Ramesh Kumar Sharma · Salvatore Parisi

Toxins and Contaminants in Indian Food Products

Springer

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Springer

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ISBN 978-3-319-48047-3 ISBN 978-3-319-48049-7 (eBook)
DOI 10.1007/978-3-319-48049-7

Library of Congress Control Number: 2016955526

Printed on acid-free paper

This Springer imprint is published by Springer Nature
The registered company is Springer International Publishing AG
The registered company address is: Gewerbestrasse 11, 6330 Cham, Switzerland

Contents

Chapter 1
Insecticides in Indian Food Products

Abstract The current usage of insecticides and pesticides in modern food industry and agriculture is surely evident in many industrialised countries such as India. Despite their use as crop protection chemicals, their toxic action has been remembered by environmentalists as well as food and agricultural scientists. Organic insecticides—mainly organochlorines, organophosphorus, carbamates and pyrethrins/pyrethroids—are extensively used for crop protection, but their limitation is correlated with safety consequences. Azadirachtin, the interesting natural insecticidal compound extracted from *neem* trees, may be a solution against environmental harms caused by synthetic insecticides and pesticides. Indian food business operators have to face consequences of the excessive use of insecticides in farms as rejections of export consignments. Countries possessing enough dense infrastructure, particularly European countries, are capable of keeping insecticide at minimum residue levels lower than India. Also for this reason, the Indian Country needs dense forestation.

Keywords Carbamate · Forestation · Insecticide · Organochlorine · Organophosphorous · Pyrethrin · Pyrethroid

Abbreviations

BHC	Benzene hexachloride
DDT	Dichlorodiphenyltrichloroethane
FAO	Food and Agricultural Organization
FSSR	Food Safety and Standards Regulation
HCN	Hydrogen cyanide
LD_{50}	Lethal dosage
MRL	Maximum residue level
UNEP	United Nations Environment Programme

R.K. Sharma and S. Parisi, *Toxins and Contaminants in Indian Food Products*,
DOI 10.1007/978-3-319-48049-7_1

1.1 Introduction

With the technical advancement in the twentieth century in the fields of food processing, agriculture, and public health, the control of pests and insects is now a part of human tasks instead of natural action. The food production and farming and hygiene techniques for the reduction of insect populations, originally limited to promotion of natural biocontrol (as lizards and the frogs eat up flies and mosquitoes), have got the new dimension of use of insect–pest controlling substances: insecticides and pesticides. Well known for the contribution to agricultural yield safety and chronic contagion control, man-made insecticides and pesticides are also known for polluting the environment, water and foods. Despite the fact that insecticides adversely affect the environment, their use as sprays is almost unavoidable in food industries (not in food, but in building) and agriculture farms for protection of foods and crops from microorganisms, pests and insects. The modern food industry and agriculture cannot exclude the use of different chemical substances with peculiar function including insecticidal function. This situation is surely evident in many industrialised countries such as India, where age-old insect controlling techniques like biocontrol promotion and use of natural insecticides—mainly *neem* (*Azadirachta indica*) leaves' juice—have been becoming obsolete since mid-twentieth century.

The use of synthetic pesticides in India commenced in 1948 when the country imported *p*, *p′*-dichlorodiphenyltrichloroethane (DDT) for the control of contagion malaria (Kumar and Kumar 2007). In the same year, benzene hexachloride (BHC) was imported to control insect locusts for safety of agricultural yield.

In 1952, India initiated the indigenous production of both insecticides; at present, approximately 145 pesticides are registered for use (Kumar and Kumar 2007). In India, forests and pastures, which had been publicly utilised and maintained too as a commonly shared property since centuries, were subjected to government acquisition followed by conversion for mining and housing purposes. This situation of deforestation led to decrease in soil conservation (or soil fertility) and compelled farmers, particularly belonging to non-irrigated lands, to use increasing amounts of fertilisers like urea and superphosphates in place of natural manures like animal dung and urine as well as synthetic insecticides in place of natural *neem* leaf juice.

Indian farmers have initially owned small farms. The big agriculture companies in India began to run with effect from commencement of nineteenth century when Dupont India and Rallis India Limited were established in 1802 and 1815 at Gurgaon (Haryana) and Bangalore (Karnataka), respectively. Both these companies deal in agro-based products including synthetic insecticides. On the other hand, Foabs Organic Estates—established in 1889 at Tiruvalla (Kerala) dealing in tea, coffee and spices—has till-to-date maintained traditional farming employing the ways of natural manure insecticide applications. Recently, from 2000 onwards, Insecticides India Ltd. emerged as one of the fastest growing agrochemicals manufacturing companies with insecticides based on chlorpyriphos, monocrotophos, imidacloprid and other active principles. Nowadays (from 2000 onward) it may be estimated that more than half of food commodities in India are contaminated with insecticide–pesticide residues; out of these one-fifth cross allowed maximum residue levels (MRL) (Kumar and Kumar 2007), when the dire need of traditional (or organic) farming is underlined by both environmentalists and food scientists.

In this context, it is worthwhile to get an overview of insecticides in Indian food products in terms of chemistry, and limits and consequences for food business operators. It is worth mentioning that Indian agrichemicals market, which was stood at 641 million $ in 2000, is currently poised at over 2.5 billion $ (Kaki 2015).

1.2 Chemistry of Insecticides

1.2.1 Definitions

A substance used for reducing or controlling insect/pest populations is called insecticide or pesticide. The elimination of insect populations is mainly required for disease prevention, crop protection, wood/paper/cloth preservation and people/animals injury reduction. Insecticides and pesticides are broadly defined as follows (Carter 1976): '*Insecticides and pesticides are the substances used to kill insects and pests or affect their life cycle to reduce and control their populations*'.

Insecticides and pesticides are well known for contributing to agricultural yield safety and chronic contagion control and, at the same time, for environmental pollution. These substances are normally classified by (a) the selective toxic effect, or (b) the way to target a particular insect, or (c) the chemical structure, or (d) the toxicity level or the health hazards for humans.

At present, environmentalists worldwide suggest alternative insect-control techniques (Agriculture Census 2016):

(a) Physical control (infested parts of vegetables have to be destroyed/removed)
(b) Cultural control (after harvest operations, remaining insects have to be eliminated with profound ploughing; in addition, sowing times can be defined preventively with the aim of reducing insect incidence)
(c) Biological control (natural enemies of crop insects can be favoured).

On the other hand, Indian farmers still prefer chemical control techniques to protect crops from the attack of insects and pests due to immediate action. Insecticides are popularly known as crop protection chemicals in India and applied in farms with proper equipment. From the agricultural viewpoint, an appropriate definition of insecticides and pesticides is as follows (Carter 1976): '*Insecticides and pesticides are crop protection chemicals applied to control different insects-pests as dusts, sprays or granules on the crops and/or incorporated into the soil for the control of soil-inhabiting insects*'.

The toxic action of pesticides, mostly organic molecules that are released intentionally in the environment against pests and different disease agents, has been recently described (WHO-UNEP 1990).

1.2.2 Chemical Structures of Insecticides

Insecticides belong to both categories of chemicals: inorganic and organic substances. Nowadays, inorganic insecticides—arsenicals, fluorosilicates, hydrogen cyanide, hydrogen phosphide, bromides, etc., are not much used in India. However, hydrogen cyanide (HCN) occurs in crops as natural toxin. At the same time, agricultural scientists feel that arsenicals could be advantageously used against leaf-feeding insects, particularly parasites or predators. The Food Safety and Standards Regulation (FSSR) 2011 permits MRL of 37.5 and 25 ppm in food grains for HCN and inorganic bromide, respectively. At the same time, FSSR 2011 does not permit hydrogen phosphide even in residual traces (FSSR 2011). Among the organic insecticides, there are a few substances of bacterial and plant origin: nicotine sulphate, pyrethrins, rotenone, etc., as well as a large number of synthetic insecticides. Organic insecticides are categorised as hydrocarbons, organo-nonmetallics and organometallics.

In general, organo-nonmetallic insecticides include organophosphorus and organosulphur compounds, while organometallic insecticides include mercury, tin, copper and zinc compounds. The FSSR 2011 permits 148 insecticide residues with prescribed MRL or tolerance limits for particular food articles. However, it also mentions hydrogen phosphide with nil tolerance limit (FSSR 2011).

Organic insecticides, extensively used for crop protection, cover the wide range of chemical structures, including hydrocarbons, carboxylic acid derivatives, alcohols, aldehydes, ketones, amines, nitro compounds, quinones, thiocyanates, mercaptans, heterocyclic compounds, etc. However, a four-class subdivision may be proposed: organochlorines, organophosphorus, carbamates and pyrethrins/pyrethroids (Buchel 1983), despite a wide range of chemical structures.

1.2.2.1 Organochlorides

The first important synthetic organic insecticide, DDT, was synthesised by the German scientist Ziedler in 1873 (Kroschwitz 1998). The Swiss scientist Paul Muller first noticed its insecticidal property in 1939. It was obviously the first discovered organochlorine insecticide and the first synthetic organic insecticide to be used in crop protection and contagion controls: this compound was hailed as a miracle for its broad-spectrum activity, low cost, and easy use (Kenneth 1992).

Organochlorine insecticides with four or more chlorine atoms are known for disrupting nervous system of insects and thus paralysing them. On the other side, they are resistant to chemical and microbial degradation; therefore, these compounds remain in the environment for a long time and adversely affect biodiversity and public health (Kumar and Kumar 2007). Two of the most important organochlorine insecticides, with prevalent name and molecular formula/structures are shown in Figs. 1.1 (DDT) and 1.2 (dieldrin).

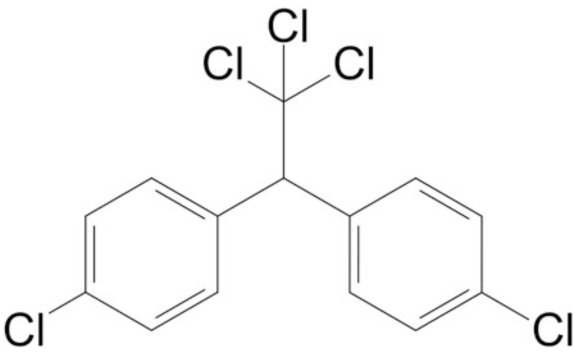


Fig. 1.1 The molecular structure of *p′,p′*-dichlorodiphenyltrichloroethane (DDT). BKchem version 0.13.0, 2009 (http://bkchem.zirael.org/index.html) has been used for drawing this structure

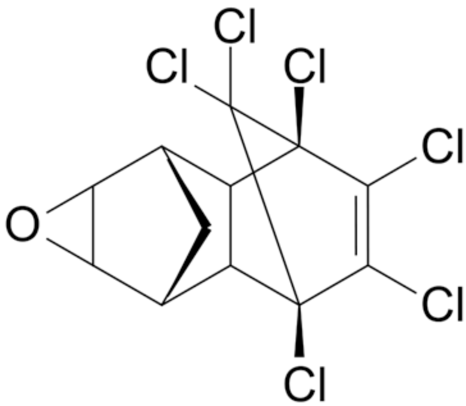


Fig. 1.2 The molecular structure of the insecticide dieldrin, also named 1,2,3,4,10,10-hexachloro-6,7-epoxy-1,4,4α,5,6,7,8,8α-octahydro-1,4-endo,exo-5,8-dimethanonaphthalene. BK chem version 0.13.0, 2009 (http://bkchem.zirael.org/index.html) has been used for drawing this structure

1.2.2.2 Organophosphorus Insecticides

Since 1968, when Martin stated that unlike organochlorines, organophosphorus insecticides are easily decomposed in the environment by various chemical and biological reactions (Martin 1968), the latter have been much more used for crop protection. The structural formula for organophosphorus insecticides, as initially proposed by Schrader, is shown in Fig. 1.3, where R_1 and R_2 substituents are usually alkyl groups (particularly methyl or ethyl groups), alkoxy, alkylthio or amino groups, whereas X might be an aliphatic, homo- or heterocyclic substituent. The basic formula may be partially modified as shown in Fig. 1.4 (Festa and Schmidt 1982), where the X group is one of the following substituents: halides,

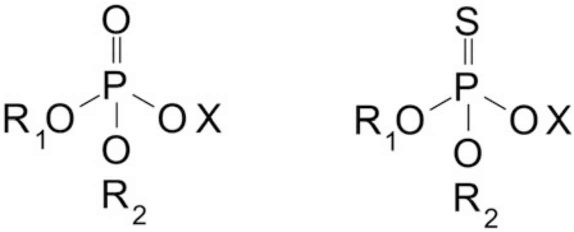


Fig. 1.3 The structural formula for organophosphorus insecticides, as initially proposed by Schrader. R_1 and R_2 substituents are usually alkyl, alkoxy, alkylthio or amino groups, whereas X might be an aliphatic, homo- or heterocyclic substituent. BKchem version 0.13.0, 2009 (http://bkchem.zirael.org/index.html) has been used for drawing this structure

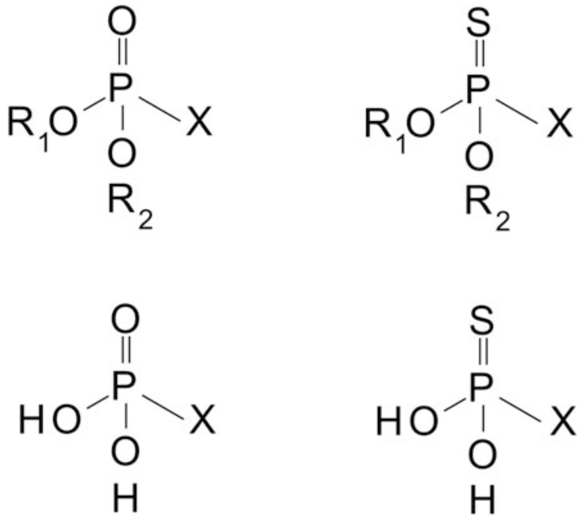


Fig. 1.4 The structural formula for organophosphorus insecticides, as proposed by Schrader and modified by Festa and Schmidt. R_1 and R_2 substituents are usually alkyl, alkoxy, alkylthio or amino groups. R_1 and R_2 can be also replaced by hydrogen atoms. This figure displays four possibilities only. BKchem version 0.13.0, 2009 (http://bkchem.zirael.org/index.html) has been used for drawing this structure

cyano, phenolic, aryloxy, etc. Some of the extensively used organophosphorus insecticides with prevalent name and molecular formula/structures are also displayed in Figs. 1.5 (malathion) and 1.6 (glyphosate).

1.2.2.3 Carbamates

Carbamates are used because of their high insect toxicity as a result of cholinesterase inhibition. At the same time, these insecticides inhibit cholinesterase in humans and other mammalians. Drum stated in 1980 that the cholinesterase inhibition of carbamates differ from that of organophosphorus insecticides because of their species specificity and reversibility (Drum 1980). The word 'carbamate' stands for an ester formed by an alcohol, general formula: ROH, and carbamic acid, usual formulas:

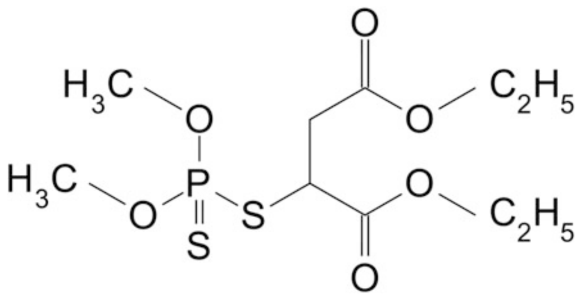


Fig. 1.5 The molecular structure of malathion, also named *S*-1,2-bis (ethoxycarbonyl) ethyl-*O,O*-dimethylphosphorodithioate. BKchem version 0.13.0, 2009 (http://bkchem.zirael.org/index.html) has been used for drawing this structure

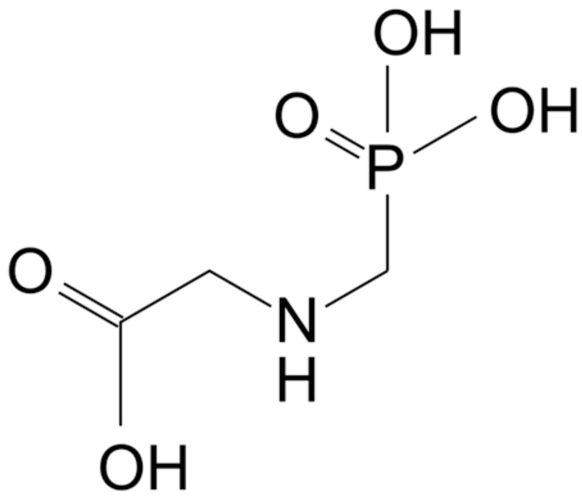


Fig. 1.6 The molecular structure of glyphosate. BKchem version 0.13.0, 2009 (http://bkchem.zirael.org/index.html) has been used for drawing this structure

NH_2COOH or NR_1R_2COOH (R_1 and R_2 are different substituents). The general structure for carbamates insecticides with R_1 and R_2 groups is shown in Fig. 1.7.

1.2.2.4 Pyrethrins and Pyrethroids

Pyrethrins I and II are two of the six naturally occurring, main insecticidally active ingredients of pyrethrum flowers (botanical names: *Chrysanthemum cinerariae-folium*, *C. coccineum* and *C. mashalli;* localisation: Africa, India and southern Europe). Pyrethrum flowers are also known as Persian insect flowers, because it is said that Persians (Iranians) initiated their use in killing insects. Pyrethrins I and II, cinerins I and II, and jasmolins I and II are the primary ingredients of pyrethrum flowers having insecticidal property. The molecular structure of one of these molecules, pyrethrin I, is shown in Fig. 1.8.

The FSSR 2011 of India considers collectively the term 'pyrethrins' (with relation to tolerance limits in food articles) as the sum of pyrethrins I and II and other structurally related insecticide ingredients of pyrethrum. In other terms, the

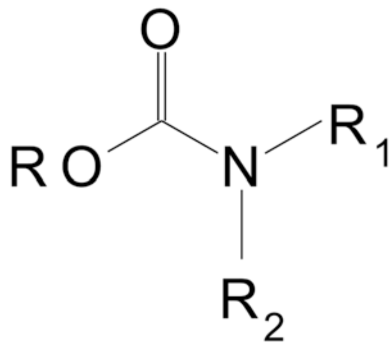


Fig. 1.7 The general structure for carbamates. R_1 and R2 are different groups. BKchem version 0.13.0, 2009 (http://bkchem.zirael.org/index.html) has been used for drawing this structure

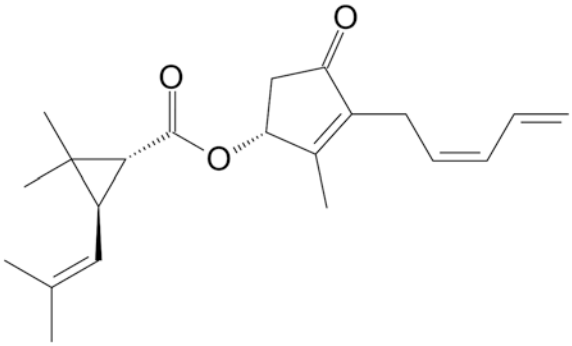


Fig. 1.8 The molecular structure of pyrethrin I, also known as the pyrethrolone ester of chrysanthemum monocarboxylic acid. BKchem version 0.13.0, 2009 (http://bkchem.zirael.org/index.html) has been used for drawing this structure

term ‘pyrethrins’ is tacitly referred to all the six insecticidally active pyrethrum ingredients. Pyrethrins have replaced organophosphorus and organochlorines insecticides to a great extent due to their considerable insect killing property as well as their low toxicity for humans and other mammalians. In addition, it has to be observed that pyrethrins can aggravate pre-existing asthma in humans if these substances are not handled properly by the user, in particular when related concentration is 0.2 % or more, even in shampoos (Wagner 2000).

