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NUTRITIONAL CHARACTERISTICS of ORGANIC, FRESHLY STONE-GROUND, SOURDOUGH & - CONVENTIONAL BREADS

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INTRODUCTION

Consumers concerned about their health are changing their dietary habits. Yet most are unaware of the potential nutritional value of bread, which makes up a major part of their diet. However, comprehensive information concerning this topic is not readily available. This paper compares the nutritional characteristics of organic, freshly stone-ground, sourdough breads with conventional breads, highlighting the factors which inhibit or enhance its nutritional value.
A brief history of wheat, its milling, and bread-making are included to enable the reader to better understand factors that are responsible for the decline or the improvement of the nutritional quality of bread.

IMPORTANCE OF WHEAT AND BREAD

Cereal grains and legumes play an important role in supplying the nutrients, as well as over 70% of the daily energy requirements, of over two-thirds of the world's population (Edwards et al. 1971). A Nationwide (USA) Food Consumption Survey in 1977-78 found that cereal product consumption was equivalent to 226 grams of flour per day for men and 156 grams for women (Guthrie, 1989). Bread, the most common form of cereal intake in many countries has been designated the Staff of life, and rightly so, since it contains more nutrients per weight than meat, milk, potatoes, fruits, and vegetables (Thomas, 1976).
Egyptians are believed to be responsible for introducing the process of leavening around 4000 B.C. (Spicer, 1975). For a long time, bread was in fact central to their economy, as wages and bills were often paid in the form of dough (Bread Winners, 1978).
Bread may be made from various cereals, grains, and legumes. Wheat, being the oldest cereal known to man (Jenkins, 1975), is the most common. Today, wheat is the world's dominant cereal crop (Davidson & Passmore, 1986). Total world production is about 250 grams per person per day. In its unrefined state this could supply 800 calories and 30 grams of protein per person were it evenly distributed worldwide (Davis, 1981). This amount would also supply a 25 to 49 year old man with 30% of his energy requirements and 49% of his protein requirements (Health & Welfare, 1990). Although wheat consumption in the US decreased until the early 1970s, it has since stabilized (Pomeranz, 1988). Wheat-based foods now supply only about 20% of the daily energy

requirements of US citizens but are the main source (30%) of dietary fibre in the USA (Anderson, 1985).

Wheat's pleasant flavor, long shelf-life, and unique gluten-forming characteristics (Nelson, 1985) make it the most popular grain for bread-making. Other grains used include barley, millet, oats, and rye, as well as nuts and acorns. As a result of wheat- breeding, many of the early wheat varieties, including emmer and spelt, were neglected and are little known today. Wheat breeding focused on improving both crop yield and baking qualities. In Germany, 1000-grain weight has increased by about 40% between 1938 and 1971, resulting in a larger wheat endosperm - and therefore proportionally more starch and protein, yet less vitamins and minerals (Thomas, 1990).

Rye is a grain commonly used for bread-making in some European countries and in the Soviet Union (Jenkins, 1975), partly because rye produces higher yields on poorer soils than does wheat.

NUTRITIONAL VALUE OF WHEAT AND RYE

The kernel of wheat is composed of the outer bran layer, the germ, and the endosperm. It is rich in nutrients, many of which are concentrated in the bran and germ. Of special importance is that it contains the entire B complex, except for vitamin B12. B vitamins function as cofactors in many metabolic reactions involved in the release of energy (Birdsall, 1985).

The germ, which includes the scutellum, is especially rich in vitamins B and E, high quality protein, unsaturated fats, minerals, and carbohydrates. The bran consists mostly of the insoluble carbohydrate cellulose, and contains incomplete protein, traces of B vitamins, and minerals - especially iron. The endosperm is the largest part of the grain, and consists mostly of the carbohydrate starch, incomplete protein, and trace amounts of vitamins and minerals.

Significant variations in the content of grains occur because of variety, crop year, area, fertilizer, and soil type. It must therefore be kept in mind that values expressed in tables reflect average values. The following table, taken from Guthrie (1989), shows the percent distribution of the major nutrients in cereal grains.

The following table of data for the major components of wheat was taken from Souci (1981). Values are in grams per 100 crams of the grain portion referred to, except for minerals quantities which are expressed in milligrams and the energy units which are kilocalories and kilojoules.

Because of its high content of vitamin E, wheat germ is promoted as a health food, and has been proposed as a cure for almost every disease. Recent studies have shown that vitamin E increases the desirable HDL cholesterol in women, though in men only if they initially had low levels. Animal studies have also shown that vitamin E protects against free radicals released by the body when it is exposed to toxic chemicals. Vitamin E is used to treat intermittent claudication, which involves cramps in the calf muscles at night and extreme pain while walking. Vitamin E may be helpful for fibrocystic breast disease (Guthrie,1989).

Other vitamins and numerous other minerals are found in the wheat kernels, though in small amounts. These include carotene, vitamin B6 or pyridoxine, pantothenic acid, biotin, and folic acid, vitamin C, and vitamin K. Other minerals are sodium, calcium, chlorine, manganese, zinc, copper, cobalt, nickel, chromium, molybdenium, fluoride, iodine, boron, selenium, lead, aluminum, and siliconioxide (Souci, 1981). The body is capable of converting the carotene to produce one sixth its amount as vitamin A (Health ~ Welfare, 1990).

The nutritional value of wheat is improved by milling, which increases its digestibility, and by moderate heat and humidity which inactivate enzyme inhibitors and other heat-sensitive toxic factors, and denature protein (Nierle, 1984).

Despite all its many nutritional qualities, wheat cannot meet all nutritional needs. Since it lacks adequate amounts of certain essential nutrients - vitamins A, B12, and C, fats and the amino acid Iysine. These must come from other sources.

