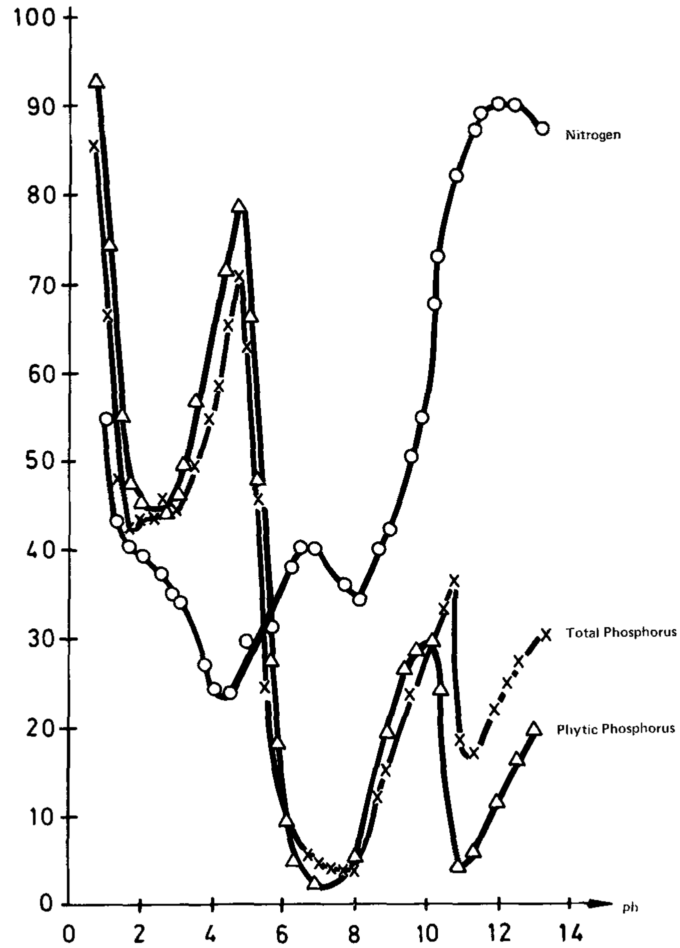


FIG. 5. Solubility in relation to pH.

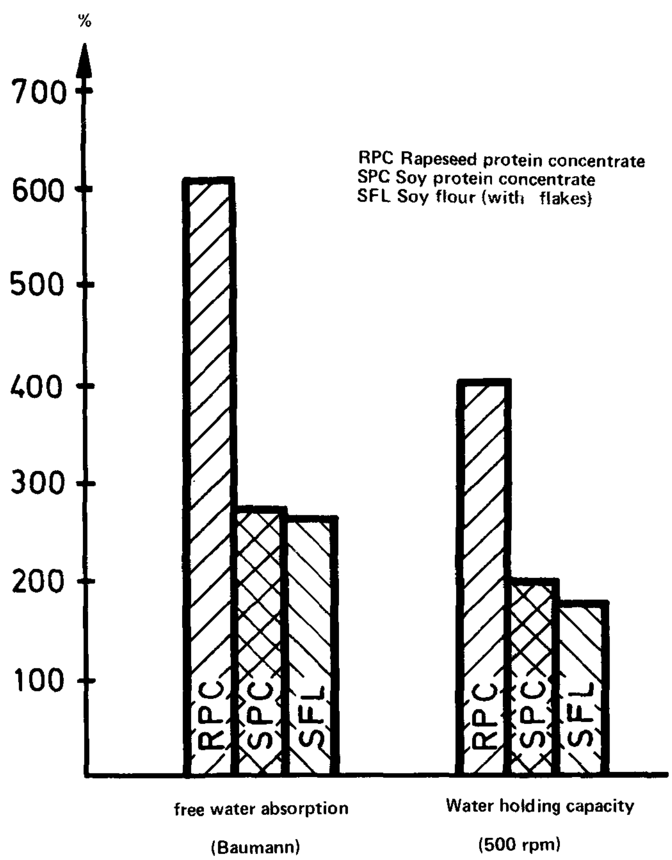


FIG. 6. Water absorption of RPC and soy protein.