Pyrethroids are the synthetic analogues of pyrethrums and are obtained mostly by:

(a) The introduction of a phenolic group, and
(b) The substitution of some hydrogen atoms with halogens, and/or cyanide groups, and
(c) The modification (increase or decrease) of the chrysanthemic or pyrethroic structural chain.

The molecular structure of one of these prominent pyrethroid insecticides, permethrin, is displayed in Fig. 1.9.

Pyrethroids, similar to naturally occurring pyrethrum insecticide compounds, are well known for effective insect killing properties. However, differently from pyrethrins, they are susceptible to photochemical degradation (Linde 1994). Therefore,

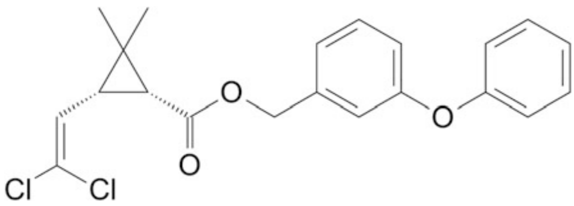


Fig. 1.9 The molecular structure of an important pyrethroid insecticide, permethrin. BKchem version 0.13.0, 2009 (http://bkchem.zirael.org/index.html) has been used for drawing this structure

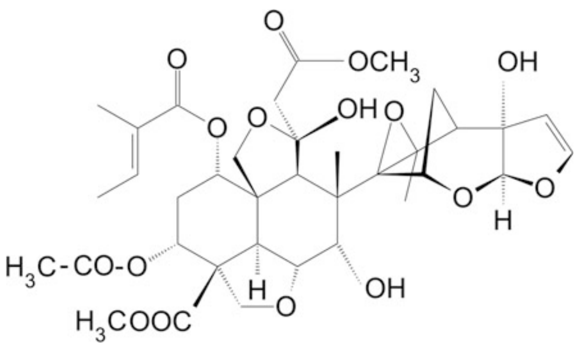
the real advantage of pyrethroids is that those are more effective insecticides than pyrethrins when speaking of farm application or crop protection. On the other side, their limitation is correlated with safety consequences (they are not as safe for the environment as pyrethrins are).

1.2.2.5 Miscellaneous Groups

Although organochlorines, organophosphorus, carbamates, pyrethrins and pyrethroids are the most extensively used organic insecticides for crop protection and contagion control applications, a wide range of peculiar substances such as phenoxyacetic acid, bipyridyls, tetranortriterpenoids, etc., are still considered in this ambit.

In particular, azadirachtin (Fig. 1.10) is an interesting insecticidal compound: it is extracted from *neem* (an Indian tree, Sect. 1.1) seeds. It has an oxidised tetranortriterpenoid molecular structure (Veitch et al. 2007) which includes enol ether, acetal, hemiacetal and tetra-substituted oxirane groups as well as a variety of carboxylic acid. With relation to natural insecticidal characteristics of *neem* tree seeds, it is the most distinguished example of oxygen functionalism. It is worth mentioning that Indian farmers have been applying *neem* leaf juice and *neem* seed extracts since centuries for crop protection. Azadirachtin is considered as very effective insecticide as well as safe for the environment.

Fig. 1.10 The molecular structure of azadirachtin. BKchem version 0.13.0, 2009 (http://bkchem.zirael.org/index.html) has been used for drawing this structure



1.3 Toxicity of Selected Insecticides

The toxicity of insecticides is not only considered in context of its efficacy to kill the targeted insects which affect farm crop and public health, but also in relation to safety concerns for the biosphere, particularly humans and other mammalians, or the entire environment.

For determining toxicity value of an insecticide, test animals such as rats, mice, or rabbits are employed. The calculated lethal dosage (LD_{50}) is defined as the amount of insecticide at which 50 % of test animals expire. LD_{50} is expressed as insecticide dosage in milligrams per kilogram of body weight (of test animals).

A perusal of LD_{50} data of different insecticides leads to conclude that natural insecticides pyrethrins and azadirachtin are safe for mammals including humans, as compared to synthetic insecticides. At the same time, the comparison between LD_{50} values of two natural insecticides shows that azadirachtin is safer than pyrethrins and practically non-toxic to mammals. Azadirachtin is known for feeding inhibition activity towards over 200 insect species including S*chistocerca gregaria* (locust) and *S. littoralis* (Butterworth and Morgan 1968). A low LD_{50} value—15 mg/kg—has been recently reported (Boeke et al. 2004). It may be assumed that azadirachtin is safe for the entire biosphere, while pyrethrins are highly toxic for fish species such as trouts with LD_{50} values of 14 mg/kg (Coats et al. 1989).

1.4 Limits of Insecticides in Indian Food

Names of 149 insecticides are enlisted for protection of particular foods within the prescribed tolerance limits in the FSSR, 2011, Sect. 2.3: Residues. In detail, the FSSR states clearly, with relation to restriction on the use of insecticides (Sect. 2.3.1), that:

(a) Insecticides cannot be used directly on articles of food; however, this declaration does not concern '*fumigants which are registered and recommended for use as such on articles of food by the Registration Committee, constituted under section 5 of the Insecticides Act, 1968 (46 of 1968)*'
(b) Anyway, mentioned insecticides (annexed Table to Sect. 2.3) cannot exceed prescribed tolerance limits in relation to cited foods.

The interested reader is invited to consult the FSSR 2011, Sect. 2.3 (Residues). For example purposes, it can be noted here that:

1. Insecticides aldrin and dieldrin (related values are expressed as dieldrin as single molecules or in combination) have different tolerance limits as mg/kg or ppm depending on foods. As an example, these values can be 0.01 mg/kg in food grains or 0.2 mg/kg in eggs.
2. Carbaryl is not allowed in milled food grains (tolerance limit: nil), while it could be permitted in okra and leafy vegetables up to 10.0 mg/kg.

1.5 Consequences for Food Business Operators

The Food Safety and Standards Act 2006 of India, Chap. 3—General Principles of Food Safety—part 3, states clearly that '*the provisions of the Act shall not apply to any farmer or fisherman or farming operations or crops or livestock or agriculture, and supplies by a farmer at farm level or fisherman in his operations*'. This statement of the Act should be discussed thoroughly when speaking of food safety. The procurement of safe raw material is quite essential for the production of a safe processed food article. For example, synthetic insecticides are used in farms where law of insecticide limitation is not applied. Consequently, the question obviously concerns the penalisation of a food business operator (FBO) with relation to the detection of insecticides above tolerance limits in his or her processed food article(s).

The Indian FBO have to face consequences for procurement of raw material indigenously grown in farms if found to exceed the prescribed insecticide tolerance limit or MRL mentioned in the FSSR 2011. This does not mean that Indian agricultural products contain high amount of insecticides. India is one of the countries which adhere to the Codex Alimentarius—International Food Standards (http://www.fao.org/fao-who-codexalimentarius/en/) with different aims, including the definition of MRL for insecticides. FSSR 2011 does not allow the presence of many insecticides like chlorpyriphos, cypermethrin, diazinon, dichlorvos, ethion, malathion, parathion phorate and phosalone in spices (FSSR 2011); India maintains normally insecticide amounts in foods much below Codex MRL. On the other side, European and other Western countries like United States of America and Canada are capable of keeping insecticide MRL in agricultural produce—due to cost-effective organic farming followed by dense forestations—even lower than India. This situation offers a tough challenge to Indian food exports, with particular reference to traditional spices. India is well known for the high quality of exported spices. Under the supervision of Spices Board in India, selective organic farming without use of synthetic insecticides is carried out for growing spices. However, Indian spices consignments still have to face some rejections at EU borders. As a consequence, India needs dense mountain forestation and cost-effective organic farming; fortunately, naturally grown *neem* tree insecticide products are abundant in the country.

References

Agriculture Census. All India Report on Input Survey 2011–12. Agriculture Census Division, Department of Agriculture, Cooperation and Farmers Welfare, Ministry of Agriculture and Farmers Welfare, New Delhi; 2016.

Boeke SJ, Boersma MG, Alink GM, van Loon JJ, van Huis A, Dicke M, Rietjens IM. Safety evaluation of neem (Azadirachta indica) derived pesticides. J Ethnopharmacol. 2004;94(1): 25–41. doi:10.1016/j.jep.2004.05.011.

Buchel KH. Chemistry of pesticides. New York: Wiley; 1983. p. 270–1.

Butterworth JH, Morgan ED. Isolation of a substance that suppresses feeding in locusts. Chem Commun (London). 1968;1:23–4. doi:10.1039/C19680000023.

Carter LJ. Pest control: NAS panel warns of possible technological breakdown. Science. 1976;191 (4229):836–7. doi:10.1126/science.191.4229.836.

Coats JR, Symonik DM, Bradbury SP, Dyer SD, Timson LK, Atchison GJ. Toxicology of synthetic pyrethroids in aquatic organisms: an overview. Environ Toxicol Chem. 1989;8 (8):671–9. doi:10.1002/etc.5620080805.

Drum C. Soil chemistry of pesticides. Pittsburgh: PPG Industries Inc; 1980.

Festa C, Schmidt KJ. The chemistry of organophosphorus pesticides. Berlin: Springer; 1982.

FSSR. Food Safety and Standards (contaminants, toxins and residues) Regulations, 2011 F. No. 2-15015/30/2010. Gazette of India 1st Aug 2011. Available http://www.fssai.gov.in.

Kaki AH. India has a great Potential for New Gen Agrochemicals. Business of Agriculture 22–23 Mar–Apr 2015. Available http://www.businessofagriculture.com/. Accessed 07 July 2016.

Kenneth M. The DDT story. Farnham: The British Crop Protection Council; 1992.

Kroschwitz JI, editor. Kirk-Othmer encyclopedia of chemical technology. 4th ed. New York: Wiley; 1998.

Kumar M, Kumar A. Application and health effects of pesticides commonly used in India. ECO Services International. 2007. http://www.eco-web.com/edi/070526.html. Accessed 04 July 2016.

Linde CD (1994) Physico-chemical properties and environmental fate of pesticides. Environmental hazards assessment program, p. 53. Environmental Protection Agency, Washington.

Martin H. Pesticides manual: basic information on the chemicals used as active components of pesticides. 1st ed. Farnham: The British Crop Protection Council; 1968.

Veitch GE, Beckmann E, Burke BJ, Boyer A, Maslen SL, Ley SV. Synthesis of azadirachtin: a long but successful journey. Angew Chem Int Ed Engl. 2007;46(40):7629–32. doi:10.1002/anie.200703027/abstract;jsessionid=E1D8534A72D3582876C4345F9A1C898C.f04t01.

WHO-UNEP. Public health impact of pesticides used in agriculture. World Health organization (WHO) and United Nations Environment Programme (UNEP). World Health Organization, Geneva; 1990.

Wagner SL. Fatal asthma in a child after use of an animal shampoo containing pyrethrin. West J Med. 2000;173(2):86–7.

Chapter 2
Aflatoxins in Indian Food Products

Abstract Hepatitis cases have been reported in India in the past due to consumption of food contaminated by some aflatoxin, a mycotoxin produced by *Aspergillus flavus* and generally developed in food articles grown and/or stored in hot and moist environment. The main target organ of hepatic disease, caused by regular consumption of aflatoxin-contaminated foods, is liver which may suffer from jaundice and cancer in later stages. Milk is an ideal food for such patients provided it is free from aflatoxins. The Indian Food Safety and Standards Regulation, 2011 enlists aflatoxins among crop contaminants and naturally occurring toxins. In the European Union, food regulation ascertains much lower values for maximum aflatoxin contents in food articles than that the Indian food low does. Indian food business operators seldom have to face consequences due to high aflatoxin contents, particularly in samples of exported goods, despite the fact that detoxification (removal of aflatoxins from foods) to some extent is possible.

Keywords Aflatoxin · Aspergillus · Crop contaminant · Detoxification · Food rejection · Moist storage · Mycotoxin

Abbreviations

AAA	Aromatic amino acid
BCAA	Branched-chain amino acid
DNA	Deoxyribonucleic acid
EU	European Union
FBO	Food business operator
FSSAI	Food Safety and Standards Authority of India
ICRISAT	International Crop Research Institute for the Semi-Arid Tropics
IUPAC	International Union of Pure and Applied Chemistry
mRNA	Messenger ribonucleic acid
ppb	Part per billion
ppm	Part per million
U.S. FDA	United States Food and Drug Administration

R.K. Sharma and S. Parisi, *Toxins and Contaminants in Indian Food Products*,
DOI 10.1007/978-3-319-48049-7_2

2.1 Introduction

In 1974, the people of India came across to recognise hepatitis as a result of the consumption of maize contaminated with *Aspergillus flavus*. The outbreak of disease, lasted for 2 months, was confined to the Western Indian tribal population belonging to Banswada district of Rajasthan and Panchmahals district of Gujarat. The people suddenly began to show the symptoms of ascites and oedema of lower limbs and portal hypertensions. Hepatitis was reported in 200 villages confirming 106 deaths. The analysis of contaminated maize samples showed that the diet of affected people contained the fungus *A. flavus* in the range of 6.25–15.6 parts per million (ppm). This result means affected people might had consumed 2000–6000 μg/kg or parts per billion (ppb) of aflatoxins, daily over a period of 1 month (Krishnamachari et al. 1975). Tandon, Krishnamurthy and coworkers presumed that an epidemic of jaundice in north-Western India (1974) was also due to toxic hepatitis which affected both humans and dogs (Tandon et al. 1977). However, the word 'aflatoxicosis' had appeared in public news domain of India in the 1960s with reference to the sudden death of 2219 chicks in poultry farms of Mysore and other parts of Karnataka state (Gopal et al. 1969). In October, 1985, the egg production dropped from 85 to 40 % in and around Warangal in Andhra Pradesh, as impact of severe aflatoxicosis in poultry; this outbreak gradually increased when bird mortality rate decreased sharply after the feed—maize and groundnut cake, contaminated by aflatoxin—was changed (Sastry et al. 1965). The *post-mortem* examination of dead birds revealed liver lesions while aflatoxin content in feed samples was detected to be 600 ppb (Choudary 1986). In 1994, more than 0.2 million broiler chicken died in Ranga Reddy district of Andhra Pradesh after eating aflatoxin-contaminated groundnut cake feed. The International Crop Research Institute for the Semi-Arid Tropics (ICRISAT) revealed this fact (ICRISAT 2002). That conclusion means that the establishment of aflatoxin-disease correlation is till to date a challenging task, despite innovative laboratory testing procedures. In fact, the diagnosis of aflatoxicosis—like other mycotoxicoses—is difficult due to its symptoms being similar to those of diseases with other causes as well as presence of several mycotoxins along with aflatoxins in foods or feeds which synergise effects.

It may be remembered that the name 'aflatoxin' was first created around 1960 when it was discovered that the source of Turkey X—an avian disease spread in Great Britain—was an *A. flavus* toxin (Wannop 1961). The toxic material was extracted from it and chromatographically separated into four distinct compounds based on fluorescent colour—B for blue and G for green—with scripts relating to relative mobility in early 1960s (Nesbitt et al. 1962; Sargeant et al. 1963); two forms B_1 and G_1 were synthesised in late 1960s and early 1970s (Buechi and Weinreb 1971). The first reliable correlation between aflatoxin contamination and hepatomegaly among the children of Canara district of Karnataka in India was reported in mid-1970s (Sreenivasmurthy 1977). Despite several limitations of symptom distinction and co-mycotoxins' synergy effects, Sreenivasmurthy's studies of the correlation aflatoxin–hepatomegaly are till to date considered worthy when a hepatitis, is likely to be named 'aflatoxicosis.' On the other hand, the scientific knowledge of aflatoxin development in farm produce is extremely clear. Reddy and Raghavender report that adequate food monitoring programs are needed with relation to the possible occurrence of mycotoxins in notable amounts, because related outbreaks continue to be signalled in India (Reddy and Raghavender 2007).

It is worth mentioning that the prevention of mycotoxin contamination in farm yields is progressively becoming tougher worldwide due to global warming and flash floods. India is called the land of climatic contrasts with temperatures shot up to 50 °C in certain parts of Rajasthan and south-west Punjab in hot summer afternoon as well as dipped up to −40 °C in cold arid region of Cargill in severe winter night. Therefore, global warming and flash floods in India can determine the fast development of aflatoxins in food articles. Fast deforestation gives rise to adverse environmental conditions that affect farm produce in both pre-harvest and postharvest stages; therefore, Food business operators (FBO) in India have to face consequences as export consignment rejections and credibility loss.

2.2 Chemistry of Aflatoxins

2.2.1 The Aflatoxin/Foodborne Diseases Correlation

With relation to intoxications and infections, there are basically two types of food-borne diseases. Intoxications are food-borne diseases caused by the consumption of intoxicants like:

(a) Synthetic insecticides (chemicals) sprayed in farms, or
(b) Naturally poisonous plant or animal tissues, or
(c) Metabolic toxic products formed by bacteria, algae and fungi.

On the other hand, infections are caused by the enterotoxigenic or invasive penetration of pathogenic microorganisms into the body, via foods, and the consequent production of mycotoxins. Aflatoxins are mycotoxins produced by *A. flavus* and *A. parasiticus* species of fungi which colonise and contaminate crops before harvest or during storage in generally hot and moist environments. Host crops for these fungi species include maize, sorghum, groundnut, rice, wheat, cassava, pistachio, cashew, almond, cottonseed, turmeric, chilli, peppers and even the cattle fodder. Aflatoxin can enter in form of feed in cattle farms or dairies too if made from affected fodder and oil seed cakes (ground nut, cottonseed, etc.). Should animals graze aflatoxin-contaminated feed, obviously they would produce milk containing a different form of aflatoxin as the result of the metabolisation of the original molecule in the consumed feed. Eggs and other poultry products can be contaminated in the same way with aflatoxins when birds consume such kind of affected grains.

The disease can be observed in humans and animals, including birds, due to the consumption of aflatoxin-contaminated foods or feeds: this disease is called aflatoxicosis. It is worth mentioning that the presence of *Aspergillus* fungi does not always indicate harmful levels of aflatoxins. Actually, this contamination might be safe to some extent if present in minor amount, but the consumption of *Aspergillus*-contaminated food or feed is always risky (Hudler 1998). Aflatoxins are heterocyclic compounds and exert toxic effects after consumption in the body within several ways. High-level aflatoxin consumption can give rise to hepatic necrosis, resulting later in cirrhosis or carcinoma of the liver. Generally, the patient might be in very serious condition in absence of cures at early stages: consequences might lead the subject to coma and even death. It has been observed that adult humans can tolerate these mycotoxins with low consequences, while children may suffer serious damages and animals are not so resistant (Abbas 2005; Williams et al. 2004). Aflatoxins are among the most carcinogenic substances known (Hudler 1998).