The quality of a protein is determined by the kind and composition of its constituent amino acids. When all essential amino acids are present in the proportions capable of promoting growth, the protein is complete, of good quality, and of high biological value (BV), and would result in a high net protein utilization (NPU) by the body. If a protein has a relatively small amount of one essential amino acid (called the limiting amino acid), body tissue repair will occur, but growth cannot be

supported (Guthrie, 1989).
Lysine is the limiting essential amino acid in cereals. A greater intake of Iysine than that found in wheat is especially important for children. Wheat protein is adequate for adults, since they have been shown to maintain nitrogen equilibrium (intake of nitrogen from protein = loss), or to be in slightly positive nitrogen balance (intake = loss) when consuming bread diets (Bolourchi et al., 1968; Betschart et al., 1985; Young and Pellett, 1985). The requirements for Iysine are about three times less for adults than for children (Thomas, 1986). Protein from rye has a higher biological value (or net protein value which is net protein utilized) than does wheat because of its superior amino acid composition (Mender, 1983). Wheat contains about 20% to more protein than rye. However, rye contains 30% more of the amino acid Iysine than does wheat. Rye also contains more calcium and fluoride (Thomas, 1986).
To assure an adequate supply of Iysine, bread made solely from grain should be consumed in combination with milk products, meat, nuts, or legumes. There is a need for some animal products, since they are the only sources of vitamin B12, apart from intestinal bacteria capable of producing some (Thomas, 1986). Large deficiencies of this vitamin lead to anemia (Guthrie, 1989). Fruits and vegetables are required to provide the missing vitamins A and C, and fats are needed to supply essential fatty acids, because wheat and rye contain very little fat (about 2%).

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STONE-GRINDING OF GRAIN

In the third century B.C., rotary grindstones powered by animals, and small rotary hand mills called querns, replaced stone or wooden mortars and pestles for the grinding of grains. Querns are still used in rural areas of the Middle East, Far East, and parts of Africa (Hall, 1974).
There are several advantages to stone-ground wheat flour. The endosperm, bran, and germ remain in their natural, original proportions. Because the stones grind slowly, the wheat germ is not exposed to excessive temperatures. Heat causes the fat from the germ portion to oxidize and become rancid and much of the vitamins to be destroyed (Aubert, 1989). Since only a small amount of grain is ground at once, the fat from the germ is well distributed which also minimizes spoilage (Mount, 1975). Nutritive losses due to oxygen exposure are also limited by the fact that stone-ground flour is usually coarser (Thomas, 1976). As expressed in The Bread Book (Leonard, 1990), stone-ground flour is preferred by many bakers and natural food advocates because of its texture, its sweet and nutty flavour, and the beliefs that it is nutritionally superior and has a better baking quality than steel-roller-milled flour. Moritz and Jones (1950) and Schultz et al. (1942) showed that stone-milled flour was relatively high in thiamin, compared to roller-milled flour, especially when from hard wheat.

ADVANTAGES OF FRESH FLOUR

Because grains contain only about 12% water (or about 0.6 water activity), they are not predisposed to spoilage. However, grinding removes the protective layers and endangers the grain's biological stability. Deterioration of sensory and nutritional qualities depends on storage conditions, such as temperature, humidity, oxygen concentration, and light exposure. The lower the water activity, the lower is the loss of vitamins (Munzing, 1987). For example, a vitamin E loss of only about 23% occurred after a 13 months of storage at a 0.6 water activity (Rothe 1963, Plasch 1984, Pelschenke 1961). In order to reduce oxidation of Essential compounds and the development of rancidity, many authors recommend storing ground flour for no more than two weeks (Solder 1984, Bruker 1984, Schnitzer 1986, Schnitzer (no year), Thomas 1982, Thomas 1986, Koerber 1986). Antioxidants present naturally in grains (vitamin E and lecithin) help prevent oxidation of the fatty acids and the associated rancidity only for a limited time, and under 'favourable' conditions.
Glutamic acid decarboxylase, the most sensitive enzyme in the grain, is used to indicate the health

of the grain. When heated or exposed to increased humidity, even under 'favourable' conditions, it losses activity very quickly in wheat. It was found to be even more sensitive in rye (Muzing, 1987).

The B vitamins are liable to be destroyed by light and air, and it also seems that other substances, still unknown, are quickly destroyed (Aubert, 1989). Other deteriorations include denaturation of lipoproteins, phospholipid hydrolysis, auto-oxidation of unsaturated fatty acids of phospholipids, polymerization within lipoproteins, browning, Maillard reaction of amino groups from phospholipids and aldehyde groups from sugars, and carotene and aroma losses (Lea, 1957; Thomas, 1976).

Lipids in milled wheat are much more susceptible to enzymatic degradation, because enzymes are incorporated into the flour with fragments of bran and germ and with microorganisms from the surface of the grain. Associated with lipid deterioration are losses of carotenoids and vitamin E (Galliard, 1983).

The nutritional importance of using fresh stone-ground grains for bread-making was revealed in the results of feeding studies in Germany (Bernasek, 1970). Rats were fed diets consisting of 50% flour or bread. Group 1 consumed fresh stone-ground flour. Group 2 was fed bread made with this flour. Group 3 consumed the same flour as group 1 but after 15 days of storage. Group 4 was fed bread made with the flour fed to group 3. A fifth group consumed white flour. After four generations, only the rats fed fresh stone-ground flour and those fed the bread made with it maintained their fertility. The rats in groups 3 to 5 had become infertile. Four generations for rats is believed to be equivalent to one hundred years in humans.

Different ecological standards for flour storage set limits of 15 to 60 days (Picker & Pedersen, 1990), although rancidity has been detected as early as 2 to 14 days after milling (Larsen, 1988). Nutrient analysis studies are required to determine the exact nutrient losses accompanying the development of rancidity and thereafter.

DEVELOPMENTS IN THE MILLING OF GRAIN

The Egyptians were the first to use a selective milling system. With hand sieves, they separated the flour from large bran particles, dirt, and stone chips that had broken off their implements (Davis 1981; Hall 1974; Marine & Van Allen 1972). Stone chips are not a problem with modern mills. In 1950, the degree of contamination of stone-milled flour with stone-dust was shown to be so slight as to not alter the mineral content of flour markedly (Moritz et al., 1950).

Since Roman times, white flour and bread have been regarded as the foods of upper classes. Flour, however, was far from white compared to today's flour (Marine & Van Allen, 1972). It was not until the 19th century that major changes in the milling processes took place.

