

PROMOTION OF TURMERIC FOR THE FOOD/PHARMACEUTICAL INDUSTRY IN NIGERIA

J.O.NWAEKPE*, H.N.ANYAEGBUNAM*, B.C.OKOYE* AND G.N.ASUMUGHA*.

*National Root Crops Research Institute, Umudike, Abia state, Nigeria.

Corresponding author's e-mail: janenwaekpe2013@gmail.com; nwaekpejane@yahoo.com.

Abstract

This paper seeks to promote turmeric (*Curcuma longa* Linn) through increased awareness of the potentials of the crop in the food, cosmetic and pharmaceutical industries in Nigeria. Nigeria can take the lead in turmeric production but this potential has not been fully tapped as the techniques needed for its production have not been properly understood by the farmers which have led to low production. Increased production and processing of turmeric as highlighted in this paper, has the potential of making a significant impact on the economy. This is because it has diverse uses and it is highly valued at the international market. Turmeric is used as a spice and is the major component of curry powder. Besides its use as a spice, turmeric finds a place in the cosmetics industry for its brilliant yellow colour and characteristic perfume. It is also being used as a dye for colouring fabrics. It is medically used for the prevention and treatment of diverse kinds of diseases as also highlighted in the paper. It is thus recommended that there should be adequate awareness on the potentials of turmeric especially in the southern part of Nigeria where the Research Institute that has the mandate to research into the crop is located. There is also need to develop improved varieties of the turmeric to boost production. Farmers should be provided with inputs like fertilizers and other agro-chemicals at subsidized rates in order to increase their production.

Keywords: Awareness; Turmeric; Food and Pharmaceutical industry; Nigeria

Introduction:

Turmeric is a shallow-rooted crop and an herbaceous plant with thick and fleshy rhizomes. It belongs to the genus *Curcuma* and to the family, *Zingiberaceae*, and consists of many species. *Curcuma longa* Linn is the highest yielding turmeric of commercial value. Its origin has been traced to South and Southeast Asia. Turmeric is used as a spice and is the major component of curry powder. Among the several spices, turmeric ranks second with regard to its foreign exchange earning being next only to chilli (Babu, 2008 In: Akinpelu, 2012). Besides its use as a spice, turmeric finds a place in the cosmetics industry for its brilliant yellow colour and characteristic perfume. It is also being used as a dye for colouring fabrics among other uses. It is medically used for the prevention and treatment of different kinds of diseases. As reported by Njoku et al., (2012), turmeric has yellow food pigment called curcuminoid (6%) and essential oils (5%) (Nunes, 1989), and it's a major source of foreign exchange in the international market. Curcuminoids, the active principles in turmeric-rhizomes, have anti-inflammatory, antimutagen,

anticancer, antibacterial, anti-oxidant, antifungal, antiparasitic and detoxifying properties (Sugiyama et al, 1996; Ishimine et al., 2003 In: Njoku et al., 2012). Curcumin and volatile oils of turmeric improve liver and kidney functions, and could be used against biliary disorders, diabetic and hepatic disorders (Hermann and Martin, 1991 In: Njoku et al., 2012).

India is the world's largest producer of turmeric supplying 94% of the world's demand (Plant Cultures 2005 In: Akinpelu et al., 2012). In India, turmeric is cultivated on a large scale and exported as dried rhizomes which are later processed into other products for various end uses.

According to FAO (2004), there are two important types of turmeric found at the international market: 'Madras', and 'Alleppey', both named after the regions of production in India. The orange-yellow flesh Alleppey turmeric is predominantly imported by the United States, where users prefer it as a spice and a food colorant (ASTA, 2002). Alleppey turmeric contains about 3.5% to 5.5% volatile oils, and 4.0% to 7.0% curcumin. (Buescher and Yang, 2000; ASTA 2002; Weiss, 2002 In: FAO, 2004). On the other hand, the Madras type contains only 2% of volatile oils and 2% of curcumin (ASTA, 2002 In: FAO, 2004).

In Nigeria, turmeric is cultivated mostly on subsistent bases in about 19 states and given different local names depending on the area (Olojede et al., 2005). It is called *atale pupa* in Yoruba; *gangamau* in Hausa; *nwandumo* in Ebonyi; *ohu boboch* in Enugu (Nkanu East); *gigir* in Tiv; *magina* in Kaduna; *turi* in Niger State; *onjonigho* in Cross River (Meo tribe) (Foodhaccp.com).

