

Review

Anti-nutritional factors (ANF) in nutrient utilization in Plant Products for human consumption

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Accepted 10 May, 2015

Anti-nutritional factors (ANF) are compounds which reduce the nutrient utilization and/or food intake of plants or plant products used as human foods or animal feeds and they play a vital role in determining the use of plants for humans and animals. Apart from cyanogenic glycosides, food poisoning arising from anti-nutritional factors, otherwise known as plants' secondary metabolites has not been properly addressed in most parts of the developing world. People have died out of ignorance, poverty and inadequate nutrition information and education, especially within the African societies. There are reports from time to time of deaths after consumption of some type of beans despite cooking. Also, cases of renal and liver diseases are increasing and this calls for a need to properly address the issue of thorough and adequate processing of foods/feeds before consumption. The aim of this review is to emphasize on the adequate processing of foods/feeds and to educate the people on the dangers of consuming improperly processed foods especially legumes which are reported to contain very high concentrations of anti-nutritional factors.

Key words: Processing methods, anti-nutritional factors, plants, human foods, animal feeds.

INTRODUCTION

There is a wide distribution of biologically-active constituents through out the plant kingdom, particularly in plants used as animal feeding stuff and in human nutrition (Igile, 1996). The knowledge that these compounds elicit both toxic and advantageous biological responses has given rise to several investigations in recent times as to their possible physiological implications in various biological systems (Igile, 1996).

It is well known that plants generally contain anti-nutrients acquired from fertilizer and pesticides and several naturally-occurring chemicals (Igile, 1996). Some of these chemicals are known as "secondary metabolites" and they have been shown to be highly biologically active (Zenk, 1991). They include saponins, tannins, flavonoids, alkaloids, trypsin (protease) inhibitors, oxalates, phytates, haemagglutinins (lectins), cyanogenic glycosides, cardiac glycosides, coumarins

and gossypol. The list is inexhaustible. Some of these plant chemicals have been shown to be deleterious to health or evidently advantageous to human and animal health if consumed at appropriate amounts (Kersten et al., 1991; Sugano et al; 1993)

Most of these secondary metabolites elicit very harmful biological responses, while some are widely applied in nutrition and as pharmacologically-active agents (Oakenfull and Sidhu, 1989; Soetan, 2008) . The pharmacological and other beneficial effects of these anti-nutritional factors in plants have been reviewed by Soetan (2008).

Food poisoning arising from plant secondary metabolites, otherwise known as anti- nutritional factors, other than cyanogenic glycosides, has not been properly addressed in Nigeria, and indeed in most parts of the developing world/countries, that depend/feed mostly on vegetable- based diets. People have therefore died out of ignorance, poverty and inadequate nutrition education, especially within the African societies (Igile, 1996).

The anti-nutritional factors (ANFS) may be defined as

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those substances generated in natural food stuffs by the normal metabolism of species and by different mechanisms (e.g. inactivation of some nutrients, diminution of the digestive process, or metabolic utilization of feed) which exert effects contrary to optimum nutrition (Kumar, 1992). Being an ANF is not an intrinsic characteristic of a compound but depends upon the digestive process of the ingesting animal (Kumar, 1992). For example, trypsin inhibitors, which are ANFs for monogastric animals, do not exert adverse effects in ruminants because they are degraded in the rumen (Cheeke and Shull, 1985). The utility of the leaves, pods and edible twigs of shrubs and trees as animal feed is limited by the presence of ANFs (Kumar, 1992).

Much of the available data and information on the nutrient and anti-nutrient composition of the more commonly used local foods and feeds do not cover all the foods and feeds and where available, needs updating. This is because of the possible effects of variety/genetic origin, climate, soil, processing methods, pesticides and fertilizers on the chemical composition of the food plants (FAO, 1966).

Several considerations justify the continued surveillance, knowledge and future research on antinutritional factors/toxic substances naturally present in plants used as foods and feedstuffs and ways of reducing them to safe level of consumption.

Firstly, the possibility that newly developed or exotic foods may contain natural toxicants must be taken into account in evaluating their usefulness (Osagie, 1998). Also, introduction of new plant varieties into our diets may expose humans and animals to new toxic factors with unsuspected biological effects.