The earliest version of today's iron roller mills were first used in Hungary in 1839. Between 1870 and 1890, they quickly replaced the stone mills throughout Europe and North America, and milling soon became completely automated (Davis 1981; Hall 1974). The roller mills were more economical and more efficient. The milling process could be controlled to produce as white a flour as the public demanded (Mount, 1975). However, the resulting flour was devoid of bran and germ, and consequently many nutrients were lacking.

MILLING TODAY

A very sophisticated process is currently employed for the milling of grain. Cleaning is accomplished by means of separators, aspirators, scourers, magnets, and washer-stoners. The wheat is tempered or conditioned in water to toughen the bran to reduce fragmentation when it is removed, and to obtain a moisture content resulting in particles of the desired size. The processes of drying and conditioning rye with steam (25% humidity and 60°C), have been shown to cause minerals such as potassium and phosphorus migrated to the endosperm, whereas more strongly bound minerals like calcium and magnesium did not migrate (Pelshenke, 1970). This may increase the content of certain minerals in refined flour. During the milling process, steel rollers crush the grain, and the flour released from the endosperm is separated by sifters into different grades or streams, according to fineness. Each of these has different mineral and protein contents, and may be recombined later to form a variety of flours to be sold for diverse baking purposes (Jenkins, 1975; Davis, 1981). The bran and germ, which make up about 28% of the wheat, are totally removed in this process. They are used in the production of animal feeds (Davis, 1981), as -well as by pharmaceutical laboratories for making diet supplements (Sablier, 1984).

Whole wheat flour is produced by recombining ground bran with endosperm flour, but the germ is usually left out, because it would go rancid. The resulting flour may represent only 95% to of the total grain (by weight), or in other words a 95% extraction (Day, 1966)

About 95% of the flour used in the USA is white and of only about 72% extraction. Only 20 to 30% of the grains original vitamins are retained, and the protein content is about 1 - 1.5 To lower. However, since bran decreases protein digestibility, the available protein does not significantly change (Pomeranz, 1988; Nierle, 1989). The NPU is similar in 66 to 100% extractions (Pedersen and Eggum, 1983).

ENRICHMENT OF FLOUR

In the 1940s, a flour enrichment program was instituted to compensate for wartime shortages of other foods. However, in the 'enriched' flour only the B vitamins - thiamin, riboflavin, and niacin - and the mineral, iron, were added, in amounts approximately equivalent to those removed from whole wheat (Jenkins, 1975). Flour 'Enrichment' implies a loss of nutrients and should not be equated with wholesomeness. For approximately 20 nutrients, there is an average loss of 70-80% to in refined and enriched flour (Davis, 1981). Its consumption clearly places the body at a disadvantage, casting a burden on the rest of the diet. The addition of more nutrients to refined flour has been considered, but it is limited by, for example, the effect of some nutrients on sensitive individuals (Pomeranz, 1988).

Since research is incomplete concerning nutrient requirements, interactions, optimal ratios, and toxicities (Allison et al., 1980), many believe that the safest option is to consume flour containing the nutrients in their natural proportions.

ADULTERATION OF FLOUR

As with most raw commodities, grains included, processing is the primary means used to maintain and increase market share. Typically, relatively little time and money is invested to examine possible health implications of such processing. Concerning grains, the separation of the milling and baking industries has led to the adulteration of flour with various chemicals, as flour manufacturers have sought to maximize profits and meet customer demands. For example, removing the germ not only prevents flour spoilage, it generates profits when sold to millfeed producers and pharmaceutical companies.

For centuries, bakers have known that 'good quality' baked goods could not be made with freshly milled flour, because the dough would lack strength and resilience to trap gas. Until the 20th century it was common practice of storing flour for months to allow oxygen to condition it. However, as well as storage costs, spoilage and insects caused losses. Chemical oxidizing agents or bleaches were developed to produce the same aging effects in 24-48 hours (Baker's Digest, 1962). They cause one of two effects: oxidation of the gluten (so less sulfhydryl groups are left to disturb disulfide bonds that need to form during dough fermentation for the bread to rise), and bleaching of the yellowish carotene pigments which could have been sources of vitamin A (Thomas, 1986; Jenkins 1975; Freeland-Graves & Peckham, 1987).

Bleaching agents did not come into use without opposition. A 1954 issue of the National Police Gazette, reports that, Harvey W. Wiley, Chief of the Food and Drug Administration early this century, won a Supreme Court decision outlawing bleaches, but he Was forced out of the FDA, and the Supreme Court order was bypassed through administrative actions. The approval of chlorine dioxide as a bleaching agent was not without protests by U.S. Army nutrition experts (Rorty, 1954).

Today, the Canadian Food and Drug Act and Regulations Division 13, B.13.001 permits the addition of numerous chemicals to white, whole wheat, and rye flours (Daniels, 1978). These include chlorine, chlorine dioxide, benzoyl peroxide, potassium bromate, ammonium persulfate, ammonium chloride, acetone peroxide, azodicarbonamide, ascorbic acid, l-cysteine, mono-calcium phosphate. Regulations also specify the acceptable levels. The addition of a variety of chemicals to bread is also permitted in the USA, but in many European countries the use of additives is almost completely prohibited (Jenkins, 1975). In Germany, for instance, chemical oxidizing agents were banned in 1958 (Marine & Van Allen, 1972).

Nitrogen bichloride, also known as agene, was one of the earliest bleaching agents. After 40 years of use, it was finally found to cause canine hysteria, and was outlawed (Rorty, 1954). The currently most common bleaching agent is benzoyl peroxide. It must be neutralized by adding such substances as: calcium carbonate (chalk!), calcium sulphate, dicalcium phosphate, magnesium carbonate, potassium aluminum sulphate, sodium aluminum sulphate, starch, and tricalcium phosphate.

The most common maturing agent in use is potasssium bromate, and it is added with carriers such as calcium carbonate, dicalcium phosphate, or magnesium carbonate. An alternative method to oxidize the flour to cause the same improvements in bread quality, is overmixing the dough three to four times normal to bring it in contact with oxygen. The lipoxidase enzyme in wheat germ or in soya flour, if it is added, uses the oxygen to oxidize the flour (Horder et al., 1954).

