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NUTRITIVE AND FUNCTIONAL

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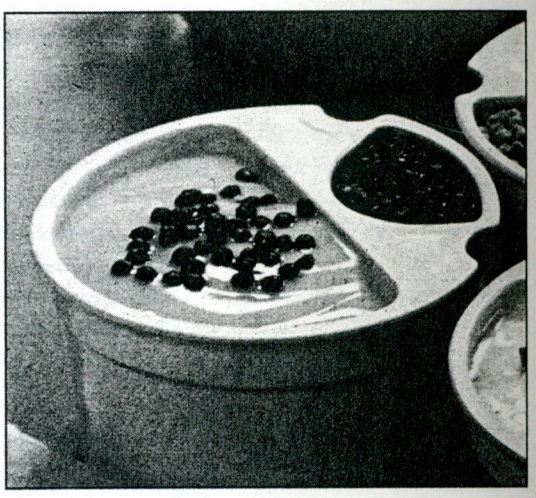
The multifunctional properties of wheat germ make this versatile ingredient suitable for a broad range of applications. The several functional and nutritional qualities of wheat germ take care of the improvement of food stability, food texture, organoleptic properties, and colour and flavour development in the food products in which it is being applicated.



"BIOGERM crisp" with its crunchy wheat germ filling and milk-caramel coating is to be applicated in sour cream products, desserts, ice cream and muesli. (Photo: Multiforsa)

Before talking about wheat germ itself, it is important to look at the morphology of a wheat grain. In figure 1 a longitudinal section of a wheat kernel is shown with its four main compartments: the outer pericarp and the aleurone layer (together known as bran), the starchy endosperm as basis for all wheat flours and the germ (embryo), which is usually removed during the preparation of wheat flours.

If we quantify the different parts of wheat grain in figure 2, we realize, that the germ accounts for only 2,5% of the total weight of a wheat grain. Nevertheless the germ represents an important fraction, as far as nutritional and functional properties are concerned.

GRAN COMPOSITION

If the composition of wheat germ is compared with other raw materials of wheat (figure 3) it appears that the germ is extremely rich in proteins, contains many more lipids than the other wheat fractions and has a relatively small amount of available carbohydrates. As expected, bran is rich in dietary fibre and contains the lowest amount of available carbohydrates, whereas the grain and especially the white flour are poor in lipids, dietary fibre and also in minerals, but contain large amounts of starch. Figure 4 shows the effect of certain treatments of the overall composition of wheat germ. The untreated, the stabilized and the partially lipid free germ, Biogerm 1080 -produced and commercialized by the Swiss company Multiforsa- are compared. There are only small differences, the fibre content of Biogerm is slightly enhanced, the available carbohydrate content diminished. Some minor constituents are listed at the bottom of the figure. Wheat germ is rich in vitamins and also in minerals. The stabilization process (removal of a part of the lipids) also has an influence on the vitamin content and particularly on tocopherols (vitamin E), which belong to the fat-soluble vitamins.

PROTEIN CONTENT

In figure 5 the amino acid content of white flour, wheat bran and wheat germ type 1080 are indicated. The protein content of the germ flour is approximately 2.5 times higher than the one of white flour and 1.5 times higher than the one of wheat bran. If we compare the figures we find for example: aspartic acid and threose are enriched in the germ, lysine is approximately 10-fold enriched compared to the white flour. On the other hand, glutamic acid, proline and also cysteine are enriched in the white flour compared to the other wheat fractions. This example demonstrates that the proteins in the white flour, the bran and in the germ flour belong to different populations. This is even better seen in figure 6. Technology acid is the predominant amino acid in the endosperm proteins, followed by proline. These two amino acids together account for approximately 50% of the total amino acids in the endosperm proteins. Important for the functional properties of the endosperm of flour protein is the relatively large amount of cysteine, the sulfur coating amino acid, responsible for the oxidative cross-linking of the gluten proteins. On the other hand, the distribution of the amino acids with the germ proteins is more even. Cysteine is present in minute amounts, the germ proteins don't have therefore the

PROPERTIES OF WHEAT GERM

Wheat germ makes biscuits and cereals more crunchy and nourishing and also prolongs shelf life. (Photo: Multiforsa)