Secondly, improper processing of plant food like beans and pulses may expose humans and animals to high concentrations of these toxic factors. An example is the production of soymilk and its use as an alternative to cow's milk in infant formula. It is reported that soymilk, if not properly processed and supplemented with iodine, causes goitre in infants (Hydowitz, 1960). Raw soybeans also cause goitre in rats and chicks. Another example is the report by Abeke et al. (2003), that most farmers would prefer to use raw *Lablab purpureus* (lablab beans) to feed chicken in order to eliminate the cost of transporting the raw beans to the processor and back to the farm as well as trying to avoid the processing and other handling costs involved.

Thirdly, these anti-nutritional factors are increasingly recognized as significant items of the diet of humans and animals (Osagie, 1998). Thus, they affect the overall nutritional value of foods and feeds.

Fourthly, the plant breeder, in an attempt to develop higher -yielding or disease- resistant crop varieties must, at the same time, be alert to the possible production of undesirable components (Osagie, 1998).

Fifthly, amounts of certain food substances that are relatively safe when consumed individually can sometimes, when taken together, have serious and even fatal events

(Osagie, 1998). An example is the presence of tannins in a protein-marginal diet.

Sixthly, Public health authorities and other food regulatory bodies need to be informed about the possible dangers related to the widespread, longstanding practices previously regarded as safe (Osagie, 1998). For example, cassava and some legumes have been consumed in the tropics for a long time without apparent consideration for their high cyanide contents. Also, information on the anti-nutritional components of foods/feedstuffs will help dieticians, veterinarians, human and animal nutritionists to avoid recommending foods/feeds that their patients cannot tolerate, possibly because of the inability to metabolize or detoxify certain substances therein.

In the last few decades or more, large numbers of scientific data have emerged, linking diet and food selection patterns to the maintenance of health and the prevention of some chronic diseases (Oyewole and Atinmo, 2008). There is a consensus among physicians that nutrition constitutes an essential aspect of health care.

The aim of this review therefore are as follows: 1) to revisit the issue of processing foods/feeds so as to reduce or eliminate these health threatening plants' secondary metabolites whose occurrence and concentrations/levels in food plants vary according to genetic origin, soil, fertilizer, pesticides and other environmental conditions; 2) to emphasize the need to properly process human foods and animal feeds to the level which are safe for consumption.

THE ANTI-NUTRITIONAL FACTORS (PLANTS' SECONDARY METABOLITES)

The abundance of anti- nutritional factors and toxic influences in plants used as human foods and animal feeds certainly calls for concern. Therefore, ways and means of eliminating or reducing their levels to the barest minimum should be discovered. It could be wrongly argued that since the African cultural method of preparing food involves cooking, there is no cause for alarm. This is not entirely correct because although the toxic effects of most anti-nutritional factors present in plant food and feedstuffs can generally be eliminated by proper heat treatment, it should be appreciated that conditions may prevail whereby complete destruction may not always be achieved (Aykroyd et al., 1982). For example, it has been reported that phytic acids (phytates) are not destroyed by being cooked even in boiling water (Ranhotra et al., 1974).

Korte (1973) also observed that in mixtures of ground beans and ground cereals prepared under the field conditions prevailing in Africa, the haemagglutinin was not always completely destroyed, and that cooked products produced diarrhoea and other toxicity signs. A reduction in the boiling point of water in mountainous regions could also

result in incomplete destruction of toxicity or incomplete elimination of the lectins. Also, people do not patiently prepare or process beans to the recommended level to destroy the anti-nutrients because of the high and prohibitive cost of energy sources like kerosene and gas and the scarcity of firewood, especially during the rainy season. As a result of this, people are forced to eat improperly cooked nutritionally toxic beans (Pusztai et al., 1993). There has also been some press reports of food poisoning leading to mortality in humans after consumption of bean meal. The adverse effect of excessive cooking on protein denaturation is also an important factor to be considered during food / feed processing.

A review of the occurrence of nitrate in unprocessed foods showed that high concentrations are frequently found in vegetables (Walker, 1975). Nitrates are present in all plants and are an essential source of nitrogen for normal growth. The increasing incidence of various forms of cancer in the world at large and in Nigeria in particular may be attributed to the levels of certain chemicals in our foods and drinks (Okafor and Nwogbo, 2005).

