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## THE ADVERSE EFFECTS OF FOOD ADDITIVES ON HEALTH (BOOKLET)

With a special emphasis on Childhood Hyperactivity

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### INTRODUCTION:

A food additive is any substance not commonly regarded or used as food, which is added to, or used in or on, food at any stage to affect its keeping quality, texture, consistency, taste, colour, alkalinity or acidity, or to serve any other technological function in relation to food, and includes processing aids in so far as they are added to or used in or on food (1,2). Food additives in use today can be divided roughly into three main types: cosmetics, preservatives and processing aids, totaling presently about 3,794 different additives, of which over 3,640 are used purely as cosmetics, 63 as preservatives and 91 as processing aids (3). The growth in the use of food additives has increased enormously in the past 30 years, totaling now over 200,000 tonnes per year (4,5). Therefore it has been estimated that as today about 75% of the Western diet is made up of various processed foods, each person is now consuming an average 8-10 lbs of food additives per year, with some possibly eating considerably more (57). With the great increase in the use of food additives, there also has emerged considerable scientific data linking food additive intolerance with various physical and mental disorders, particularly with childhood hyperactivity (8-31).

### CHILDHOOD HYPERACTIVITY:

It is clear that the definition and the diagnosis of Childhood Hyperactivity, which has been various also labelled as Attention Deficit Disorder, Minimal- or Cerebral Brain Dysfunction Disorder, Hyperkinesis etc., has been rather imprecisely defined in the medical literature (25,29,32,33). One explanation why this syndrome, which will be called here by its more popular name, hyperactivity, seems to be so poorly understood may stem from the fact that its diagnostic criteria differs considerably from one country to another (32,33). However, in general terms, the diagnosis of hyperactivity is usually applied to childhood behavioural disorders with quite a diverse symptomatology, which includes; distractibility, poor tolerance to frustration, temper tantrums, excitability, aggression, difficulties with co-ordination, lability of mood, anxiety, impulsiveness, inattentiveness, and disabilities with both cognitive and learning functions (32,33). In short, the diagnostic criteria of hyperactivity seem to cover a substantial proportion of the children usually seen in child psychiatric practice (34).

### THE DIAGNOSIS OF HYPERACTIVITY:

The short form of the Conners' Scale is the most generally accepted index of childhood hyperactivity (35). The higher the score, the more severe is considered to be the problem. By following the Conners' Scale criteria, especially tranquil children may score as low as 0, whereas the most severely hyperactive children can attain scores as high as 40. Different commentators seem to have set their criteria of hyperactivity at different levels; however 15 seems to be the most frequent figure. Obviously therefore the higher the cut-off point for the diagnosis is set, the more strict also would be the criteria (33). Holborow and Berry examined and compared some of the literature on childhood hyperactivity published from the 1970's onwards in various parts of the world (36). For example, one Australian study of 1759 children from seven schools and from various socio-economic areas used the Conners' Scale cut-off point of 19. The results showed that 9% of the boys and 2.4% of the girls scored above 19, while 18% of the boys and 5% of the girls had a score above 15 (36). One New Zealand study used a more random sample of children and a relatively high cut-off point of 21. The final evaluation indicated that 22% of the boys and 9% of the girls reached scores 15 or higher, while 5% of the boys and 4% of the girls scored 21 or above (37). An American study, which used a cut-off point of 15, reported that 9% of their sample of boys and 2% of the girls exceeded this limit (38). A German study, which drew one of the largest samples of 5,357 children, used a cut-off point of 18. The final evaluation showed that 12% of the boys and 5% of the girls scored 15 or more (39). Some British statistics were obtained from 711 children, drawn from carefully balanced social groups. The final results indicated that 14.6% of the boys and 5.5% of the girls scored 15 or more, while 9.3% of the boys and 2.6% of the girls had scored 18 or above (40).

Using different diagnostic criteria, the term of hyperactivity was applied only to 0.08% of children on the Isle of Wight (41). Whereas, in sharp contrast, one American study representing over 5000 children from San Francisco district concluded that "The maximum prevalence rate of hyperactivity in an elementary school population, when all possible methods of identifying hyperactivity are considered, and each child is represented only once in the estimate, is about 12-14%" (42). Another American study of 500 children found 20% hyperactivity among 6-9 years olds (43). After carefully examining the extent of diagnostic variations between studies on childhood hyperactivity from the different parts of the world, Holborow and Berry concluded that if the diagnostic criteria for this disorder could be standardized, the incidence of hyperactivity among boys in the U.K. would be approximately 9.3%, in Australia and in the U.S.A 9%, in Germany 6% and in New Zealand in the region of 5% (36). Their findings seem to confirm earlier suggestions that the apparent discrepancies in the prevalence of childhood hyperactivity in world-wide medical literature seem to stem primarily from the lack of uniform diagnostic criteria (33,42).