2.2.2 Types of Aflatoxins

20 fungal metabolites are known: at least 14 of these compounds are mostly studied as typical aflatoxins. Only six of these molecules—aflatoxins B_1, B_2, G_1, G_2, M_1 and M_2 are normally found in foods.

The most toxic among all types, aflatoxin B_1, is produced by both *A. flavus* and *A. parasiticus*. The same thing can be affirmed for aflatoxin B_2, the dihydro-derivative of aflatoxin B_1. Aflatoxins G_1 and G_2 (the last compound is the dihydro-derivative of the G_1 type) are produced by *A. parasiticus*. Aflatoxin M_1 is the metabolite of aflatoxin B_1 in human and animal milk; the type M_2—the metabolite of aflatoxin B_2—is also found in human and animal milk.

2.2.3 Chemical Structure of Aflatoxins

The chemical structures of three of the six major aflatoxins are shown in Figs. 2.1, 2.2 and 2.3 with relation to aflatoxins B_1, G_1 and $M_{1,}$ respectively. The following list shows basic properties of above-mentioned six aflatoxins:

(a) Aflatoxin B_1 (Fig. 2.1). This compound[1]exhibits blue fluorescence; crystals have melting points between 268 and 269 °C (letter B)
(b) Aflatoxin B_2. Its crystals have melting points between 286 and 289 °C. The compound[2] exhibits blue fluorescence

[1]International Union of Pure and Applied Chemistry (IUPAC) name: (6aR-*cis*)-2, 3, 6a, 9a-tetrahydro-4-methoxycyclopanta(c)furo[3′, 2′; 4, 5] furo[2, 3-h] [1] benzopyran-1,11-dione.

[2]IUPAC designation: (6aR-*cis*)-2, 3, 6a, 8, 9, 9a-hexahydro-4-methoxycylopenta (c) furo [3′, 2′; 4, 5] furo [2, 3-h] [1] benzopyran-1,11-dione.

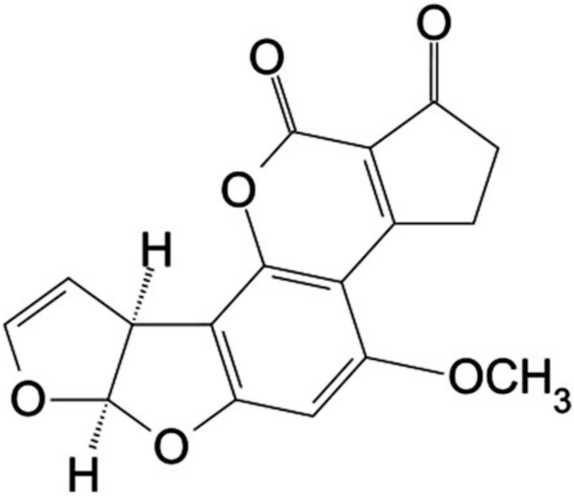


Fig. 2.1 The chemical structure of aflatoxin B_1. BKchem version 0.13.0, 2009 (http://bkchem.zirael.org/index.html) has been used for drawing this structure

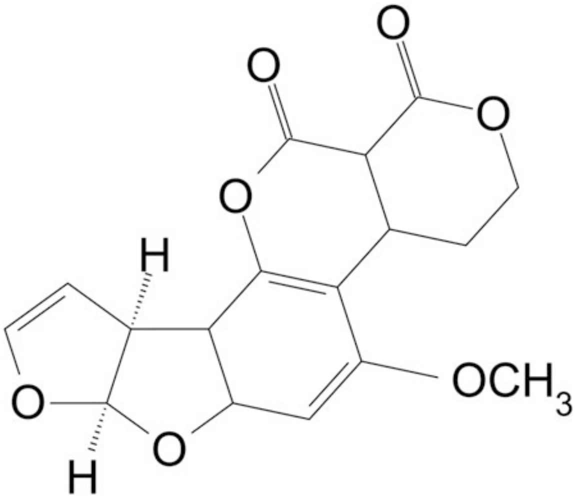


Fig. 2.2 The chemical structure of aflatoxin G_1. BKchem version 0.13.0, 2009 (http://bkchem.zirael.org/index.html) has been used for drawing this structure

(c) Aflatoxin G_1 (Fig. 2.2). Crystals have melting points between 244 and 246 °C. The compound[3] exhibits green fluorescence (letter G)
(d) Aflatoxin G_2. The compound[4] exhibits green-blue fluorescence. Its crystals have melting points between 237 and 240 °C

[3]IUPAC name: 3, 4, 7aα, 10aα-tetrahydro-5-methoxy-1*H*,12*H*-furo[3′, 2′; 4, 5]furo[2, 3-h]pyrano [3, 4-c] (1) benzopyran-1,12 dione.

[4]IUPAC designation: 3, 4, 7aα9, 10, 10aα-hexahydro-5–methoxy-1H, 12*H*–furo[3′, 2′: 4, 5]furo [2, 3-h] pyrano [3, 4-c] [1] benzopyran–1, 12-dione.

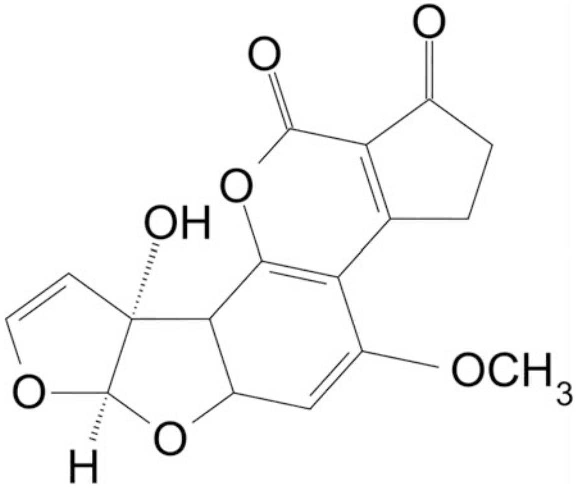


Fig. 2.3 The chemical structure of aflatoxin M_1. BKchem version 0.13.0, 2009 (http://bkchem.zirael.org/index.html) has been used for drawing this structure

(e) Aflatoxin M_1 (Fig. 2.3). The compound[5] exhibits blue–violet fluorescence. It is found in milk; consequently, the affix 'M' exists in its name. Crystals of aflatoxin M_1 have melting point: 299 °C

(f) Aflatoxin M_2. Its crystals have melting point: 293 °C. This compound[6] exhibits violet fluorescence.

2.2.4 Physiological Actions of Aflatoxins

Aflatoxicosis is primarily a hepatic disease: as a result, its main target organ in humans and other mammals is liver. In other words, aflatoxins are capable of developing liver diseases in mammals including humans. The liver, found in front of the stomach at the top of the abdominal cavity, is the vital organ that tends to protect body from several poisons, insecticides and environmental pollutants. The main function of liver is the transformation of these harmful chemicals into harmless or less harmful products that can be removed from the body in bile or urine. It also removes food particles and microbial products from blood coming from intestines. A well-functioning liver is characterized by a normal pattern of amino acids circulation with the balanced concentrations of branched-chain amino acids (leucine, isoleucine and valine) and aromatic amino acids (phenylalanine, tyrosine and tryptophan) leading to the production of true neurotransmitters. When

[5]IUPAC name: 2, 3, 6a 9a–tetrahydro—9a hydroxy–4–methoxycyclopenta[c] furo [3′, 2′ :4, 5] furo [2,3-h] [1] benzopyran–1,11–dione.

[6]IUPAC designation: 2, 3, 6a, 8, 9, 9a hexahydro–9a–hydroxy–4- methoxycyclopenta[c] furo [3,′ 2′: 4, 5] furo [2, 3—h] [1] benzopyran–1, 12–dione.

food-containing toxic substances are consumed beyond tolerance limits, the person might suffer from chronic liver disease, called hepatic disease or hepatitis. The patients with chronic liver disease are likely to be intolerant with relation to enteral proteins. Therefore, the balance between branched-chain amino acids (BCAA) and aromatic amino acids (AAA) is disturbed, with decrease in BCAA concentration and increase of AAA amount, in the case of hepatic disease. In other words, BCAA/AAA ratio falls in patients with hepatic encephalopathy with the production of false neurotransmitters. Commercial enteral nutrition products formulated for patients with chronic liver disease have low levels of total proteins, high BCAA concentrations and low AAA amounts (Alpers et al. 2002).

The high-level aflatoxin intake initially produces an acute hepatic necrosis which later on results in cirrhosis or carcinoma of the liver. Bleeding, oedema and mental changes are the common symptoms of acute liver failure. In the later stage, the patient might suffer from jaundice and subsequently liver cancer if BCAA/AAA ratio is not timely maintained along with reduction of protein contents. The prolonged exposure of aflatoxin may lead to the increased degradation of heme (the part of hemoglobin of blood) into bilirubin (the pigment of bile) and cause jaundice. It is worth mentioning that bilirubin—the major end-product of biological breakdown of heme—is the chromophore responsible for colouration in various forms of jaundice; should it exceed limit exposure, high risk of developing liver cancer should be expected, as aflatoxin metabolites may intercalate into deoxyribonucleic acid (DNA) and alkylate bases through epoxide moiety. Probably, this is the cause for mutations in the p–53 gene (Aguilar et al. 1993).

With concern to foods for liver-disease patients, these products should necessarily be rich in BCAA, but the amount of total proteins should be relatively low. Furthermore, taken meals should release less carbon dioxide per calorie. This reflection means fat/carbohydrate ratio should relatively be higher, with high water contents. Such a naturally available wonder food is milk.

Cow milk normally contains 86.5 % of water, 3.4 % of proteins, 0.7 % of ash, 3.0–4.6 % of fat matter, and the remaining 4.8–6.4 % of lactose. However, needless to say that milk given to patient should be almost free from or quite well within prescribed limits for M-type aflatoxins, and the patient should not suffer from lactose intolerance. At this point, it is essential to know toxicity of aflatoxins and its prescribed limits in Indian commodities.

2.3 Toxicity of Aflatoxins

The toxicity of aflatoxins B_1, B_2, G_1 and G_2 is mostly measured as oral LD_{50} (dosage of the toxin at which 50 % of test animals are killed) in μg per 50 grams of body weight (1-day old duckling), while for toxic aflatoxins like M_1 and M_2 it is measured as oral LD_{50} in μg per duckling. Carnaghan, Buchi and Holzapfel have extensively measured LD_{50} measurements with relation to aflatoxins. In general, the most toxic aflatoxins appear to be types B_1 and M_1: LD_{50} are ≤ 18 and 12–16 mg/kg, respectively), while aflatoxin G_2 seems to show very low values if compared with other aflatoxins (Budavari and O'Neil 1989; D'Mello 2003; Westendorf 1999).

2.4 Placement of Aflatoxins in Food Safety and Standards Regulations 2011

2.4.1 Limits of Aflatoxins in Indian Food Commodities

The FSSR 2011 enlists aflatoxins among crop contaminants like patulin and ochratoxin—antibiotics from metabolites of a number of fungi, such as *A. clavatus, A claviforme, A. gigateus, A. sulphureus, Penicillium patulum*—and naturally occurring toxic substances like agaric acid, hydrocyanic acid, hypericin, and safrole (FSSR 2011, The interested Reader is invited to consult the FSSR 2011, Chap 2, Sect. 2). For example purposes, it can be noted here that patulin is allowed in apple juice and apple juice ingredients in other beverages up to 5.0 mg/kg, while aflatoxin M_1 is permitted in milk up to 0.5 mg/kg only.

2.4.2 Chemical Structures of Crop Contaminants and Naturally Occurring Toxins Other Than Aflatoxins

Patulin[7] and ochratoxin A,[8] like aflatoxins, are crop contaminants related to groups of fungal metabolites (Budavari and O'Neil 1989). The former compound (Fig. 2.4) possesses a furo-pyran structure and the latter has a typical benzo-pyran structure. Agaric (or agaricic) acid,[9] hydrocyanic acid, hypericine[10] and safrole[11] (Fig. 2.5) are not crop contaminants, but those exist in flora as naturally occurring constituents with recognised toxicity in nature.

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[7]IUPAC name: 4-hydroxy-44-furo [3, 2-c] pyran -2 (6*H*)-one.

[8]IUPAC designation: (*R*)-*N* [(5-chloro -3, 4-dihydro -8-hydroxy-3-methyl-1-oxo-1*H*-2-benzopyran-7-yl) carbonyl]-*L*-phenylalanine.

[9]IUPAC name: 2-hydroxy-1, 2, 3-nonadecane-tricarboxylic acid.

[10]IUPAC designation: hexahydroxy dimethyl phenanthro perylene dione-
1, 3, 4, 6, 8, 13, - hexahydroxy—10, 11- dimethyl phenan-thro [1, 10, 9, 8—opqra] perylene—7, 14-dione.

[11]IUPAC name: 4-allyl -1, 2 methylene dioxy benzene.

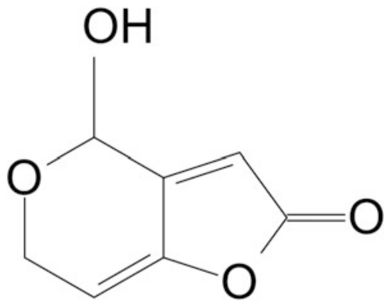

Fig. 2.4 The chemical structure of patulin. BKchem version 0.13.0, 2009 (http://bkchem.zirael.org/index.html) has been used for drawing this structure

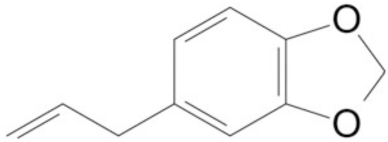

Fig. 2.5 The chemical structure of safrole. BKchem version 0.13.0, 2009 (http://bkchem.zirael.org/index.html) has been used for drawing this structure

2.5 Comparison of Aflatoxin Limits in Indian Food Law with EU Standards

The maximum permissible limit for aflatoxins (B_1, B_2, G_1, G_2, etc.) contents in all food commodities for sale in Indian market is 30 µg/kg or ppb, while the tolerance value for aflatoxins M in milk is 0.5 µg/kg. If these aflatoxins limits in Indian food commodities, as per FSSR 2011, are compared with European Union (EU) standards, the EU regulation looks much more stringent. In detail, EU regulations are considered among the stringiest food laws if compared with Indian regulations and those of other countries, around 100 in number, which have regulations governing aflatoxins in food and feed.

The EU sets limits for aflatoxin B_1 and for total aflatoxins in nuts, dried fruits, cereals and spices. Limits vary according to commodity and range from 2 to 12 µg/kg for B_1 and from 4 to 15 µg/kg for total aflatoxins. There is also a limit of 0.050 µg/kg for aflatoxin B_1 and M_1 in milk and milk products in EU regulations. Maximum aflatoxin B_1 and M_1 limits for infant foods in EU regulations are 0.10 and 0.025 µg/kg, respectively (Lawley 2013).

The EU regulation permits the maximum total aflatoxin contamination limit varying from 4 to 15 µg/kg (general commodities), while total aflatoxin limit for all commodities is 30 µg/kg in India. Therefore, food commodities (with the exclusion of milk), in India may legally have aflatoxin contamination as high as 2–7.5 times that similar food articles in Europe. Indian milk may legally be 10 times more contaminated than EU milk when speaking of aflatoxin M_1 (0.5 versus 0.05 ppb).

2.6 Indian Market Surveys for Aflatoxin Contents in Commodities

Fungi are capable to produce aflatoxins in food commodities in favourable conditions (higher moisture, temperature and adequate substratum). Aflatoxin contamination in food articles in India is observed to be highest when humidity is above 13 % and temperature is between 24 and 37 °C.

The warm and wet sea-shore regions of southern part of India possess the favourable environment for fungal synthesis of aflatoxins in foods. A valuable study was conducted on market samples of food grains, such as Bengal gram, *bajra/cumbu*, maize and *jowar*/sorghum and grain flour procured from Chennai, Tamil Nadu, in the first decade of the twenty-first century with the aim of analysing aflatoxin B_1: recovery percentage for this aflatoxin was reported to be 90 % (Ramesh et al. 2013). In detail, the contamination of aflatoxin B_1 was found to be 68.18 % in food grains whereas 100 % in grain flour. This result might be due to improper postharvest technology and storage conditions; consequently, the assessment of contamination should be improved. Ramesh and co-workers have also reported, on the basis of their own study, that analysed food grains for aflatoxins were within safe limit of Indian and United States Food and Drug Administration (U.S. FDA) standards, except maize, but higher than EU standards (Ramesh et al. 2013).

The surveys of aflatoxin M_1 in commercial milk samples and infant formula milk samples in Goa (in early 2010s) and different parts of India (in mid-2000s) are mostly found to exceed not only EU recommended limits but also Codex Alimentarius, Food Safety and Standards Authority of India (FSSAI) and U.S. FDA recommended limits. Similar results have been published by the ICRISAT with reference to '*Aspergillus* and aflatoxins in groundnuts' and consequent high values in milks. In detail, the ICRISAT has recently revealed that aflatoxin levels in peanuts (area: southern India) may be 40-times higher than allowed limits with relation to Indian permitted levels (Gandhi 2016).

2.7 Consequences for Food Business Operators

The issue of aflatoxins contamination in crops, finished grains and processed foods is often concerned with environmental conditions from pre-harvest to storage steps. The warm humid environment during harvesting in semi-arid tropical zones (and sea shores also) cannot be defined nowadays as a natural event because of the Earth global warming since decades; most probable causes are generally considered deforestation and pollution increase in air and water. The storage step is surely correlated with anthropic activities; therefore, highly elevated levels of aflatoxins in food articles detected in market surveys in India are mainly ascribed to the responsibility of human beings. Although aflatoxin contamination begins to develop in the pre-harvest stage (abnormally hot moist environment), it should be noted that farmers are not responsible for the current weather conditions. The horizontal urbanisation on the original (or natural) forest-pasture tract, particularly on mountains, seems to be the most accountable phenomenon for vast deforestation. Consequently, remarkable temperature augments and a considerable contribution to global warming on a local scale are observed.

FBO have to face the consequences for high aflatoxins contents in samples of both indigenous and exported goods. India has been exporting spices, nuts and grains with difficulty and sometimes facing rejections due to stringent requirements with close limit of aflatoxin contents in food articles. ICRISAT has recently observed the situation in context of both the public health and the business scenario in India (Gandhi 2016):

The dense mountain forestation is the first requirement, in India, to maintain unfavourable conditions for aflatoxin formation in crops. Predictable consequences should obviously lead to agribusiness promotion with reduced export consignment rejections. Second, detoxification of aflatoxin containing foods can perhaps work to some extent in Indian agribusiness improvement. Roasting treatments on certain food articles (example: roasting coffee at 180 °C), γ-radiation treatments of grains, and fermentation processes on milk (for curd or yoghurt productions) are currently employed to partly detoxify *Aspergillus*-contaminated foods with the possible reduction of aflatoxin levels in food articles to 30 % at least (Herzallah et al. 2008).