The consequences/implications of toxic factors in plants used as food/feedstuffs are not their direct toxicity to man and animals alone, but also the inconvenience and the economic loss associated with poisoning of domestic animals and the cost of preventing or reducing such happenings. It is worthy of note that plant poisons can either be accumulated in the animal or in certain organs or they are metabolized and excreted in milk (Liener, 1969). Ruminants may convert cyanide to the less toxic thiocyanate, which is goitrogenic (Jones et al., 1997). By this food chain, toxins or their metabolites thereof may become harmful to man (Habermal, 1987).

Nutrition education should emphasize adequate and thorough preparations of human foods and animal feeds, especially in humans where there are increases in reported cases of renal diseases (Salako, 2005). Oxalate, which is an anti-nutritional component of plant, if consumed in large quantities is associated with blockage of renal tubules by calcium oxalate crystals and development of urinary calculi (Blood and Radostits, 1989). All these can lead to renal disease and hence death in susceptible individuals. There is also the need to re-visit studies on the levels of anti-nutritional factors in our common foods due to the influence of soil, fertilizer, pesticides, and other chemicals and environmental conditions on the levels of these anti-nutritional factors in plants.

METHODS FOR QUANTIFICATION OF THE ANTI-NUTRITIONAL FACTORS IN PLANTS

Several methods are used for the quantitative determination of anti-nutritional factors in foods based on reports by different authors. These are: trypsin inhibitor activities are determined according to Liener (1979);

haemagglutinin, Jaffe (1979); cyanogenic glucosides (HCN), Bradbury et al (1999); oxalates, Fasset, (1996); phytates, Maga (1983); tannin, Dawra et al. (1988); saponin, Brunner (1984); and alkaloids, Henry (1973). There are other new methods for quantification of anti-nutritional factors due to recent advances in the nutritional sciences.

CLASSIFICATION OF THE ANTI-NUTRITIONAL FACTORS

The anti-nutritional factors in plants may be classified on the basis of their chemical structure, the specific actions they bring about or their biosynthetic origin (Aletor, 1999). Although this classification does not encompass all the known groups of anti-nutritional factors, it does present the list of those frequently found in human foods and animal feedstuffs. The anti-nutritional factors may be divided into two major categories. They are:

- (1). Proteins (such as lectins and protease inhibitors) which are sensitive to normal processing temperatures.
- (2). Other substances which are stable or resistant to these temperatures and which include, among many others, polyphenolic compounds (mainly condensed tannins), non-protein amino acids and galactomannan gums (Osagie, 1998).

More often than not, a single plant may contain two or more toxic compounds, generally drawn from the two categories, which add to the difficulties of detoxification. According to Aletor (1993), there are several anti-nutritional factors that are very significant in plants used for human foods and animal feeds.

They are: (i) Enzyme inhibitors (trypsin and chymotrypsin inhibitors, plasmin inhibitors, elastase inhibitors), (ii) Haemagglutinins (concanavalin A, ricin), (iii) Plant enzymes (urease, lipoxygenase), (iv) Cyanogenic glycosides (phaseolunatin, dhurrin, linamarin, luteostralin), (v) Goitrogens (pro-goitrins and glucosinolates), (vi) Oestrogens (flavones and genistein), (vii) Saponins (soya saponin), (viii) Gossypol from *Gossypium species* e.g. cotton, (ix) Tannins (condensed and hydrolysable tannins), (x) Amino acid analogues (BOAA, DAP, mimosine, N-methyl-1-alanine), (xi) Alkaloids (solanine and chaconine), (xii) Anti-metals (phytates and oxalates), (xiii) Anti-vitamins (anti-vitamins A, D, E and B₁₂) and (xiv) Favism factors.

BIOCHEMICAL EFFECTS OF THE ANTI-NUTRITIONAL FACTORS

The biochemical and toxicological/adverse effects of plant's secondary metabolites (anti-nutritional factors) have been reviewed by several authors (McLean, 1970; Cheeke and Shull, 1985; Aletor, 1993; Osagie, 1998; Fu et al., 2002). However, their adverse effects will be briefly

highlighted.