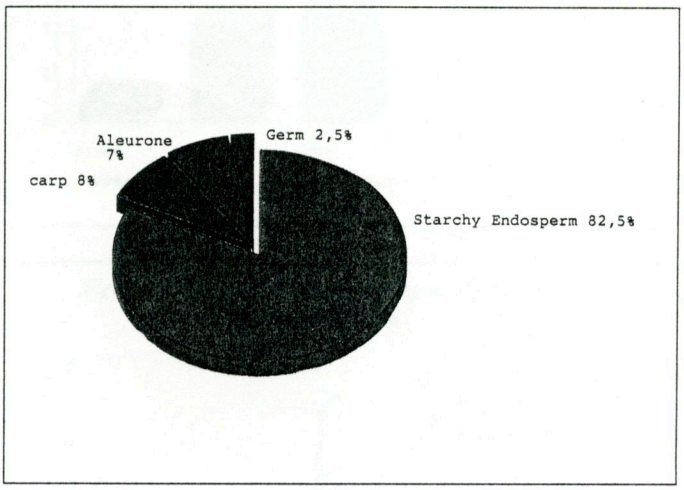


Figure 2: Distribution of constituents within the wheat grain (in percentage of grain weight)

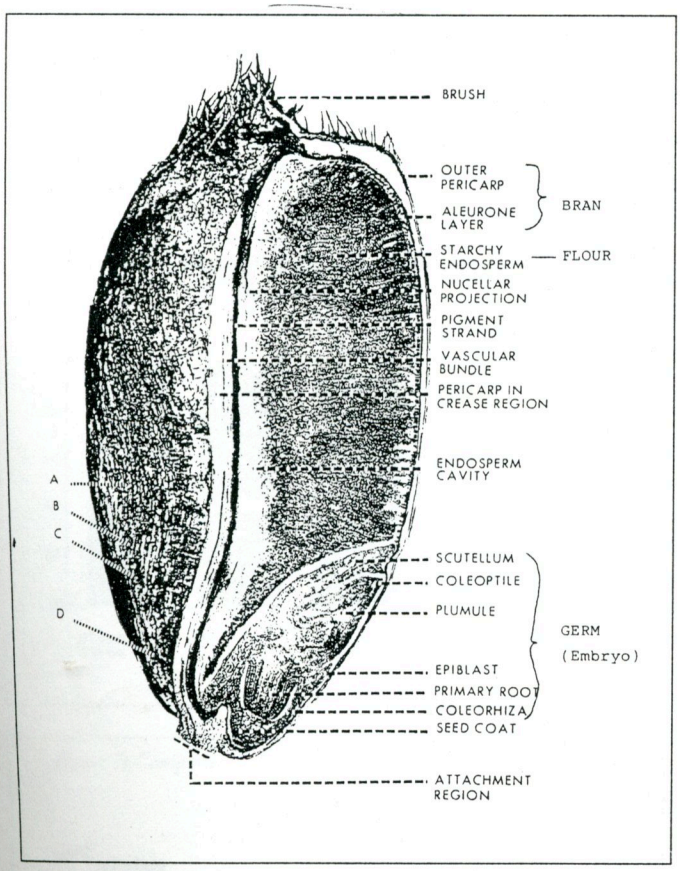


Figure 1: Longitudinal section through a wheat grain

tendency to form supramolecular structures. But, important for the nutritive aspect of the germ, some of the essential amino acids are enriched in the germ fraction, for example lysine.

CARBOHYDRATES AND LIPIDS

In figure 7 the contents of white flour, bran and germ in carbohydrates are summarized. While in the white flour the carbohydrate fraction accounts for approximately 75% of the fresh matter, the bran fraction contains 60% and the germ fraction, 45% of carbohydrate material. Starch, which belongs to the available carbohydrates, accounts for practically all the carbohydrate material of the endosperm flour, whereas in the bran, dietary fibre represents a total of 80% of the carbohydrate material. On the other hand, the distribution of the carbohydrate material is much more even in the germ. The lower molecular sugars, sucrose, raffinose, fructose and glucose and the high molecular carbohydrate starch account together for 2/3 of the carbohydrate material, whereas the dietary fibre represent 1/3 of the carbohydrates.

In figure 8, white flour, wheat bran and untreated wheat germ are compared, with respect to their lipid content and the different lipid classes. The total amounts of lipids in the three products are approximately 1%, 4.6% and 9.5% respectively. The relative distribution shows that in the flour the group of the phospholipids, to which the lecithins belong, is predominant, whereas in the bran and in the germ the triglycerides account for more than 50% of the total lipids. The relatively high amount of free fatty acids, mono- and diglycerides in the germ are mainly responsible for the instability of the germ lipids. It is primarily this fraction of the germ lipids which has to be removed in order to get a stable product. Figure 9 shows the fatty acid distribution with the whole grain, the bran and the untreated germ fractions. The distribution in the three diagrams is more or less the same, linoleic acid being the most important from the nutritional point of view.