As reported by Olojede et al., (2009), turmeric can grow under diverse tropical conditions with altitudes ranging from sea to 1500m above sea level (Rena and Madan 2001) on a well drained sandy or clay loamy soil and temperature ranging between 20-30°C with an annual rainfall of 1500 mm or more.

Turmeric is propagated through vegetative means using the rhizome and is ready for harvest at about 7 to 10 months after planting which is indicated by the drying of the plant. The rhizomes are carefully harvested with a spade after loosening the soil with a small digger, and clumps manually lifted. It is advisable to cut the leaves before harvesting the rhizomes. Rhizomes are cleaned up by soaking them in water, as well as removal of long roots and leaf scales. Rhizomes are then further cured and processed, or stored for the next year's planting (Govindarajan, 1980; Dahal, and Idris, 1999; Anandaraj, et al., 2001; Weiss, 2002 In: FAO, 2004). Rhizomes for next year's planting should be stored in well-ventilated rooms and covered with dry leaves to prevent dehydration; or stored in pits covered with sawdust, sand, or panal (*Glycosmis pentaphylla*) leaves that may act as insect repellent (Govindarajan, 1980; Anandaraj et al., 2001 In: FAO, 2004).

Nigeria can play a leading role in turmeric production considering the prevailing favourable soil and climatic conditions in the country. Despite this, its potential has not been fully tapped as the techniques needed for its production have not been properly understood by the farmers which have led to low production (Olojede et al., 2005). The production of turmeric per unit area is

very low because of the poor knowledge on proper cultivation technology of the farmers (Ishimine et al., 2003 In: Njoku et al., 2012). Weeds can lead to reduction in the crop yield and adds to the total labour cost. As reported in Njoku et al. (2012) , weed results in 65% reduction in yield of root and tuber crops and takes 25% of total labour use in production (Akobundu, 1987).

Turmeric powder is the major constituent of curry powder used in confectionery industries for food seasoning and in the international market as a functional food due to its health promoting properties (Akinpelu et al., 2012). Turmeric is used in many religious observances, as a cosmetic, a dye, and it enters in the composition of many traditional remedies (Dahal et al., 1999; Narayana et al., 2000; ASTA 2002 In: Akinpelu, 2012). As spice, turmeric is used in adding flavor and color to dishes. Turmeric is also used as herbal medicine in the treatment of ulcers and liver disorders. The anti-bacterial and antiseptic properties of turmeric are well known. According to Akinpelu (2012), scientists have discovered that turmeric is a natural protectant, having an effective cancer chemo-preventive agent. On account of its flavour and medicinal properties, turmeric is also used in the preparation of cosmetics, soaps, ointments, face creams, toothpastes *etc.* (Pujari et al., 1986).

As reported by Akinpelu (2012), Curcuminoids the active ingredient in turmeric rhizomes is known to have some medicinal properties and has been used efficiently in the treatment of circulatory problems, liver diseases, dermatological disorders and blood purification (Ishimine et al., 2003). The average composition of turmeric is moisture (6.0%), protein (6.5%), ash (6.0%), crude fibre (3.0%), starch (5.0%), fixed oil (3.5%), volatile oil (4.5%) and curcumin (3.1 %) (Manjunath et al., 1991).

Turmeric and its potentials

Table 1: Turmeric, Nutritive Value per 100g.

Principle	Nutrient Value	Percentage of RDA
Energy	354 Kcal	17%
Carbohydrates	64.9 g	50%
Protein	7.83 g	14%
Total Fat	9.88 g	33%
Cholesterol	0 mg	0%

Dietary Fiber	21 g	52.5%
Vitamins		
Folates	39 µg	10%
Niacin	5.140 mg	32%
Pyridoxine	1.80 mg	138%
Riboflavin	0.233 mg	18%
Vitamin A	0 IU	0%
Vitamin C	25.9 mg	43%
Vitamin E	3.10 mg	21%
Vitamin K	13.4 µg	11%
Electrolytes		
Sodium	38 mg	2.5%
Potassium	2525 mg	54%
Minerals		
Calcium	183 mg	18%
Copper	603 µg	67%
Iron	41.42 mg	517%
Magnesium	193 mg	48%
Manganese	7.83 mg	340%
Phosphorus	268 mg	38%
Zinc	4.35 mg	39.5%

(Source: USDA National Nutrient data base; Cited in www.nutrition-and-you.com)

Table 2: Turmeric imports in the US in the period 1998-2002 (metric tons; US \$1,000)

	1998	1999	2000	2001	2002
Turmeric (MT)	2,284	2,641	2,427	2,404	2,383
Value (US \$1,000)	3,849	3,614	2,904	2,488	2,955

Source: FAO, 2004.