Anti-nutritional factors diminish animal productivity but may also cause toxicity during periods of scarcity or confinement when the feed rich in these substances is consumed by animals in large quantities (Kumar, 1992). Cyanogenic glucoside on hydrolysis yields toxic hydrocyanic acid (HCN). The cyanide ions inhibit several enzyme systems, depress growth through interference with certain essential amino acids and utilization of associated nutrients. They also cause acute toxicity, neuropathy and death (Osuntokun, 1972; Fernando, 1987).

Alkaloids cause gastrointestinal and neurological disorders (Aletor, 1993). The glycoalkaloids, solanine and chaconine present in potato and *Solanum spp.* (Saito et al., 1990; Aletor, 1991) are haemolytically active and toxic to fungi and humans. Some of the toxicological manifestations of potato glycoalkaloids involve gastro-intestinal upsets and neurological disorders, especially in doses in excess of 20 mg/100 g sample. Coumarins, which are constituents of forage, have been associated with the so-called bleeding disease in cattle consuming spoiled or putrid sweet clover (Aletor, 1993). It is believed that cinnamic acid or its derivatives are the precursors of coumarin and that when plant tissues containing derivatives are disrupted by mastication, freezing, drying or microbial spoilage, coumarin is transformed to the haemorrhagic factor, dicoumarol (Aletor, 1993). Dicoumarol depresses blood prothrombin concentration and by implication reduces clotting time. More detailed review of the implications of dietary coumarin and dicoumarol in livestock production has been published by Gustine (1972).

Tannins cause decreased feed consumption in animals, bind dietary protein and digestive enzymes to form complexes that are not readily digestible (Aletor, 1993a). They also cause decreased palatability and reduced growth rate (Roeder, 1995).

Saponins cause hypocholesterolaemia by binding cholesterol, making it unavailable for absorption. They also cause haemolysis of red blood cells and are toxic to rats (Johnson et al., 1986). Saponins from *Bulbostemma paniculatum* and *Pentapamax leschenaultii* have also been demonstrated to have anti-spermal effects on human spermatozoa (Su and Guo, 1986; Pant et al., 1989). They significantly inhibited acrosome activity of human sperms and the spermicidal effect was attributed to strong damage of the spermal plasma membrane (Su and Guo, 1986).

Trypsin (protease inhibitor) causes pancreatic enlargement and growth depression (Aletor and Fetuga, 1987). Haemagglutinins are proteins known for agglutinating red blood cells. They depress animal growth by interfering with the digestion and absorption of nutrients in the gastrointestinal tract (Aletor and Fetuga, 1987). Phytates bind minerals like calcium, iron, magnesium and zinc and make them unavailable (Nelson et al., 1968). Oxalates, like phytates, bind minerals like calcium and magnesium and interfere with their metabolism. They

also cause muscular weakness and paralysis. Oxalates also cause gastrointestinal tract irritation, blockage of the renal tubules by calcium oxalate crystals, development of urinary calculi and hypocalcaemia (Oke, 1969; Blood and Radostits, 1989). Jones et al. (1997) reported that oxalates cause nephrotic lesions in the kidney. Oxalate, phytate and tannins are anti-nutrients, which could be toxic when consumed in an unprocessed food (Ojiako and Igwe, 2008). The bioavailability of the essential nutrients in plant foods could be reduced by the presence in these plants of some anti-nutritional factors such as oxalates and cyanogenic glycosides (Akindahunsi and Salawu, 2005). Too much of soluble oxalate in the body prevents the absorption of soluble calcium ions as the oxalate binds the calcium ions to form insoluble calcium-oxalate complexes. As a result of this, people with the tendency to form kidney stones are advised to avoid oxalate-rich foods (Adeniyi et al., 2009).

Gossypols are reported to cause animal and human toxicity and high incidence of irreversible testicular damage. Dietary gossypol can also bring about increased requirement, not only for lysine, but also for iron which it can chelate (Aletor, 1993). At the physiological level, gossypol reduces oxygen availability in the blood, while Skutches (1974) showed that proteins were reduced by approximately 20% in pigs fed 0.06% free gossypol in the diet. Other physiological abnormalities include hypertrophy and dilution of heart muscles and changes in electrocardiogram. Dietary free gossypol of up to 0.02-0.03% has been reported to cause death in growing pigs while poultry can tolerate fairly high dietary levels (Aletor and Onibi, 1990). Gossypol is rapidly deposited in the eggs and has been implicated in egg yolk discoloration (Aletor, 1993).