The solvent extraction for aflatoxins removal is somewhat more effective; however, this process may produce toxic by-products due to the use of polar solvents like alcohols and ketones. Biological decontamination is nowadays considered quite safe to remove aflatoxins. For example, *Flavobacterium aurantiacum* is reported to reduce aflatoxin B_1 amounts in contaminated corns (Khanafari et al. 2007).

References

Abbas HK, editor. Aflatoxin and food safety. Boca Raton: CRC Press; 2005.

Aguilar F, Hussain SP, Cerutti P. Aflatoxin B1 induces the transversion of G– > T in codon 249 of the p53 tumor suppressor gene in human hepatocytes. Proc Natl Acad Sci USA. 1993;90 (18):8586–90.

Alpers DH, Stenson WF, Bier DM. Manual of nutritional therapeutics. 4th ed. Philadelphia: Lippincott Williams & Wilkins; 2002.

Budavari S, O'Neil MJ. The Merck index: an encyclopedia of chemicals, drugs, and biological. 11th ed. Inc, Rahway: Merck & Co.; 1989.

Buechi G, Weinreb SM. Total syntheses of aflatoxins M_1 and G_1 and an improved synthesis of aflatoxin B_1. J Am Chem Soc. 1971;93(3):746–52. doi:10.1021/ja00732a032.

Choudary C. An outbreak of 'fatty liver syndrome' in commercial layer farms. Poult Advis. 1986;19:59–60.

D'Mello JPF (ed). Food safety: contaminants and toxins. Oxon: CABI Publishing; 2003.

Gandhi MS. 'Carcinogens now even in samples considered safest': Maneka Gandhi advises against drinking milk. Firstpost.com; 2016. http://www.firstpost.com/india/carcinogens-now-

even-in-samples-considered-safest-maneka-gandhi-advises-against-drinking-milk-2571542.html. Accessed 04 July 2016.
Gopal T, Zaki S, Narayanaswami M, Premlata S. Aflatoxicosis in fowls'. Indian Vet J. 1969;46: 348–9.
Herzallah S, Alshawabkeh K, Fataftah AA. Aflatoxin decontamination of artificially contaminated feeds by sunlight, γ-radiation, and microwave heating. J Appl Poult Res. 2008;17(4):515–21. doi:10.3382/japr.2007-00107.
Hudler GW. Magical mushrooms, mischievous molds: the remarkable story of the fungus kingdom and its impact on human affairs. Princeton: Princeton University Press; 1998.
ICRISAT. Aflatoxin: a deadly hazard, 1 May, 2002. International Crop Research Institute for the Semi-Arid Tropics (ICRISAT). http://www.icrisat.org/newsroom/news-releases/icrisat-pr-2002-media9.htm. Accessed 05 July 2016.
Khanafari A, Soudi H, Miraboulfathi M. Biocontrol of Aspergillus flavus and aflatoxin B_1 production in corn. J Environ Health Sci Eng. 2007;4(3):163–8.
Krishnamachari KAVR, Bhat RV, Nagarajan V, Tilak TBG. Investigations into an outbreak of hepatitis in parts of Western India. Indian J Med Res. 1975;63(7):1036–48.
Lawley R. Aflatoxins. Food safety watch: the science of safe food. 2013. www.foodsafetywatch.org/factsheets/aflatoxins/. Accessed 05 July 2016.
Nesbitt BF, O'Kelly J, Sargeant K, Sheridan A. Aspergillus Flavus and Turkey X disease: toxic metabolites of aspergillus flavus. Nature. 1962;195:1062–3. doi:10.1038/1951062a0.
Ramesh J, Sarathchandra GV, Sureshkumar V. Survey of market samples of food grains and grain flour for Aflatoxin B1 contamination. Int J Curr Microbiol Appl Sci. 2013;2(5):184–8.
Reddy BN, Raghavender CR. Outbreaks of aflatoxicoses in India. Afr J Food Agric Nutr Dev. 2007;7:5.
Sargeant K, Carnaghan RBA, Allcroft R. Toxic products in groundnuts. Chem Origin Chem Ind (London). 1963; 53.
Sastry GA, Narayana JV, Rama Rao P, Christopher KJ, Hill KR. A report on the groundnut toxicity in Murrah buffaloes in Andhra Pradesh (India). Indian Vet J. 1965;42:79–82.
Sreenivasmurthy V. Mycotoxins in foods—a public health problem. Arogya J Health Sci. 1977;3:4–13.
Tandon BN, Krishnamurthy L, Koshy A, Tandon HD, Ramalingaswami V, Bhandari JR, Mathur MM, Mathur PD. Study of an epidemic of jaundice presumably due to toxic hepatitis in North West India. Gastroenterology. 1977;72(3):488–94.
Wannop CC. The histopathology of turkey "X" disease in Great Britain. Avian Dis. 1961;5 (4):371–81. doi:10.2307/1587768.
Westendorf J. Natural compounds. In: Marquardt H, Schäfer SG, McClellan RO, Welsch F, editors. Toxicology. San Diego and London: Academic Press; 1999.
Williams JH, Phillips TD, Jolly PE, Stiles JK, Jolly CM, Aggarwal D. Human aflatoxicosis in developing countries: a review of toxicology, exposure, potential health consequences, and interventions. Am J Clin Nutr. 2004;80(5):1106–22.

Chapter 3
Botanical Ingredients and Herbs in India. Foods or Drugs?

Abstract Botanical ingredients and herbs have been well known in India for both taste and cure aspects. Despite the fact that herbs and spices bear a toxin load in the forms of synthetic insecticides, fungi, microbial and allergens, the Indian therapy system 'Ayurveda' deals with herbal compositions for cure applications. Herbs and spices have been found to contain antimicrobial compounds. In detail, herbs with lower microbial load exhibit higher antimicrobial property and hence have food preservation concerns. Spices such as cinnamon, cloves, thyme, mustard and garlic are considered as food preservers and taste sources. Other spices such as long pepper, cinnamon, ginger, black pepper and thyme are extensively used in Ayurvedic medicine. Dense forest infrastructure is required in India for an effective soil and water conservation with concern to the elimination or minimisation of synthetic insecticides and aflatoxins in botanical ingredients for culinary and medicinal reliability.

Keywords Allergen · Antimicrobial agent · Ayurvedic medicine · Botanical ingredient · Food preservation · Side effect · Synthetic insecticide

Abbreviations

API	Active pharmaceutical ingredient
FSSR	Food Safety and Standards Regulation
ppm	Part per million

3.1 Introduction

The culinary herbs and spices, and several botanical ingredients used in minute or limited amounts in foods for taste development are also capable to keep body fit or healthy. Otherwise, herbs may turn a consumer uneasy or ill (even with possible fatal consequences) if consumed in large quantities. The entire botanical biosphere or vegetation contains biologically produced toxins: microbial toxins, allergens,

R.K. Sharma and S. Parisi, *Toxins and Contaminants in Indian Food Products*,
DOI 10.1007/978-3-319-48049-7_3

alkaloids, stimulants, depressants, etc. Processed food articles, including packaged herbs and spices, might contain several food additives or processing aids of industrial origin. Of course, herbs and spices prove to be natural substances with food ingredient status. On the other side, the production and commerce of native botanical ingredients and herbs is nowadays very much concerned with technical or analytical details when speaking of toxin contamination.

In general, herbs and spices are worldwide used as food ingredients. It is also possible to declare health, nutrition and risk-reduction claims on the basis of botanical ingredients provided insecticides and fungal toxins are under allowed limits (Chaps. 1 and 2). The biologically produced toxin load of a herb or spice can be very important if considered with the concomitant presence of added insecticides and fungal toxins (aflatoxins, etc.). The safety importance can be increased if herb and spice toxins are regularly consumed in appreciable amounts, or for a longer time, as food ingredient.

Allergic effects of concerned molecules vary from person to person. For example, few people are prone to lactose intolerance and avoid consumption of milk, while some subject prefers to take gluten-free meals and avoid eating wheat flour-based food articles. In the same way, herbs and spices too contain substances including biologically produced toxins; allergic molecules, or stimulant or depressant compounds in nature. With relation to these chemicals, skin allergens should be discussed in detail.

In India, botanical ingredients and herbs, singularly or in mixture, are also used as medicine. Cure aspects of herbs are reported to be quite evident. Ayurveda considered as science of longevity deals with medicine, on the basis of several herbal compositions. In India, herbs are used as taste-source as well as healing medicine. For Ayurveda, six tastes—sweet, sour, salty, pungent, bitter and astringent—have to be defined (Frawley and Lad 1993). These tastes are reduced to three single varieties in their post-digestive effect (called *vipaka*); as a result, sweet, sour and pungent tastes give rise to three physiological stages—*Kapha*, *Pitta* and *Vata*. The knowledge of these stages is considered for Ayurveda the basis of diagnosis and healing (Frawley and Lad 1993). On the other hand, modern medicine utilises herbal extracts and isolated herbal compounds contributing to specific antimicrobial properties. Due to the same reason, food preservation aspects of herbs and spices are self-evident; however, regular consumers of herbal products should always take precautionary measures regarding doses depending upon toxin load.

3.2 Toxin Load Considerations in Botanical Food Ingredients, Herbs and Spices

Herbs and spices, and their essential oils, are extensively used in the Ayurvedic medicine but their application in food preservation is limited due to their tastes as well as the toxin load. In addition to synthetic insecticides and fungi, herbs and spices contain biologically produced toxins: microbial compounds, allergens like terpenes, alkaloids, stimulants, depressants, etc. Since food is consumed in much larger quantity than medicinal products, the toxin load of food ingredients and additives is therefore much worth considering. The Food Safety and Standards Regulation (FSSR) 2011 (Contaminants, Toxins and Residues) specifies limits of metal contaminants, crop contaminants—aflatoxins, patulin, ochratoxin A—naturally occurring toxic substances—agaric acid, hydrocyanic acid, hypericine, safrole—and insecticide residues (Chaps. 1 and 2). In the ambit of herbs and spices, terpenes, which mostly act as skin allergens should be considered with much attention. Safrole, limonene, phellandrene, geraniol, citronellol, borneol, citral, etc. are a few terpenes of plant origin with skin allergenicity. Out of these, safrole, is the most harmful terpene and FSSR, 2011 specifies maximum limits for its presence in food articles up to 10 parts per million (ppm).

3.3 Chemistry of Ingredient-Specific Intoxicants and Skin Allergens

The medical science related to natural drugs and their natural constituents is called pharmacognosy. It deals with the testing of different parts of bio-origin materials, mostly plants, and the extraction of active pharmaceutical ingredients (API) and related purification. On the other hand, Ayurveda—the ancient Indian system of medicine—utilises herbs in integral form. These herbs should be naturally grown in proper climate: in other words, these vegetables should be completely free from synthetic insecticides and aflatoxins, without much consideration of biologically produced toxins.

Ayurvedic medicine is used in small dosage for a limited time period, but herbs and spices are used in appreciable amounts in Indian cuisines. Therefore, the chemistry of certain ingredients and specific intoxicants at the same time—particularly acting as skin allergens—is important by the viewpoint of safety practices for Indians who might be prone to skin allergy. Microbial contamination episodes in herbs and spices are mainly ascribed to *Clostridium perfringens* and *Bacillus cereus*. As far as carcinogenic alkaloids and other substances in herbs are concerned, the regular consumption of several food articles is not supposed to be safe due to this reason. The excessive use of snuff from *Nicotina tabacum* can lead to fatal malignant polyps of nose. Tannin-rich plants, like black or coloured tea, are mostly found to give rise to incidences of nasal cancer. Needless to say tobacco, cottonseed oil and cocoa (*Erythroxylon coca*) can contain alkaloids quite capable to cause oral cancer, while edible mushroom might contain ethionine, a synthetic carcinogen. Certain non-nitrogenous organic compounds like phenylpropanes—present in nutmeg and mace—and tetrahydrocannabinol—present in marihuana, known in India as *bhang*—affect psycho-activity. These substances can act as hallucinogens, stimulants, or depressants. Several plants like *Capsicum* spp contain irritant substances. Herbs contain several terpenes, which are typically capable to cause skin allergy. Skin allergens of plant origin are mainly terpenes and their alcohol and aldehyde derivatives: limonene, phellandrene, geraniol, citronellol, borneol, citral and safrole.

As far as the definition of terpene is concerned, terpenes may be considered as isoprene polymers and may be either open chain- or cyclic-structures with one or more benzenoid groups.

3.3.1 Limonene

Limonene is a widely distributed optically active terpene, with molecular formula $C_{10}H_{16}$: it occurs naturally in both *D*- and *L*-forms.

The racemic mixture of two optical isomers is known as dipentene and normally found in lemon, neroli, bergamot, caraway, orange, spearmint and peppermint oils. This liquid mixture is colourless. *D*-form has specific gravity 0.8419 at 21 °C (Kimball 2012), while *L*-form has specific gravity between 0.837 and 0.841 at 25 °C (United States Pharmacopeial Convention 2009).

3.3.2 Phellandrene

α-phellandrene (4-isopropyl-1-methyl-1,5-cyclohexadiene) is a monocyclic terpene occurring as both *D*- and *L*-optical isomers; it appears as a colourless oil and soluble in ethers. The *D*-form has specific gravity 0.8463 (at 25 °C) and refractive index 1.4777, while the *L*-form has specific gravity 0.8410 (at 20 °C) and refractive index 1.4709 (Kar 2003). It is found in ginger oil, cinnamon oil and eucalyptus oil.

ß-phellandrene (4-isopropyl-l-methylene-2-cyclohexene) is a monocyclic terpene occurring as *D*– and *L*–optical isomers, with pleasant odour and burning taste. The *D*–form has specific gravity 0.8520 (at 20 °C and refractive index 1.4788, while the *L*–form has specific gravity 0.8497 (at 15 °C) and refractive index 1.4800 (Kar 2003). Both substances are insoluble in water and alcohol, but soluble in ethers. These are found in lemon oil and Japanese peppermint oil.

3.3.3 Geraniol

Geraniol (*trans*-3,7-Dimethyl-2,6-octadien-1-ol) is a colourless—to pale yellow liquid oil with pleasant geranium-like odour, specific gravity 0.8894 (at 20 °C), refractive index 1.4766 (at 20 °C), soluble in alcohol as well as in ethers but insoluble in water. It is the major constituent of rose oil and palmarosa (Indian grass) oil; it is also found in appreciable amounts in citronella oil (used as insect repellent).

3.3.4 Citronellol

Citronellol (mixture of the less abundant 3,7-dimethyl-6-octen-1-ol form and 3,7-dimethyl-7-octen-1-ol form), normally found in oils of citronella, geranium, rose, savin and other essential oils is a colourless liquid with somewhat rosy odour. It is soluble in two or more volumes of 70 %–alcohol and in the most part of oils.

3.3.5 Borneol

Borneol (2-hydroxyl camphene), also called 2–camphanol or bornyl alcohol, is found in several essential oils such as thyme oil. It is commercially derived from wood of *Dryobalanops camphora*, a tree in Sumatra and Borneo. It has camphor-like odour and burning taste, specific gravity 1.011, melting point 208 and 210.5 °C for enantiomers and the racemic mixture, respectively, (Surburg and Panten 2016). It is soluble in alcohol and ethers, and very slightly soluble in water.

3.3.6 Citral

As a mixture of α- and β-isomers, citral (3,7 dimethyl–2,6 octadienal) is the principal constituent of lemon grass oil, having strong lemon odour. It is soluble in 5 volumes of 60 %–alcohol.

3.3.7 Safrole

Safrole (4-allyl-1,2-methylene dioxybenzene, Fig. 2.5), is a colourless or pale yellow-liquid oil with sassafras odour. It is found in sassafras and camphorwood and other essential oils. It has specific gravity 1.096 (at 20 °C), melting point 11 °C, boiling point range 232–234 °C and refractive index 1.5383 at 20 °C (Kar 2003). It is soluble in alcohol and ethers but insoluble in water. Safrole is considered as the most harmful allergen and FSSR, 2011 specifies maximum limit for its presence in food articles up to 10 ppm.

3.4 Cure Aspects of Herbs and Spices

3.4.1 General Overview

Foods are very much concerned with pleasure, requiring herb or spice—the natural taste-source—alone or as a herbal combination called *masala* (like *garam masala*) or as a seasoning for the purpose of taste development during processing (Frawley and Lad 1993). A processed food normally incorporates a wide range of herbal (or spice) composition as prime minor constituents along with major ingredients like flour, oil or fat and water. The most prevalent herbs and spices used along with sugar and/or honey and/or salt in Indian cuisine are listed in Fig. 3.1.

The taste along with odour of a food product perceived by eater or drinker consumer is called 'flavour'. The hot decoctions of tea leaves and coffee beans are popularly consumed as stimulant or energy drink in India due to the influence of western cultures, although people believe that the former is indigenous (localisation: Assam, India) and the latter is ascribed to Arab countries. Indians also consume cocoa powder and butter-based bakery products and chocolates (origin: Africa and tropical America). Nervous impulses on the brain centres as an outcome

The most prevalent herbs and spices used in Indian cuisine , in alphabetical order			
Almond Kernels Aloe Amla Asafoetida	Basil leaves Bay leaves Black pepper	Caraway Cardamom Chili Cinnamon Clove Coconut Coriander Cumin	Dates
Fennel Fenugreek	Garlic Ginger	Lemon juice Licorice Long pepper	Mace Mustard seeds
Pomegranate seeds Poppy seeds Pumpkin seeds	Raisins Rose petals	Nutmeg	Onion
	Saffron Sesame seeds	Tamarind Thyme Turmeric	

Fig. 3.1 The list of most important herbs and spices used along with sugar and/or honey and/or salt in the Indian cuisine. This list is in alphabetical order

of a distinct activity of receptors located on tongue and nose linings decide the perception of a person for flavourings (combination of herbs and spices and/or their oleoresins, extracts and/or synthetic flavour substances). In India, taste-making herbs are also considered as unique medicine for slow but consistent or permanent treatment of specific diseases. Ayurveda considered as the science of longevity (long life) and sometimes the science of self-healing (in very limited contexts) deals with medicines, which primarily are based on herbs. In this way, herbs are used in India as taste-source as well as healing medicine. Therefore, people worldwide are interested to analyse or examine the taste and possible cure issues linked with herbs and spices, as the following questions obviously arise:

(1) Could the taste of a herb hint at its therapeutic value?
(2) Are herbs foods or drugs?
(3) How much safe has to be considered any herb as a drug, when it is not safe as a food due to the presence of intoxicants?

3.4.2 Herbs and Spices Correlations with Tastes in the Ancient Medicine

For Ayurveda, six tastes—sweet, sour, salty, pungent, bitter and astringent—have to be defined. These tastes are reduced to three single varieties in their post-digestive effect (*vipaka*). According to Frawley and Lad, two of these tastes—sweet and salty types—are associated to a sweet post-digestive effect (*vipaka*) in the Ayurvedic medicine, while sour determines a sour *vipaka*, and pungent *vipaka* has to be defined as the result of bitter, astringent and pungent tastes. Consequently, sweet, sour and pungent tastes give rise to three physiological stages—*Kapha, Pitta* and *Vata* (Frawley and Lad 1993). Interestingly, different herbs are correlated to tastes: in other words, herbal products are classified in the Ayurvedic medicine in function of different tastes. Because of the direct effect of taste types on human beings, Ayurveda correlates different healthy effects with selected herbs. The interested Reader is invited to consult specialised books on this matter.