#### **HYPERACTIVITY FROM INFANCY TO ADULTHOOD:**

Retrospective studies have shown that children diagnosed as hyperactive as an infant had suffered considerably more from varied health/ behavioural problems than non-hyperactives (32,44). For example, a research database on 357 hyperactive children, based at Surrey University, showed that 82% of them were already extremely restless as an infant, 61% suffered from poor and irregular sleep patterns, 75% displayed excessive crying or screaming, 52% rejected any contact or affection, 50% were poor feeders, 74% seemed to have an exaggerated thirst and 67% suffered from colic (45). Hyperactive toddlers, on the other hand, are described as children who never walk but run, are incapable of playing with any object for more than few seconds, and who combine unnaturally impulsive behaviour with a complete lack of any apprehension or fear (32). When at school, these children are usually extremely restless, inattentive, distractable and frequently display aggressive and anti-social tendencies (32,45). Primarily because of these behavioural problems, their academic school performance is generally poor and failed school grades are not uncommon. In fact follow-up studies of young adolescents diagnosed as hyperactives when children have shown, when compared to controls, a significantly higher drop-out and expulsion rate from schools (46-49), a greater involvement in both drug and alcohol abuse (48-51), a higher rate of motor vehicle accidents (48), a greater risk of developing criminal tendencies, as well as appearing before courts (48,49,5,2). For example one follow up study on 64 adolescents diagnosed hyperactive when children, showed that when they reached ages 17 to 25 years, 25% of them were still engaged in antisocial and delinquent behaviour (53,54). Similar findings have also been observed by other investigators (55,56). In short, the prognosis of hyperactive children, when they mature into adulthood, seems to be relatively poor. Despite an apparent decrease in the ratings of hyperactivity over the years, as adolescents and adults they still seem to continue to use impulsive rather than reflective approaches to cognitive tasks, are still distractable, generally emotionally immature, have a poor self-image and are frequently unable to maintain goals (52-57).

#### **THE AETIOLOGY OF HYPERACTIVITY:**

Many causal hypotheses for childhood hyperactivity have been entertained in both medical and psychiatric literature including; genetic factors (58-61), implications of central nervous system dysfunction (62,64), improper embryological development or subtle chromosomal irregularities (65), birth complications (66), interactions between childrearing factors and biological disposition (67). During the years there also has accumulated increasing scientific data on various toxicological and environmental factors that can have a clear potential in either causing an infant to be born hyperactive or, alternatively, having a serious adverse effect on children diagnosed as hyperactive. These include an excessive maternal pre-natal alcohol and/or tobacco consumption (47,68-71), toxicological environmental factors, such as sub-clinical lead contamination (47,72-78), food allergies (26-32,79-85) and, as previously stated, the consumption of artificial food additives (8-13,83-85).

#### **THE FEINGOLD HYPOTHESIS:**

Dr Benjamin F. Feingold, M.D., Chief Emeritus, Allergy Department, Kaiser Permanente Hospital, San Francisco, and his team, when working under a National Institute of Health grant, discovered in 1964 that low molecular weight compounds, like artificial food dyes, can produce behavioural disorders in susceptible individuals (8-13, 83-85).

After collecting evidence based on over 1,200 cases, they found that hyperactivity, including other neurophysiological disturbances, can be induced in some children when they consume certain chemicals such as food additives, as well as some naturally occurring salicylates. He arrived at this conclusion by observing that certain children, who seem to react neurophysiologically to aspirin, reacted also in a similar manner to natural foods containing salicylates.

This led him to study further the effect of other low molecular compounds, such as artificial food additives, on children's health and behaviour, finding similar results. He also observed that as the affected individuals seem to react negatively to allergy skin tests, the reaction involved could not be based on an allergic/ immunological mechanism, but rather on some pharmacological/toxic mechanism (13).

Using clinical observations and parental testimony Dr Feingold found that in approximately 30-50% of hyperactive children, the adverse behaviour pattern displayed could simply be a direct manifestation of an elevated sensitivity to certain low molecular weight compounds, such as synthetic food additives as well as to foods containing natural salicylates. He observed further that the children, whose hyperactive behaviour was a direct manifestation of this elevated sensitivity, could be treated effectively by simply removing from their diet all foods containing artificial food additives as well as foods containing natural salicylates (13).

Using a similar dietary regimen, he also claimed success in helping children suffering from a variety of learning disabilities (10). As previously mentioned, Feingold's claims originated primarily from anecdotal reports; however, there have been several subsequent scientific evaluations to test his hypothesis, some supportive (14-22), some unsupportive (86- 90) and some finding only a very limited support i.e. that only the very youngest of the children responded (20,90-92). It has been speculated, however, that this wide discrepancy between different observations may have been due to the differentiation between the levels of food colours used in the test conditions (19,25). This may have been indeed the case.

For example, both Conners (90) and Harley (92) employed in their challenge procedure 26mg artificial food colours daily, Weiss used 35mg (20), and a study by Swanson, which incidently found a clear supportive evidence to Feingold's hypothesis, used a daily challenge dose of 100-150mg (19). In fact it has been found that this highest daily challenge dose of 100-150mg of food additives is the most realistic amount to be employed in any test procedure. This became apparent when the Food and Drug Administration studied 5,000 randomly selected children between ages 5-12, determined that the 90th percentile for daily consumption of artificial food dyes within this age group was 150mg. For the population as a whole the FDA found an average daily mean to be 57.5mg, while the 90th percentile range was between 100-300mg per day (28,93).