NUTRITIVE ASPECTS

Every group of constituents fulfils certain nutritive functions. The main function of the food ☞

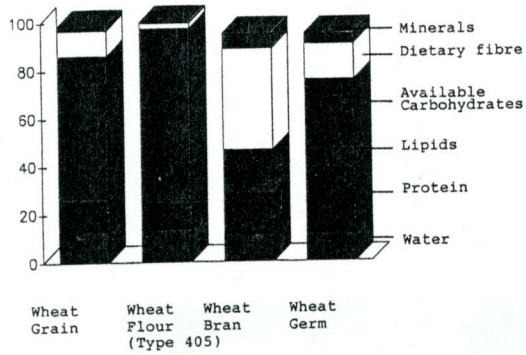


Figure 3: Overall composition of the grain, flour, bran and germ (in g per 100 g)

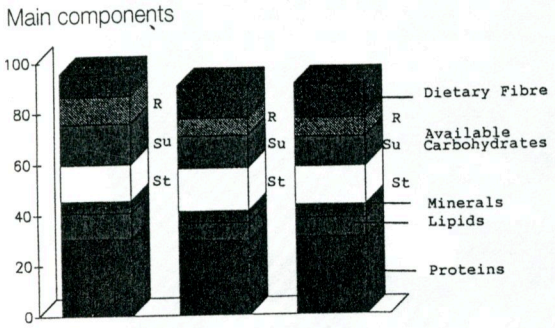


Figure 4: Overall composition of the germ (in g per 100 g dry matter)

Minor constituents: (in mg/100 g dry matter)

Tocopherol	13.25	11.58
Thiamin	2.27	2.11
Riboflavin	0.79	0.63
Pyridoxin	3.74	3.47
Niacin	5.10	5.26
Pantothenic acid	1.13	1.05
Biotin (ug/100g)	19.25	10.53

proteins is to provide the body with a sufficient amount of the amino acids needed for growth, development and for all metabolic processes. The food proteins are digested in the stomach and in the upper intestine by proteases and the amino acids liberated are absorbed through the intestinal membrane. Part of the amino acids can be synthesized by our body cells themselves, whereas some others, the so-called essential amino acids isoleucine, leucine, lysine, methionine, cysteine, tyrosine, phenylanaline, threonine, tryptophan and valine cannot be synthesized. We must ingest these amino acids through the food proteins. The nutritive quality of a protein is therefore dependent on the content of these essential amino acids.

NUTRITIVE QUALITY OF PROTEINS

Different chemical and biological methods are available for the determination of the nutritive quality of a protein. One of these, the so-called amino acid score, measures the content of the food proteins in essential amino acids and compares this content to a reference protein, containing exactly balanced amounts of essential amino acids.

If the nutritive quality of wheat germ to other wheat fractions is compared (figure 10), we realize that the germ proteins are of a very high quality. The content in essential amino acids is only slightly lower than the one of the optimal proteins. Two amino acids are mainly responsible for this fact. Lysine is the first limiting amino acid in the grain, in the flower and also in the bran.

The gluten proteins of the flour are deficient in lysine and therefore have a limited nutritive value. In rat growth experiments it has been shown that the diet containing 10% of proteins from different wheat fractions led to completely different weight gains:

whole wheat	41.9 g
patent flour	19.2 g
wheat bran	101.5 g
wheat germ	131.8 g

The proteins also have another nutritive function, namely to provide the body with energy. In a diet which is deficient in lipids and carbohydrates, the proteins can be used as source of energy and provide 17 kJ/g. But this function is not relevant in wheat products.

NUTRITIVE QUALITY OF LIPIDS, CARBOHYDRATES AND VITAMINS

The main nutritional duty of the lipids is to provide energy for the body. Lipids have a high energy density providing 39 kJ/g. Besides this important function, some fatty acids are responsible for the synthesis of membranes, hormones and other important substances. These fatty acids are essential, the body is not able to synthesize them by itself. Wheat germ contains large amounts of them, especially linoleic acid, and is therefore a good source of essential fatty acids.