In addition, herbs and spices contain both microbial and antimicrobial agents (Sharma 2016; Snyder 1997). Their properties in many different situations have been extensively studied in the past (Bullerman 1974; Bullerman et al. 1977; Crouch and Golden 2005; Hintz et al. 2015; Huhtanen 1980; Johnson and Vaughn 1969; Pafumi 1986; Paster et al. 1995; Sharma et al. 1979; Shelef 1984; Shelef et al. 1984; Zaika 1988). In detail, five antimicrobial substances have been found to be extremely interesting: cinnamaldehyde, eugenol, allicin, thymol and allyl isothiocyanate (Sharma 2016). Their chemical properties can be of interest (Kar 2003; Mangathayaru 2013; Poucher 1974).

3.5 Precautionary Measures for Consumers

Ayurvedic physicians or Vaidyas utilise several herbs as medicine, some of which are to be taken by patients for a small period, while some botanical ingredients-based medicine can be continued for a longer time. Founders of Ayurveda—Dhanvantari, Charak, Sushrut, etc.—were aware of the side effects of herbs if consumed in large dosage or on long periods. In India, products such as tea, coffee, cocoa products like chocolates, spicy smacks and high-spice cuisines are very much prevalent as daily food requirement of people. No doubt, botanical ingredients and herbs are considered in India as both drugs and foods. Despite this, the use of botanical ingredients in daily life demands important precautions. Indian consumers are hardly aware of the toxin load of herbs, spices and several botanical ingredients, which they regularly consume. As far as drug status of botanical ingredients is concerned, even tobacco leaves (*Lobelia inflate*) can be used in small dosages for a short time because of its physiological actions as respiratory stimulant, expectorant, antispasmodic and sweating inducer. However, should tobacco be regularly consumed for a long time, the consumer might suffer from cancer owing to tobacco alkaloids.

Serving tea and coffee along with spicy snacks, nowadays, has become a part and parcel of hospitality in India. Caffeine (1,3,7-trimethylxanthine), extracted from coffee, tea, *guarana,* or *kola* nuts, is used in medicine in form of basic alkaloid or as benzoates or arsenates because of their solubility in alcohol and water. Ayurvedic physicians shall now hardly suggest tea and coffee decoctions to patients because people are accustomed to use these beverages and might be suffering from effects of excessive consumption of caffeine and tannin, as people are regularly consuming those in the form of ingredients of tea and coffee beverages. In the same way, several spices and taste-making ingredients in snacks and sweets[1] are almost used and also employed in Ayurvedic medicine for cure of several diseases. Patients already suffering from effects of excessive consumption of these botanical ingredients cannot be expected to recuperate effectively with the help of any Ayurvedic medicine composed of those ingredients prescribed by Vaidya. Therefore, careful precautions should be taken with relation to these herbs, spices and botanical

[1]A list of these ingredients can be provided here: Asafoetida or *hing* (*Ferula asafoetida*), *Aloe vera* or *ghrut Kumari* (*liliaceae*), basil or *tulsi* (*Ocinum spp*), black pepper or *kali mirch* (*Piper nigrum*), cardamom or *elachi* (*Elettaria cardamomum*), chilli or *mirch* (*Capsicum fruitescens*) Cinnamon or *dalchini* (*Cinnamomum zeylancium*), cloves or *laung* (*Eugenia caryophyllata*), fenugreek or *danamethi* (*Trigonella foenumgraecem*), garlic or *lahsun* (*Alium sativum*), dry ginger or *sonth* (*Zigiber officinale*), honey or *madhu* or *shahad*, licorice or *mulethi* (*Glycyrshiza glabra*), mace or *javitri* (*Myristica fragrans*), nutmeg or *jaiphal* (*Myristica fragrans*), onion or kanda or *pyaj* (*Allium cepa*), poppy seeds or *khuskhus dana* (*Papaver spp.*) rose flowers or *gulab pushpa* (*Rosa spp.*) saffron or *kesar* (*Crocus sativus*), thyme or *ajwan* (*Apium graveolens*) and turmeric or *haldi* (*Curcuma longa*).

ingredients. The unlimited—or much frequent—use of botanical ingredients, particularly as tea, coffee, snacks, sweets, biscuits, etc. should be avoided so that Ayurvedic herbal compositions might effectively work in case the person suffers from disease.

Several Indians prefer taste-making herbs clove, which is antiseptic, stimulant and analgesic in nature as well as cinnamon, which is a stimulant, antiseptic and antiviral agent. Both of them contain tannins; on the other hand, they tend to avoid garlic, which is an expectorant, blood pressure normalising and anti-diabetic agent in nature with constituents like vitamins A, B, C and E. The process of selection of herbs with notable amounts of biologically produced toxins for taste development on the one hand, and rejection of nutrient herbs is an anti-health way. Consequently, careful precautions should be taken with relation to the selection of nutritious herbs with low toxin load for taste development in cuisines. Like garlic, there are a few herbs with low toxin loads and high-nutrient amounts: turmeric, onion and chilli are good examples. The food status really goes to a few herbs, which are enriched with nutrients, and bear low toxin amounts.

The last, but not the least, precautionary measure for Indian consumers—in the context of herbs and botanical ingredients—is that insecticide residues and aflatoxin contents of the products be within the limits ascertained by the food law. Herbs containing intoxicants as well as synthetic flavours are unsafe by both food or drug viewpoints.

In the ambit of drug-like properties, herbs and spices cannot be obviously regarded safe unless these are safe as per food requirements. Synthetic and so-called nature-identical flavours are obviously questionable because these contain the principle functional ingredient but not the entire range of natural ingredients responsible for safety of a natural flavour. For example, the synthetic and nature-identical vanilla flavours contain vanillin, the chief flavour-ingredient in natural vanilla. However, in absence of the entire range of healthy–supportive ingredients, the alone ingredient vanillin (mostly used in ice-creams) can exert carcinogenic effect if regularly consumed. The issue of use of herbs and spices as food supplements, or in functional foods and beverages is not so much well debated at present, similarly to the problem of the quantification of mineral trace elements in several waters for commercial purposes.

At this point, the question arises how long any soil or water can remain isolated as perfectly conserved, if deforestation and intensive farming practices continue. The Earth planet urgently demands dense forestation with entire biodiversity almost uniformly on at least 33.33 % of surfaces for the perfect conservation of soil and water. The soil of the Indian subcontinent has been seriously suffering from depletion of trace minerals due to severe deforestation and intensive farming practices.

References

Bullerman LB. Inhibition of aflatoxin production by cinnamon. J Food Sci. 1974;39(6):1163–5. doi:10.1111/j.1365-2621.1974.tb07344.x.

Bullerman LB, Lieu FY, Seier SA. Inhibition of growth and aflatoxin production by cinnamon and clove oils, cinnamic aldehyde and eugenol. J Food Sci. 1977;42(4):1107–9, 16. doi:10.1111/j.1365-2621.1977.tb12677.x.

Crouch E, Golden N. A risk assessment for *Clostridium perfringens* in ready-to-eat and partially cooked meat and poultry products. Washington, D.C.: United States Department of Agriculture, Food Safety and Inspection Service; 2005. Available http://www.fsis.usda.gov/wps/wcm/connect/670dd8ce-8388-4bed-8547-d52e8c61eaae/CPerfringens_Risk_Assess_Sep2005.pdf?MOD=AJPERES. Accessed 06 July 2016.

Frawley D, Lad V. The yoga of herbs: an ayurvedic guide to herbal medicine. Twin Lakes: Lotus Press; 1993.

Hintz T, Matthews KK, Di R. The use of plant antimicrobial compounds for food preservation. BioMed Res Int. 2015;2015:246264. doi:10.1155/2015/246264.

Huhtanen CN. Inhibition of *Clostridium botulinum* by spice extracts and aliphatic alcohols. J Food Prot. 1980;43(3):195–6.

Johnson MG, Vaughn RH. Death of *Salmonella typhimurium* and *Escherichia coli* in the presence of freshly reconstituted dehydrated garlic and onion. Appl Environ Microbiol. 1969;17(6):903–5.

Kar A. Pharmacognosy and pharmacobiotechnology. New Delhi: New Age International (P) Limited, Publishers. 2003.

Kimball D. Citrus processing: a complete guide. Seciobd ed. Gaithersburg: Aspen Publishers Inc; 2012.

Mangathayaru K. Pharmacognosy: an Indian perspective. Noida and New Dehli: Pearson Education India (Chennai and Delhi) and Dorling Kindersley (India) Pvt. Ltd.; 2013.

Pafumi J. Assessment of microbiological quality of spices and herbs. J Food Prot. 1986;49(12):958–63.

Paster N, Menasherov M, Ravid U, Juven B. Antifungal activity of oregano and thyme essential oils applied as fumigants against fungi attacking stored grain. J Food Prot. 1995;58(1):81–5.

Poucher WA. Perfumes, cosmetics and soaps: volume I—the raw materials of perfumery. Netherlands, Dordrecht: Springer; 1974.

Sharma RK. Herbs and spices: the potent source of natural food preservatives. Food and Beverage News. 2016. http://www.fnbnews.com/Top-News/herbs-and-spices-the-potent-source-of-natural-food-preservatives-39172. Accessed 06 July 2016.

Sharma A, Tewari GM, Shrikhande AJ, Padwal-Desai SR, Bandyopadhyay C. Inhibition of aflatoxin producing fungi by onion extracts. J Food Sci. 1979;44(5):1545–7. doi:10.1111/j.1365-2621.1979.tb06484.x.

Shelef LA. Antimicrobial effects of spices. J Food Saf. 1984;6(1):29–44. doi:10.1111/j.1745-4565.1984.tb00477.x.

Shelef LA, Jyothi EK, Bulgarellii MA. Growth of enteropathogenic and spoilage bacteria in sage-containing broth and foods. J Food Sci. 1984;49(3):737–40. doi:10.1111/j.1365-2621.1984.tb13198.x.

Snyder OP. Antimicrobial effects of spices and herbs hospitality institute of technology and management, St. Paul. 1997. Available http://www.hi-tm.com/Documents/Spices.html. Accessed 05 July 2016.

Surburg H, Panten J, editors. Common fragrance and flavor materials: preparation, properties and uses. 5th ed. Weinheim: Wiley-VCH Vergal GmbH & Co. KGaA; 2016.

United States Pharmacopeial Convention. Food chemical codex. 6th ed. United States Pharmacopeial Convention. 2009.

Zaika LL. Spices and herbs: their antimicrobial activity and its determination. J Food Saf. 1988;9(2):97–118. doi:10.1111/j.1745-4565.1988.tb00511.x.

Chapter 4
Organic Foods and Farming Practices in India

Abstract Indian agriculture continued following path of green revolution even in the twentieth century extensively utilising intensive farming practices with synthetic fertilisers and pesticides application leading to micronutrient mineral deficiencies in soil, water and food. At the same time, many countries—mostly European Nations—used to leave the path of conventional or intensive agriculture. The diversion or deviation from intensive agricultural practices today implies minimisation or elimination of synthetic fertilisers and pesticides in farms with the concomitant use of natural manures, mainly compost manure, and natural pesticides like *neem* leaf juice. This concept of organic farming works a little in the state of deforestation or loss of biodiversity due to mineral deficiencies in soil and water, while in ancient India soil fertility was considered as the function of biodiverse forestation. Indian crops partly suffer from immune system weakness and are prone to bacterial and fungal growth. India is on the way of following integrated farming practices along with organic farming; however, India sometimes faces certain difficulties because of the high number of rejections at EU borders, mostly due to the presence of *Salmonella* spp. or aflatoxins beyond limits. Therefore, discussions on environmental factors and land use polity are relevant in India.

Keywords Compost manure · Green revolution · Integrated farming · Intensive farming · Micronutrient minerals · Organic farming · Traditional farming

Abbreviations

APEDA	Agricultural and Processed Food Products Export Development Authority
BPS	Biogas plant slurry
CD	Cow dung
EU	European Union
FSSA	Food Safety and Standards Act
FSSAI	Food Safety and Standards Authority of India
GMO	Genetically modified organism
HACCP	Hazard analysis and critical control points

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DOI 10.1007/978-3-319-48049-7_4

IFOAM	International federation of organic agriculture movements
ISAAA	International service for the acquisition of agri-biotech applications
MRL	Maximum residue limit
MFA	Minerals for all
NPOP	National programme for organic production
NPK	Nitrogen, phosphate and potash
RASFF	Rapid alert system for food and feed
SWOT	Strengths, weaknesses, opportunities, and threats
USA	United States of America

4.1 Introduction

Sir Jagdish Chandra Bose is considered as the prime plant physiologist among the pioneers of botany who experimentally studied answers of plants to environmental stimuli, in the last decade of the nineteenth century with the invention of the crescograph for the measurement of vegetable growth. However, Sir Bose is not the first Indian observer of life in trees and plants. The mention of inclusion of vegetation among living objects species is found in age-old Indian scriptures like Brihat Vishnu Purana, stating that out of around 8.4 million *yoni* (living objects species), the following subdivision can be observed (approximate values):

(a) Two millions belong to *sthavar* (stationary objects or vegetation)
(b) 0.9 millions are named *jalaja* (creatures living in water)
(c) 0.9 millions belong to *kurma* (creatures living both in water and on land surface)
(d) One million are named *pakshi* (creatures having wings to fly)
(e) Three millions belong to *pashu* (animals)
(f) 0.4 million are named *vanara* (commonly considered as monkeys, but this word stands for ‘near to humans’)
(g) 0.2 millions belong to *manava* (humans).

This figure considerably differs from the number of current species recognised on the planet Earth. On the other side, it is still relevant to discuss the ancient Indian scenario of foods and farming practices based on biodiversity leading to soil conservation. Several creatures nowadays have been facing serious threat of extinction due to increasing pollution or undesired substances of industrial as well as agricultural origin in environment. Indian agriculture continued following the path of green revolution even in late twentieth century, extensively utilising synthetic fertilisers and pesticides in farms when many countries, mostly European Nations, used to leave the path of conventional or intensive agriculture.

The conventional or intensive farming practices lead to micronutrient deficiencies in soil, water and foods, particularly in the state of loss of biodiversity or deforestation. At present, a few isolated regions or islands, like Utah Lake in the United States of America (USA), exist in the world where traditionally conserved soil and water (river, lake or groundwater) are found. Forest products, farm crops or water from such isolated regions might be considered as conserved or enriched with proper mineral diversity, may be quite suitable for public health purposes. However, diversion or deviation from intensive agricultural practices today implies minimisation or elimination of synthetic fertilisers and pesticides in farms, with the concomitant use of natural manures, mainly compost manure, and natural pesticides like *neem* (*Azadirachta indica*) leaf juice. This concept of organic farming is running parallel to intensive industrial farming, wherever it is possible to isolate a cultivable land from conventionally or intensively utilised farms. Integrated farming practices (use of genetically modified seeds, mineral supplements, etc.) and improved mechanisation have also been employed to increase organic crop yield.

The National Programme for Organic Production (NPOP) has been created in India with the aim of introducing and implementing standards for organic production, farming and accreditation.[1] The 'strengths, weaknesses, opportunities, and threats' (SWOT) analysis for food quality assurance and organic certification—a big point of concern for Indian policymakers and risk managers—is directly correlated to farming practices. A notable percentage of Indian foods may be often intended as natural or organic products if compared with industrial or semi-organic foods obtained by conventional (intensive) or integrated farming systems, respectively.

Despite European Union (EU) and USA recognise that NPOP conformity assessment procedures of accreditation are at least equivalent to their own instruments, Indian organic products have been rejected on a number of occasions by importing countries, including the EU. This situation is perhaps mainly due to large-scale deforestation in India resulting into difficulties in maintenance of soil conservation even after following integrated farming practices.

Indian organic food products are developed in limited scope for organic farming and are often 'organic' foods in the sense that synthetic pesticides application in farms has been appreciably controlled. However, those products seldom exhibit high pesticide amounts and many times high aflatoxin and bacteria contents. Therefore, Indian food exporters have to face consequences as their organic products are several times rejected, particularly at the EU borders.

[1]The NPOP is described in detail at the following website address: http://apeda.gov.in/apedawebsite/organic/Organic_Products.htm. This site is owned by Agricultural & Processed Food Products Export Development Authority (APEDA), New Delhi, India.

4.2 Ancient Indian Scenario of Foods and Farming Practices

Dr. Vidyadhar Sharma Guleri describes in his Hindi book '*Sanskrit Men Vigyan*' (English translation: The Science in Sanskrit) how agricultural activities like sowing, measuring rain, grafting, etc., were conducted in ancient India as explained by Parashar, Garg and Varahmihir (Guleri 2000). It is worth mentioning that the prediction of rain—as mentioned in '*Karsi Parasan*' (Majumdar and Banerji 2001)—might not be appropriately tallied now due to climate change.

The important message for success in agriculture might be derived from Indian epics like *Ramayan* and *Mahabharat*, both having descriptions regarding contribution of *aranya* or *vana* (forest) to farm yields as the trees drink water through roots and keep groundwater elevated (Vyas 2001). Also, the entire biodiversity in the forests is capable to timely bring the monsoon. Sanskrit dictionary provides a few words in this context. The word '*aranya*' is used for describing lands neither cultivated nor grazed, but able to produce a corn without sowing seeds or anthropic activities; moreover, the biodiversity concerns at least seven animal groups. *Aranya* includes both *vana* (forests) and the *maru* (deserts).

The corn or any grain naturally grown without sowing in forests and deserts is termed as *aaranya* in Sanskrit. A few examples of these wild food produce are *aaranya Kadali* (wild Plantain), *aaranya Dhanya* (wild rice), *aaranya jeeram* (wild cumin), etc. and these plants normally grow in the dense forests possessing a wide range of biodiversity. This simple dictionary depiction of '*aranya*' and '*aaranya*' clarifies that forest, desert, cropland, pasture and housing land (village, town or city) are basic land territories for the coexistence of creatures. It appears that forests are the contribution of nature to biosphere, so that all creatures can live together. Of course, deserts suffer from water scarcity; some kinds of fauna and flora still exist there. Forests and deserts represent a wide range of biodiversity, the former broad and latter short, but human skill can afforest deserts and human error can desertify forests.

The process of desertification of forests (or destruction of biodiversity for housing or industrial purposes) leads to soil deterioration and monsoon disturbance with serious consequences for crop yields in farms. The presence of big cat animals such as lions and tigers (both named '*vanaraj*' *or* forest kings), etc., is quite helpful for the maintenance of dense forests. Forestry has been the important human profession in ancient India; however, agriculture is necessary for development of biosphere including humans, animals and birds. Parashar states that agriculture provides capital and talent; therefore, it is considered the basis of animal life (Majumdar and Banerji 2001).