### **SOME FOOD ADDITIVES AND THEIR SIDE-EFFECTS:**

#### **Cosmetics; Dyes/Colourants:**

Tartrazine (E102), which is primarily used by the soft drink industry, is one of the colours most frequently implicated in food intolerance studies (2,5,16,31,33,48,94-102). Adverse reactions to tartrazine seem to occur most commonly in subjects who are also sensitive to acetylsalicylic acid (ASA), a finding which was also observed by Feingold and his team. Depending on the test protocol followed, it has been found that between 10-40% of aspirin-sensitive patients are usually also affected by tartrazine (101), the reactions including asthma (2,95,101-104), urticaria (2,99,101,105), rhinitis (102-104) and, as previously mentioned, childhood hyperactivity (9-13).

This may come about because the chemical structure of the tartrazine molecule has similar features to those of benzoates, other azo compounds, pyrazole compounds and the hydroxyaromatic acids, which also include salicylates (2). Furthermore, it has been established that the azo compounds can be reduced in the intestine and in the liver (106,107), indicating that as one of the several routes through which these molecules, too small to be antigenic in themselves, may act as a hapten, thus conjugating a larger molecule to form an antigenic compound (2,108,109).

A major breakthrough in the understanding of the mechanisms involved in ASA intolerance came also with discovery that aspirin, including other non-steroidal anti-inflammatory drugs, inhibit the synthesis of prostaglandins, by selectively blocking the cyclooxygenase pathway, resulting in an enhanced production of leucotrienes (110-112). An excessive leucotriene production in turn leads to vascular permeability, causing oedema and inflammation, which is directly associated with various airway constriction disorders, including asthma (2,113,114).

One study found that an oral administration of 50mg tartrazine to 122 patients suffering from allergy-related disorders, evoked the following reactions; feeling of suffocation, weakness, heat sensation, palpitations, blurred vision, rhinorrhoea, pruritus and urticaria. Even though 50mg could be considered as a substantial dose, such a quantity of tartrazine could easily be consumed by an individual drinking only a few bottles of soft drinks per day (96).

Another carefully conducted double-blind placebo-controlled trial on 76 children diagnosed as hyperactive, showed that tartrazine and benzoates provoked abnormal behaviour patterns in 79% of them (29). In addition, a double-blind placebo-controlled trial on 10 hyperactive children when compared to controls, found that tartrazine increases urinary zinc secretion, and decreases serum and salivary zinc concentration in the hyperactives, with a corresponding deterioration in their behaviour. This phenomena was not found among the controls. It was suggested therefore that tartrazine seems to act as a zinc chelating agent in susceptible individuals. Furthermore, that zinc depletion may also be one of the potential causes of childhood hyperactivity (100).

Although tartrazine seems to be most frequently associated with adverse reactions (115), there are also other colouring agents which are known to cause mental and/or physical effects (33,116).

Curcumin (E100), used mainly in flour, confectionery and margarine, has been found to cause mutations in bacteria and

when fed to pigs, it increased the weight of their thyroid glands causing, in high doses, severe thyroid damage (5,33).

Sunset Yellow (E110), used in biscuits, has been found to damage kidneys and adrenals when fed to laboratory rats (33). It has also been found to be carcinogenic when fed to animals (5).

Carmoisine (E122), used mainly in jams and preserves, was found by the US Certified Color Manufacturers Association to be unavoidably contaminated with low levels of beta-naphthylamine, which is a well known carcinogen (33); it has also been found to be mutagenic in animal studies (5).

Amaranth (E123) has been found, when fed to laboratory rats, to cause cancer, birth defects, still-births, sterility and early foetal deaths. Subsequent work has also found that amaranth can cause female rodents to reabsorb some of their own foetuses (5,33).

Ponceau 4R (E124), used mainly in dessert mixes, has been found to exhibit a weak carcinogenic action (5,33).

Erythrosine (E127), used in candied cherries and childrens' sweets, has been found to act as a potent neurocompetitive dopamine inhibitor of dopamine uptake by nerve endings when exposed in vitro on a rat brain (117). Other studies have shown that erythrosine can have an inhibitory action also on other neurotransmitters, resulting in an increased concentration of neurotransmitters near the receptors, thus functionally augmenting the synaptic neurotransmission (118-120). There is now some evidence that a reduced dopamine turnover may lead to childhood hyperactivity (121). Similar findings have been linked with a reduction of noradrenaline (122). Erythrosine also has been found to have a possible carcinogenic action when tested on animals (5).

Caramels (E150), of which over 100 different formulations are currently in use, are widely used by the cola drinks industry, as well as the beer and alcohol industry. It is also used as a colouring agent in crisps, bread, sauces, gravy browning etc. The main recurring problem about the safety of caramels concerns the presence of an impurity called 4-Methylimidazole, produced by processes using ammonia, which leads to convulsions when fed to rats, mice and chicks. It has been also found that ammoniated caramels can affect adversely the levels of white blood cells and lymphocytes in laboratory animals. Furthermore, a study on rabbits provided evidence that even small doses of ammoniated caramels seem to inhibit the absorption of Vitamin B6 (33).