Primary Products

The primary products of turmeric according to FAO, 2004 are as follows:

- ***Dried rhizome***

Turmeric is mainly imported whole and then processed into powder or oleoresin used in the industrial sector and in confectionaries (ASTA, 2002; Govindarajan, 1980). Rhizomes appear as fingers, bulbs and splits. Rhizome quality is judged by a clean and smooth skin, uniform skin and flesh colors, and a clean snap when broken (Weiss, 2002).

- ***Turmeric powder***

As reported by FAO (2004), turmeric rhizomes are ground to approximately 60-80 mesh particle size (Buescher and Yang, 2000). Turmeric powder should be packed in a UV protective packaging and stored appropriately because the color deteriorate with light and to a lesser extent, under heat and oxidative conditions (Buescher and Yang, 2000). Turmeric powder is a major constituent in curry powders and pastes. It is mostly used to color and flavor food in the food industry (ASTA 2002).

Secondary and derived product

- ***Curry powder***

Turmeric is an important ingredient in curry powder. The turmeric content in curry powder blends ranges from 10-15% to 30% (Govindarajan, 1980 In: FAO, 2004). Typical Indian curry powder for meat and fish dishes contains 20-30% turmeric (Govindarajan, 1980) while curry mixes for vegetarian dishes contain less turmeric, in the range of 5 to 10%, because of the bitter flavor it would impart to the dish.

- ***Oleoresins***

Oleoresins from turmeric are obtained by solvent extraction of the powdered or comminuted rhizome (FAO, 2004). This process yields about 12 % of an orange/red viscous liquid, which, depending on the solvent used for extraction and on the turmeric type and cultivar, contains various proportions of the coloring matter, i.e. the curcuminoids, the volatile oils which impart the flavor to the product, and non-volatile fatty and resinous materials (Govindarajan, 1980 In: FAO, 2004).

The compounds of interest in turmeric oleoresin are the curcuminoids (40 to 55%), and the volatile oils (15 to 20%) (Govindarajan, 1980; Buescher and Yang, 2000 In: FAO, 2004). The curcuminoids, which consist mostly of curcumin, and also demethoxycurcumin, and bisdemethoxycurcumin, can be further purified to a crystalline material, and will be used preferably in products where the turmeric flavor is undesirable, such as cheese, ice cream, beverages and baked products (ASTA, 2002). Curcumin has similar color characteristics than the synthetic food colorant tartrazine; however, unlike tartrazine, it is highly sensitive to light and alkaline pH, and is also degraded by heat and chemical oxidants. It is therefore not easy to use in food processes and products destined to long-term storage (FAO, 2004).

- ***Essential oil***

Turmeric essential oil has little interest in the Western food industry, and it has no commercial value, as opposed to oleoresin (Govindarajan, 1980; Weiss, 2002 In: FAO, 2004). Turmeric essential oil is obtained by distillation (Weiss, 2002), or by supercritical fluid extraction of the powdered rhizome (Gopalan et al., 2000).

How to Use Turmeric:

According to Katie-wellness mama (2013),

- Turmeric can be used externally in poultices to soothe skin and reduce inflammation. It is often used in lotions or preparations for skin with eczema or psoriasis.
- When incorporated into the diet it can be helpful for reducing inflammation in those with arthritis.
- Turmeric can be made into a paste with water or honey to make a skin scrub that cools inflammation and helps stop acne.
- Externally, a paste of turmeric and aloe vera gel can ease pain and itching from burns, bites, chicken pox, poison ivy or eczema.
- In a soothing Turmeric Tea to soothe during illness or improve sleep. This is one of my favorite uses! See my recipe below.
- It is wonderful to add to grilled foods, vegetables, mashed cauliflower, sauces and spice blends. I add a pinch to my eggs in the morning and to most dishes that I cook.
- Turmeric's high antioxidant content benefits the skin which makes it a constituent of some natural sunscreens and bronzers. A paste of Turmeric and strong brewed black tea will temporarily darken the skin and there is some evidence that it might also provide some sun protection.
- Turmeric is said to be great for the skin and can be used in facial washes and scrubs to soothe skin and even out skin tone. Turmeric can cause hair to become less thick so it is often used by Indian women on unwanted facial hair but should be avoided on the head or by men on their faces.