In addition to the chemicals permitted to be added to flour, many more are permitted to be added to bread before baking to facilitate the manufacturing process, to produce a light texture, and to improve conservation quality. These chemicals include emulsifiers, conditioners, and preservatives (Hall, 1974). At the present time, the Health Protection Branch in Canada allows the addition of almost 30 different chemicals, in limited quantities, to flour and bread. Yeast may also contain the Yeast foods additives: calcium sulfate and ammonium chloride (Aubuchon, 1990). Chemicals likely to be found in conventional breads include: lecithin, mono- and di- glycerides, carragheenan, calcium sulfate, calcium carbonate, dicalcium sulfate, ammonium chloride, potassium bromate, calcium bromate, potassium iodate, calcium peroxide, azodicarbonamide, tricalcium phosphate, monocalcium phosphate, calcium propionate, sodium propionate, sodium diacetate, lactic acid, calcium stearoyl-2-lactylate, lactylic stearate, sodium stearyl fumarate, succinylated monoglycerides, ethoxylated mono- and all-glycerides (Marine & Van Allen, 1972)

In Germany, propionic acid, sodium propionate, calcium propionate, and potassium propionate have been banned as preservatives since March 1988. This was in response to earlier experiments which found that rats fed these substances developed tumors. These results have been questioned, however, because the tumors were reversable. Nevertheless, the German government decided that as few additives as possible should be found in food, and therefore saw no need to reverse their decision ("Nach..." 1987, "Jetzt..." 1988).

A topic receiving more attention, as people become more concerned about the foods they eat, is food irradiation. Approval for irradiation of wheat and wheat flour for disinfection was granted in 1969 in Canada (Conference on Irradiation, Laval, Que. 1984). Wheat irradiation prevents insect eggs, larvae and pupae from developing (Vanderstoep, 1986), but may also cause nutritional damage. Vitamins damaged by irradiation include vitamin A, B1, B2, B3, B6, B12, folic acid, vitamin C, E, and K. Essential polyunsaturated fatty acids are also affected (Webb et al.,1987). Although wheat, white flour, and whole wheat flour are treated with lower-energy ionizing radiations from Cobalt-60, there is still a possibility that some compounds within the food become radioactive, although the radioactivity rapidly decays (Josephson & Peterson, 1983). Toxic chemicals called radiolytes may also form, which may cause health problems over the long term. Some adverse effects have been found related to these, but there is still much scientific uncertainty (Josephson & Peterson, 1983). Irradiation technology is a serious health hazard and environmental hazard, especially if accidents occur where it is used.

STUDIES OF THE HEALTH EFFECTS OF BREAD

Since bread and wheat products are such an important part of daily food consumption, it follows that such food items be healthy and wholesome. Today's milling, refining, bleaching, enriching, and addition of various chemicals to flour and baked breads cause many scientists and medical workers to question their nutritional quality as well as their safety. There is little information on what bleaching and maturing agents do to the flour other than meet bakers' criteria, and toxicology tests may not realistically assess the dangers, since chemicals are tested separately. The general public, has become conditioned to commercial bread products, and is uninformed about the effects of the processing that flour undergoes. Many recorded cases demonstrate the effects of the quality of flour on the health of people or animals, and illustrate the importance of the nutritional value of bread to physical health.

Refined flour has been found less effective in promoting the growth of weanling rats than wholemeal, if the flour was the main source of protein (Chick, 1958).

Steel roller mills were introduced in Britain in 1872. By 1876, the birth rate began to decline from 36/1000 to less than 14/1000 in 1941, at which time the National Loaf became compulsory (85% extraction, including the germ). In the next two years, the birth rate rose to 16/1000. Vitamin E deficiency was the suspected cause, since it was believed to have something to do with human and animal reproduction, and is destroyed in the refining of flour. Friend Sykes was said to get his horses and cows to breed by feeding them wheat germ for two months, and Dr. L. J. Picton did the same with his stallions (Day, 1966).

Documented in 1936, was the diversity in physique of the different tribes of India, showing the effects of foods on health (McCarrison, 1936). The northern races were much stronger, due to wheat being the staple of their diet. They consumed chapattis cakes made from fresh coarse whole wheat flour. Experiments with albino rats determined the value of some of the Indian diets, and these results conformed with their effects observed on men. About 1 000 rats were fed a diet equivalent to the northern Indians' for a period equivalent to 50 human years. None were ill or died, or even delivered dead offspring. Deficiently-fed rats under the same conditions developed many ailments. Overall, 30% of the rats fed white flour died while only 4% of those fed whole wheat died. It was concluded that adequate nourishment could be found in a diet of whole cereal grains, milk products, legumes, fruits and vegetables, and eggs and meat occasionally.

Rats on the healthy northern diet were also compared to rats fed a diet equivalent to that of the poorer classes of England (McCarrison, 1936). This diet, deficient in vitamins and minerals, consisted of white bread, margarine, very sweet tea with a little milk, boiled cabbage and potato, cheap tinned meat, and jam. These rats had stunted growth, were badly proportioned, had dull coats, were nervous, bit attendants, and by the 60th day, began killing and eating the weaker ones. Post-mortem examinations revealed a high incidence of lung and gastrointestinal diseases. McCarrison believed that vitamin deficiency was responsible for the many health problems.

Dr. Estelle Hawley, of Rochester University, fed a group of rats McCay-Cornell bread made with unbleached flour, wheat germ, and soybean flour and a lot of milk solids. She fed another group commercial enriched white bread. Both groups also received an amount of margarine equivalent to 10% of the weight of the bread (Rorty, 1954). The first group lived healthy, but the second group became ill, produced stunted offspring and were extinct by the fourth generation.

A journal article, written in 1942, discusses the deterioration of the physique of the British, between the 18th century and the Boer War around 1900 (Alvarez, 1942). The most probable explanation was that they had come to depend too much on white flour and sugar, whereas their ancestors had eaten plenty of 'whole wheat flour.

In Denmark, during World War II, due to a food crisis, many domestic animals were slaughtered and their grain rations fed to humans. Consumption of white bread was stopped, and replaced by a bread made from a wholemeal of 67% rye, 21% oats, and 12% bran, called Kleiebrot. Consequently, the death rate fell to the lowest level ever registered in Europe. There were significant declines in the incidence of high blood pressure, heart disease, kidney problems, diabetes, and cancer, and there were no cases of digestive troubles (Marine & Van Allen, 1972; Day, 1966).