Within the carbohydrate fraction of the germ two nutritive groups have to be considered. The available carbohydrates provide energy to the body. Starch and sucrose are degraded to glucose or fructose in the intestine, absorbed and completely burned in the cells to yield 17 kJ/g. The second group of carbohydrates which should be considered are the dietary fibres. This group of mainly plant cell wall polysaccharides is not digested by our intestinal enzymes and fulfils some important physiological functions within the gast-

Figure 5. Amino acid composition of flour, bran and germ (in g/100g)

Amino acid	flour (type 405)	bran	germ flour (type 1080)
Aspartic acid	0.52	1.57	2.96
Threonine	0.34	0.64	1.55
Serine	0.71	0.97	1.75
Glutamic acid	3.94	3.87	5.00
Proline	1.56	1.23	1.62
Glycine	0.45	1.42	1.96
Alanine	0.40	1.15	2.14
Cysteine	0.26	0.42	0.14
Valine	0.53	0.95	1.66
Methionine	0.18	0.27	0.58
Isoleucine	0.50	0.83	1.05
Leucine	0.86	1.21	2.18
Tyrosine	0.34	0.50	0.86
Phenylanaline	0.59	0.70	1.28
Histidine	0.24	0.47	0.88
Lysine	0.26	0.78	2.26
Arginine	0.46	1.33	2.90
Tryptophan	0.13	0.27	0.18
Total protein	**12.27**	**18.58**	**30.95**

Figure 6: Distribution of amino acids within the proteins of wheat flour, bran and germ

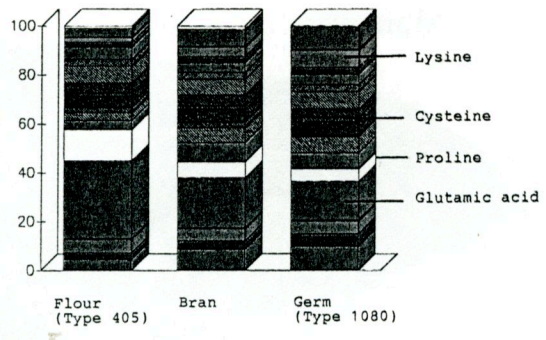


Figure 7: Components of the carbohydrate fraction of endosperm (flour), bran and germ

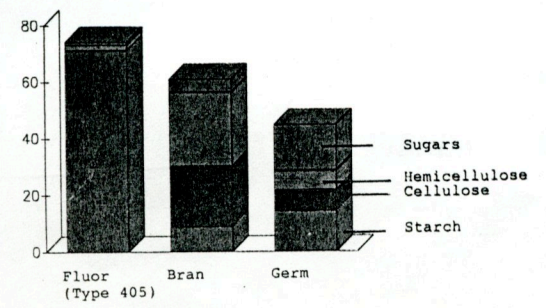


Figure 8: Components of the lipid fraction of endosperm (flour), bran and germ

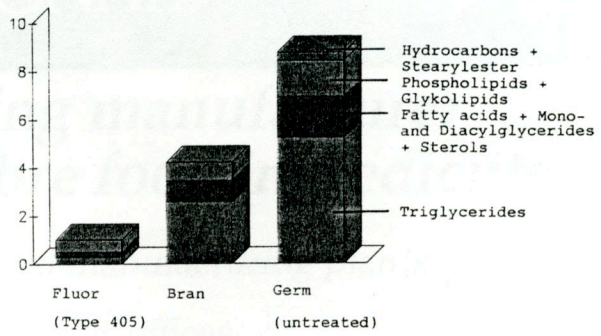
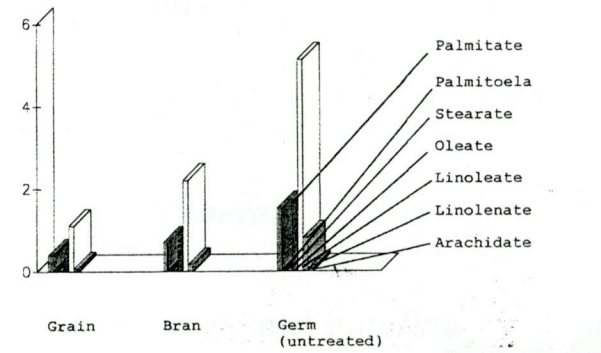


Figure 9: Fatty acid distribution of lipids of wheat grain, bran and germ



rointestinal tract (stomach emptying, increasing the peristaltic activity, stool bulking effect etc.) Wheat germ contains a large umber of different vitamins and minerals. The most prominent vitamins in the germ is vitamin E (tocopherol), which has anti-oxidative properties. The main mineral constituents of the germ are phosphorous and potassium, followed by magnesium, calcium and sodium. Minor amounts of iron, zinc, manganese, copper and molybdenum are reported to be part of the germ mineral fraction. The phosphorous is present as inorganic phosphate or as organic phosphoric acid esters, the other minerals occur as inorganic salts.