Plant oestrogens also cause toxicity in animals. For example, it has long been recognized that sheep grazing subterranean clover (*Trifolium subterraneum*) are prone to poor reproductive performance (Aletor, 1993). The causal chemical agent has since been identified as the isoflavone and genistein. Chronic exposure to these oestrogenic principles in plants may lead to biochemically and physiologically active levels. There is ample evidence that uncontrolled use of plant oestrogens could produce various types of tumours in animals. More detailed information on the oestrogenicity of certain forage species and the accompanying physiopathological implications have been reviewed by Price and Fenwick (1985).

There are some anti-nutritional factors in some plants, especially leguminous plants, whose mode of action is poorly understood. These are anti-vitamin factors. Raw kidney beans are believed to contain an antagonist to vitamin E as evidenced by liver necrosis in rats and muscular dystrophy and low concentration of plasma tocopherol in chicks (Liener, 1980). Anti-vitamin E has also been noted in isolated soya protein, which is suspected to be -tocopherol oxidase. Unheated soyabean

flour has been found to be deficient not only in Vitamin B₁₂, but it also contains a heat-labile factor that increases

the requirement for vitamin B₁₂ (Liener, 1980). Alkaloids are also reported to cause alteration of normal foetal developments resulting in foetal malformation in ewes. These are caused by teratogenic alkaloids (Mulvihill, 1972). Glycoalkaloids are reported to cause haemolysis and toxicity to humans (Saito et al., 1990; Aletor, 1991). Some plant alkaloids are reported to cause infertility (Olayemi, 2007). Saponins are characterised by a bitter taste and foaming properties. Erythrocytes lyses in saponin solution and so these compounds are toxic when injected intravenously. The anti-nutritional effects of saponins have been mainly studied using alfalfa saponins. In non-ruminants (chicks and pigs), retardation of growth rate, due primarily to reduction in feed intake, is probably the major concern (Cheeke and Shull, 1985). Such effects have also been noted when *Sesbania sesban* leaf meal (saponin 0.71%) was incorporated in a chick diet (Shqueir et al., 1989). Furthermore, because saponins may also undergo bacterial degradation in the rumen, they may not retard the growth of ruminants. Nevertheless, recent studies indicate that they inhibit microbial fermentation and synthesis in the rumen (Lu and Jorgensen, 1987). Ricin occurs in castor beans (*Ricinus communis*) which have been reported to cause poisoning in all classes of livestock. Due to ricin, deoiled castor seed cake (CP 35%) is seldom used as a livestock feed. However, the mature leaves of *R. communis* have been found suitable for feeding to sheep (Behl et al., 1986); hence precautions against bean contamination are necessary. Castor bean meal can be detoxified by autoclaving at 20 psi for 60 min for incorporation in sheep diets (Rao et al., 1988).

PROCESSING TECHNIQUES ON THE ANTI-NUTRITIONAL FACTORS

Information on the effect of different processing techniques on the anti-nutritional factors in human foods and animal feeds will attract interests by human and animal nutritionists, dieticians, veterinarians, public health and food regulatory bodies/authorities on the exploitation of these techniques so that the nutritive values of foods and feeds could be efficiently maximized. Although data on the necessary optimal processing techniques, if any, is scanty, this should be established to ensure optimal utilization of human foods and animal feeds.

EFFECTS OF DIFFERENT PROCESSING METHODS ON THE ANTI-NUTRITIONAL FACTORS

Gharaghani et al. (2008) reported the effect of gamma irradiation on anti nutritional factors and nutritional value of canola meal for broiler chickens. Glucosinolate content

was reduced to 40, 70 and 89% at irradiation dose levels of 10, 20 and 30 kGy, respectively ($p < 0.01$). Their observation indicated that the irradiation treatment has a significant effect on the glucosinolate content of canola meal. Gamma irradiation treatment with its radiolytic effects can destroy glucosinolate molecules. Other investigators reported that anti nutritional factors, such as protease inhibitors (Farag, 1989; Sattar et al., 1990; El-Morsi et al., 1992; Farag, 1998), α -amylase inhibitors (Abu-Tarboush, 1998; Al-Kahtani, 1995), phytohemagglutinins (Farag, 1989; Mahrous, 1992; Farag, 1998), oligosaccharids (Rao and Vakil, 1983; Ghazy, 1990) and tannin (Abu-Tarboush, 1998) were significantly inactivated by gamma irradiation.