In 1970, Dr. Roger Williams, of the University of Texas's Clayton Research Foundation, recorded the effects, on 64 weanling rats, of being fed bread made from enriched flour (Passwater, 1975). Forty were dead within ninety days, and the rest had stunted growth, whereas similar rats fed whole-grain bread were normal; only three were not well.

A fear exists, among medical professionals, that emulsifiers, some of which are added to bread, may promote the absorption of otherwise non-absorbed substances, some of which may be carcinogenic. Emulsifiers include monoglycerides, diglycerides, and poly compounds which usually go by variations of the words 'stearate' and 'sorb' (ea. stearyl, polysorbate). Although glycerides are naturally produced by the body, this does not prove that their artificial use is safe. Some emulsifiers have been found to increase vitamin A absorption tremendously. This may be dangerous if the rest of an individual's diet supplies a large amount of vitamin A. Dr. Anton Carlson expresses the view that many have by stating, n...Small amounts of injury in certain percentages of the people may go undiscovered for generations. This is a serious problem involved in the changes of such a fundamental thing as the type of food for mans (Marine & Van Allen, 1972).

Enriched flour may have a lower vitamin bioavailability, since synthetic vitamins have been found to act different',y. For instance, they react differently to light, and synthetic vitamin C does not cure scurvy in mice as quickly as natural vitamin C (Day, 1966). Enriched flour products have also been found to lose more vitamins due to heat than do non-enriched products, because added vitamins are less heat-resistant. This is believed to be due to the absence of naturally occurring stabilizers (Mender, 1983; Thomas, 1990).

Many people claim to control allergic symptoms by eliminating bleached wheat products from their diets (Marine & Van Allen, 1972).

These are only a few examples to illustrate the nutritional inadequacy of refined flour products.

BENEFITS OF WHEAT FIBER

As a result of the refining of flour and changes in dietary habits, the consumption of dietary fiber has decreased by at least one half during the past two centuries. Epidemiological studies relate low fiber intake to many disease states, particularly those of the gastrointestinal tract (Birdsall, 1985). From his observations, Dr. Dennis Burkitt claimed that the large amount of plant fibers consumed by African natives protected them from suffering from many diseases common to Western man such as cardiovascular disease, colon cancer, diverticulae, appendicitis, hemorrhoids and varicose veins of the legs (Burkitt, 1972).

Diets high in complex carbohydrates such as whole cereal grains, legumes, and Units and vegetables are usually the custom in populations with very low incidence of cardiovascular disease (Brown et al.,1985). Studies indicate that high-fiber diets decrease blood pressure in normal as well as in hypertensive subjects (Birdsall, 1985). For elevated blood serum lipids, dietary recommendations include increasing carbohydrate consumption to make up 65% of total daily calories, emphasizing complex carbohydrates from nature', sources (Gotto et al.,1984), because they influence the absorption of fat-soluble substances from the digestive tract, and the reabsorption of bile acids and neutral steroils (Hodges et al.,1985). These recommendations are given to diabetics as well, since cardiovascular disease is their most likely cause of death (Anderson et al., 1990)

A diet rich in complex carbohydrates also improves glucose metabolism in diabetic subjects, by increasing their sensitivity to insulin, therefore resulting in reduced dosages requirements (Birdsall, 1985). In a study, Finnish wholemeal rye bread (100% wholemeal rye flour) was found to induce slower postprandial blood glucose responses in insulin-dependent diabetics than did mixed wholemeal bread (50% wholemeal rye flour & 50% white wheat flour) and white bread (100% white wheat flour). Grained wholemeal rye (35% of the wholemeal rye flour was replaced by whole rye grains) resulted in a blood glucose response similar to that after consumption of wholemeal rye bread. In non- insulin-dependent diabetics, the differences were not statistically significant, but wholemeal rye bread produced the lowest blood glucose response. The results believed to be due to the higher content of bran or non- digestible or non-absorbable carbohydrate in wholemeal flour, or grain (Heinonen et al., 1985). Perhaps wheat fiber's effect of reducing starch digestibility was also involved (Anderson, 1985: Leeds, 1985).

Numerous studies demonstrate that populations with the highest fiber intake have the lowest incidence of colon cancer. There is, however, also a correlation with total fat intake (Birdsall, 1985). A diet consisting of a low-fat, whole grain staple food, such as whole grain bread, would provide protective effects against colon cancer. Because bran reduced the number of tumors induced by chemical carcinogens in animal models (Bingham, 1990), it was concluded that it protects humans from colon cancer. A hypothesis for this effect is that fiber decreases intestinal contact with carcinogens.

For the Western population, constipation is a major problem. It may lead to hemorroids, diverticulae, and even contribute to the development of varicose veins (Burkitt, 1982). Wheat bran decreases intestinal transit time (Payler et al. 1975), because it decreases intestinal pressure, and increases peristalsis (Thomas, 1976). It is one of the best fecal bulking agents identified (Cummings et al., 1982), and is even more effective in raw form, because of the structural changes that occur in the latter, increasing the amount of bacterial degradation it undergoes in the intestine (Pomeranz, vol. 2, 1988). Wheat fiber is also claimed to strengthen, by stimulation, the intestinal mucosa, and decrease the incidence of gastroenteritis, or inflammation of the stomach or intestine (Thomas, 1976).

The phytates in wheat bran and germ bind minerals and have been believed to drastically reduce the bioavailability of minerals. Drastic reduction is not the case, and many factors, including what other foods are consumed at the same time, improve bioavailability. For example, consumption of meat, sufficient protein, and vitamin C increase the absorption of iron, for example (Pomeranz, 1988). Since whole wheat contains many more nutrients, a somewhat decreased bioavailability would be far from the detrimental effects of excluding bran altogether. Consumption of whole wheat flour has been shown to result in a greater absorption of iron than if low extraction flour was consumed (Burk et al., 1985). Studies also showed that, although the percent of zinc absorbed from white bread was twice that from whole wheat bread, since whole wheat bread supplied greater than three times more, the absolute quantity absorbed was more from whole wheat bread (Sanderstorm et al., 1980). Calcium is an exception, and phytates are said to have a drastic effect upon its absorption (Pomeranz, 1988). Smaller particles of fiber would be expected to lead to a greater bioavailability of the nutrients in the bran (Pomeranz, 1980), although smaller particles may not be as effective stimulating the bulking effects and the speeding up of intestinal transit (Wheaton, 1990). A certain degree of adaptation to phylates may occur as well, as observed in an experiment where, on the first five days of a fifteen day period, the absorption of some minerals was lower, with untreated as well as dephytinized wheat bran (Morris and Ellis, 1982; Morris et al., 1984).