- Turmeric is a wonderful spice to add to soups and stews as it gives them a rich, warm flavor and a beautiful color. If you make homemade bone broth, a couple teaspoons of Turmeric are a great addition.
- Many people take it as a supplement to help reduce inflammation and pain, especially those with arthritis or other inflammatory conditions.

Medicinal Uses of turmeric

Turmeric has the following medicinal uses (according to www.nutrition-and-you.com):

- Research results reveal that *Curcumin*, a poly-phenolic compound, found in turmeric may inhibit the multiplication of tumor cells, including multiple myeloma, pancreatic cancer, and colon cancer.
- It contains health benefiting essential oils such as *termerone*, *curlone*, *curumene*, *cineole*, and *p-cymene*. These compounds have applications in cosmetic industry.
- *Curcumin*, along with other antioxidants, has been found to have anti-amyloid and anti-inflammatory properties. Thus; it is effective in preventing or at least delaying the onset of Alzheimer's disease.
- The root herb contains no cholesterol; however, it is rich in anti-oxidants, and dietary fiber. Together, they help to control blood cholesterol levels, offer protection from coronary artery disease and stroke risk.
- Early laboratory studies have been suggestive that turmeric is liver protective, anti-depressant, anti-retroviral effects.
- It has been in use since a very long ago as an important ingredient in traditional Chinese and ayurvedic medicines for its anti-microbial, anti-inflammatory, carminative, and anti-flatulent properties.

Little or no toxicity is reported for humans receiving large (8 g/day) therapeutic doses of curcumin, an important major component of turmeric (Cheng et al., 2001 In: FAO, 2004). All these revelations about the potentials of turmeric make it a good crop for development of pharmaceuticals, nutraceuticals, or food ingredients with functional properties (FAO, 2004).

Problems faced by the turmeric growers

According to the findings of Karthik and Amarnath (2014), some of the challenges faced by turmeric growers in India are:

- Non-availability of labour
- Pest and disease attack
- High cost of hiring labour
- High costs of fertilizer and plant protection chemicals
- Water scarcity

Conclusion and Recommendation

Turmeric is an important plant with diverse uses. The benefits of the crop is enormous with little or no none side effects. Tumeric production should thus be encouraged by sensitizing farmers properly on the potentials of turmeric especially in the southern part of Nigeria where the Research institute that has the mandate to research into the crop is located. There is also need to develop improved varieties of the turmeric to boost production. Farmers should be provided with inputs like fertilizers and other agro-chemicals at subsidized rates in order to increase their production. There is also need to provide market information like price of turmeric products to the farmers.

References

- Akinpelu, C.A.; Adebayo O.S.; Adewale O.M.; and Adebisi-Adelani O. O. (2012). 'An analysis of turmeric utilisation pattern in Ekiti state, Nigeria'. Nigerian Journal of Horticultural Science Vol. 17. pp.68-72
- Akobundu, I.O. (1987). Weed science in the tropics. Principles & practices John Wiley and Sons, London 522pp
- Anandaraj, M., Devasahayam, S., Zachariah, T.J., Eapen, S.J., Sasikumar, B., and Thankamani, C.K. 2001. Turmeric (Extension Pamphlet). J. Rema and M.S. Madan, Editors. Indian Institute of Spices Research, Calicut, Kerala. API-Ayurvedic Pharmacopoeia of India 1989. New Delhi: Government of India-Ministry of Health and Family Welfare-Department of Health. 45-46.
- ASTA 2002. A concise guide to Spices, Herbs, Seeds, and Extractives. American Spice Trade Association. pp. 48-50.
- Babu, V; 2008: Physiological Studies on Weed Control Efficiency in Turmeric (*Curcuma Longa* L.). M Sc. (Agri.) Thesis, Univ. Agric. Sci., Dharwad, Karnataka, India.
- Buescher, R., and Yang, L. 2000. Turmeric. In: Natural Food Colorants. Science and Technology. G.L. Lauro, and F.J. Fancis (Eds). Marcel Dekker, New York. pp. 205-226.
- Cheng, A.-L., C.-H. Hsu, J.-K. Lin et al 2001. Phase I clinical trial of curcumin, a chemopreventive agent, in patients with high-risk or pre-malignant lesions. Anticancer Research 21: 2895-2900.
- Dahal, K.R., and Idris, S. 1999. *Curcuma longa* L. In : de Guzman, C.C. and Siemonsma, J.S. (Editors) : Plant Resources of South-East Asia No 13. Spices. Backhuys Publishers, Leiden, The Netherlands. pp.111-116.