4.2.1 Vruksh Ayurveda and Agriculture

Botanist Dr. Girija Prasanna Majumdar studied the ancient Indian text '*Vruksh Ayurveda*' (these words stand for 'Tree Life Science') written by Parashar (Sircar 1950). He translated its summary in English and described it in his book '*History of Science in India*'. Subdivided in six parts, the text deals with formation of seed, varieties of soil, types of forests, plant physiology and cell structure, parts of flowers, plant's food intake, etc. Indians were aware of several plant diseases, which are classified into four types by Varahmihir in his book '*Brihat Samhita*' (Guleri 2000):

(1) *Pandu Patrata* (now known as 'cholorosis of leaves')
(2) *Praval Avriddhi* (now known as 'falling of buds')
(3) *Shakha Shosh* (now known as 'drying up of branches')
(4) *Ras Sruti* (now known as 'exudation of sap').

Parashar explains in *Vruksh Ayurveda* how a plant receives food via its leaves and how leaves receive nutritious sap. The text clarifies also that plants get their food via *vaat* (air), *aatap* (sunlight) and *ranjak* (pigment or chlorophyll); and nutrients from soil. Soil properties appreciably vary according to biodiversity existing on it or nearby it. In this way, contrary to the principle of Darwin of 'struggle for existence', ancient Indian lifestyle enjoyed the '*principle of co-existence and mutual dependence of creatures*' particularly in the context of forestry and farming professions. It was believed that farm soil gets nutrients for plant life from excreta of various creature species existing in adjacent forests; therefore, forestry and agriculture professions were considered complimentary agents. In other words, soil fertility was considered in India as a function of biodiverse forestation.

Mechanisation was adopted in ancient India to sustain agriculture. India is known for sowing in line by dragging plough in soil. Therefore, the word *krushi* (agriculture) was derived from the verb *kru* (to drag or to plough). It is said that the Agricultural Board of England received in 1797 sets of Indian ploughs which were considered more effective or useful, and also economical, in comparison to British ploughs (Dharampal 2000). Ancient Indian farming practices were based on biodiversity and sustained by mechanisation. Nowadays, it is well known that animal excreta facilitates the spreading of earthworms tending to stabilise organic matter and modify physical and chemical properties of soil-enhancing fertility via bio-oxidative processes.

4.3 Soil Conservation Aspects of Food Quality and Crop Yield

A nitrogen-enriched soil having an entire range of mineral nutrients, capable of stabilisation of organic matter with enough surface area for aeration, keeps almost all the basic requirements of soil for its fertility or ability to quantitatively as well as qualitatively produce crops. These soil conservation aspects of food quality and crop yield are discussed in the context of natural traditional farming practices based on biodiversity or forestation.

4.3.1 Nitrogen Enrichment

The cow dung is considered as the suitable natural manure if the farm soil is properly enriched with nitrogen. Average organic carbon and nitrogen contents of cow dung are found to be 427 ± 12 and 8.5 ± 0.33 g/kg, respectively, with carbon/nitrogen ratio equal to 50.24 ± 0.34 g/kg, while carbon/nitrogen ratio in soil for effective farm yield is expected to be approximately 9.0 (Yadav et al. 2013). Therefore, the soil should be well conserved or enriched with nitrogen if cow dung is used as manure. The urine from entire fauna diversity existing in Indian forests was probably helpful, in ancient times, for the reduction of carbon/nitrogen ratio values. Animal urine, conserved by soil, is an important source of nitrogen for the growth of crops. It is believed in India that the perfect conservation of soils is possible when minimum 33.33 % of country surface areas are almost uniformly covered by dense forests.

4.3.2 Mineral Content Enrichment

Cow dung contains 5.0 ± 0.30 of phosphorus, 8.8 ± 0.33 g/kg of potassium, 1,859 ± 19 mg/kg of iron, 234 ± 15 mg/kg of copper, 110 ± 9 mg/kg of zinc and 84 ± 3.8 mg/kg of chromium. However, requirements of these mineral nutrients for the effective growth of crops should be (Yadav et al. 2013):

- Phosphorus: 10.0 g/kg
- Potassium: 10.0 g/kg
- Iron: 1900 mg/kg
- Copper: 270 mg/kg
- Zinc: 115 mg/kg
- Chromium: 100 mg/kg.

Excreta from entire fauna diversity existing in Indian forests were capable to enrich soil with enough mineral micronutrients for growth and immune system development of crops in farms, in ancient times.

4.3.3 Organic Matter Stability and Surface Enlargement

Soils enriched with nitrogen and mineral nutrients are able to produce bumper crops with good quality in farms, on condition that organic matter in soils is stabilised and atmospheric oxygen is available to plant roots. Therefore, properly enlarged surface areas for action, turnover and physical or mechanical aeration are required. A few species of earthworms can effectively determine the increase of superficial areas. As a consequence, organic matter is easily degraded and nitrogen contents increase.

It is worth mentioning that the Indian subcontinent was almost uniformly covered in ancient times with dense forests (52 *shaktipeetha*, also called *singhkshetra* or lion territories) and dense pastures (12 *Jyotirlinga*, also called *nandikshetra* or bull territories). Therefore, the cropland soil naturally received organic manure in the forms of wild fauna and cattle excreta (urine and dung) as well as possessing a range of biodiversity of earthworms. Needless to say, this type of farm soil biodiversity easily contributes to optimum aeration for organic matter degradation and nitrogen enrichment, necessary for bumper qualitative crop production. The efficacy of vermicomposting as an eco-friendly and sustainable procedure has been reported recently (Yadav et al. 2013).

4.4 India Towards Intensive Industrial and Integrated Farming Practices

In 1947, when India was an independent sovereign country, there were limited natural resources; biodiverse dense forests accounted for 22 % of the 70 % entire forest-pasture cover, and basic infrastructures were dedicated to traditional or biodiversity-based farming practice.

In the last decade of the nineteenth century, the British government passed the Land Acquisition Act which stated that forests, pastures and agricultural land could be acquired for any urban development scheme. In due course of time, the government's direct interruption on forests and pastures began to take place via the industrial Dispute and Public Safety Act. During that period, the people of India clearly experienced the correlation between rupee (national currency) depreciation and deforestation. Public life in the country remained pressurised within limits generated by the economic policy, including the hike in prices due to rupee depreciation and losses of jobs for cattle keepers and forest-based people due to ruin of pastures and forests. These situations gave rise to the public movement led by Lala Lajpat Rai, Bal Gangadhar Tilak and Bipin Chandra Pal (popularly known as *Lal Bal Pal*). Despite achieving freedom on 15 August 1947, the economic and industrial policies of British period continued as such, due to which Dr. Shyama Prasad Mookerjee, independent India's first industries minister, had to resign. The century-old Land Acquisition Act was amended recently, but these amendments did not express the determination of imposing a minimum surface of 33.33 % for forest-pasture destination. Due to this reason, amendments were not helpful for the conservation of soil resources and the wellness of forest-dependents, animal keepers and peasants of India. Basically, regulatory norms just assure that the land will never be acquired in the name of any construction or development work against the will of farmers (Sharma 2013).

There were two alternatives for independent India as policy issues in the context of agricultural development, either to increase dense forest areas of the country up to 33.33 % (and follow the path of biodiversity-based traditional agriculture), or to use synthetic fertilisers and pesticides for bumper crop production (and follow the path of intensive industrial farming practices). The first eco-friendly alternative was not difficult in 1940s or 1950s, but Indian policymakers opted for a second anti-ecology alternative perhaps due to easygoingness. The first alternative was demanding the strict area limitation for urban development with multi-storey housing model. India could not select this alternative even in 1960s and 1970s when European countries and Japan used to opt it. India continued to follow the path of intensive industrial farming practices (use of synthetic fertilisers and pesticides in farms) even up to 1980s. The process of obtaining bumper crops by means of synthetic fertilisers and pesticides and the concomitant use of hybrids species in farms, even with increasing deforestation, is called 'Green Revolution'. The name linked with Green Revolution is Norman Ernest Borlaug, an agricultural scientist once described as the '*World's greatest fighter against hunger and poverty*'. Since India had been losing forest-pasture infrastructure for the sake of horizontally expanding housing development in the name of urbanisation, Indian policymakers utilised very much 'Green Revolution' slogan to highlight agricultural yields with added-cost factors of modern varieties of seeds. Generally, these approaches concerned hybrids and the use of urea, superphosphates and other synthetic fertilisers as well as synthetic pesticides applied in farming processes.

In early 2010s, the impact of Green Revolution was assessed critically (De Gregori 2004; Evenson and Gollin 2003). Ammann warned of advantages and risks correlated with productivity augments (Ammann 2008).

India had enjoyed hardly the success of Green Revolution up to 1980s, when its detrimental effects began observable: upsurge of pests or insects, growing insect resistance against applied pesticides, decline in soil fertility, and increase in number of herbicide weeds. The Indian agriculturist M.S. Swaminathan had warned the country against these expected detrimental effects in 1968 giving adjective 'exploitive agriculture' to conventional industrial farming practices (Swaminathan 1968).

M.S. Swaminathan came forward with the slogan 'Evergreen Revolution' with emphasis on the superior infrastructure with sustainable management of natural resources (forests, pastures. etc.) for soil fertility enhancement and biodiversity maintenance (Kesavan and Swaminathan 2008; Swaminathan 2006).

M.S. Swaminathan has been a distinguished agricultural scientist and internationally known for his efforts over 40 years in the conservation of biological diversity. The connotation of his submission 'From Green Revolution to Evergreen Revolution' was that India should follow the traditional agriculture, based on biodiversity, with the technological advancement in irrigation and farm mechanisation and the minimum use of synthetic fertilisers and pesticides in farms (Kesavan and Swaminathan 2006). He was the strong supporter of dense forestation and was disappointed on increasing deforestation in India. At present, one aspect of safe food production in India (which could be derived from Swaminathan's submission) has been the minimisation of synthetic pesticides with the concomitant moderate application of synthetic fertiliser in farms. In 2014 India's share in worldwide pesticides consumption was 3.75 % only, while EU countries and USA share were 45 and 25 %, respectively (De et al. 2014). Similarly, average nitrogen, phosphate and potash (NPK)-based fertilisers consumption of India in the period 2011–15 has been 157.8 kg per hectare of arable land, against 364.4 kg per hectare in China, 1,097.8 kg per hectare in Kuwait and 15.2 kg/ha in the Russian Federation, according to the World Bank.[2]

In 1980 onwards the consequences of intensive industrial agriculture were too visible to run concerned farming practices, particularly with relation to synthetic insecticides in farms. Also, India could not re-establish the lost dimension of dense forests with the entire biodiversity to run agriculture profession in the traditional manner. However, Indian agriculturists tried to minimise synthetic pesticides application in farms with the establishment of required biodiversity at farm level, particularly by means of earthworms via preparation and use of suitable manure using cattle dung (compost manure). This kind of agriculture, called organic farming, is running in India within limited scope for quantitative and qualitative crop yield, but with insufficient results. India is also on the way to adopt integrated farming practices with the consequent adoption of modern plant breeding and transgenesis.

It is worth mentioning that the creation of transgenic plants has been ascribed to four different groups (USA and Belgium) in the 1980s. These teams worked in an independent way (Pathak 2007). It is further worth mentioning that India is one among 28 countries who are planting 'biotech' or transgenic crops. On the other side, Indian attempts of biotech crop plantation are limited to cotton production only, while USA, Canada, China, Australia, etc., are planting cereal crops too (Clive 2014). At present, India is also planning to apply transgenic cereals seeds in farms, although nine nations—Bulgaria, France, Germany, Indonesia, Iran, Poland, Egypt, Sweden and Ukraine—have stopped planting biotech crops (but they import biotech crops) and most of the African and Arab countries neither plant nor import transgenic crops (Clive 2014).

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[2]These data can be found at the following website address (accessed 19 July 2016): http://data.worldbank.org/indicator/AG.CON.FERT.ZS.

4.5 Mineral Nutrients Deficiencies in Indian Foods

The regular consumption of foods, including water, with some deficiency in nutrient minerals can make people suffer from several diseases like diabetes, skin diseases, fatigue and stress, blood pressure elevation, etc. Therefore, mineral deficiency in foods may be defined as a kind of intoxication and can devastate the human body if proper mineral supplements are not timely taken to balance mineral contents. In fact, minerals cannot be synthesised and their entrance in human body is only possible via intake of food and water. The human body demands normally mineral supplements when foods belong to crops grown in mineral-deficient soils and rivers or groundwater due to the same reason (soils suffer from deficiency of nutrient minerals). A person consuming regularly mineral-deficient food without suitable mineral supplements may suffer from various diseases. Consequently, the following facts should be considered:

(1) Non-conserved soils, belonging to a region where biodiversified dense forests are absent, are too loosely packed to withstand heavy rains. They undergo a process, called soil erosion, in which a fraction moves along with rain water and ultimately goes to the sea turning seawaters gradually richer in minerals. In this way, obviously, the soil mineral profile goes on to be poorer and poorer
(2) 72 out of the total 92 naturally occurring elements in the periodic table are required for proper human body maintenance; these elements can be suitably absorbed from food and water belonging to conserved soils and waters. A good example is the United States' Utah lake water (Minerals For All 2012).
(3) The human body is capable to retain effectively 59 elements; oxygen is the most abundant element (43 kg) in an average (70 kg) healthy person, while beryllium and tungsten are <50 μg(Adler and Tanner 2013).
(4) A food article may be unsafe for consumers if mineral-deficient in spite of the absence of synthetic insecticides, naturally developed toxins like aflatoxins and natural toxic constituents like alkaloids.

4.5.1 Mineral-Deficient Foods—The Indian Scenario

It is said that a low probability of presence of synthetic insecticides (and other contaminants) may be observed in Indian food articles. Also, those foods are not so safe due to mineral nutrient deficiency. The plea for this simple submission for impact of Indian food and water consumption on public health is very simple.

Nowadays, India is tending towards minimisation of synthetic pesticide application in farms (De et al. 2014); so, the probability of their presence in foods is very low. Since India is passing from climate change or global warming, the probability of presence of aflatoxins in Indian foods is obviously somewhat higher. The local warming factor or India's contribution to the global warming appears to be unfortunately much dominant due to vast deforestation. Obviously, this situation gives rise to increasing soil erosion (when heavy rainfall takes place) and subsequent mineral nutrients deficiency. Of course, macronutrient minerals belonging to elements such as nitrogen, phosphorus and potassium are available to plants grown in farms via NPK synthetic fertilisers. The supplementation of iron, copper, zinc, chromium and a few more micronutrient minerals is also prevalent nowadays. However, the supplementation of the entire 72-element mineral range in Indian agriculture is perhaps expensive or non-efficient. As a result, Indian crops probably suffer from serious mineral deficiency and immune system weakness.

There are many chances of bacterial developments in Indian crops, in particular fruits, vegetables and other high water content foods. In fact, storage and transportation of foods in high temperature and moisture conditions is much responsible for bacterial growth in Indian foods. On the other hand, mineral deficiency in foods has become nowadays a real agribusiness feature in the Indian scenario, with possible serious threats to public health. Therefore, routine mineral supplementation seems to be reasonable: some commercial application has been proposed recently and studied with relation to possible beneficial effects in certain patients. Public health in India, truly, demands biodiversified dense mountain forestation for well-conserved soil capable of storing mineral-enriched groundwater and producing crops with high mineral contents.

4.6 Concept of Organic Farming

With the continued reduction of biodiversity and forest-pasture density to meet out the demand of rapid urbanisation (unfortunately undergoing horizontal expansion), the Indian traditional agriculture, had been losing its potential as subsistence for farmers. Then agriculture, in India, followed the path of synthetic fertiliser and pesticide application in farms. This kind of agriculture, known as intensive industrial agriculture, posed a question mark on food safety, environmental purity, biosphere coexistence and public health. The follow-up of integrated farming in India with production of hybrid crops could enable the country to reduce synthetic pesticide applications in farms and maintain the yield to some extent with diminishing results. This situation probably happened because farm soil features did not concern the entire biodiversity of earthworms and the expected complete mineral profile due to increasing soil erosion.

However, Indian farmers could maintain earthworms in farm soils along with animal excreta such as cow dung (CD), or with biogas plant slurry (BPS) through a biological process called ‘vermicomposting’. The kind of farming with use of earthworm (mostly *Eisenia fetida*) inoculated CD or BPS manures instead of synthetic fertilisers (urea, super phosphates, etc.) is called ‘organic farming’ in India. This practice definitely contributed to crop yield maintenance with comparatively stable and not so diminishing results as well as crop quality maintenance with insecticide contents below maximum residue limits (MRL) which are established by Indian, EU and USA Regulations.

Conceptually, organic farming in the Indian context is the middle path between conventional or industrial farming and traditional or biodiversity-based farming. In other words, this strategy represents a way for the minimisation of synthetic fertilisers and insecticides in farms with the aim of producing safe crops as per residue limits established by food laws.

On the other hand, crops produced in this way might be judged unsafe if their mineral profile is considered too low. In fact, organic farming with manure vermicompost application tends to improve soil mineral profiles to a little extent if compared with results obtained via traditional farming with dense forest-pasture infrastructure. It is worth mentioning that in the absence of suitable agro-environment with a biodiversity outside the production field (forests and pastures), the field biodiversity of earthworms in the forms of compost manures is quite capable to effectively enhance NPK nutrient contents of soils. At the same time, mineral micronutrient profiles are not ameliorated.

For example, zinc content is 110 ± 9 mg/kg in CD manure and 116 ± 3.4 mg/kg in CD-vermicompost (not much increased), while the EU limit range for zinc content in vermicompost is 210 to 4,000 mg/kg. In other terms, CD in Europe is much more enriched in mineral micronutrients if compared with India, perhaps due to much more conserved soils. In this context, it would be appropriate to mention that Europe is the ideal 'eco-friendly' continent where almost 40 % of the total land is covered by dense biodiversified forests. On the other hand, in India, only 5 % of Indian areas are densely covered with forests; 21.6 % of total lands are covered by forests in 2000 (Rudel et al. 2005), but biodiversity could not be entirely conserved. Consequently, infrastructure dense forest-pasture cover with entire biodiversity is the basic requirement for cost-efficient organic farming capable of producing mineral-enriched crops. It does not mean that European agriculture is defined 'traditional' or 'organic' in nature because average usages of synthetic pesticides per hectare in Europe are too high in comparison to India. However, the EU is still able to set the lowest MRL for food articles. It seems that EU farmers adopt safer techniques for pesticide application; alternatively or at the same time, it may be assumed that synthetic pesticides are degraded faster in case of more conserved soil.

4.6.1 Definition of Organic Farming

Organic farming is defined in the broader sense of environment protection, economical crop production, social concerns, local self-supporting systems development, nutrients' recycling and nature's respect. A complete definition has been recently published (Ammann 2008) by the International Federation of Organic Agriculture Movements (IFOAM).