Wheat fiber helps to neutralize acid secreted by the stomach, and is therefore of therapeutic value for persons with ulcers (Thomas, 1976).

Wheat fiber-rich foods are less energy-dense than low-fiber foods, and produce a feeling of fullness or satiety more quickly. The insoluble fiber in wheat bran slows digestion by decreasing the surface area of starch and other ingredients exposed to hydrolytic enzymes, slows absorption in the small intestine (Schneeman, 1982), and increases fecal excretion of fat and nitrogen (Anderson, 1985; Leeds, 1985). It may increase fecal energy loss by 60 to more than 300 kca/day via fat and protein loss (Vahouny, 1985). Wheat fiber-rich foods can therefore be beneficial in the treatment or prevention of obesity (Thomas, 1976).

The importance of wheat fiber cannot be overlooked. Pomeranz (1988) writes, n Thus the additional nutrients present in whole wheat products and the physiological effect of the fiber on fecal bulk and transit time suggest that Western industrialized populations would continue to benefit from the consumption of more whole wheat foods."

EFFECTS OF ORGANIC FARMING ON NUTRITIONAL QUALITY OF WHEAT

Organically grown wheat and bread made from it are becoming more common on the market. Organic farming is defined by Dietrich Knorr Ph.D., Department of Food Science and Human Nutrition at the University of Delaware, Newark (Knorr, 1984), as "...a production system which avoids or largely excludes the use of synthetically compounded fertilizers, pesticides, growth regulators and livestock feed additives. To the maximum extent feasible, organic farming systems rely upon crop rotations, crop residues, animal manures, legumes, green manures, off-farm organic wastes, mechanical cultivation, mineral-bearing rocks and aspects of biological pest control to maintain soil productivity and filth, to supply plant nutrients and to control insects, weeds and other pests."

In a survey of mid-Western Americans conducted in 1987, the leading advantages of organic farming expressed were health benefits for the farmers, family, livestock, environment, and soil, and a lower production cost (Institute of Food Tech..., 1990).

After approximately fifty years of utilizing chemicals in conventional agriculture, their health hazards are beginning to be recognized. Health risks to farmers and consumers from pesticides are the major concerns. Chronic exposure may cause neurotoxicity, infertility, dermatologic legions, immune system incompetence, and a number of pesticides are probably carcinogenic (Edwards, 1990). The U.S. Council on Scientific Affairs estimated, in 1988, that approximately 110 000 cases of poisoning and 200 deaths per year are due to pesticides (Edwards, 1990). To demonstrate the seriousness of the effect on the environment, well water in 34 States was found contaminated with 73 pesticides (Anderson, 1988). Nitrates due to fertilizer nitrogen also contaminated water (Hallberg, 1987).

Organic farming techniques are not harmful to the environment since herbicides, insecticides, and fungicides which may cause permanent damage to the earth are not used (JADA, March 1990).

Diatomaceous earth is used as a non-toxic alternative to pesticides and fumigants. It is made up of crushed geological deposits from fossils and tests of siliceous marine and fresh water organisms, especially diatoms (grass of oceans and lakes) and other algae. Its small sharp edges damage insects on grain. Several tests conducted between 1963 and 1970 by the US Department of Agriculture concluded that DE gave even better protection to grains than toxic chemicals like malathion (Hill, 1986; Wheeler, 1986).

The toxicity of pesticide residues on food depends on whether organs, including the liver, have the ability to metabolize them and their resulting metabolites (Hayes & Borzelleca, 1982). There is evidence that pesticides also interact with other chemicals and nutrients in the diet (Dubois, 1972). Many experts have failed, however, to find any differences in pesticide residues on grain (Meuser et al., 1984; Seibel, 1983). It is necessary to clean organic grain intensively also, because of the risk of mold toxin contamination such as aflotoxins. Siebel (1983) states that often organically grown grains are not cleaned sufficiently. Chronic poisonings have occurred from ingesting aflatoxins from grain due to inappropriate cleaning (Opitz, 1984; Pfander et al., 1985). Agriculture Canada Research report, though, that "In Canada, the incidence of toxin-contaminated grain is extremely low relative to the volume of grains produced. Occurrence of toxins is influenced by field moisture, temperature, and bin storage conditions of a particular year" (Mills, 1990).

Common agricultural methods now in use are causing the soil to become deficient in various elements, because many are not replenished. Usually, only nitrogen, phosphorus, and potassium fertilizers are applied unless gross deficiencies of others are recognized. As a result, crops cannot obtain optimal amounts of minerals, and are more susceptible to pests and diseases (tinder, 1985).

Spelt is a preferred grain for organic farming since, although it requires a balanced nitrogen content in the soil, it grows well without excessive application of nitrogen fertilizers (Beck, 1991).

Many feeding experiments have been done to try to prove the nutritional superiority of organically grown food.

In Pfeiffer's experiments the number of mortalities among 80 mice fed organic grains was about half of that among 80 mice fed mineral-fertilized grain (about 9% vs. 17%). Both groups preferred the organically grown wheat (90% of the time). Chickens on organic grain began laying earlier, and at faster rates. They laid twice as many fertile eggs, and the eggs kept better. Pfeiffer also found that heating the mineral-fertilized wheat decreased the capacity of most of it to germinate, whereas it had almost no effect on the organic wheat.

Pfeiffer (1938) repeatedly demonstrated that earthworms migrated away from a box with soil and mineral fertilizers to one with organic compost.

In another study, chickens fed organic food were of significantly greater weight after 32 weeks and gained more weight after illness. The weight of their eggs, and egg yolks were more. Also, significantly more hens preferred beets that were organically grown (Plochberger, 1989).