Brown FK is mainly used as a colouring agent in fish, such as kippers. Two of the primary metabolites of this colouring have been found to act as a cardiotoxin. It has been also observed, when fed in the long term to mice, to cause potentially hazardous nodules to form in the liver. Furthermore it has been found to cause mutations in some bacteria, implying that it may also act as a mutagenic and/or carcinogenic agent in humans (5,33).

#### **PRESERVATIVES/ANTIOXIDANTS:**

Benzoates (E210-E219), used mainly in marinated fish, fruit-based fillings, jam, salad cream, soft drinks and beer, have been found to provoke urticaria, angioedema and asthma (2,33,123). Furthermore, they have also been directly linked with childhood hyperactivity (29).

Sulphites (E220-E227), used mainly in dried fruits, fruit juices and syrups, fruit-based dairy deserts, biscuit doughs, cider, beer and wine, have been linked with pruritus, urticaria, angioedema and asthma (2,31,33,124,125). When fed to animals, sulphites have also been found to have a mutagenic action (5).

Nitrates and nitrites (E249-E252), used in bacon, ham, cured meats, corned beef and some cheeses, have been found to cause headaches in susceptible individuals (125). In addition, these chemicals have been linked with ~cancer both in animal (5,33) and human studies (126). They have also been found to be mutagenic when fed to mammals (5).

Butylated hydroxyanisole - BHA (E320), used in soup mixes and cheese spread, has been found to be tumour-producing when fed to rats (127). In human studies it has been linked with urticaria, angioedema and asthma (2,33,128,129).

Monosodium glutamate (MSG), a flavour enhancer, used in savoury foods, snacks, soups, sauces and meat products, has been associated with a conjunction of symptoms in susceptible individuals, such as severe chest and/or facial pressure and overall burning sensations, not unlike a feeling that the victim is experiencing a heart attack (48). MSG has been also found to precipitate a severe headache and/or asthma in susceptible individuals (130,131). In susceptible children MSG has been linked with epilepsy-type "shudder" attacks (132). In animal studies it has been found to damage the brains of young rodents (48).

#### **SWEETENERS:**

Saccharin, used as sweetening tablets and widely used by the soft drink and sweet food industry, has been shown to produce cancer when tested on animals (68,133-135). Saccharin has also been found to be mutagenic (68,136,137) and growth inhibiting (138), as well causing congenital malformations in animal studies (139).

The fact that any substance which has been found to be carcinogenic also seems to have a mutagenic action, was established by testing 300 different carcinogenic chemics for mutagenicity. The results showed that of the 300 carcinogenic chemicals tested, 90% were also found to have a mutagenic action (140).

Aspartame, of which the key ingredient is the amino acid phenylalanine is also widely used by the soft drink and sweet food industry. When fed to rats, aspartame was found to double the level of phenylalanine in their brains, which redoubled when other carbohydrates were consumed at the same time. This combination was found to give a great rise in brain tyrosine, followed by a considerable reduction in brain tryptophan levels (141,142). Low tryptophan levels have been directly linked with both aggressive and violent behaviour (143-149). Furthermore, as dietary tryptophan acts as a precursor for serotonin (5-hydroxytryptamine, 5HT), reduced tryptophan levels will also result in a reduction of brain serotonin levels, which has been directly linked with both hyperactive and aggressive behaviour (150-155).

Sucrose/table sugar, which is a simple molecular substance artificially refined from complex carbohydrates, thus called a refined carbohydrate, can be found in most of our foods. An excessive refined carbohydrate consumption has been directly associated with a high incidence of both criminal and antisocial behaviour (28,47). Schoenthaler and his team conducted several double-blind, design-over studies among thousands of incarcerated juvenile offenders, finding clear correlation between high sucrose/junk food intake and the incidence of antisocial behaviour.

In all studies the primary dietary revision to reduce sugar consumption was organised by simply replacing sugary drinks and junk food snacks with fruit juices and nutritious snacks, such as nuts and fresh fruits. After implementing this simple dietary policy with 276 incarcerated offenders, informal disciplinary actions were lowered 48%, when contrasting the twelve months before and a nutritional revision. Assault and battery was lowered 82%, theft 77%, horseplay 65% and refusal-to-obey-an-order 55% (156,157). When similar diet policy was designed for 1382 offenders confined in three different juvenile institutions, there was a clear 25% reduction in rule violations. All 1382 juveniles served as their own controls and the length of the pre- and post-intervention period lasted for three months each (158). Similar findings were observed when the behaviour of 2005 incarcerated offenders was analyzed for 24 months. In the second half of experiment i.e. after 12 months of the initial observation period, offenders were no longer allowed foods/drinks containing sucrose or artificial additives; instead they were offered nuts, fruit and fruit juices. After implementing the low-sugar diet policy the incidence of rule violations fell 21%, assaults and fights 25% and general disruptions 42% (159).

The consumption of sucrose/additive-rich foods was not only seen to worsen the behaviour of young offenders, but when given to children diagnosed as hyperactive, these foods seemed greatly to increase their restless and destructive behaviour (160,161). Similar results were established among a group of normal pre-school children, as sucrose was found significantly to correlate with their "inappropriate behaviour" pattern (162).