Agricultural scientists are not unanimous on the use of transgenic or genetically modified organism (GMO) seeds in the context of organic farming. For example, IFOAM emphasises on refraining from use of GMO in organic agricultural practice. On the other hand, Ammann argues for why organic farmers should use transgenic crops (Ammann 2008). In fact, despite using heavy amounts of synthetic pesticides, most of EU countries have stopped GMO seed application in farms (Clive 2014). On the other side, India approved in 2015 field trials of transgenic crops—rice, cotton, maize, mustard, *brinjal* and chickpea—within practices for organic farming (Kumar 2015). In the context of Indian organic farming practices, the success story of the Indian NPOP in the twenty-first century is worth mentioning.

4.6.2 Indian Programme for Organic Production

The National Programme for Organic Production (NPOP) has been created in India with the aim of introducing and implementing standards for organic production, farming and accreditation. Because of three basic requirements with relation to the definition of 'organic food'—high quality for ready-to-eat foods, absence of synthetic fertilisers, pesticides and additives with preservation functions, and labelling assurances for diet—the Indian traditional agriculture has been judged the ideal procedures. Despite mutual acknowledgement of NPOP standards on the international level, at present many rejections have been observed for Indian products so far particularly at EU border.

4.6.3 SWOT Scenario for Food Quality Assurance and Organic Certification in India

NPOP, as well as Food Safety and Standards Authority of India (FSSAI) and recognised laboratories, are interested in the expansion of organic farming and food quality assurance systems, including 'hazard analysis and critical control points' (HACCP) approaches. On the other side, certain coordination with the forest department would be expected and useful at present (Sharma 2014). For these reasons, a SWOT analysis of Indian food quality assurance systems and organic certifications may be carried out and related results can be shown in Sects. 4.6.3.1 and 4.6.3.2, respectively.

4.6.3.1 SWOT Analysis of Indian Food Quality Assurance Systems

Strengths

- The Food Safety and Standards Act (FSSA), 2006, plays a vital role in providing information to consumers via food articles' labels

- The law effectively speaks about good manufacturing practices and sanitation aspects (Schedule 4) for food, including big, medium and small industries, vendors or Indian people employed in confectionery and sweet-making activities (*halwais*)
- The FSSAI runs scientific panels with proper documentation for approval of health and nutrition claims
- The law encourages food enterprises to apply HACCP or follow food processing control points based on HACCP approaches.

Weaknesses

- The FSSA, 2006, does not discuss the use of lands for forestry in the densest way, as the demand for cost-effective organic farming. Different Ministries and Departments are involved in the development of organic food, but coordination among them could be improved
- Separate laws (other than FSSA, 2006) exist for 'street foods' or the informal food sector. Despite the follow-up of sanitation aspects in Schedule 4, the formal food sector could use non-organic raw materials, synthetic preservatives (within certain limits), fat, sugar and salt
- Theoretically, a 'junk' food leading to imbalanced diet with non-organic nature and synthetic preservation can make a nutrition claim
- Only a few officials are committed to food processing control activities.

Opportunities

- The food quality assurance system is expanded with reference to the number of accredited laboratories, organic certification bodies and campaigning organisations for public health concerns
- The awareness about food safety and foodborne diseases has been increasing, thanks to the media. The theme of food safety and quality has attracted a few writers who regularly contribute to food journals.

Threats

- Primary food safety issues or public health requirements could be highlighted better
- Due to the low literacy rates (particularly in rural areas), people's access to food and health journals/magazines/television channels is limited. Some writers exaggerate food-related issues, and some do not consider them while writing on food products.

4.6.3.2 SWOT Analysis of Organic Certifications in India

Strengths

- Farmers' awareness as well as government interests are rising when speaking of organic production and certification
- The consumption of chemicals in Indian farms was less than in developed Nations when the Green Revolution and intensive farming era was initiated in the mid-twentieth century
- Indian corporate companies tend to invest in agriculture and agribusiness, particularly in organic farming
- NPOP is effectively running in India and organic pockets exist in different parts of the country
- A wide variety of organic fruit and vegetables can be grown in India.

Weaknesses

- Cost-effective organic production is a difficult task in India, due to vast deforestation and soil non-conservation
- In India, fertilisers and insecticides remained in use in increasing patterns even after 1980, when Europe began to practice cost-effective organic farming along with dense mountain plantations or forestation
- Agriculturists advise farmers till date to use fertilisers and synthetic insecticides for bumper crops
- Corporate companies do not appear interested in setting up forestry or biotechnology-based units. The old set-ups for herb and spice selling and animal keeping need to be updated. This scenario is unfavourable to organic farming
- Shelf life values are short. The oxygen-free aseptic packaging technology is less prevalent in India.

Opportunities

- The World Trade Organisation is offering global opportunities for organic farming agribusiness; export opportunities for India exist at present
- Resources and knowledge bases are available for research in the organic farming sector
- The private sector is keen to join organic chains because of the clear added value in agriculture; organic food retail stores are opening up worldwide.

Threats

- The demand and supply of organic products has been often unbalanced, and non-tariff barriers appear seldom-imposed by developed Nations
- Indian spices, herbs and other products are now facing the problem of rejection at the EU borders and in developed countries due to the high levels of microbial, aflatoxins, insecticides, etc.
- Organic farming is effectively conducted with dense forestation. The formation of organic pockets within a chemical-based agricultural tract, like those running in India, is not very beneficial.

4.7 Indian Organic Products Developing in Limited Scope for Organic Farming

Indian food articles have recently faced 19 EU border rejections from 5 to 25 January 2016—the highest fraction of total rejections—as per notifications list at the Rapid Alert System for Food and Feed (RASFF) portal.[3] Next to India, major EU alerts and border rejections of food articles belong to Iran (13), Turkey (10) and Egypt (8). Indian food articles for export rejected by European countries have been fruits and vegetables, nuts and nut products, seeds, herbs and spices. The higher amounts of aflatoxins, ochratoxin A and insecticides (fipronil and monocrotophos) in herbs and spices, with the additional detection of *Salmonella* spp. in other food articles have been the reasons for rejection of Indian food articles at EU borders.

Despite the fact that Indian export consignments are rejected in larger number in worldwide comparison at EU border, India's preparation for organic farming—particularly in Madhya Pradesh, Rajasthan and Uttar Pradesh—is worth considering. As per the data from government laboratories (reports on vegetable, fruits and milk and other food samples collected from various retail and wholesale outlets), people might be assured that Indian agriculture is now on the 'organic track', because no insecticide residue was detected in 16,761 samples (81.3 %) out of 20,618 analysed samples (Express News Service 2015).

4.8 Organic Products Development in India

The Indian agriculture is sustained by mechanisation but constrained by deforestation. However, Indian agriculture and dairy industry are now initiating to follow the organic way and write the success story of NPOP. It has been recently reported that 70 % of milk in India is adulterated with addition of baking soda, starch, urea,

[3]The RASSF portal is available at http://webgate.ec.europa.eu.

water, etc. (Sankari 2014). It may be supposed shelf life values of milk are increased, but health consequences are surely severe. In such a serious situation, attempts to produce organic milk and milk products by a few enterprises are really challenging. The milk product can be defined 'organic milk' on condition that cows or other animals are fed on fodder free from synthetic insecticides and artificial fertilisers. In addition, antibiotics or banned hormones have to be absent, and milk has to be piped from udders to chillers and pasteurisers without hand touch.

4.9 Indian Food: The Safety Concern

Indian agriculture, known for biodiversity-based traditional farming practices even up to 1950s, began to follow the path of industrial farming and allow the use of synthetic fertilisers and insecticides in farms when vast deforestation simultaneously was also going on, to meet out the requirement of horizontally expanding urbanisation. By the viewpoint of environmental protection and public health, avoidance or minimisation of synthetic insecticides and fertilisers was considered as the prime requirement. In due course of time, Indian farms gradually used to apply animal excreta (mainly cow dung) as manure and *neem* leaves juice as insecticide in almost same way as ancestors were practising. Advantages offered by the biodiversity of earthworms were not much available due to vast deforestation; therefore, soil was not properly enriched with mineral nutrients, and hence the farm yield began to decline. This type of farming is, nowadays, called organic farming. With the use of hybrid and transgenic seeds, both kinds of farming practices—conventional or industrial as well as organic—gained the new amplitudes of bumper crop production. It would be appropriate to mention that Indian farmers use GMO for cotton production only; however, the Indian government has now planned for field trials of transgenic crops including rice, maize, mustard, *brinjal* and chickpea also. This plan is called integrated approach of farming. In this way, three kinds of farming practices in India are prevalent at present:

(1) Conventional Farming (use of synthetic fertilisers, synthetic insecticides, hybrid seeds and transgenic seeds)
(2) Organic-Integrated Farming (no use of synthetic fertilisers, synthetic insecticides, but hybrid and transgenic seeds are used)
(3) Organic Farming (no use of synthetic fertilisers, synthetic insecticides and transgenic seeds, but hybrid seeds are used).

A notable percentage of Indian foods may be often intended as 'natural' or 'organic' product if compared with industrial or semi-organic foods obtained by conventional or integrated farming systems, respectively. This simple postulate in the context of Indian food products might be further elucidated as follows:

(a) Low synthetic pesticide usage. A small fraction of worldwide consumption of synthetic pesticides, 3.75 % only is shared by India; while USA and Europe share 25 and 45 %, respectively (De et al. 2014). Although pesticides globally cover only 25 % of the cultivated land, there is a remarkable difference with reference to pesticide usages per unit area for different countries. Among the Asian countries, the usage of pesticides in Japan and Korea corresponds to 12 and 6.6 kg/ha, respectively, while in India this value is 0.5 kg/ha (a nominal number in comparison to several countries). It is also worth mentioning that among all pesticides the worldwide consumption of herbicides is the maximum value: 47.5 %, followed by insecticides (29.5 %), and fungicides/other pesticides (23 %).The Indian scenario of pesticide consumption is somewhat reverse; insecticides 80 %, herbicides 15 %, others 5 % only. It is believed that weed control is mostly manually done by hand in India; therefore, herbicides are not so much required by farmers (De et al. 2014)

(b) Moderate synthetic fertiliser usage. Indian farmers moderately use synthetic fertilisers, if compared with other countries. The total fertiliser consumption of fertilisers in India corresponds to 144.8 kg per hectare of arable land between 2012 and 2013 according to the World Bank[4] and a recent Indian document (Department of Fertilizers 2014). This average value is very different from those ascribed to Kuwait and the Russian Federation in 2013 (1097.8 and 15.2 kg of fertilisers per hectare of arable land, respectively)

(c) A remarkable probability of finding safe food in India in the context of presence of synthetic insecticides. No synthetic pesticide residues were detected in 81.3 %—Indian food samples collected at national level (Express News Service 2015). Although this result indicates a good probability of finding safe food in India, it should be still much higher to ensure that Indian foods are quite safe.

Despite the fact that Indian food is often ‘organic’, this food sometimes faces rejection at EU borders. In detail, India ranks several times among countries standing with higher number of rejections in the RASFF notifications list, mostly due to presence of *Salmonella* spp. (bacterial growth) in fruits and vegetables and the detection of aflatoxins in herbs and spices. Therefore, the discussion on environmental factors (climate change or global warming), storage and transport conditions and land use policy issues (like deforestation) becomes relevant in the context of development of detrimental chemicals in farm-level operations and postharvest food storing in India to safeguard interests of consumers, farmers and businessmen, particularly exporters.

References

Adler FR, Tanner CJ. Urban ecosystem processed. In: Urban ecosystems: ecological principles for the built environment. Cambridge: Cambridge University Press; 2013.

Ammann K. Integrated farming: why organic farmers should use transgenic crops. New Biotechnol. 2008;25(3):101–7. doi:10.1016/j.nbt.2008.08.012.

[4]These data are available at the following web address: http://www.worldbank.org/.

Clive J. Global status of commercialized Biotech/GM crops: 2014. In: International service for the acquisition of agri-biotech applications (ISAAA), Brief No. 49. Ithaca, NY: ISAAA; 2014.

De A, Bose R, Kumar R, Mozumdar S. Worldwide pesticide use. In: Targeted delivery of pesticides using biodegradable polymeric nanoparticles. Springer India, New Delhi; 2014. doi:10.1007/978-81-322-1689-6.

De Gregori TR. Green revolution myth and agricultural reality? J Econ Issues. 2004;38(2):503–8. doi:10.1080/00213624.2004.11506711.

Department of Fertilizers. Indian fertilizer scenario 2013. Department of Fertilizers, Ministry of Chemicals and Fertilizers, Government of India, New Delhi. 2014. Available http://fert.nic.in/sites/default/files/Indian%20Fertilizer%20SCENARIO-2014.pdf. Accessed 15 July 2016.

Dharampal S. Indian science and technology in eighteenth century, vol. 1. Mapusa, Goa, India: Other India Press; 2000.

Evenson RE, Gollin D. Assessing the impact of the green revolution, 1960 to 2000. Sci. 2003;300(5620):758–62. doi:10.1126/science.1078710.

Express News Service. Pesticide residue found in vegetables, fruits and milk. New Indian Express 02nd October 2015. 2015. Available http://www.newindianexpress.com/nation/Pesticide-Residue-Found-in-Vegetables-Fruits-and-Milk/2015/10/02/article3059369.ece. Accessed 04 July 2016.

Guleri VS. Sanskrit men Vigyan (Hindi book). New Delhi: Sanskrit Bharati; 2000.

Kesavan PC, Swaminathan MS. From green revolution to evergreen revolution; pathways and technologies. Curr Sci. 2006;90(2):145–6.

Kesavan PC, Swaminathan MS. Strategies and models for agricultural sustainability in developing Asian countries. Philos Trans R Soc Lond B Biol Sci. 2008;363(1492):877–91. doi:10.1098/rstb.2007.2189.

Kumar S. India eases stance on GM crop trials. Nature. 2015;521(7551):138–9. doi:10.1038/521138a.

Majumdar GP, Banerji SC. Karsi Parasaran. Kolkata: The Asiatic Society; 2001.

Minerals For All. Volume 1 (March 2012). USA: Minerals Resource International; 2012.

Pathak R. Introduction to biotechnology. New Delhi: Atlantic Publishers & Distributors (P) Ltd.; 2007.

Rudel TK, Coomes OT, Moran E, Achard F, Angelsen A, Xu J, Lambin E. Forest transitions: towards a global understanding of land use change. Glob Environ Change. 2005;15(1):23–31. doi:10.1016/j.gloenvcha.2004.11.001.

Sankari R. Where to find: organic milk in India. The Alternative. Sattva Media and Consulting Pvt Ltd. 2014. http://www.thealternative.in/lifestyle/cool-dhoodh-where-to-find-organic-milk-in-india/.

Sharma RK. Currency value, soil and food quality concerns in research. Mumbai: Food Beverage News, Saffron Media Publication; 2013. 16–31 Dec 2013.

Sharma RK. FSSAI not authorised to suggest land improvements. Mumbai: Food Beverage News, Saffron Media Publication, p. 9–10. 16–31 Mar 2014.

Sircar NN. An introduction to the Vrksayurveda of Parasara. J Royal Asiat Soc Bengale Lett. 1950;16(1):123–139.

Swaminathan MS. The age of algeny, genetic destruction of yield barriers and agricultural transformation. Presidential Address, Agricultural Science Section. In: Proceedings of the 55th Indian Science Congress, Varanasi, India; 1968.

Swaminathan MS. An evergreen revolution. Crop Sci. 2006;46:2293–303.

Vyas V. Mahabharat (Chapter 184). Gorakhpur: Gita Press; 2001.

Yadav A, Gupta R, Garg VK. Organic manure production from cow dung and biogas plant slurry by vermicomposting under field conditions. Int J Recycl Org Waste Agricult. 2013;2(1):1–7. doi:10.1186/2251-7715-2-21.

Chapter 5
Pesticides Detection and Detrimental Chemicals in Indian Farming. Reasons for EU Border Rejections

Abstract Indian food trade is facing the problem of detection of several undesired and detrimental chemicals in food articles with additional food scandals, while Europe is stepping forward to effectively act against planned adulterations. The reasonable follow-up of ethics for biosphere protection from detrimental chemicals and of forest policy is obviously needed in India. Humans, being integral part of biosphere, should consume the same kind of food and water and air which all the creatures do; this statement is the fundamental postulate of 'Integral Humanism'. The control of global warming should require adequate monitoring actions of free-flowing water in rivers. Spacious water dams on mountains for hydroelectricity generation and elongated canals for irrigation contribute to stagnation of water with release of the lightest greenhouse gas. Therefore, regular check-up of farming effluents for dissolved oxygen, pathogens, heavy metals and pesticides—as per analytical protocols—and land reforms to contract agricultural and housing tracts and expand forest-pasture tract are essentially required in India.

Keywords Analytical protocol · Dissolved oxygen · Food fraud · Global warming · Integral humanism · Land reform · Pathogen agent

Abbreviations

DO	Dissolved oxygen
EU	European Union
FSSAI	Food Safety and Standards Authority of India
GHG	Greenhouse gas
MRL	Maximum residue limit
NPOF	National Project on Organic Farming
NPK	Nitrogen, phosphate and potash
ppm	Part per million
RASFF	Rapid Alert System for Food and Feed
USA	United States of America

R.K. Sharma and S. Parisi, *Toxins and Contaminants in Indian Food Products*,
DOI 10.1007/978-3-319-48049-7_5

5.1 Introduction

Although the list of contamination typologies in food articles is remarkable, just a few types are developed at farm level due to abnormal weather conditions, industrial agricultural practices, toxicity of particular natural constituents in crop or food and non-conserved soil and water situations. A few attempts of global food safety monitoring actions have resulted in the classification of 264 contamination types among 3400 non-compliant food products. In general, the most non-complaint food article types are seafood, vegetables, fruits, herbs and spices, dairy products, grain, meat, and nut/seed. The top seven contamination types (out of 264), frequently detected in foods, are (Datta 2015; Food Safety News 2014):

- Pesticides
- Pathogens
- Filth
- Mycotoxins
- Chemicals/additives
- Toxic metals
- Antibiotics.

With relation to Indian products ('organic' foods), the detection trendset might considerably differ from the global trendset due to the minimisation policy of pesticide application, despite conditions of Indian soils (excessive deforestation for horizontal urban development). There may be a relatively high probability of detection of disease-causing microbial agents, pathogens and mycotoxins in Indian foods, if compared to that of pesticides. This hypothesis (or presumption) is probably evaluated in the context of European Union (EU) border rejections of Indian food articles.

For example, 31 border rejections for products from India were signalled out of 200 Rapid Alert System for Food and Feed (RASFF) notifications (both alerts and border rejections) within periods 05–25 January 2016 and 28 January–01 February 2016.[1] In detail, 25 Indian food articles samples were rejected due to higher *Salmonella* contents, three for high contents of aflatoxins, one due to high amounts of both aflatoxins and ochratoxin A, and two due to high pesticide residues. However, a different trendset of Indian food contamination episodes in comparison to global data cannot be used with the aim of verifying the safe nature of Indian foods. Certainly, low pesticide and high microbial contents in Indian foods can lead to the violation of food laws. Unfortunately, Indian foods are considered the worst example of food violation if compared with other countries, despite these products are often 'organic': 11.1 % on 3600 and more food safety events are directly ascribed to India (Datta 2015; Food Safety News 2014).