FAO (2004). Turmeric: Post-Production Management Organisation. Food and Agriculture Organization of the United Nations (FAO), AGST. Prepared by Anne Plotto. Edited by François Mazaud, Alexandra Röttger, Katja Steffel. Last reviewed: 22/04/2004.
www.fao.org/fileadmin/Post_Harvest_Compendium_-_Turmeric.pdf

Ferreira, L.A.F., Henriques, O.B., Andreoni, A.A.S., Vital, G.R.F., Campos, M.M.C., Habermehl, G.G., and de Moraes, V.L.G. 1992. Antivenom and biological effects of arturmerone isolated from *Curcuma longa* (Zingiberaceae). *Toxicon*. 30:1211-1218.

Foodhaccp.com. 'Turmeric, garlic, others offer protection against aflatoxin 'damage', breast cancer'. http://www.ngrguardiannews.com/natural_health/article01/indexn2_html?update=230709&ptitle=Turmeric,%20garlic,%20others%20offer%20protection%20against%20aflatoxin%20'damage',%20breast%20c

Gopalan, B., Goto M., Kodama, A., and Hirose, T. 2000. Supercritical carbon dioxide extraction of turmeric (*Curcuma longa*). *J. Agric. Food Chem.* 48:2189-2192.

Govindarajan, V.S. 1980. Turmeric - chemistry, technology, and quality. *Crit. Rev. in Food Sci. & Nutr.* T.E. Furia, Ed., CRC Press, Boca Raton, FL. Vol. 12:199-301.

Ishimine, Y., M.A. Hossain, Y. Ishimine and S. Murayama, 2003; Optimal planting depth for turmeric (*Curcuma longa* L) cultivation in dark red soil in Okinawa Island, Southern Japan. *Plant Prod.Sci., J. Biol. Sci.*, 6, pp. 83-89.

Karthik V. and J.S. Amarnath (2014). 'An economic analysis of turmeric production in Tamil Nadu India'. *Direct Research Journal of Agriculture and Food Science*. Vol.2 (6), pp. 66-76, July 2014. <http://directresearchpublisher.org/drjafs>.

Katie-wellness mama (2013), Herb Profile: Turmeric. www.wellnessmama.com.

Kinchi, F., Y. Goto, N. Sugimoto et al. 1993. Nematocidal activity of turmeric synergistic action of curcuminoids. *Chem. Pharm. Bull. (Tokyo)* 41(9):1640-1643.

Kiso, Y., Y. Suzuki, N. Watanabe et al. 1983. Antihepatotoxic principles of curcuma *longa* rhizomes. *Planta Medica* 49:185-187.

Lim, G.P., T Chu, F. Yang, W. Beech, S.A. Frautschy, G.M. Cole 2001. The curry spice curcumin reduces oxidative damage and amyloid pathology in an Alzheimer transgenic mouse. *Journal of Neuroscience* 21(21) 8370-8377.

Lutomski, J., B. Kedzia, W. Debska 1974. Wirkung des äthanolextractes und activer

substanzen aus *Curcuma longa* auf bakterien und pilze (Effect of an alcohol extract and active ingredients from *Curcuma longa* on bacteria and fungi).(English abstract) *Planta Medica* 26: 9-19.

Manjunath, M. N., Sattigeri, V. V. and Nagaraj, K. V., 1991, Curcumin in turmeric. *SpiceIndia*, 4(3),pp. 7-9. Manjunath et al., 1991

Mazumder, A., K. Raghavan, J. Weinstein, et al. 1995. Inhibition of human immunodeficiency virus type-1 integrase by curcumin. *Biochemical Pharmacology* 49(8): 1165-1170.