An excessive refined carbohydrate consumption can also lead in susceptible individuals to a disordered carbohydrate metabolism, especially to reactive hypoglycaemia (163,164), which in turn has been found to be particularly prevalent among violent offenders (28,164-176). Reactive hypoglycaemia has also been associated with diverse personality and psychiatric disorders, such as neuroses, panic attacks, agoraphobia and schizophrenic episodes (177).

### **ALLERGY OR INTOLERANCE?**

Allergic intolerance in susceptible individuals can be caused by a variety of substances. However, in the majority of cases, cross-sensitivity and the possibility that several nutritionally related factors are working together, should not be overlooked. The most convincing evidence that this is indeed so, comes from a well conducted double-blind, placebo-controlled crossover trial by Dr Egger and his team when studying 76 hyperactive children to find out whether diet can contribute to behavioural disorders. The results showed that 79% of the children tested reacted adversely to artificial food colorants and preservatives, primarily to tartrazine and benzoic acid. These produced a marked deterioration in their behaviour.

However, no child reacted to them alone. In fact, 48 different foods were found to produce symptoms among the group of children tested. For example; 64% reacted to cow's milk, 59% to chocolate, 49% to wheat, 45% to oranges, 39% to hens' eggs, 32% to peanuts, and 16% to sugar. Interestingly enough, it was not only that the children's behaviour improved after the individual dietary modification. Most of the associated symptoms also improved considerably, such as headaches, fits, abdominal discomfort, chronic rhinitis, aches in limbs, skin rashes and mouth ulcers (29).

Another similar double-blind controlled food trial by Dr Egger and his team was conducted on 88 children suffering from frequent migraines. As before, most children reacted to several foods/chemicals. However, the following foods/chemicals were found to be most prevalent: cow's milk provoked symptoms in 27 children, egg in 24, chocolate in 22, both orange and wheat in 21, benzoic acid in 14 and tartrazine in 12.

Yet again, interestingly enough, after dietary modification, not only migraine improved but also associated symptoms such

as abdominal pain, aches in limbs, fits, rhinitis, recurrent mouth ulcers, asthma, eczema, as well as various behavioural disorders (178). These two studies are a prime example of how problems created by adverse dietary factors are typically polysymptomatic and multisystem in type.

Furthermore, that in order to create reaction in susceptible individuals, probably a whole range of mechanisms co-exist. It has been already established that a reaction to low molecular compounds, such as artificial food additives do not appear to be immunological but rather pharmacological or toxic in type. Also it has been suggested that low molecular compounds, such as food additives, may simply act as haptens and, after attaching themselves to macromolecules, can become antigenic, thus producing an allergenic reaction in susceptible individuals (109,179). Even Feingold was careful not to talk about allergy in its true sense in connection with food additives, but rather preferred the term "elevated sensitivity".

### **WHO ARE AFFECTED?**

Young children seem to serve always as the first sentinels of any environmental contamination, because of their immaturity of enzymatic detoxifying mechanism, incomplete function of excretory organs, low levels of plasma protein capable of binding toxic chemicals and incomplete development of physiological barriers such as the blood-brain barrier (180).

The young, developing nervous system seems to be particularly vulnerable. For example, results of some research studies, which incidently were rather critical of Feingold's claims, found that only the very youngest of the children tested reacted adversely to artificial food additives (20,87,90-92).

It should be stressed however that the period of organ formation and development stretches long beyond the moment of birth. The Fetal Alcohol Syndrome is a useful example, which arises with fetal exposure to neurotoxic agents such as alcohol (68-70).

Similar adverse effects have been attached to maternal smoking (68,69,71), to lead contamination (68,69,75-78) and now, more recently, to food additives (48,68,69,180). Using animal experiments, it has been found that the fetus may be more susceptible to tumour development than an adult animal. Evidence is also accumulating that non-carcinogenic substances may cause a variety of biochemical changes, including alterations in the fetal enzyme development at levels at which the mother is asymptomatic (180).

One class of compounds dangerous to the fetus, often in very low concentration, are the mutagens, which are able to react with and injure chromosomes and genes carrying the genetic code. Furthermore, it has been found that mutagens not only cause mutations but are also capable of damaging and killing living cells, thus inflicting the greatest damage very early in pregnancy or during the weeks before conception (68).

Mutagens are reported to differ from other poisons in that the human or animal body does not seem to have a metabolic space within which they could be metabolized and rendered harmless i.e. there appears to be no satisfactory evidence of 'no effect' doses or 'threshold doses' at which they would not inflict genetic chromosomal damage (68).

The mutagenicity of mutagenic substances varies widely, depending on the dose consumed. As previously mentioned, most substances which have been found to be mutagenic, also seem to have a carcinogenic action (140). Out of the food additives mentioned in this paper, the following have been found in animal studies to have either mutagenic or carcinogenic action: curcumin (E100), carmoisine (E122), amaranth (E123), ponceau 4R (E124), erythrosine (E127), brown FK, sulphites (E210-E219), nitrates and nitrites (E249-E252), butylated hydroxyanisole (E320) and saccharin. Furthermore, the following food additives have been found to be teratogenic when tested on animals: amaranth, butylated hydroxyanisole, monosodium glutamate, saccharin and aspartame (5).