VARIETALS DIFFERENCES AND EFFECTS OF METHODS OF DOMESTIC PROCESSING AND COOKING

Khokhar and Chauhan (1997) reported the anti-nutritional factors in Moth Bean (*Vigna aconitifolia*). The dry seeds were given different treatments including soaking, sprouting and cooking and the changes in the level of the anti-nutritional factors were estimated. Soaking the seeds in plain water and mineral salt solution for 12 h decreased phytic acid to the maximum (46–50%) whereas sprouting for 60 h had the most pronounced saponin lowering effect (46%). The other methods of processing were less effective in reducing the levels of these anti-nutritional factors. The processing methods involving heat treatment almost eliminated trypsin inhibitor activity while soaking and germination partly removed the activity. El-Adawy (2002) reported the nutritional composition and anti-nutritional factors of chickpeas (*Cicer arietinum* L.) undergoing different cooking methods and germination. The studies involved the effects of cooking treatments (boiling, autoclaving and microwave cooking) and germination on the nutritional composition and anti-nutritional factors of chickpeas. Cooking treatments and/or germination caused significant ($p < 0.05$) decreases in fat, total ash, carbohydrate fractions, anti-nutritional factors, minerals and B-vitamins. Germination was less effective than cooking treatments in reducing trypsin inhibitor, hemagglutinin activity, tannins and saponins; it was more effective in reducing phytic acid, stachyose and raffinose. Cooking treatments and germination decreased the concentrations of lysine, tryptophan, total aromatic and sulfur-containing amino acids. However, cooked and germinated chickpeas were still higher in lysine, isoleucine and total aromatic amino acid contents than the FAO/WHO reference. The losses in B-vitamins and minerals in chickpeas cooked by microwaving were smaller than in those cooked by boiling and autoclaving. Germination resulted in greater retention of all minerals and B-vitamins compared to cooking treatments. *In vitro* protein digestibility, protein efficiency

ratio and essential amino acid index were improved by all treatments. The chemical score and limiting amino acid of chickpeas subjected to the various treatments varied considerably, depending on the type of treatment. Based on these results, microwave cooking appears to be the best alternative for legume preparation in households and restaurants.

Mosha et al. (1995) reported the effect of blanching on the content of anti-nutritional factors in selected vegetables. Levels of both tannic acid and phytic acid were significantly ($p < 0.05$) reduced by conventional and microwave blanching methods while oxalic acid levels were not significantly ($p > 0.05$) reduced in most of the treatments by either of the blanching methods. In general, they recommended blanching as an effective method for reducing the anti-nutritional factors in green vegetables; however, further investigation on the heating times for both conventional and microwave blanching methods has been suggested.

Alonso et al. (2000) reported the effects of extrusion and traditional processing methods on antinutrients and *in vitro* digestibility of protein and starch in faba and kidney beans. De-hulling significantly increased protein content and greatly reduced condensed tannin and polyphenol levels in both legumes. Extrusion was the best method to abolish trypsin, chymotrypsin, α -amylase inhibitors and haemagglutinating activity without modifying protein content. Furthermore, this thermal treatment was most effective in improving protein and starch digestibilities when compared with dehulling, soaking and germination.

Van Bruggen et al. (1993) reported the methods and devices for reducing the amount of anti-nutritional factors in a mixture of raw material for animal feed. The invention relates to a method for reducing the amount of anti-nutritional factors in a raw material mixture for producing an ingredient for animal feed such as cattle fodder or domestic animal feed, which raw material mixture contains at least rape seed in a quantity between 1 and 100%, by subjecting the raw material mixture to a steam treatment for a predetermined time at a predetermined temperature. Due to the steam treatment, the anti-nutritional factors are at least partially broken down and determined constituents such as fats also become better accessible, whereby the nutritional value of the final animal feed increases.