The nutritive functions of the minerals are multiple. Phosphorous is primarily incorporated into the bones, potassium is important for the electrolyte balance outside the body cells, the minor constituents often act as cofactors for certain body enzymes and are thus involved in the intermediate metabolism.

FUNCTIONAL ASPECTS

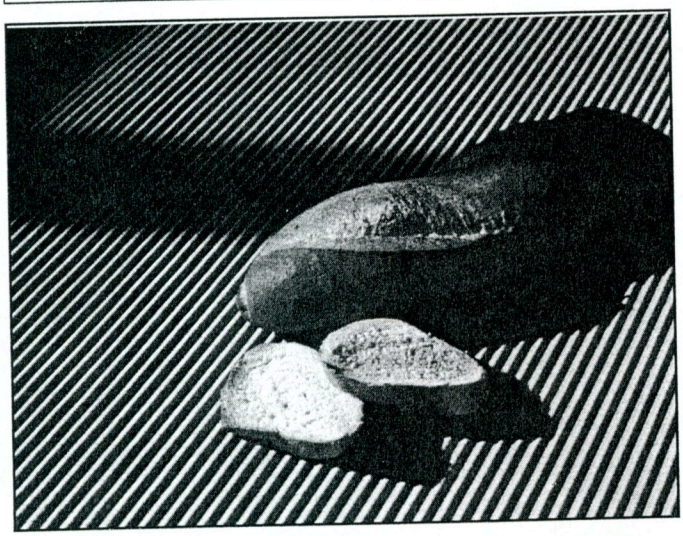
Figure 11 mentions the functional aspects of the different groups of constituents of a given group. Proteins have the ability to bind and to retain water, thus influencing the rheological properties of food. By building up three dimensional networks they may also retain gases (bread). Some proteins having polar structures may act as emulsifiers, the gas retention ability gives proteins a high foaming activity and finally proteins also influence the sensorial (organoleptic) properties of a food. ☞

Figure 10: Nutritive quality of the proteins from different parts of the wheat grain. (essential amino acids as compared to the FAO/WHO reference protein)

Amino acid	whole grain	patent flour	bran	germ
Ile	95	98	88	88
Leu	96	96	86	89
Lys	49	35	73	98
Met + Cys	111	117	103	106
Phe + Tyr	128	130	112	110
Thr	73	68	83	93
Trp	120	100	160	110
Val	94	86	100	102

Figure 11. Functional aspects

Proteins	water binding water retention rheological properties gas retention emulsifying properties foaming sensorial properties - texture - colour/flavour
Lipids	sensorial properties - "mouthfeeling" antioxidative properties emulsifying properties
Carbohydrates	water binding gas formation sensorial properties - texture - colour/flavour

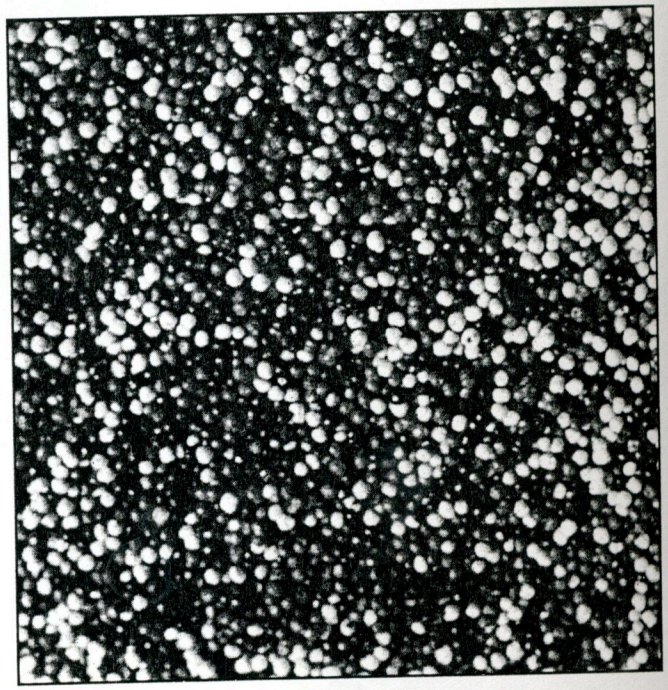


Natural baking mixtures (BIOGERM-mix) form one of the applications of wheat germ. (Photo: Multifora)

Lipids primarily give a sensorial sensation which is called "mouth-feeling", even though lipids themselves are subject to auto-oxidative processes, leading to off-flavours and loss of essential fatty acids. Therefore germ needs the antioxidative property of the vitamin E. The presence of large amounts of polar lipids (phospholipids, lecithines) in the germ is responsible for a further functional property, the emulsifying activity.