However, it has been argued that these toxicological food additive tests on animals for the assessment for human safety levels are really a waste of time. First of all, experiments on animals are conducted on healthy species fed on a nutritious diet, not on the malnourished, elderly or sick. Secondly, only one agent is tested at a time, whereas humans are known to consume an elaborate cocktail of 12 to 60 different additives in the course of a single meal (5). This may also be a reason why we still remain ignorant of the number of people really affected by the consumption of food additives.

An EEC report, published in 1982, estimated that 0.03-0.15 per cent of the population may react adversely to food additives and 0.01-0.1 per cent may be intolerant to tartrazine (181). A later report by MAFF in 1991 suggested an estimated figure may be one person in 1d,000 (182).

On the other hand, other surveys on food intolerance per se have shown that as many as 2 in 10 people believe that they react badly to certain foods or to their constituents, whereas less than 2 in every 100 has been considered to be the official figure. This finding is based on the fact that only the latter statistical results can be measured using presently

acceptable diagnostic techniques (183).

However, a recently published report indicates that small children are much more likely to react to certain foods. Although the exact numbers are not known, surveys suggest that one child in 10 may be affected in some way (184).

#### **NUTRITIONAL AND TOXIC CHEMICAL INFLUENCES ON BEHAVIOUR:**

Dietary and toxicological factors in behavioural disorders have been sadly neglected by mainstream psychiatry, even though it is known that brain function itself involves subtle chemical and electrical processes, which can be easily altered and modified with the use of various psychoactive drugs. Therefore it is difficult to comprehend why the role of nutritional influences on behaviour has been completely ignored, even though the precursors of neurotransmitter molecules, essential for the brain function, are only found in foods. Furthermore, that they cannot be synthesized nor stored by the brain, unless introduced by appropriate dietary substances.

When the availability of these dietary precursors is reduced, the neurotransmitter synthesis will become impaired, with the consequent changes in both thinking process and behaviour. When this happens, learning and memory tasks may become impaired or disturbed, intellectual development inhibited and overt behaviours disordered, depending upon which dietary precursor is deficient or missing. In addition, various neurotoxins such as alcohol, heroin, LSD, nicotine, lead, organic solvents, individual food intolerances and some food additives can modify neurotransmitter release, resulting in subtle or exaggerated behavioural changes (47,142,204,205).

#### **FOOD ADDITIVES AND MALNUTRITION:**

Another form of risk posed by additives is the loss of the nutritional value of the food, which can result in inappropriate diets and subclinical malnutrition. The wide use of food additives can contribute to malnutrition in the following ways; the common factor in most foods containing additives is high salt, sucrose and fat content.

Pure sucrose, by definition, contains literally no nutrients, only calories; fat, on the other hand, contains few nutrients and is very high in calories. In addition, foods containing additives are mainly processed foods, which have lost a substantial proportion of their nutritional value through the processing procedure.

Even though some vitamins and/or minerals are sometimes added to some foods after processing, the ratio of essential nutrients to calories is usually still quite inadequate, resulting in a high calorie, but a low nutritional, intake. This type of diet, because of the high calorie and low nutritional content, can result in less than optimum nutrition and therefore subclinical and/or marginal malnutrition.

#### **WHAT ARE OUR CHILDREN EATING?**

A recent study examined the nutritional status of 65 inner city school children. The results showed that 63% of the children obtained more than 35% of their calorie intake from foods as fat and 88% of the children consumed more than 11 % of their calories from added sucrose. A third of the children had nothing to eat for breakfast before going to school and the remainder consumed only confectionery and/or crisps. 40% of the girls and 34% of the boys ate no fresh fruit during the week they kept the diary.

For the majority of children the mean intake of essential nutrients such as calcium, magnesium, iron, zinc, vitamin A, riboflavin and folate were found to be considerably below the lower reference nutrient intake (LRNI). Both for the boys and for the girls the top foods in order of priority were chips and/or crisps, white bread, confectionery, meat, biscuits, cakes, buns and soft drinks (185). Even though the amount of additives per food item may be insignificant, it is frightening to speculate the amount of food additives a child on the above diet will consume during his/her school life.

In addition, iron deficiency is directly associated with attention deficit disorders, irritability and with poor scholastic achievement (186-188); zinc deficiency with irritable, tearful, sullen, and possibly also hyperactive behaviour (100,189); calcium deficiency with anxiety neurosis (47); and magnesium deficiency with fidgeting, anxious restlessness, as well as with learning disabilities (190). Furthermore, the lack of an adequate high protein breakfast in schoolchildren has been linked with a poor academic performance (191-193).

Finally, an excessive sucrose-rich food consumption, without the presence of an adequate amount of protein, can lead to reactive hypoglycaemia, with its most disturbing, antisocial and behavioural consequences (28,164-177). Also, the diets on which the schoolchildren existed seem to be so low in essential nutrients, vitamins and minerals that it may not be inappropriate to suggest that most of these children were also suffering from a sub-clinical malnutrition, which in turn has been directly linked with behavioural disorders and scholastic failures, as well as with antisocial and criminal behaviour (47,194-201).