Plant phytochemicals exhibit diverse pharmacological and biochemical actions when ingested by animals and man (Amadi et al., 2006; Soetan, 2008). Most of the toxic and anti-nutrient effects of these compounds in plants could be removed by several processing methods such as soaking, germination, boiling, autoclaving, fermentation, genetic manipulation and other processing methods (Soetan, 2008). Food processing methods such as boiling reduces the amount of these phytochemicals in plant products (Piorrock et al., 1984). The toxic effects of oxalate, phytate and tannins could be avoided, provided

the plant food is cooked before consumption (Enechi and Odonwodu, 2003). Osman (2007) reported the effect of different processing methods on nutrient composition, anti-nutritional factors and *in vitro* protein digestibility of *Dolichos lablab* bean [*Lablab purpureus* (L) Sweet]. The trypsin inhibitor values were significantly reduced ($P < 0.05$) by the different treatment methods, with cooking being the most effective. Soaking of the beans overnight reduced the trypsin inhibitor activities (TIA) by 6.3% and cooking of the soaked beans caused further reduction in the TIA content by 66.7%. The report of Osman (2007) agrees with that of Marquez and Alonson 1999) who reported a reduction in trypsin activity level during soaking and boiling of chickpea. Also, Kadam and Smithard (1987) observed a significant decrease in TIA in winged bean after cooking of the presoaked bean. Devaraj and Manjunath (1995) found that the *D. lablab* proteinase inhibitors activity was completely lost by 60 min cooking.

Roasting and autoclaving significantly reduced the amount of TIA by 23.05 and 12.09%, respectively. Their data agree with that found by Kapoor and Gupta (1978), Carlini and Udedibie (1977) in other legumes. Osman (2007) further reported that germination significantly decreased the TIA activities in *D. lablab* by 19.3%. This result was similar to those observed on other legumes like soybean (Collins and Sanders, 1976), lentil (Frias et al., 1995; Vidal-Valverde et al., 1994), great Northern bean (Sathe et al., 1983), faba bean (Rahma et al., 1987) and chick bean (Savage and Thompson, 1989). Apart from the trypsin inhibitor activity, different treatment methods caused significant decrease in phytic acid (PA) level. The phytic acid content of the raw lablab bean is lower than that reported by Deka and Sarkar, (1990) but higher than those reported by Al-Othman (1999). Osman (2007) reported that roasting caused greater reduction (60.69%) on phytic acid followed by autoclaving (52.29%), germination (48.94%) and cooking (44.85%), while soaking showed the lowest reduction (22.19%). Reduction in the phytic acid content during soaking, cooking or germination has been reported by many investigators (Chau and Cheung, 1997; Alonso et al., 1998; Alonso et al., 2000; Desphande and Sheryan, 1983; Vidal-Vilverde et al., 1994; Sievwright and Shipe, 1986) for Chinese legumes, pea, faba bean, dry bean, lentil and black bean, respectively. The decrease in phytic acid content by soaking, cooking of presoaked bean or germination may be due to leaching out of this compound in water (Osman, 2007). Roasting and autoclaving has been reported to decrease phytic acid in dry bean (Tabekhia and Luh, 1980), chick pea and black gram (Duhan et al., 1989), cowpea (Akinyele, 1989) and black bean (Siewwright and Shipe, 1986). Vijakumari et al. (1995) reported that cooking or autoclaving of *D. lablab* seeds reduced the tannin contents by 70 and 60%, respectively. Germination significantly increased *in vitro* protein digestibility of *D. lablab* seeds to 92.27% whereas,