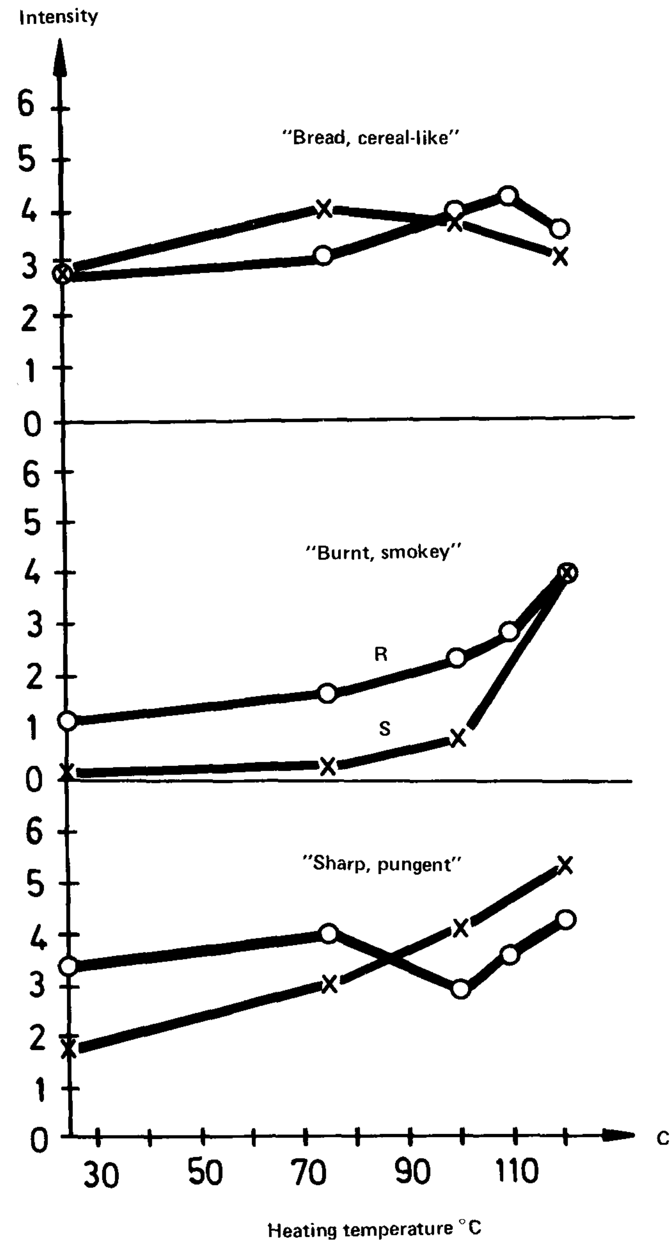


FIG. 7. Mean panel intensities of three odor qualities for soy(S) and rapeseed (R) protein heated in model systems for 60 min at temperatures between 75 and 120.

molecular weight, straight and branched-chain aldehydes and sulphur compounds. Several furan derivatives and nitrogen-containing compounds are probably also important. Mean panel intensities of three odor qualities for soy (S) and rapeseed (R) proteins heated in model systems for 60 min at temperatures between 75 C and 120 C are shown in Figure 7.

## RPC IN MEAT PRODUCTS

Functional properties of protein preparations can provide information about the action of a protein when incorporated into a food. Capacities for emulsification, water absorption, and fat absorption are examples of such properties. Andersson tried to find relevant methods of instrumental and sensory analysis of meat patties containing untextured rapeseed protein concentrates. Addition of untextured RPC required the same force at 50% penetration with an Instron testing machine as the addition of textured soy flours, and it gave far better results than did additions of soy protein isolate or casein. (27). Consist-

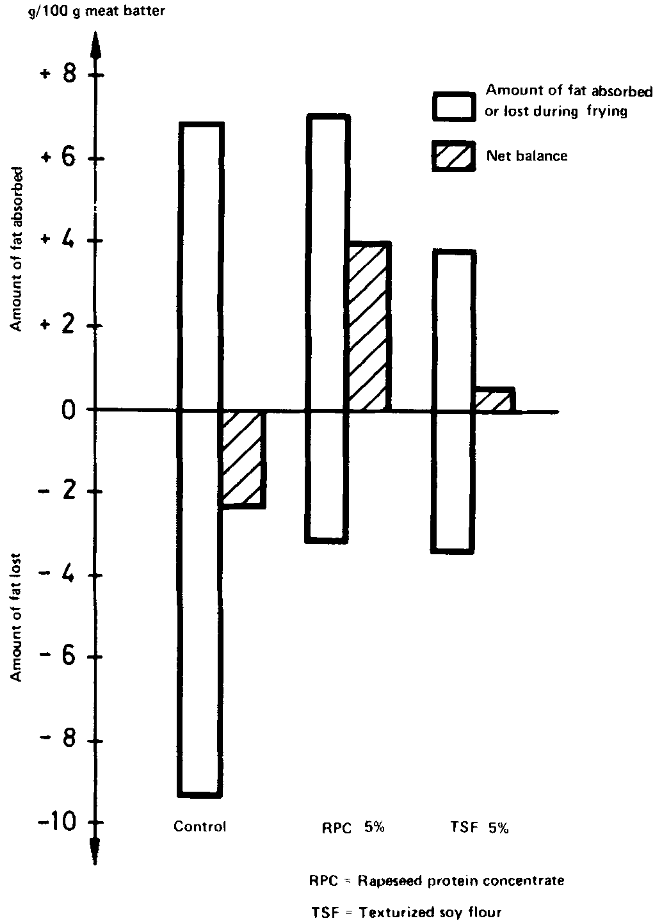


FIG. 8. Change in the total amount of fat bound and lost during deep fat frying and net balance fat after frying.