Another dietary survey among 836 schoolchildren found that, although the proportion of 11-16 year old children having breakfast had marginally risen, 5% still leave home without having anything to eat or drink. Also the tendency to snack on

crisps, sweets, chocolate and fizzy drinks was high and many children were found to buy these food-snacks and drinks on the way to school, during the mid-morning break and on the way home (202).

#### **SUBCLINICAL MALNUTRITION IN REPRODUCTION:**

Inefficient diet not only affects the brain and behaviour of an individual, it also has serious long-term consequences on reproduction and on the future infant's health, as a good maternal diet is of paramount importance in relation to healthy fetal development and to a successful pregnancy outcome (68,69,203,204). For example folic acid deficiency has been directly linked with spina bifida (205,206).

Zinc in turn is involved in the process of cell differentiation and replication, therefore zinc deficiency can lead to diverse teratogenic congenital malformations (207,208) and premature delivery (209), as well as small for gestational age babies (210). The adverse effects of a reduced state of other single essential nutrient compounds on reproduction have also been well documented (69,211). Subclinical maternal malnutrition has also been frequently associated with low birth weight infants (68,69,203,204), which in turn appears to have a clear negative effect on the infant's future health (212). It has been found that infants born with low birth weight are more prone in adult life to suffer from cardiovascular diseases (213), have a high serum cholesterol concentration (214), as well as suffer from hypertension, hyperlipidaemia and diabetes mellitus (215).

Subclinical maternal malnutrition can also lead to reduction of fetal brain development and subsequently to various intellectual deficits. The brain develops much more rapidly than most other organs in the embryo. In fact by about the 20th week of pregnancy it already contains most of the neurons present in the adult brain, excluding the cerebellum which is initially slower to develop but quicker to mature. By mid-pregnancy, almost all the neurons found in the adult brain have been produced.

If the maternal diet is not sufficient during this rapid fetal brain neuronal development, this can permanently reduce the number of neurons formed in the foetal cerebrum with its negative consequences to the future intellect (47,142,216- 219).

Although it has been speculated that the brain might recover from early nutritional deprivation, it is not known however which aspects of the brain are relevant to higher mental functioning. Hence it is extremely difficult to interpret these findings in terms of subsequent brain formation and intellect (217,218).

However there is now no doubt whatsoever, that in order to make sure that a child is born undamaged, both mentally and physically, all appropriate dietary changes of both the would-be parents must start well before conception to ensure that both the ova and the sperm are undamaged. This entails both future parents adopting a good nutritional diet and avoiding all toxicological and mutagenic agents well in advance of the planned conception.

Toxicological agents include; alcohol (70), nicotine (71), lead pollution (78) and other heavy metal pollution, all unnecessary medication whether self or medically prescribed, as well as foods containing mutagenic and teratogenic food additives (68,69,221).

Even though this paper has not the capacity to discuss all food additives currently in use, the following food additives at least have been found to have either mutagenic or teratogenic action: curcumin (E100), carmoisine (E122), amaranth (E123), ponceau (E124), erythrosine (E127), Brown FK, sulphites (E210-E219), nitrates and nitrites (E249-E252), butylated hydroxyanisole (E320), monosodium glutamate {MSG}, aspartame and saccharin.

Now one could argue about what harm a minute amount of any food additive mentioned above could do, especially when their mutagenic and teratogenic action is practically insignificant. The answer is that none of the food additives would certainly do any harm by themselves. However, unfortunately they are never by themselves but in many combinations, and it is the total cumulative xenobiotic burden of which one should be wary (68).

#### **DISCUSSION AND RECOMMENDATIONS:**

The use of food additives has increased enormously in the last few decades. As the result, it has been estimated that today about 75% of the Western diet is made up of various processed foods, each person consuming an average 8-10 lbs of food additives per year, with some possibly eating even more. The following 16 adverse effects have been attributed to the consumption of food additives: eczema, urticaria, angioedema, exfoliative dermatitis, irritable bowel syndrome, nausea, vomiting, diarrhoea, rhinitis, bronchospasm, migraine, anaphylaxis, hyperactivity and other behavioural disorders (31).

There is also now clear evidence that the health of the nation in the U.K. has deteriorated considerably during the last few decades. This was found by Dr Michael Wandworth, when he compared the health records of over 5000 people born in 1946 to their first-born children a generation later. The survey found among the new generation a substantial increase in hospital admissions of children up to the age of four, a tripling of instances of asthma, a six-fold increase in both eczema



and juvenile diabetes, as well a double increase in obesity (222).

The number of children admitted to psychiatric hospitals has also risen sharply. The latest official figures have shown between 1985 and 1990 a 42% rise in the number of under 10 year olds seen by the psychiatric services and a 65% increase in children aged between 10 to 14, whilst the admissions of 15 to 19 year old juveniles to psychiatric hospitals had increased 21 %. Even some children as young as 5 years of age are ending up in psychiatric wards (223,224).