roasting and autoclaving significantly decreased it to 85.28 and 86.97%, respectively. Similar results were obtained in *D. lablab* by Shastry and John (1991) and Sorghum by Bhis et al. (1988) and Romo-Parade et al. (1985). Vijakumari et al. (1995) reported that soaking, cooking or autoclaving of *D. lablab* seeds increased the *in vitro* protein digestibility values by 3 and 13%, respectively. Osman (2007) concluded his report that soaking, cooking of presoaked beans and germination are good potential methods for improving the nutritional value of lablab beans by reducing the antinutritional factors such as trypsin inhibitors and phytic acid and this enhances the utilization of the lablab beans. Ogundipe et al. (2003) reported that cooking had significant effects on the utilization of *Lablab purpureus* beans by pullet chicks. Cooking lablab seeds for about 30 min gave the best results in terms of final weight, weight gain, feed consumption and feed-gain ratio. Omeje (1999) also reported that cooking of legume seeds for about 30 min resulted in the destruction of the anti-nutritional factors such as trypsin inhibitors, haemagglutinins, phytic acids, lectins and goitrogens, thereby improving the nutrient availability for better performance of the bird fed such diets. Amaefule and Obioha (2001) reported better performance in broilers fed pigeon pea seed meal based diets as compared to diets containing the raw meal. Kaankuka et al. (2000) also reported that cooking soybean seeds for about 30 min improved the performance of weaned pigs better than cooking for lesser time periods. Ogundipe (1980) reported that moist cooking of soybeans gave better performance in broilers than other processing methods. In order to utilize beans effectively as human foods, it is essential to inactivate or remove these anti-nutritional factors (Osman, 2007). This also applies to animal feeds. Generally, adequate heat processing inactivates the trypsin and chymotrypsin (Dipitero and Liener, 1989; Osman et al., 2002). Heat stable compounds in cereals and legumes such as tannins and hydrates are easily removed after germination (Reddy et al., 1985) and fermentation (Osman, 2004). A better understanding of the effects of different traditional processing methods on nutritive value may lead to wider use of legumes in the food industry (Osman, 2007). Omoruyi et al. (2007) reported the anti-nutritional factors, zinc, iron and calcium in some Caribbean tuber crops and the effect of boiling or roasting on them. Boiling reduced the phytic acid to zinc molar ratio for yellow yam and cocoyam. Boiling or roasting reduced the levels of cyanoglucosides in sweet potato, yellow yam and cocoyam. Roasting greatly lowered the level of trypsin inhibitor activity compared to boiling. Omoruyi et al. (2007) concluded that boiling and roasting were effective in lowering the levels of anti-nutritional factors. Ikemefuna et al. (1991) reported the effects of soaking, sprouting, cooking and fermentation on some nutrient composition and anti-nutrients factors of sorghum (*Guinesia*) seeds. They reported that a combination of cooking and fermentation improved the nutrient quality

and drastically reduced the anti-nutritional factors to safe levels much greater than any of the processing methods tested. Ikemefuna et al. (1991) also reported that soaking and fermentation decreased the tannins content. These processes produce enzymes that break down complexes to release free tannins. The free tannins leached out. Fermentation reduced cyanide in soaked seeds. Cooking and fermentation reduced cyanide in soaked seeds to safe levels. The HCN is soluble in soaking water as such was leached out in the atmosphere. They further reported that cooking and fermentation synergistically reduced tannins. Cooking and fermentation broke down tannin-enzyme and protein-tannin complexes and released free tannins which subsequently leached out the products. Ikemefuna et al. (1991) concluded that soaking, sprouting, cooking and fermentation appeared to have beneficial effects as methods of processing. Combinations of cooking and fermentation improved the nutrient quality and reduced the anti-nutritional factors inherent in sprouted cereal products to safe levels much greater than any of the other processing methods tested.

Chavan et al. (1981) reported a ten-fold increase in some reducing sugars and disappearance of galactooligosaccharides during sprouting.

Panasuik and Bills (1984) observed that the endogenous autolytic enzymes responsible for hydrolysis of cyanogenic glycosides may remain partially active, even in the dry products. They could be fully activated on re-hydration, as in fermentation. Soaked seeds had slight decrease in starch. Sprouting for 36 and 96 h caused the greatest decrease. They reported that the decreases may be due to (a) reduced tannins by amylolytic enzymes and (b) microbial enzyme hydrolysis (Ogunsua, 1980; Osuntokun, 1981). Fermentation also influenced the levels of reducing sugars in sprouted seeds. Fermentation caused increases in lipids for both soaked and sprouted seeds. The increases were more than two-fold in seeds soaked for 48-96 h. The cause of the increases might be due to increased activity of lipolytic enzymes which produced more free fatty acids. These imparted their flavour to the products. A similar observation was reported by Kazanas and Fields (1981).

Conclusion

Factors that determine the nutritive value of foods and feedstuffs are very complex. All available information, both qualitative and quantitative must be used in making judgments about the feed value of particular plant species. The fact that a plant or part of a plant is eaten by animals is only an indication of acceptability. Too much emphasis is usually put on the analyses of crude protein and fibre as indicators of feed value. More importance should be given to the presence of secondary plant compounds such as tannins and hydrolysable phenolics, which may interfere with the level of protein and fibre contents which are used as indicators of high nutritional value.

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