Farming practices are not the only responsible agent for farm crop safety status. In general, the entire industrialisation—including industrial farming—is responsible

[1]The RASSF portal is available at http://webgate.ec.europa.eu.

for release of certain detrimental chemicals into the environment (pesticides, toxic metals, etc.) with consequences for biodiversity and public health. There are selected chemical tests to infer, confirm and estimate the amount of pesticides, heavy metals and other detrimental chemicals in foods as well as farming operations.

The detection of pesticide residues and other undesired chemicals may represent a serious problem for Indian farmers and industries: many food commodities have been rejected so far at the EU borders because of the demonstrated detection of intoxicants, in spite of recent Indian actions (organic farming, reduction of pesticides in farms, etc.). Because of deforestation effects, soils tend to gradually turn into sands or reduce its natural fertility; consequently, crops can lose their natural defences against infections and microbial spreading.

Second, the Indian food trade is nowadays facing various food scandals like increasing weight and improving appearance of vegetables and fruits by injecting peculiar hormones (oxytocin) and adding colourants such as copper sulphate. As a result, it seems reasonable to understand reasons for EU border rejections. In this context, the EU policy is vital enough and it is important to know how Europe is stepping forward to effectively act against food scandals. The recent Elliott Review has discussed the current status of official controls in the UK (Elliott 2014).

5.2 Industrialisation and Release of Detrimental Chemicals into the Environment

At present, food cannot be visualised simply by means of the ‘from farm to fork’ approach. In fact, one more phenomenon—‘from forest to farm’—in the context of soil conservation is almost complimentary to ‘from farm to fork’ approach.

Soil non-conservation factors are too dominant today to properly maintain cost of farming because of vast deforestation actions (the reason is mainly horizontally expanding urbanisation) and mining purposes. Organic farming is still considered comparatively more cost-efficient than the conventional or industrial farming due to use of cheaper inputs like natural compost manure and natural *neem* (*Azadirakta indica*) leaf juice pesticides instead of artificial fertilisers and pesticides. On the other side, Indian foods might show higher pathogen contamination probably due to weak plant immune systems.

Several detrimental chemicals are released by industries into air, water, soil and food. Heavy metals, although optimally required for conservation by the soil and groundwater (used for irrigation), may be excessively ejected out in natural water streams by industries. Some of these heavy metals, well known for their toxic effects (cadmium, mercury, lead, chromium and arsenic), pose serious threat for biodiversity as well as human health. As a result, final crops are found to be highly contaminated.

The World Health Organization enlists arsenic, cadmium, lead and mercury among ten chemicals or group of chemicals of major public health concern (Ikehata et al. 2014); other examples are benzene and highly hazardous pesticides.

In the food contamination scenario of India, food frauds have been recently observed with increasing rates due to the following reasons:

(a) Hormones like oxytocin (particularly in milk, vegetable and fruits)
(b) Unallowed synthetic colours including red lead oxide and metanil yellow (particularly in sweets)
(c) Several antibiotics like nisin
(d) Excessive amounts of fibres without mention on label
(e) Oil bleaching chemicals in cooking oils
(f) Oxidants like benzoyl peroxide (particularly in bread).

The Indian Union Health Minister, Dr. Nadda, confirmed in March 2016 several of above-mentioned concerns. In addition, the increase of food fraud episodes has been reported to reach 20 % in 2013–2014 from 13 % in 2011–2012.

The reasonable follow-up of ethics regarding protection of biosphere from detrimental chemicals and of forest policy by the Indian government is obviously needed. According to Indian forest policy, a minimum amount of 33.33 % of country lands should be covered with dense forests. For this purpose, the proper planning and execution of land use policy is perhaps required in India.

5.3 Ethics Regarding Protection of Biosphere from Detrimental Chemicals. Anti-pesticide Movement and Integral Humanism

C. Pointing will be ever known for remarks on the rise and collapse of civilisations on account of farming methods, mentioned in the book '*A Green History of the World*'. Threats of modern industrial agriculture systems—exorbitant consumption of fossil fuel, synthetic fertilisers and pesticides—are reported to be essentially air and water pollution, soil depletion and biodiversity decline (Horrigan et al. 2002). However, these reflections concerned old civilisations when synthetic pollutants were not used in farms, and animals only were employed for ploughing. Therefore, Pointing perhaps wants to suggest that even the traditional type of agriculture cannot be allowed to excessively utilise lands; forests and pastures converted to agricultural tract might lead to erosion of soil and depletion of groundwater, and therefore harm to these natural resources for agriculture. Consequently, the maintenance of dense forest-pasture tract appears to be the basic ethical commitment of society for growth of agriculture and the rise of civilisation on the planet Earth. India is perhaps alone (otherwise one of the few countries) in the world, where half of land areas and 60 % of workforce are devoted to agriculture profession.

Second, forest-pasture tract has been continuously converted into urban tract for expanding human colonies. Therefore, the basic ethics for growth of agriculture and the maintenance of dense forests (to at least 33.33 % of total land areas) have not been followed in India.

At present, industrial agriculture appears much more polluting in comparison to traditional farming practices. Therefore a farmer, like any industrialist, might be reasonably expected for ethical commitment to confirm that pesticides are properly degraded and soils as well as water are pesticide-free after their application in farms. Apparently, this approach appears a difficult task, but it is a matter of relief for India that Indian farmers are now adopting the 'organic' way; as a consequence, pesticides consumption per hectare is quite low. It is also worth mentioning that the excessive use of pesticides for contagion control and farming was initiated in developed countries, and the so-called 'anti-insecticide movement' was run in 1960s by Carson (2002). In the same decade, Pandit Deen Dayal Upadhyay (1916–1968) presented the theory of Integral Humanism in India to make people feel that they are integral part of biosphere instead of mechanical or robotic networks (Walker 2011). In other words, humans—being integral part of biosphere—should consume the same kind (quality) of food and water and air which all the creatures do.

5.4 Effects of Toxic Metals and Other Detrimental Chemicals on Environment, Biodiversity, and Public Health

Each year, industrial activities release remarkable amounts of toxic substances in the environment, including known carcinogens. Needless to say, industrial farming is also one of such industrial facilities which might employ carcinogenic pesticides for killing pests, lead-contaminated fossil fuels (for running tractors), and follow the practices leading to various kinds of environmental exploitation.

In the Indian agricultural system (50 % of total lands are used for agriculture), the 'elongated canal' system might lead to stagnation of waters resulting into organic matter decay and thereby generation of methane, a greenhouse gas (GHG). The generation of hydraulic electricity in India by means of spacious water dams is also carried out on the cost of forest destruction, biodiversity decline, water stagnation and GHG emission. Methane, the lightest GHG, is capable to reach—and deplete—ozone layer due to low density compared to nitrogen and oxygen. In this way, India's share to global warming and climate change is perhaps bigger than the European countries and Japan where forests occupy more than 40 % of total land areas (and agriculture activities are performed on less than 25 % of lands). Needless to say that global warming phenomenon has resulted in making harsh environment—droughts, floods, monsoon disturbance—in India.

5.5 Detection of Detrimental Chemicals

At present, Indian farming may be defined 'organic' in the sense that the principle of pesticide reductions is followed. However, food articles, produced in India, have been often found 'organic' at EU borders but seldom rejected for high pesticide contamination. Perhaps, India does not possess, nowadays, dense forest infrastructure for a reliable and cost-efficient organic farming activity.

The destruction of forests has been a regular feature in India: the original forest area has been progressively converted into horizontally expanding housing (or urban) tract and economical mining tract on mountains. Spacious water dams for economical hydroelectric generation have also been constructed on high-altitude mountains. This situation might lead to remarkable pathogen contamination with associated high amounts of heavy toxic metals in Indian crops.

For these reasons, a regular monitoring action of farming actions is required at present when speaking of detection and determination of the following detrimental agents:

1. Dissolved oxygen (DO) in canals for irrigation purposes
2. Pathogens in water
3. Heavy Toxic Metals in soil and water
4. Pesticides, if applied, in agricultural effluents.

It is further worth mentioning that

(a) Improperly treated industrial effluents can damage agricultural activities, if they are released into rivers (or irrigation waters) or buried in ground
(b) Unfavourable (hot and moist) storage and transportation conditions are quite favourable to microbial growth in postharvest crops or high-moisture food articles.

5.5.1 Dissolved Oxygen

The flow of water on earth surface is considered as the measure for its purity. Rivers flowing with their original velocity are capable to host various creatures like fishes and crocodiles who receive oxygen from water. Flowing waters maintain its dissolved oxygen level perhaps due to proper interaction with atmosphere. Should dams be built or elongated canals be taken out of rivers, water would get stagnant due to low DO content. This amount may be much more lowered by organic reducing agents in industrial effluents (if thrown into rivers without proper treatment). This situation leads to demise of creatures (fishes, crocodiles) of rivers and the development of microbial organisms in water, giving rise to increased pathogen contents in crops grown on soils irrigated with stagnant canal water. The Indian Government is nowadays planning for the purification of rivers, particularly the

Ganges, by chemical treatment and removal of decayed organic matter. Despite expensive costs of purification, artificially purified water is not perhaps as effectively purified as naturally purified free-flowing river water. Determination of DO contents in water may be done by the Winkler method.

Minimum DO limits for aquatic life is considered to be 3 parts per million, although shallow water fish need 4–15 mg/l DO in water. However, DO of free-flowing rivers (with entire biodiversity) appear to be the most interesting data in the context of cost-efficient irrigation system with short canals, also named 'the Bhagirath attempt' (task done with firm determination).

5.5.2 Pathogens

A bacterial, viral, fungal or prionic pathogen may be shortly defined as an agent specialised to infect body tissues, which causes diseases, be able to reproduce itself and cause serious damages with correlated symptoms, based on a longer definition of the Association of the British Pharmaceutical Industries. Inhaled air, imbibed water and eaten food are the vehicles of pathogens.

Only a few pathogenic agents which cause infectious diseases are discussed at present with remarkable frequency when speaking of foodborne diseases. In detail, the most part of rejected Indian foods at EU borders, particularly fruits and vegetables, have been found contaminated with *Salmonella* spp. With relation to fungi, these organisms mostly contaminate crops (or plants) particularly under high-temperature and high-moisture conditions. Indian seeds and nuts are seldom rejected at EU border because of high aflatoxin contents.

Prescribed 'Food Safety and Standards Authority of India' (FSSAI) limits for microbes in foods are shown in the 'Food Safety and Standards Regulations' document, 2009, Appendix B: Microbiological Requirements for various products including seafood, milk products, herbs and spices, and fruits and vegetables.

5.5.3 Heavy Toxic Metals in Soils and Water

The FSSAI limits for heavy toxic metals in foods are shown in the 'Food Safety and Standards Regulations' document, 2009, Chap. 4, Part 4.3: Contaminants and Toxins—Regulation 4.3.1: Metal Contaminants. With relation to analytical protocols, toxic metals in water soil and foods may be easily determined by isolation, conversion in coloured compounds—lead and cadmium can be turned in the corresponding sulphides—and colorimetric estimation. Many different methods may be proposed.

5.5.4 Pesticides in Agricultural Effluents

The use of pesticides in farms varies from country to country. It appears that soils with dense forest infrastructure (more than 33.33 % of land areas) are conserved enough and capable to efficiently breakdown synthetic pesticides. On the other hand, non-conserved soils might not have similar performances. Consequently, there are not fixed standards for pesticides contents in agricultural effluents, at present. For India, agricultural effluents are expected to be almost pesticide-free, and pesticide detection in effluents is required if applied in farms.

With relation to analytical protocols, pesticides in foods and water can be determined by gas chromatography/mass spectrometry approaches.

5.6 India Towards Reduction of Detrimental Chemicals in Farming

At present, four important amplitudes of any project for reduction of detrimental chemicals in farming can be cited:

1. Minimisation of synthetic pesticides and fertilisers application in farms
2. Dense forestation for monsoon regularity, soil conservation, groundwater elevation, and the reliable control of aflatoxins and microbial in crops
3. Contraction of mining activities and housing tracts for control of toxic heavy metals in soils, irrigation water and crops
4. Contraction of the agricultural tract and shortening of canal system for control of GHG, in particular methane.

The Government of India seems currently to work in an effective way upon the first amplitude of reduction of detrimental chemicals in farms. The government has launched the National Project on Organic Farming (NPOF). Strength points of this project are

- The reduction of usage with relation to synthetic pesticides (threat to biosphere) and nitrogen, phosphate and potash (NPK) fertilisers (threat to yield consistency)
- The application of cow dung, compost manure, animal urine and natural *neem* leaf juice (as eco-friendly insecticide compound).

Lok Sabha (Parliament's lower house) Secretariat's Committee on Estimates (2015–2016) presented report on NPOF on 13 August 2015. The introductory part of this report discusses the negative impact on ecology, soil modifications, decreasing yields and the detection of toxic substances in food products (Ministry of Agriculture 2015). Consequently, the inclusion of a minimum percentage of land areas covered by dense forests (33.33 %) is defined necessary with concern to the reduction of detrimental chemicals in farming activities.

5.7 Reasons for EU Borders Rejections

5.7.1 Salmonella Detection in Indian Foods at EU Borders

India faced 31 border rejections out of 200 RASFF notifications (both alerts and border rejections) from 5 to 25 January 2016 and from 28 January to 09 February 2016. Of these notifications, 25 were due to *Salmonella* spp. detection only. This simple statistics is enough to conclude that *Salmonella* detection and growth in Indian foods are frequently observed among EU border rejected samples. It is further worth noting that 21 of these 25 detected samples belonged only to the product category: fruits and vegetables—betel leaves. The remaining four *Salmonella*-affected samples belonged to the product category 'nut, nut products and seeds'—hulled sesame seed only. Although betel leaves' share in EU border rejection (due to *Salmonella* detection) is much more than sesame seed, official controls in India for food safety purposes are more required to grow up in case of latter items than that in former products. Seeds are not as moist as fruits and vegetables; as a result, better controls are possible.

No considerable developments, as per rejection statistics of sesame seeds, have been observed in the last 1 year. Between 01 October 2014 and 06 January 2015, there were 14 notifications for India on the RASFF system, with relation to *Salmonella* spp. in sesame seeds (Whitworth 2015). Nowadays, India is said to be equipped with better cold chain storage and transportations systems, so it is hopefully presumed that the country would be soon in a position to ensure that not only sesame seeds, but also betel leaves imported to EU are safe.

5.7.2 Despite Following Organic Farming, Pesticides in Indian Foods Seldom Detected at EU Borders

India faced 31 border rejections out of 200 RASFF notifications (both alerts and border rejections) from 5 to 25 January 2016 and from 28 January to 09 February 2016. Two of these notifications were due to excessive pesticide contents, one in the product category: 'herbs and spices' (chilli peppers) and one in: 'fruits and vegetables' (chilled okras). According to these notifications, the hot chilli pepper sample from India contained fipronil (0.3 mg/kg) and unallowed monocrotophos (0.06 mg/kg). In chilled okras sample from India, triazophos (0.82 mg/kg) was detected. It is worth mentioning that monocrotophos is an unauthorised substance according to EU food laws, while Indian food law allows it in various food products with varying limits. In fruits for sale in India, monocrotophos might be present up to 1.0 parts per million (ppm), except for citrus fruits—maximum residue limit (MRL): 0.2 ppm—and in chillies up to 0.2 ppm. Therefore, chillies containing 0.06 ppm or even up to 0.2 ppm of monocrotophos will pass for sale in India, but not a trace of monocrotophos will pass for sale at EU borders. In addition, triazophos is allowed in India for chillies up to 0.2 ppm, rice up to 0.05 ppm, cottonseed oil up to 0.1 ppm, and soybean oil up to 0.05 ppm. On the contrary, it is not allowed in okras in India.

5.7.3 Aflatoxins in Indian Chilli. The Situation at EU Borders

Four of the 31 Indian food samples rejected at EU borders from 5 to 25 January 2016 and from 28 January to 09 February 2016 (200 total notification) belong to the estimation of aflatoxins above permissible limits; three are referred to chilli samples in the 'herbs and spices' category, and one concerns the 'nuts, nut products and seeds category'. Among three chilli samples, one was containing both aflatoxins and ochratoxin above MRL. The matter of aflatoxins in Indian spices, particularly chilli samples, has been an issue at EU borders.

5.8 Land Reforms in India Are Essential

Nowadays, food frauds are posing a big question mark before the laboratory experimentation and specified standards. Several adulterations are made for attractive looking and false freshness of a food article. Also, the use of growth hormones at farm level for increasing crop yields has been carried out since decades. Such fraudulent practices in food business should be thoroughly considered by lawmakers worldwide. Recently, the 'Elliott Review' and correlated recommendations (Elliott 2014) to EU Authority for food authenticity are seen as good policy issues to encounter food frauds. It would be relevant to consider this matter by the viewpoint of Indian consignments at EU borders.

However, food adulterations in India appear to take place more to cut costs than to make economic profits. For this reason, land reforms in India are required: the basic problem is that organic foods have excessive global costs at present in areas with scarcely conserved soils (Sharma 2014).

References

Carson R. Silent spring. Fortieth Anniversary Edition. Boston: Houghton Mifflin; 2002.

Datta D. Is that food on your plate? Indiatoday. 2015. Available http://indiatoday.intoday.in/story/maggi-noodle-food-quality-fssai-cover-chemicals/1/443877.html. Accessed 11 July 2016.

Elliott C. Elliott review into the integrity and assurance of food supply networks—Final report. Department for Environment, Food & Rural Affairs and Food Standards Agency, London; 2014. Available https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/350726/elliot-review-final-report-july2014.pdf. Accessed 11 July 2016.

Food Safety News. U.S. makes top 10 list of worst food safety violators. Food Safety News; 2014. http://www.foodsafetynews.com/2014/08/u-s-in-top-ten-worst-food-safety-violators/#.V4i7ydKLRkh.

Ikehata K, Jin Y, Maleky N, Lin A. Heavy metal pollution in water resources in China—occurrences and public health implications. In: Sharma SK, editor. Heavy metals in water: presence, removal and safety. Cambridge: The Royal Society of Chemistry; 2014.

Horrigan L, Lawrence RS, Walker P. How sustainable agriculture can address the environmental and human health harms of industrial agriculture. Environ Health Perspect. 2002;110 (5):445–56.

Ministry of Agriculture. National project on organic farming: committee on estimates (2015–16), Ninth Report. Ministry of Agriculture (Department of Agriculture & Cooperation, National Project on Organic Farming, New Delhi. 2015. Available http://admin.indiaenvironmentportal.org.in/files/file/national%20project%20on%20organic%20farming.pdf. Accessed 11 July 2016.

Sharma RK. Land reforms essential for genuine food regulatory practices. Ramesh Kumar Sharma; Business of Agriculture: Nov–Dec 2014. L.B. Associates, Noida; 2014.

Walker R. Hindutva: Indian nationalism and the politics of religious violence. In: Denton PH, editor. Believers in the battlespace: religion, ideology and war. Kingston: Canadian Defence Academy Press; 2011.

Whitworth J. India cannot ensure sesame seeds imported to EU are safe. Food Quality News.com, 4th August 2015. Available http://www.foodqualitynews.com/Regulation-and-safety/Follow-up-controls-RASFF-and-sampling-concerns-in-Indian-audit. Accessed 11 July 2016.