Crime is also presently on top of the political agenda. In fact the present rising trend of the criminal statistics and violence resembles today more of an epidemic disease, with symptoms including mental disarrangement combined with a complete lack of any behavioural or emotional control (201). Whilst the crime statistics relentlessly rise, the Government and the media are trying to put the blame on varied sociopolitical influences such as TV and film violence, poverty, lack of parental guidance, alleged child abuse, frustration, lack of motivation, lack of appropriate prisons or institutions, the police etc. In fact, the blame has been pointed at most things, but never on faulty nutrition. Yet, as this paper has shown, an inappropriate nutrition can modify brain function resulting, in susceptible individuals, in a severe mental dysfunction, including manifestations of criminal and violent behaviour.

When this happens, several nutritional factors might be working together; however the following fundamental dietary factors must be taken into consideration when confronting anyone displaying an inappropriate behaviour pattern: is the person concerned living on a high sucrose, high food additive diet which lacks an appropriate amount of good protein? Is the diet completely lacking in foods high in vitamin and mineral content such as fresh fruits and/or salads? Could the person have an allergic intolerance to any foods he or she is consuming regularly? Could the person suffer from a toxicological burden of heavy metal contamination, such as lead, cadmium and/or aluminium, or a deficiency of an essential trace element, which can be easily diagnosed by current hair mineral analysis testing methods (78,220).

It must be stressed that this paper is most definitely not trying to insinuate that all negative behaviour manifestations are nutritional in origin, as sociopolitical influences certainly do play a part. However, it must be always remembered that a healthy and non-toxic brain can usually receive information and process it in an intelligent and positive manner, as opposed to a malnourished and toxic brain which simply does not possess the same capability.

As seen from the above, inadequate nutrition and subclinical malnutrition seem to be two of the basic reasons for a myriad of physical and mental health problems of today. This could be easily rectified by reducing the wide use of non-essential food additives, which in turn would simply restrict the amount of non-nutritious foods presently on sale, resulting in a wider uptake of more nutritionally dense foods.

The main excuse of the food manufacturers and the government officials for the importance of the use of preservatives is that without them foods would soon spoil. This argument is indeed quite realistic. However, it is interesting to note that of the nearly 4000 different additives currently in use, over 3,640 are used purely for cosmetic reasons and as colouring agents, the preservatives accounting for less than 2% of all additives when counted by number or by weight (225).

The other continued reason for the approval of the use of additives is based on the argument that they are present in foods on such a minute scale that they must be therefore completely harmless. This argument may be almost acceptable regarding additives with a reversible toxicological action. However, with additives which have been found to be both mutagenic and carcinogenic, neither the human nor animal body is able to detoxify. Therefore even very minute doses of these additives, when consumed continuously, will eventually result in an irreversible toxic burden, resulting finally in cancer formation and/or in chromosomal and fetal damage. This is quite unacceptable, particularly as the majority of these dangerous agents belong to the food colouring group.

In order to improve the present situation, the following recommendations are made:

- 1) All non-essential food additives should be banned, particularly all cosmetic agents such as food colourants.
- 2) All foods which include additives with carcinogenic, mutagenic and teratogenic properties should be clearly labelled with the appropriate warning.
- 3) All food additives should be banned from foods which may be consumed by infants and or young children.
- 4) The amount of TV advertising which encourages children to buy and eat unhealthy junk food should be vigorously cut down as children are presently surrounded by images promoting extremely unhealthy eating habits.
- 5) All foods that have little or no nutritional value should be discouraged from all promotions.

6) Recent moves towards snack school meals should be completely abolished. Instead the Government should re-introduce free nutritious school meals, preferably using organic food, which should be available to all schoolchildren.

7) Local Education Authorities should include in their health education curricula specific lectures stressing the prime importance of good nutrition in both physical and mental health.

8) All foods, drinks or medications currently exempt from declaring additives must in future be required to do so. This is particularly important and timely in connection with medicines, as presently there is no legal requirement by current British labelling regulations to oblige the drug manufacturers to disclose the presence of any of their pharmacological adjuvants. Adverse reactions to drugs themselves have been recognized, but the ever-expanding range of synthetic excipients currently in use can no longer be considered either inert or non-toxic. In fact it has been already suggested that adverse reactions to undisclosed excipients should be always suspected whenever patients present with recurrent, unexplained symptoms, particularly allergies (31).

9) Finally, all young children diagnosed as hyperactive, including children currently seen by psychiatric services, should always be screened first for evidence of a possible food/chemical intolerance, as even the simplest dietary changes i.e. by avoiding foods containing food additives such as coloured sweets, fizzy and sugary drinks etc., can bring about a remarkable improvement in their health and behaviour (226). This is particularly necessary because the present treatment for childhood hyperactivity i.e. the wide use of psychotropic drugs such as Ritalin is bordering on the barbaric, because of their most devastating side effects which include growth depression (227), dyskinesias and tics (228-231), hallucinations and delusional disorders (232,233), seizures, headaches, blurred vision, "zombie-like" behaviour and hair loss (234). In addition, the withdrawal symptoms of Ritalin include severe and prolonged depression and suicide (235).

I think it would be appropriate to suggest that we must now finally insist that the Government must pass a law refusing permission for the food industries to add continuously into our everyday foods and beverages demonstrably toxic agents for cosmetic purposes only. If not for any other reason, at least in order to protect the health of our significant population of young children, youths, adolescents and adults, as well as the health of our future generation.

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