The results of another study done by Plochberger, Volimoriv, Huspeka, and Scholt at the Ludwig

Boltzmann Institute for Biological Agriculture, now being prepared for publication, examined, over a period of three generations, the effects on rat fertility of being fed organically cultivated food. Although pregnancy rate and average litter weight were not significantly different, there were significantly fewer still born offspring, and the survival rate at four weeks was significantly higher. The rats fed organic food had a greater capacity to compensate weight loss during and after lactation and gained more weight.

A Ph.D. thesis carried out at the Ludwig Boltzmann Institute for Biological Agriculture by Irene Edelmuller, now in print, presents the effects of conventional and organic farming systems on nutrient contents of feeds. As a result of feeding tests, rabbits showed improvements, due to organic feed, in fertility, health, breeding efficiency, and increased fungi populations on their excrement. The rabbits in both groups preferred organic feed.

A study by Dr. Dorothea Staiger showed that rabbits fed organic feed, compared to conventional feed, had higher pregnancy rates, more embryos, larger litters, and were healthier, although differences in terms of ingredients were not detected analytically (Staiger, 1988).

In spite of the results of feeding experiments, many studies have been unable to find significant differences in nutrients between organically and conventionally grown grain. No significant differences were found in protein, fat, carbohydrates, minerals (micro and macro), trace elements, pesticide residues, and heavy metals for grains grown under the same climate and soil conditions (Seibel 1983, Steineck 1984). Belderock (1978, 1979), a Dutch researcher, was unable to identify significant differences in mineral and amino acid contents. Organically grown wheat and rye have only been found to have a somewhat lower protein content (Seibel, 1983) due to the absence of nitrogen fertilizers, making it more difficult to work with (Seibel, 1983; Boling et al., 1986; Belderok, 1978,1979). There is definitely a need to do carefully controlled studies to support nutrient claims concerning the superiority of organically grown foods (Clancy, 1986). There are no doubt many other advantages to organic farming which have been proven, and it is a matter of time before results of carefully conducted research are published.

Studies on yield differences between organic and conventional farming practices have been inconclusive. However, significant reductions in storage losses of organically grown crops have been reported (Patterson, 1978; Knorr & Vogtmann, 1983; Linder, 1985), which could mean higher returns in alternative systems. The need for fertilizers in the conventional system to maintain a high level of grain production on minimal space is destroying the ecosystem, and would favor the organic alternative (Meuser et al., 1984).

DOUGH PREPARATION

Bread-making involved lengthy bulk fermentation before high-speed mixers were invented. The Chorleywood Bread Process introduced in 1961 is now the most common continuous system used in bakeries in more than 30 countries (Chamberlain, 1984). The dough is developed in less than five minutes (Davidson & Passmore, 1986), but the process consumes four to eight times the energy consumed by bulk fermentation, and 50100% more yeast is used because it does not have the time to reach full activity (Pomeranz, 1988).

SOURDOUGH BREAD AND PHYTATES

Sourdough bread is made using a starter from a previous bake. Wheat and rye grains are chosen because they contain sufficient gluten and gliadin proteins which are necessary for expansion and leavening (Kollath). Sourdoughs are fermented by a variety of lactic acid bacteria, called Lactobacillus, which consume sugar to form carbon dioxide and hydrogen gas. They also produce lactic and acetic acids, which give sourdough breads their distinctive flavour. Traditional sourdoughs do not contain baker's yeast, although some yeast species do survive in that acidic environment (Freeland-Graves & Peckham, 1987).

The acidity and the lengthy fermentation affect the phytate from the wheat, and many studies have proven the resulting nutritional advantages. Phytates are known to bind minerals, such as calcium, phosphorus, iron, magnesium, and zinc, and to reduce their absorption by the body (Aubert, 1984, "Pour...n). In an acidic environment, the enzyme phytase from the wheat is very active and breaks down phytates, so they cannot reduce mineral absorption (Sablier, 1984). The pH of the sourdough bread is about 4.0-4.8, whereas yeast bread is 5.1-5.4 (Freeland-Graves & Peckham, 1987). Graphs from Aubert's studies (1984, "Pain...n) demonstrate a clear correlation between the change in acidity of the bread prepared with baker's yeast and sourdough breads with the change in their phytate contents. Studies showed, however, that the addition of milk, calcium carbonate, or 'calcium chloride to bread dough slowed phytate hydrolysis. A study showed that calcium supplementation, equivalent to that contributed by calcium-containing additives, caused a 50% decrease in free zinc and iron, and this correlated with the increase in residual phytate (Zemel & Shelef, 1982).

The acidic environment of sourdough bread has the advantage of reducing the loss of vitamin B1 due to heat (Fox & Cameron, 1989).

Sourdough bread is claimed to have a better digestibility than yeast-fermented and non-fermented breads (Aubert, 1984, "Pour...").

Many people choose to consume traditional sourdough breads because they develop an intolerance towards commercial baker's yeast in conventional breads.

OTHER FACTORS AFFECTING THE NUTRITIONAL VALUE OF BREAD

Many ingredients may be included in bread, in addition to the basic ingredients of flour, water, leavening, and salt, to increase its nutritional value.

Flax or linseeds and sunflower seeds may be added. Some nutritional aspects of flax were discussed in the Montreal Gazette's Living Section of May 15, 1991. Health professionals are fairly confident that omega-3-fatty acids are beneficial for heart disease, vascular disease, cancer and immune function (Guthrie, 1989). Paul Stitt says that flax contains more omega-3 fatty acids than fish, and more lignins, which are possible cancer preventatives, than any other foods. The National Cancer Institute has set up, in five Universities, studies on flax in products supplied by National Ovens. At the University of Illinois in Chicago, studies are being carried out concerning the effects of flax in prevention of colon and mammary cancers in animals and humans. Sunflower seeds supply significant amounts of zinc, calcium, magnesium and vitamin B6 (Lambert-Lagace, 1989), and provide essential fatty acids. However, some researchers in Europe have found that the addition of sunflower seeds to organic breads raised the cadmium level (a heavy metal) above what is considered acceptable. Determining the cadmium level in the seeds is therefore recommended (Meuser et al., 1984).

The use of sea salt in breads is another way to enrich its nutritional value. It is a source of trace minerals (Pedersen, 1990?), whereas table salt contains only sodium, chloride, and iodine (due to addition).