TABLE VIII

Organoleptic Analysis of Meat Patties

| Laboratory panel | | | |
|---|---|---|---|
| Flavor Scale 1-7 | 5% TSFL[a] | 5% TRPC[b] | 8% TRPC |
| Poor – good | 3.5 | 4.5 | 3.5 |
| Meat flavor | 3 | 4.5 | 3.5 |
| Off-flavor | 5 | 4 | 5 |

[a]TSFL = textured soy flour.
[b]TRPC = textured rapeseed protein concentrate.

ency of meat patties with textured vegetable proteins has been studied. The total impression of consistency can be equalized between patties with soy or rapeseed proteins by other binding ingredients such as bread crumbs and potato flakes.

To determine whether fat was absorbed or lost during deep fat frying, the patties were fried either in rapeseed oil or in coconut oil. These oils were chosen because they have different fatty acid compositions from those of meat. Fatty acid analysis of the oil was made before frying and of the patties before and after frying. Analyses of the fatty acid compositions showed that the control batter released a considerable amount of the original fat and at the same time absorbed a great deal (Figure 8). The net balance was negative, i.e., more fat was released than absorbed.

Batter with texturized soy flour lost about half the amount released by the control, and absorbed about the same amount, but less than the control batter. The net balance was slightly positive, i.e., some more fat was

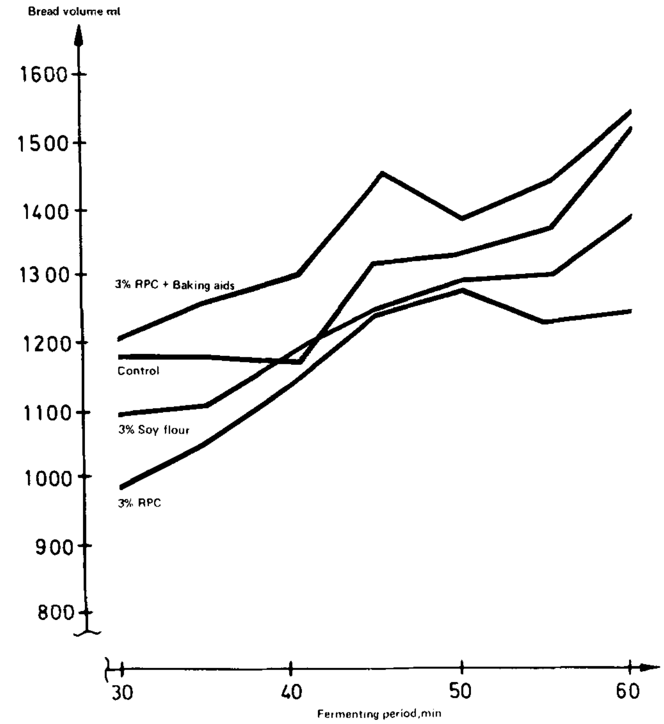


FIG. 9. Bread volume as function of fermenting period.

TABLE IX

Functional Properties of RPC

| | |
|---|---|
| Nitrogen solubility in water | 5-10% |
| Nitrogen solubility in 0.2 M NaCl | 15-20% |
| Water absorption (free) | 500-800% |
| Water-holding capacity (500 rpm) | 400% |
| Fat-binding | Excellent |
| Emulsification properties | Poor |
| Foaming properties | Poor |
| Gelling properties | Poor |
| Color | Light yellow |
| Flavor | Bland |
| pH | 6.0-6.5 |

absorbed than released. Batter with RPC released about the same amount as batter with textured soy flour, but absorbed as much as the control batter. The net balance was strongly positive; i.e., twice as much fat was absorbed as released.

The frying loss (fat and water loss) was measured in meat patties. Those with RPC had the lowest frying loss (14%) and the control with patties the soy protein concentrate the highest (18%), with patties containing textured soy protein about 15%.

The quality of wieners supplemented with rapeseed protein concentrates has been studied by, for example, Sosulski (28). Wieners containing an additional 20% of rapeseed protein were lower in fat content and emulsion stability, but showed less shrinkage during the smokehouse and cooler treatment.