Narayana, D.B.A., Brindavanam, N.B., Dobriyal, R.M., and Katuyar, K.C. 2000. Indian Spices: An overview with special reference to nutraceuticals. *Journal of Medicinal and Aromatic Plant Sciences*. 22 (1B):236-246.

Negi, P.S., Jayaprakasha, G.K., Jagan Mohan Rao, L., and Sakariah, K.K. 1999. Antibacterial activity of turmeric oil: a byproduct from curcumin manufacture. *Journal of Agricultural Food Chemistry* 47(10): 4297-4300.

Njoku S.C., A.O. Olojede, and A.A. Melifonwu (2012). 'Effect Of The Critical Period Of Weed Interference On Optimum Performance Of Turmeric At Umudike, Nigeria'. *Journal of Agriculture and Social Research (JASR)* Vol. 12, No. 1, 2012. Pp. 84 – 88.

Nunes, F. V (.1989.) *Cultivo da Curcumea Facile lucrative*, Manchete Rural, 29; 60

Olojede, A .O, Iluebbey, P, and Dixon, A.G.O (2005) IITA/NRCRI Collaborative Germplasm and data collection on minor Root and Tuber Crops in Nigeria. In: Annual report 2005 National Root Crops Research Institute, Umudike: 77-81

Olojede, A.O., Nwokocha, C.C., Akinpelu A.O., and Dalyop T.(2009). 'Effect of Variety, Rhizome and Seed Bed Types on Yield of Turmeric (*Curcuma longa* L) under a Humid Tropical Agro-Ecology'. *Advances in Biological Research* 3 (1-2): 40-42.

Plant cultures, 2005. Turmeric Production and Trade. www.plantcultures.org.uk/ Accessed 21/6/2005.

Polassa, K., T.C. Raghuram, T.P. Krishna, K. Krishnaswamy. 1992. Effect of turmeric on urinary mutagens in smokers. *Mutagenesis* 7(2): 107-109.

Pujari, P. D., Patil, R. B. and Sakpal, R. T., 1986, "Krishna" - A high yielding variety of turmeric. *Indian Cocoa, Arecanut and Spices J.*, 14:65-66.

Rao, C.V., A. Rivenson, B. Simi, B.S. Reddy 1995 Chemoprevention of colon carcinogenesis by dietary curcumin, a naturally occurring plant phenolic compound. *Cancer Research* 55(2): 259-256.

Rema, J. and Madan, M. S.(2001) Turmeric. An Extension Pamphlet, Agricultural Technology Information Centre .Indian Institute of Spice, Research .8pp Statistical Analysis System (SAS) Statistical Analysis System 2008 edition.

Ruby, A.J., G. Kuttan, K Dinesh Babu, K.N. Rajasekharan, R. Kuttan 1995. Anti-tumour and antioxidant activity of natural curcuminoids. *Cancer Letters* 94: 79-83.

Srivastava, K.C., M. Dikshit, R.C. Srimal 1985. Anti-thrombotic effect of curcumin. *Thrombosis Research* 40: 413-417.

Srivastava, K.C., A. Bordia, S.K. Verma 1995. Prostaglandins, Leukotrienes and Essential Fatty Acids 52: 223-227.

Subramanian, M., M. Sreejayan, N. Rao. T.P. Devasagayam, B.B. Singh. 1994. Diminution of singlet oxygen-induced DNA damage by curcumin and related antioxidants. *Mutation Research* 311(2): 249-255.

Sugiyama, Y., Kawakishi, S. and Osawa, T. 1996. Involvement of the B-diketone moiety in the antioxidative mechanism of tetrahydrocurcumin. *Biochem. Pharmacol.* 52: 519-525.

Surh, Y.-J. 2002. Anti-tumor promoting potential of selected spice ingredients with antioxidative and anti-inflammatory activities: a short review. *Food and Chemical Toxicology* 40: 1091-1097.

Travis, J. 2001. A spice takes on Alzheimer's disease. *Science News* 160:362.
Verghese, J. 1993. Isolation of curcumin from *Curcuma longa* L. rhizome. *Flavour and Fragrance Journal*. Vol 8(6):315-319.

USDA National Nutrient data base

Weiss, E.A. 2002. *Spice Crops*. CAB International publishing, Oxon, UK.