Soya flour, whose protein is superior to that of wheat because of a better amino acid profile, not limited in Iysine, may be added to bread in reasonable amounts to increase its protein quality (Horder, 1954). Since it is not limited in the amino acid Iysine, soya flour complements the amino acid profile of wheat. Milk-enriched bread has superior nutritive value protein-wise as well (Kon et al., 1941).

The addition of sprouted seeds to bread should enhance its nutritional value dramatically. Sprouted wheat was found to increase in vitamin A content ten fold in seven days, while vitamins B2 and B12 increased between two and ten times, and vitamin C content increased rapidly as well. Many enzymes were synthesized, which facilitate digestion and assimilation. About 40~o of the starch content was broken down, resulting in an increased, in the amount of easily digestible dextrins and sugars, greater than 150%. Some protein was broken down into amino acids, so the biological quality of the proteins increased due to the increase in usable Iysine. Most of the undesirable, flatulence-promoting oligosaccharides were destroyed, as well as the phytates and trypsin inhibitors (trypsin is an enzyme needed to break down proteins) (Aubert, 1984, "Les graines...). For their use in breads, wheat sprouts should only grow one half the length of the kernel itself, or else the bread will be sticky (Reynolds, 1973).

Many vitamins are sensitive to light, temperature, and moisture, so milling, processing, and

storage conditions affect their stability. B vitamins are susceptible to destruction by heat. During baking, 17-23% of vitamin Bt may be destroyed. Another 15% may be lost during as little as sixty seconds of toasting. (Dawson et al., 1941; Under, 1985; Menden, 1983).
During baking, proteins are denatured, which implies that they lose their three-dimensional structure, and become easier to digest, and less activating energy is required for enzyme hydrolysis (Mender, 1983). The crust, which undergoes more severe heating, has as a result, a lower amino acid availability due to the Maillard reaction (Mender & Horchler, 1978; Kasarda, 1971). Experimental animals lose weight when fed the crust only, but gain weight when fed the crumb (Mender & Horchler, 1978).

STORAGE OF BREAD

Storage methods for breads that contain no additives are very important to maintain freshness and to avoid spoilage. The staling process begins as soon as the bread is removed from the oven. It is believed to be due to a retrogradation or crystallization of the starch (Knightly, 1977), or a transfer of moisture from the gluten to the starch portion, causing a firming of the crumb (Willhoft, 1971), and may occur whether or not there is a loss of moisture. When the original moisture is retained, heating the bread to 60°C reverses the staling (Spicer, 1975). Bran helps bread retain moisture longer, and fat may also increase tenderness (McWilliams, 1989). Retrogradation occurs at 0°C but stops above 55°C (Pedersen, 1990?). Bread stales twice as fast at 30°C and four times as fast at 21°C compared to 35°C (Kim et al., 1977). It is therefore not advisable to refrigerate bread, but if kept at room temperature, mold growth may be more likely (Horder, 1954). The firmness after a day at 8°C is about the same as six days at 30°C (McWilliams, 1989). Sourdough bread has the advantage that due to its acidic environment it is better protected from spoilage (Jenkins, 1975; Thomsen, 1988). Freezing almost completely inhibits firming, and retards firming after thawing, and more so the longer the frozen storage (Malkki et al., 1978). Freezing bread also prevents microbial spoilage, including the development of rope (Horder, 1954). Baked bread can be kept frozen for three months without losing flavor (Bread Winners, 1978).
Interestingly, slightly stale bread is more easily digested than fresh bread, up to ten days, after which there is a reversal (Jackel et al., 1952).

CONCLUSION

Wheat and bread are important parts of the diets of people in many countries, and when made from whole grains, only lacks a few essential nutrients. However, in more industrialized countries, the consumption of refined flour products is much more common. Many studies with animals and recorded cases dealing with people show the serious effects of the lack of nutrients, when refined flour products make up the dietary staple.
One concern with commercial flour is the possibility that it has been irradiated, which may cause nutrient losses, the formation of radiolytes, and radioactivity in the food itself, and which poses an environmental hazard.
Only whole grain stone-ground flour is sure to contain the grain components in their original proportions and to include the germ. The way the stones grind distributes the germ oil evenly and without exposing it to excess heat, so rancidity does not develop as quickly as it would were it ground by steel roller-mills. However, many authors recommend storing freshly ground flour for no longer than two weeks, because rancidity becomes evident, and many flour components undergo chemical changes, when exposed to oxygen, increased humidity, high temperature, and light, and decreasing their availability to the body.
Nutritionally, organic grain has only been found to contain less protein, but other differences are not conclusive based on analytical studies. Feeding experiments do demonstrate the nutritional superiority of organic wheat and other foods.
Commercial bread production processes use much more energy and yeast than sourdough breads and are prepared very quickly.
Advantages of the acidic environment and the lengthy fermentation of sourdough bread include the

breakdown of phytates -increasing mineral bioavailability, increased digestibility, and decreased rate of spoilage. Various additional ingredients may also enhance the mineral and vitamin content in bread, as well its protein quality.
Freezing is the best storage method for breads containing no preservatives to prevent spoilage, whereas refrigeration enhances staling.
Many factors affect the nutritional quality of bread. Consumers need to be aware of these to make wise choices as they decide upon purchasing breads, so as not to deceive themselves. It is advisable to avoid refined, bleached flour, even if it is enriched, and to chose whole wheat flour. However, store-bought whole wheat flour is likely to be void of the germ and a part of the bran, in which the nutrients are most concentrated. Also, it is usually treated with the same chemical improvers as white flour, and may have been irradiated. Only organic, stone-ground, whole wheat flour can be complete and untreated by chemicals. To obtain maximal nutrition from bread, a traditional sourdough bread is best, since the mineral-binding phytates have undergone more breakdown and have freed minerals, so that they may be absorbed. The mineral and vitamin content may also be enhanced with other ingredients that also add variety. For better utilization of the protein in bread, it should be consumed in combination with complementary proteins, which are better sources of the limiting amino acid - Iysine - in wheat. Examples are milk products, nuts, legumes, meat or fish. The protein quality of bread itself may be enhanced by adding soya flour, since it is made from a legume.

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