Experiments have shown the RPC has a good stabilizing effect on sausage emulsions because of good fat and water-binding properties. The consistency of the sausage is somewhat mushy because of the lack of gelation ability in RPC.

Very bland rapeseed protein products can be produced. The remaining flavor in RPC seems to be better covered in meat systems than that from soy protein products (Table VIII). This may be due to the fact that we are used to the taste of glucosinolate split products through our consumption of, for example, mustard or cabbage, This may be one advantage for RPC over soy protein products.

## RPC IN BREAD

The effects of RPC in bread have been studied both in Canada and Sweden. Five to fifteen per cent of wheat flour was replaced by RPC. The quality of the dough was followed by farinograph, extensorgraph, and by SJA dough testing machines. Results show that the water uptake of RPC was about 230%, of SPC was 175% and of textured soy flour was 130% compared to 60% for wheat flour. Farinograms show some slow development time but quite good stability. Extensibility of the respective doughs with vegetable proteins was not as good as in the control. The volume of the bread baked on the dough was poor. The reason for this was not poor gas development, but poor gas retention. This effect could be more than compensated for by the use of normal baking aids, e.g., with stearoyllactylate (SSL) (Figure 9). The color of the bread is somewhat darker at high levels.

Heat-treated rapeseed flours are comparable to soybean flour in water absorption and gave much higher fat absorption, oil emulsification and whippability values. The functional properties of RPC are summarized in Table IX.

## REFERENCES


1. Appelquist, L.Å., and R. Ohlson, "Rapeseed," Elsevier, Amsterdam, (1972).
2. Brit. Pat. 1428076, 1976.
3. Gillberg, L., and B. Törnell, J. Food Sci. 41:1063, 1070 (1976).
4. Theander, O., and P. Åman, Swedish J., Agric. Res. 7:69 (1977).
5. McLaughlan, J.M., J.L. Beare-Rogers, J.D. Jones, and B.G. Shah, Nutr. Rep. Int. 15:331 (1977).
6. Gorill, A.D.L., D.M. Walker, and J.D. Jones, Can. J. Anim. Sci. 54:659 (1974).
7. Anjou, K., E. Honkanen, T. Langler, and R. Ohlson, Nutr. Rep. Int. 17:587 (1978).
8. McDonald, B.E., S-Å. Liedén, and K. Anjou, Ibid. 18:51 (1978).
9. Jones, J.D., 5th Intern. Rapeseed Conf., Malmö, 1978.
10. vanEtten, C.H., M.E. Daxenbichler, P.H. Williams, and W.F. Kwolek, J. Agric. Food Chem. 24:452 (1976).
11. vanEtten, C.H., M.E. Daxenbichler, and I.A. Wolff, Ibid. 17:483 (1969).
12. Loew, F.M., C.E. Doige, J.G. Manns, G.P. Searcy, J.M. Bell, and J.D. Jones, Toxicol. Appl. Pharmacol. 35:257 (1976).
13. Beare-Rogers, J., (To be published).
14. Sharpe, L.G., K.S. Larsson, and S-Å. Liedén, Nutr. Metabol. 18:254 (1975).
15. Eklund, A., and G. Ågren, Proc. 4th Intern. Rapeseed Conf., Giessen, 439 1974.
16. Eklund, A., Nutr. Rep. Int. 7:647 (1973).
17. Oberleas, D., M.E. Muhrer, and B.L. O'Dell, J. Nutr. 90:56 (1966).
18. McLaughlan, J.M., J.D. Jones, B.G. Shah, and J.L. Beare-Rogers Nutr. Rep. Int. 11:327 (1975).
19. Shah, B.G., J.D. Jones, J.M. McLaughlan, and J.L. Beare-Rogers, Ibid. 13:1 (1976).
20. Anjou, K., 5th Intern. Rapeseed Conf., Malmö, 1978.
21. Radwan, M.N., and B.C.Y. Lu, JAOCS 53:1063 (1976).
22. Hermansson, A.M., D. Olsson, and B. Holmberg, Lebensm. Wiss. Tech. 7:176 (1974).
23. Sosulski, F., E.S. Humbert, and K. Bui, J. Food Sci. 41:1349 (1976).
24. Honkanen, E., Proc. 22nd Meat Res. Congr., Malmö, 1976.
25. Quist, I., and E. von Sydow, J. Agric. Food Chem. 24:437 (1976).
26. Quist, I., and E. von Sydow, Lebensm. Wiss. Tech. 9:299 (1976).
27. Andersson, Y., Dissertation, Chalmers Uni. of Tech., Gothenburg, 1976.
28. Sosulski. F., Can. Inst. Food Sci. Technol. J. 10:9 (1977).