The carbohydrate exhibit a high water binding capacity, the are easily fermented, e.g. by yeast in the preparation of bread, yielding a lot of carbon dioxide.

Carbohydrates are also responsible for texture attributes of a food and, alone or together with the proteins, for colour and flavour development.



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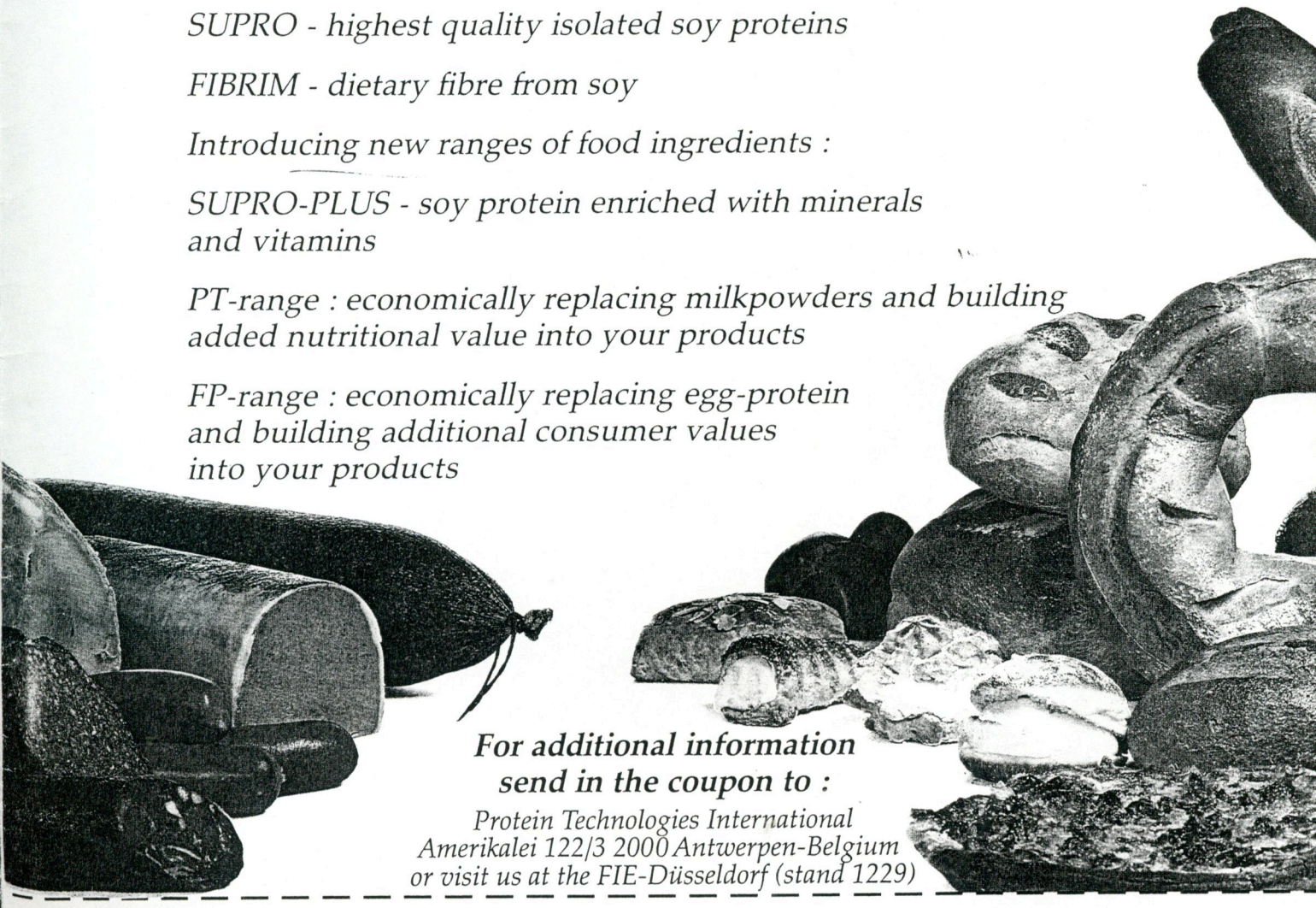

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